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Trends and challenges of medical education in the changing academic and public health environment of the 21st century

Edited by
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Trends and challenges of medical education in the changing academic and public health environment of the 21st century

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Editorial: Trends and challenges of medical education in the changing academic and public health environment of the 21st century

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Editorial on the Research Topic
Trends and challenges of medical education in the changing academic and public health environment of the 21st century

Medical education faces challenges in keeping pace with the rapidly changing healthcare needs of populations worldwide (Majumder et al., 2004; Wartman, 2019; Gaur et al., 2020). Traditional curricula, inadequate funding, and weak quality assurance and accreditation practices contribute to the production of under-equipped graduates (Torres-Calixto, 2021). To effectively address the health problems of the twenty-first century, there is a need for new, more efficient, and effective paradigms in medical and public health education. Health professional institutes must play a central role in developing evidence-based curricula, incorporating new technology, and promoting new programs (Wartman, 2019; Torres-Calixto, 2021). Major stakeholders must take a proactive role in bringing about the necessary changes in medical education and public health. Major challenges and changes include the shift toward competency-based education, the increased emphasis on interprofessional education, the use of technology, and addressing social determinants of health in medical education (Thibault, 2020).

In recent years, one of the most significant shifts in medical education has been the transition toward competency-based education (CBE) (Frank et al., 2010; Thibault, 2020). CBE focuses on acquiring specific skills and knowledge, as opposed to time-based education, and is viewed as a means of better aligning medical education with the requirements of the healthcare system and patients. Another trend in medical education is the interprofessional education which trains healthcare students from several disciplines to offer patient-centered care through teamwork (Thibault, 2020; van Diggele et al., 2020). This strategy is crucial for enhancing healthcare quality and meeting the complicated demands of patients in the current healthcare system. Furthermore, use of technology in medical education—virtual reality, simulation, and online learning are being increasingly used to supplement traditional medical education and provide students with new opportunities for hands-on learning and practice (Han et al., 2019; Thibault, 2020).

In addition to these changes, there is a growing emphasis on addressing social determinants of health in medical education (Lewis et al., 2020; Thibault, 2020). This includes teaching medical students about the impact of social and economic factors on health outcomes and providing them with the skills to work with communities to address these issues. Despite the changes mentioned above, medical education has largely failed to keep pace with the challenges facing the healthcare system; some of the challenges include the high cost associated with healthcare, concerns of health equity, racial disparities, and shortage of skilled healthcare providers. The current educational strategy fails to deliver value-based care, primarily due to traditional, didactic, fragmented, and static curricula which do not adequately prepare graduates for the complexities of modern healthcare (Wartman, 2019; Gaur et al., 2020). To design and implement cost-effective value-based care, the adaptation of updated medical educational curricula is necessary to train the next generation of healthcare providers who can contribute to improve the quality of life of the population. Additionally, global expenditure for medical education and research is inadequate, and this lack of investment in medical education has led to weak quality assurance, accreditation, and educational practices in health professional schools worldwide. To deal with the challenges of the twenty-first century, a needs-based medical education is required that produces a competency-based public health workforce (Boniol et al., 2022). This will require a significant investment in health professional education and a shift from traditional, didactic teaching methods to more innovative and effective ways of instruction (Torres-Calixto, 2021).

In this Research Topic, 35 articles have been published from 17 countries covering medical education and public health-related topics, and a total of 217 authors contributed. Among those, 22 are original articles −17 covered medical education, and the rest highlighted public health aspects. The medical education articles can be organized under two major themes: (i) the use of technology in health professional education, and (ii) health professional education and training by traditional methods.

Public health and medical education are closely linked, as both seek to improve the health and wellbeing of individuals and communities (Rao et al., 2020). Medical education equips healthcare practitioners with the competencies necessary to successfully diagnose, treat, and prevent diseases, whereas public health focuses on recognizing and addressing the broader health issues and needs of the population. Together, they aim to advance health equity and enhance health outcomes generally. To assist future physicians in understanding how to consider population health and address health inequities, medical training can also place a significant emphasis on public health education (Thibault, 2020).

Six articles investigated the impact of technology on health professional education. Technology is used for assessment, such as electronic testing and tracking student progress and to enhance the educational experience of students and faculty. Technology has been widely used during the COVID-19 pandemic for distance learning and online courses, making education more accessible to students specially in remote areas (Gaur et al., 2020). Singh et al. examined the use of smartphones and related medical education apps by medical students which improved their educational experiences. Luo et al. found that high-quality YouTube videos related to atrial fibrillation submitted by medical personnel were not popular and did not receive much attention. Gilavand showed a positive impact of M-Learning among faculty members. Bisdas et al. explored the perception of artificial intelligence among medical and dental students in 63 countries. Peng et al. evaluated the teaching effect of simulation-based education in clinical medical students and found that first aid simulation-based education effectively improved the students' proficiency in managing real emergencies. Coronel-Ocampos et al. identified that the majority of the students experienced computer vision syndrome during the COVID-19 pandemic. The pandemic has presented a unique set of challenges to health professional education. These challenges should act as catalysts for reimagining how we deliver health professional education and training in the future (Gaur et al., 2020; Singh et al., 2020; Majumder et al., 2021; Lashley et al., 2022). In the following section, a number of authors (Choi et al.; Pedro et al.; Yu et al.; Xin et al.) highlighted their experiences in relation to the implementation of modified learning strategy during the pandemic.

Eleven articles were published under the second theme—health profession education and training. Health professional education and training are essential for ensuring that healthcare professionals have the knowledge, skills, and attitudes necessary to provide safe and effective care to patients. Healthcare workers with the proper education and training are better equipped to make correct diagnoses, administer appropriate treatments, and communicate effectively with patients, relatives, and other members of the healthcare team (Boniol et al., 2022). Education and training also ensure that healthcare personnel can keep up with breakthroughs in medical knowledge and the development of novel treatments. Given the rapid rate of change in healthcare and the exponential growth of scientific information, this is particularly crucial. Furthermore, the global shortage of healthcare professionals and the rising demand for healthcare services demonstrate the significance of competency-based health professional education and training. Countries can meet the needs of their populations and enhance health outcomes when their workforces are properly educated and well-trained. In addition, as concerns about patient safety increase, the quality of care and patient outcomes are strongly correlated with the education and training of healthcare personnel. Thus, effective education and training of healthcare personnel are necessary for sustaining high standards of care and enhancing patient outcomes (World Health Organization, 2016). Tang et al. observed the improvement in the quality of training of resident physicians in China using "Plan-Do-Check-Action" Plan. An et al. assessed the training needs of continuing medical education of general practitioners in Tibet and recommended adopting "demand-oriented curriculum" and "staged training plans" to enhance the core professional capability of general practitioners. Awang et al. adopted a Clinical Practice Guideline in a Nurse-Led Ventilator-Weaning program and noticed the change in the perception of practice and professionalism among nurses in Malaysia. Noorali et al. reported the success of a nationwide virtual research education program for Medical Students in Pakistan. Choi et al. discussed the experiences of "chaos and change" in laboratories and clinical teaching in nursing education in South Korea during the COVID-19 pandemic. Pedro et al. conducted a comparative analysis of undergraduate psychiatry and mental health curricula and Yu et al. examined

the impact of the COVID-19 pandemic on the mental health and academic performance of postgraduate medical students. Xin et al. observed the impact of "Real Workload-Situated Training" in COVID-19 Prevention and control targeted for general practice residents, and Chawłowska et al. examined the potential of student volunteering in undergraduate health professional education. You et al. conducted a bibliometric analysis to explore emerging high-intensity interval training in health promotion, and Leadbeater et al. used a virtual approach to promote inter-professional learning between biomedical science and medicine to benefit patient care. Finally, Asakawa et al. conducted a qualitative study among resident physicians to assess coping and learning through self-disclosure after medical errors.

Three original studies covered public health issues focusing on exercise and physical fitness, healthcare financing, and the evolution of the healthcare system. Lv et al. reported how peri-operative exercise could improve physical fitness and health status to reduce the risk of peri-operative morbidity and mortality. Chinese people's peri-operative exercise intention level is low, and multiple factors, including biological and social environments, influence it. The authors recommended that the intention for peri-operative exercise should consider gender, the intensity of daily exercise, hospital grade, positive attitude toward daily exercise, preoperative anxiety, positive attitude toward peri-operative exercise, and social support.

The finance of health professional education serves as the basis of effective and sustainable health systems, yet relevant empirical research is scarce due to the lack of financial data. Gao et al. aimed to bridge the gap by presenting the financing of health professional institutions in China and exploring how the stratification of institutions affected their funding disparities. Using the Chinese Ministry of Education data, the authors reported that the number of health professional institutions has kept growing over the past two decades, with funding per institution and funding per student increasing steadily. The funding disparities between tiers of health professional institutions gradually became more accentuated, with the top-tier institutions taking up the largest share. Unified quality assurance of medical personnel training is a practical pathway to achieve stable and sustainable development in health professional education.

Marchenko and Bykov reported the importance of developing research in techno-scientific biomedical communication during the COVID-19 pandemic. The authors analyzed the evolution of the healthcare system in Russia with an emphasis on public communication and found that the promotion of high-tech medicine is related to the proportionate output of governmental institutions. There is also a concern over import substitution resulting from the current geopolitical crisis.

Apart from these, two brief research reports highlighted the gender differences and influencing factors in specialty choices (Yin et al.) and health communication and inter-professional care (Pati et al.). Three articles were published under the category of Curriculum, Instruction, and Pedagogy, which focused on tailored teaching of cell biology (Schoenmaker et al.), inter-professional education (Liller et al.), and nursing curriculum (Alias et al.).

Zhao et al. conducted a systematic review to examine the knowledge about, attitude toward, and practice of complementary and alternative medicine of nursing students. Four narrative reviews discussed the lifestyle interventions and oncology education (Jia et al.), pathology workforce challenges during the pandemic (Hassell and Afzal), gynecologic oncology sub-specialty training (Erem et al.), and antimicrobial resistance (Dhingra et al.). The widespread use of antimicrobial drugs to treat COVID-19 patients and the likely emergence of antibiotic-resistant microorganisms is a global health concern (Razzaque, 2021a). Integrating antimicrobial stewardship teaching in medical curricula to train future prescribers is essential to avoid such disastrous consequences (Majumder et al., 2020; Razzaque, 2021b). Dhingra et al. and Razzaque highlighted a global health threat posed by antimicrobial resistance. Razzaque wrote a commentary highlighting the importance of coordinated and collaborative efforts of national and international governmental and private organizations to counter the emerging threat. A minireview examined the trends and innovations of simulation training in medical education (Herrera-Aliaga and Estrada). Under the Perspective category, Yokomichi et al. discussed cross-disciplinary collaboration and innovation in epidemiology in Japan. Finally, Amin et al. addressed the challenges in humanistic communication during COVID-19 through medical education.

In conclusion, despite the changes in medical education, it has largely failed to keep pace with the challenges facing the healthcare system in the twenty-first century. This problem has been compounded by the traditional didactic and fragmented teaching approach to medical education, as well as the absence of funding for health professional education and research. To address the issues, medical education must take a more interdisciplinary and comprehensive approach focusing on population health, multidisciplinary teamwork, and community-based education and training. In addition, it is crucial that medical education be centered on the priority health needs and specific concerns of the community (Nzabonimana et al., 2019). It is also essential to invest in training diversified public health personnel in order to address the various health issues facing communities by including epidemiology, health promotion, and health policy in the training curricula. To effectively handle the healthcare concerns of the twenty-first century, medical education and public health training must adopt a more collaborative and community-based approach.

Author contributions

MM wrote the first draft. MM, MH, and MR revised and approved the final submitted version. All authors contributed to the article and approved the submitted version.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Tailored Teaching for Specialized (Para-)medical Students - Experience From Incorporating a Relevant Genetic Disease Throughout a Course of Molecular Cell Biology

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Worldwide, a mandatory course in Molecular Cell Biology is often part of the (para-) medical curricula. Student audiences are regularly not receptive to such relatively theoretical courses and teachers often struggle to convey the necessary information. Here, positive experience is shared on rigorously embedding a genetic disease that severely affects the movement apparatus, fibrodysplasia ossificans progressiva (FOP), in all aspects of a course for an international group of Research Master Human Movement Sciences students. Various molecular cell biological aspects of FOP were systematically implemented in the course, covering genetics, the biochemical consequences of the mutation, signaling pathways that affect bone formation and lectures on how to clone the mutation or cure the mutation. Students were invited to critically think about how to use the theories learned in the course to analyze a research paper. During the practical part of the course, students assisted in novel, cutting edge research on FOP patient derived or control cells. Research findings were reported in a research paper format. By building a Molecular Cell Biology course around an appealing disease, we managed to increase the general motivation of the students for the course as reflected in two specific questions of the course evaluations ($p < 0.05$). It convincingly taught the relevance of a course of Molecular Cell Biology to students with a primary background in biomechanics and physiotherapy for their paramedical professional life. This approach of embedding an audience-tailored human disease with a known genetic cause into a course can be implemented to many medical curriculum related courses and will increase students' perception of the relevance of a course.

Keywords: course innovation, fibrodysplasia ossificans progressiva, molecular cell biology, osteoclast, periodontal ligament fibroblast, heterotopic ossification, medical education

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INTRODUCTION, OBJECTIVES

It is probably a widespread and recognizable experience for many teachers of courses in the medical curriculum, that when finishing the course we like most of our repertoire, receive wonderful acknowledgments from our students, but in those acknowledgments we get a considerable proportion of students who ask the question we do not wish to hear: "Thanks for the nice

course, but what is in it for us? I do not see how it fits into the program." Despite the wonderful course evaluations received, such questions keep on nagging for some time. We have organized a molecular cell biology course for Human Movement Sciences students. Although most aspects of the course evaluation scored satisfactorily from the start and gradually further improved, this question, "What's in it for us?" persisted until by chance we got involved in research material of a disease that appealed to the students as it severely affects the movement of these patients. This allowed us to integrate this disease, fibrodysplasia ossificans progressiva (FOP), fully in virtually all aspects of the Molecular Cell Biology course. By this rigorous integration, the course lost its level of abstraction and came closer to all students. It uplifted the course further, resulting in students who kept their interest and attention throughout the course and in teachers that could tell a logical follow-up story. Here, we would like to share this positive experience, which we believe can be extrapolated to other courses of the paramedical curriculum.

METHODOLOGY

The Students, the Course, the Position in the Program, the Challenges

Around 10 years ago, a 2-years Research Master's program Human Movement Sciences has seen the light at the Faculty of Human Movement Sciences at the Vrije Universiteit (VU) Amsterdam in the Netherlands. For this international English taught program, 15–25 top students per year are selected based on grade average of their Bachelor's degree and a motivational interview. From its founding, Molecular Cell Biology was a part of the curriculum for three European Credits (ECTS), which is roughly 1.5 American Credits, or 2 weeks full time-basis equivalent, where 1 ECTS = 28 h. For most students, Molecular Cell Biology is the first encounter of a course in that category and therefore non-central to what they had learned before. Human Movement Scientists primarily have a background in biophysics, biomechanics, neuroscience, and physiotherapy. The course has always contained a theoretical part and a practical part of one and a half days, during which students actively participated in laboratory work, isolating RNA and performing quantitative real-time PCR (qPCR) of genes of interest. A written report that has the format of a research article was the requested output format for the practical, which made up one third of the grade. A written exam on the theory made up for the remaining two thirds of the final mark. The challenges have always been two-fold: to bridge the theoretical part with the practical, which until a few years ago was a separate entity, and to convince students of the broader context of Molecular Cell Biology, such as how to apply it to a disease-related research question. The course has long been considered an unusual requirement of the curriculum of the Research Master of Human Movement Sciences, as compared to the other courses.

The Disease FOP

As a coincidence, some 5 years ago, we were approached for culturing cells from extracted teeth, from a patient with fibrodysplasia ossificans progressiva (FOP). The VU medical center is the FOP center of expertise in the Netherlands [link: https://www.vumc.com/departments/fop-amsterdam-info-research-and-trials/fop-patient-care-vumc.htm:]. Teeth were extracted from patients with a closing jaw joint for the purpose of creating more space, such as in patients with a bony bridge that locks the jaw joint (1). All material was surgical waste material and permission to culture cells for research purposes was obtained through informed consent and further institutional ethical approval. The disease manifests itself as a disease with abnormal progressive bone formation of the connective tissue, hence the name. Especially connective tissue of tendons, ligaments, and muscles turn into bone. Gradually, the ability to move declines. Patients often end up in a wheelchair, see for instance this informative clip on YouTube, presented by the FOP specialist Dr. Frederick Kaplan [link: https://www.youtube.com/watch?v=GksggHYAA7M]. The causative mutation was discovered in 2006 (2). This one in two million occurring dominant mutation is located in ALK-2 or ACVR-1, a subunit of a bone morphogenesis protein receptor. To sum up, by this mutation, the off-switch of bone formation is defective. It was only in 2015 that the preferred ligand Activin A for this mutant ACVR-1 was discovered (3, 4). By this ligand-receptor interaction, pSmad1/5/8 signaling is elevated specifically by the mutated ACVR-1. Also an inhibitory molecule, FKBP12 does not interact properly with the mutated ACVR-1, allowing leaky signaling. Together this results in ectopic bone formation in FOP patients, disabling their possibility to move properly. Our involvement in this research came as a blessing in disguise, since now we could fully integrate a disease that severely impairs the movement apparatus into our course for human movement scientists, highly relevant for the future work field of students who will deal with patients with movement impairment. When supervised properly, students could even participate using the patient-derived and control cells in the practical. It further synergized expertise at Amsterdam Medical Center of the Vrije Univeristeit (VUmc) and at Academic Centre for Dentistry Amsterdam (ACTA), where expertise in tooth-associated osteoclast formation (5) and osteogenesis exists (6). Since taking a biopsy could lead to a flare-up inducing heterotopic bone formation, this is an absolutely forbidden procedure in FOP clinical research. Therefore, traditionally, relevant patients derived cell models has always been cumbersome. Cells obtained from teeth have been explored to some extent (7, 8). Extracted teeth are surrounded by an ultrathin layer of periodontal ligament fibroblasts, which can be readily cultured and propagated. Since these are cells from a true ligament, anchoring teeth into the bone, they are potentially a valuable cell model to study FOP associated bone remodeling processes.

RESULTS

A Disease Integrated Course of Molecular Cell Biology

The course became a disease-integrated course of Molecular Cell Biology and students benefited from this approach by connecting

TABLE 1 | Example of course schedule of a Molecular Cell Biology course and how a disease, here FOP, can be embedded throughout.

Activity	Subject	Integration of the disease FOP in the course
Class 1	Introduction of the course DNA- RNA- Protein central dogma of Molecular Biology	Introduction of disease, with movie from internet, take time to discuss all patient related aspects of disease. How to explain inheritance of a dominant gene when parents are not affected?
Class 2	Structure of genes RNA transcription and modulation	Structure of ACVR-1 gene Structure of ACVR-1 mRNA transcript and protein
Class 3	Molecular techniques I Sequencing Cloning	How does a mutation in ACVR-1 gene affect the cell function? Strategies for cloning and bio-assays for normal and mutated ACVR-1
Class 4	Molecular techniques II QPCR Microarray/RNAseq	Gene expression comparison (one or multiple genes) between healthy cells and cells with FOP mutation. Display own results of RNAseq control vs. FOP
Class 5	Signaling Flow of information from outside cell toward effects inside General aspects of signaling	Signaling with normal and mutated ACVR-1 and its negative regulator FKBP12 and downsteam molecules pSmad1/5/8, role of Activin A
Seminar	Consolidation of knowledge, both Molecular cell biology and FOP: Reading a research paper together.	A research paper on FOP such as when osteoclasts were central issue (10); or on Activin A (3).
Class 6	Bridge to practical	Explain the experiment, qPCR, and what is expected during practical on FOP patients derived cells.
Practical	RNA isolation, cDNA synthesis and qPCR of genes expressed by fibroblasts or in co-cultures of fibroblast-and osteoclast precursors Students learn laboratory techniques and how to calculate expression data in one and a half day	Control vs. FOP, such as published in (11–13). Typical genes to be assessed: ACVR-1, FKBP12, bone formation proteins RUNX-2; Osteopontin, Osteocalcin, Alkaline phosphatase, and osteoclast genes TRACP, DC-STAMP.
Exam	On theory Class 1–5 and research paper Class 6	Both questions on general molecular cell biology and related to FOP.

aspects of Molecular Cell Biology to a disease relevant for them. The course also provided the opportunity to contribute to cutting edge research. When using chapters of regularly used text books such as *Essential cell biology* (9) the incorporation of the Molecular Cell Biology of the disease FOP was relatively easy (See **Table 1**).

Teachers experienced a tremendous difference when teaching this course compared to the years before a disease was embedded. Remarkably, when critically analyzing the changes, ∼80% of the course remained the same. It was easier for one teacher to continue where the other teacher had left, primarily because the disease was the main theme of the course. Students incorporated Molecular Cell Biology at a level that was relevant for them, since the overarching disease was in the limelight, as an example of a disease effecting the movement apparatus.

The practical, which was without exaggeration announced in phrases like "you can contribute to unique work that has not been performed yet and outcomes are relevant for our understanding of the disease" nicely connected to the theory. Students following the Research Master of Human Movement Sciences are supposed to write a research paper in their 2nd year, based on their individual 1-year long research project. The course helped them to prepare for this, but now in a group setting, exploiting the individual talents of students such as writing, structuring data and final editing of a text. In the last couple of years, we assessed bone formation markers in these unique cells from FOP patients and also osteoclast markers in co-cultures of these cells and peripheral blood cells. Results contributed by the students have become part of two publications (11, 12) and it is foreseeable that they will do so in some future publications. Through the years, we have addressed differences in gene expression between control and FOP derived cell periodontal ligament fibroblasts, or osteoclasts. Since Activin A seems the disease specific activator, recent years have investigated its role in osteoclast formation and osteogenesis.

Pedagogically, our course set-up has similarities with novel teaching methods such as (hybrid forms of) Problem Based Learning (PBL), which seems as a more attractive way to teach medical students complex diseases from many perspectives (14).

Motivation and Relevance Improved

The Vrije Universiteit Amsterdam has a thorough tradition of evaluating each course. Students are asked to fill-out the course evaluation a couple of days after finalizing the course. Over the years, this questionnaire has varied to some extent, but it has always contained ∼20 questions on course content, course organization, student commitment, quality of the teachers, and on the exam. We specifically analyzed the effect of implementing a disease on two items of the yearly course evaluations by comparing two items before (3 years) and after (4 years) embedding a disease. These items were: (1) It was an interesting course and (2) The relevance of the course to the program was clear to me. Both aspects scored significantly higher after incorporation (**Table 2**). Besides the generic questions, the opportunity is provided to ask additional questions which seemed relevant for the changes that were implemented. One question was: "We deliberately incorporated a disease, FOP, that affects the movement apparatus throughout the course. Did it help to make Molecular Cell Biology more lively?" We asked this question in the year in which we first implemented the integration of FOP throughout the course and his question received a 4.68 out of 5 +/− 0.58 (S.D.) from the 19 responders.

TABLE 2 | Effect of incorporation (before and after) of a disease in experiencing relevance of the course, 5-point scale.

Question	Before ($n = 3$ years) Response: 13 ± 6 (S.D.)	After ($n = 4$ years) Response: 13 ± 5 (S.D.)	p-value (t-test)
It was an interesting course	3.62 +/– 0.42 (S.D.)	4.46 +/– 1.29 (S.D.)	0.0366
The relevance of the course to the program was clear to me	3.20 +/– 0.45 (S.D.)	4.11 +/– 0.35 (S.D.)	0.0266

DISCUSSION AND CONCLUSIONS

Translatability to Other Courses

When considering the enormous impact of incorporating this disease into how this course was experienced by both students and teachers, we would like to put our experience into a much broader perspective. Teacher-researchers should be encouraged to make their courses tailor-made to the specific (para-)medical audience they face. For instance, some of us (TJdV) have experience in teaching oral hygienist students histology of the oral tissues. For quite a few, this is a challenging and possibly even boring subject from beginning to the end, since such an audience is much more practically oriented. But, when designing a seminar where genetic defects that affect protein *function* have a disastrous outcome for the patient, histology can be approached at a different, integrated level, since the proteins do not function properly and hence the tissue structure is disrupted. This way, knowledge on histology is conveyed as extremely relevant for the working paramedical professionals. Likewise, then in a more extensive course with more techniques, we have successfully engaged students in ongoing research (15). Compared to ∼30 years ago, when the genetic causes of diseases were still in their infancy, we as scientist-teachers now have the opportunity to make courses much more *audience-tailored* for specialized (para-)medical specialists. This provides tantalizing opportunities to explain anatomy, histology, cell biology, biochemistry, and molecular biology making use of the genetic and biochemical knowledge of relevant diseases. When incorporating relevant diseases, such courses increase in relevance.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

AUTHOR CONTRIBUTIONS

TV initiated writing. TS and DD contributed their parts to the present manuscript. All authors agree on the current version of the manuscript.

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REVIEW
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Microbial Resistance Movements: An Overview of Global Public Health Threats Posed by Antimicrobial Resistance, and How Best to Counter

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Antibiotics changed medical practice by significantly decreasing the morbidity and mortality associated with bacterial infection. However, infectious diseases remain the leading cause of death in the world. There is global concern about the rise in antimicrobial resistance (AMR), which affects both developed and developing countries. AMR is a public health challenge with extensive health, economic, and societal implications. This paper sets AMR in context, starting with the history of antibiotics, including the discovery of penicillin and the golden era of antibiotics, before exploring the problems and challenges we now face due to AMR. Among the factors discussed is the low level of development of new antimicrobials and the irrational prescribing of antibiotics in developed and developing countries. A fundamental problem is the knowledge, attitude, and practice (KAP) regarding antibiotics among medical practitioners, and we explore this aspect in some depth, including a discussion on the KAP among medical students. We conclude with suggestions on how to address this public health threat, including recommendations on training medical students about antibiotics, and strategies to overcome the problems of irrational antibiotic prescribing and AMR.

Keywords: antibiotics, antimicrobial resistance, AMR, globe, public health, hazard

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INTRODUCTION

In the pre-antibiotic era, contagious microbial diseases such as smallpox, cholera, diphtheria, pneumonia, typhoid fever, plague, tuberculosis, typhus, syphilis, etc. were widespread all over the globe (1), and infectious diseases were the primary cause of morbidity and mortality (2). Until relatively recently, the average life span was limited to 4 or 5 decades, in part because minor

infectious diseases often progressed to septicemia and death (3–5). The discovery of penicillin by Sir Alexander Fleming in 1928, completely transformed medical practice., It still ranks as the most effective life-saving intervention in medicine, saving millions of lives in the years to follow (6, 7). The discovery of antibiotics reduced the death rate by 25–30% for both community-acquired and healthcare-associated pneumonia, 75% for endocarditis, 60% for meningeal or cerebral infections, and 11% for cellulitis (8, 9).

Unfortunately, within 50–60 years, these successes of medical science were starting to fade as micro-organisms began to develop resistance toward antibiotics (10–12). Thereafter, the fight against pathogens has been a losing battle despite relentless attempts by scientists to develop new and more effective agents against the micro-organisms. Although antimicrobial resistance (AMR) is a natural phenomenon, the process has been much enhanced because of the overuse, underuse, and misuse of antimicrobials both in humans and animals (10–13). Consistent expansion of AMR has stunted both the prevention and treatment of infections caused by bacteria, parasites, viruses, and fungi (14). As a result, AMR creates a progressively grave risk for global public health in the last two decades and has now been appraised as the highest health endangerment in the 21st centenary (14, 15). In the United States of America (USA), the healthcare cost related to AMR was $55 billion per year in 2013, and every year more than 2 million of the US population are infected with resistant infections, which claim over 23,000 deaths (16). The European Center for Disease Prevention and Control (ECDC) and European Medicines Agency (EMEA) jointly estimated that in 2009, the overall annual healthcare expenditure and productivity losses were over €1.5 billion because of the additional cost to AMR infectious disease management. Additionally, hospital costs were estimated to be over €900 million, and multidrug-resistant (MDR) microbial infections claimed around 33,000 lives (17–19). MDR was demarcated as resistance to at least one agent in three or more antimicrobial classes, extensively-drug-resistant (XDR) was delineated as non-sensitivity to at least one agent in all but two or fewer antimicrobial groups (i.e., bacterial isolates remain susceptible to only one or two categories) and pan-drug-resistant (PDR) was described as resistance to all medicines in all antimicrobial classifications (20). Furthermore, multiple studies reported that patients and parents of pediatric patients were ill-informed about AMR and lacked understanding of how resistance operates for treatment difficulty and failure. This lack of understanding leads to a failure of the public to recognize any responsibility for tackling the issue of AMR (21, 22).

AIMS AND METHODS

This narrative review draws on the relevant literature around the history of antimicrobial development in the context of emerging drug resistance and antimicrobial prescribing worldwide, in order to characterize the global public health threat to the prevention and control of infectious diseases with their associated morbidity, mortality, hospitalization, increased hospital stay, and healthcare cost.

We hope that by raising awareness of the issues and by discussing educational approaches to reducing antimicrobial resistance we can contribute to reducing patient miseries and improving patient care.

The review is based on published literature available to the Universiti Pertahanan Nasional Malaysia (UPNM, National Defense University of Malaysia), searches were carried out using SCOPUS, EBSCO, PubMed, and Google Scholar. The study was conducted between September-2-2019 to June-23-2020. Search terms were antibiotics, history, discovery, penicillin, golden era, challenges, obstructing, resistance, development, 1960–2000, combinations agents, 2015–2020, antimicrobial resistance, AMR, dangerous, pathogenic microbes, poor development, mechanisms, microbial resistance, rational, use, irrational, prescribing, developed, developing, countries, medical doctors, medical students, undergraduate medical course, curriculum, knowledge, attitude, practice, strategies, combat, combat antimicrobial resistance, globe, public health, risk. Relatable and appropriate journals were pinpointed through hand-searched, and references were checked to find other related published manuscripts.

HISTORY OF ANTIBIOTICS IN THE LAST MILLENNIUM

The word "antibiotics" was first coined in 1941 to describe the antibacterial drugs by Professor Selman Waksman, who discovered over 20 antibiotics (23, 24), paving the way for antimicrobial drugs to becoming one of the most efficacious forms of pharmaceutical agents in the history of modern medicine (25–27). Even earlier, Paul Vuillemin used the word "antibiose" in 1890 to describe an agent that antagonizes the activity of diverse microorganisms (28–30). Despite the widespread belief that antibiotics have only been utilized in the past century, recent evidence suggests that substances with antimicrobial activity were consumed a few thousand years back (31–34). Prehistoric people used a diversity of natural substances such as herbs, honey, and even animal feces as the remedy for infection (35–37). Fungal infected bread was successfully used in treating skin infections around the globe in ancient times, particularly in Egypt, China, Serbia, Greece, and Rome (37). The concept of using moldy bread was mentioned in 1640 when John Parkinson (1567–1650) applied "fungated" bread to his patient's skin (37). The first antibiotic in the form of pure hard-sparkling crystal was mycophenolic acid, isolated by an Italian physician and microbiologist, Dr. Bartolomeo Gosio, in 1893 from *Penicillium glaucum* (later known as *P. brevicompactum*) (38, 39). Mycophenolic acid was initially thought of as a bacteriostatic agent toward *Bacillus anthracis* and additionally showed antiviral, antifungal, antitumor, and anti-psoriasis properties (38–40). This basic and essential finding was disregarded until mycophenolic acid was found again in 1913 in the USA. The lack of attention can probably be attributed to language limitation, as the original findings were published in

Italian (41). Another claim to be the first antimicrobial utilized in human infection is made for pyocyanase, which was developed by German scientists in the late 1890s from green bacterial isolate (42–44).

Discovery of Penicillin

The breakthroughs in microscope design and their mass production in the 19th Century were vital to the study of microbe activity by bacteriologists, and crucial to the discovery of Penicillin in 1928 by Alexander Fleming, a Scottish bacteriologist working at St. Mary's Hospital in London. Upon his return from a 2-week vacation, he started cleaning his table when he noticed a petri dish comprising of staphylococcus culture left on a laboratory worktable, not in the incubator as planned. He found a fungal growth in the petri dish of *Staphylococcus* spp. culture, probably accidentally contaminated as a window of the laboratory had remained open (45). Professor Fleming detected that the staphylococcus growth near the fungal clusters was becoming extinct, as demonstrated by the liquefying and clearing of the neighboring agar gel (45, 46). He started experimenting with the fungal growth and identified it as the *Penicillium* genus, which liberates a compound that could inhibit several gram-positive pathogens responsible for scarlet fever, pneumonia, gonorrhea, meningitis, and diphtheria (45). Fleming published these findings in the British Journal of Experimental Pathology in 1929 (46). The first recorded administration in humans was a single case in 1941, at which time there was too little available to give the infected policeman a full course and he died (47). Ernst Chain and Howard Florey then isolated the pure form of penicillin in the form of penicillin G, and production was scaled up, making the antibiotic available for increasingly widespread clinical use from 1942, initially for allied force military community, but was extensively marketed for civilians after the Second World War (1, 48). Alas, the first evidence of penicillin resistance was also reported around this time. In 1945, Sir Alexander Fleming, with Sir Howard Florey and Ernst Chain, were awarded the Nobel Prize in Physiology/Medicine for the invention of penicillin to treat several infectious diseases (45, 48). Nevertheless, Fleming wrote, "I did not invent penicillin. Nature did that. I only discovered it by accident" (45).

Golden Era of Antibiotics

The introduction of penicillin and streptomycin in 1928 and 1943, respectively, presaged the time when antibiotics became a dominant component of medical care for infectious diseases. By 1950–1960 several more antimicrobials had been discovered (49). Indeed, 1930–1962 was often considered as the golden age of antimicrobial inventions as 20 different novel classes of antimicrobials were invented and developed rapidly within these two decades. Many of these went on to serve mankind for another 60 years (49–53).

A valuable introduction was the first aminoglycoside, streptomycin. This highly effective, broad-spectrum antimicrobials with a mechanism of action through inhibition of microbial protein synthesis was developed by the US scientists Waksman, Schatz, and Bugie (54, 55) from *Streptomyces griseus* and clinically first used in 1944 (56).

Development of Antimicrobials 1960-2000

In the last 40 years of the 20 century a lot of new antimicrobials molecules came to market and collectively they contributed a lot to saving human life. Four successive generations of quinolones were developed with identical pharmacodynamics, but with incremental advantages in pharmacokinetics (57, 58).

Aminoglycoside development also saw significant advances. From streptomycin (1943), neomycin (1949), kanamycin (1957), came gentamicin in 1963. This is still in widespread use around the globe. Netilmicin followed (1967), and tobramycin (1974), and amikacin (1976) (56). All these aminoglycosides acted like streptomycin, suppressing microbial protein synthesis by way of irretrievable binding with the 30S microorganism ribosome (59).

Teicoplanin, a glycopeptide antimicrobial, which was first identified in the mid-1970s, acts by inhibiting cell wall synthesis, almost like vancomycin. Pharmacodynamically, teicoplanin does not belong to a novel class as these drugs are still glycopeptide, membrane biosynthesis inhibitors (60–63). Use of teicoplanin is likely be affected by the local prevalence of MRSA (64–66).

Although cephalosporins were first invented in 1945, they were not clinically utilized until 1964 (67). There are five generations of cephalosporins currently available in medicine (68, 69), all belonging to a class of β-lactam antimicrobials acting (like penicillin) by cell wall synthesis inhibition (69, 70). The reason why successive cephalosporin molecules appeared on the medicine-market was their incremental pharmacokinetic advantages. Cefepime—a fourth-generation cephalosporin first appeared for clinical practice in 1994, for the management of moderate-to-severe infectious disease conditions, specifically for pneumonia, straightforward and difficult urinary tract infections (UTIs), skin and soft-tissue infections, intra-abdominal infections, and febrile neutropenia (71). Cefepime resistance has since been widely reported (72–75).

The carbapenems (doripenem, ertapenem, imipenem, and meropenem) are architecturally correlated to other β-lactam antimicrobials (63). These novel antimicrobials belong to -Lactam & other cell walls- & membrane-active group, thereby, mechanism of actions remain like other cell-wall inhibitors (63). Imipenem was the first agent clinically used in the carbapenem family that was developed in the United States in 1985. Carbapenems hold the broadest spectrum of activity, and proved to be extremely potent against Gram-positive and Gram-negative microbes. The carbapenems often appear in formularies as the named and considered as the "final rescuer" or antimicrobial of last resort, reserved as a potential lifesaver for patients with life-threatening infection by highly resistant pathogens (76–80). The first reports of imipenem and meropenem resistance to Klebsiella pneumoniae appeared in 2001 (81). Sadly, recent years have seen wider emergence of MDR pathogenic microorganisms that utterly evade even this last resort of infectious disease management (82).

Amoxicillin is a penicillin which has been a widespread market success over the years, alone or in combination with clavulanic acid. However, having the same mechanism of action as other penicillins, widespread drug resistance has now limited its use (63). Clavulanic acid, like tazobactam and sulbactam, is a pharmaceutical agent utilized with antimicrobials. Nevertheless,

these agents are not considered as antimicrobials, rather as microbial β-lactamases enzyme inhibitors (83).

Erythromycin was the first of a group of the macrolide group of antibiotics and was first used in 1952. Later drugs in this group, usually demonstrating some pharmacokinetic advantage, (84, 85) included clarithromycin, azithromycin, and roxithromycin. Macrolides' basic mechanism of action is similar to the earlier antimicrobials working to inhibit microbial protein synthesis by binding to bacterial 50S ribosomal subunit (86).

Trimethoprim, first used in 1962, is primarily used in urinary tract infections (87). The mode of action is to bind to dihydrofolate reductase and thereby inhibit the reduction of dihydrofolic acid (DHF) to tetrahydrofolic acid (THF), an essential precursor in the thymidine synthesis pathway. This interference inhibits bacterial DNA synthesis (88). In the early days, trimethoprim was commonly used in combination with sulfamethoxazole which inhibits dihydropteroate synthase, an enzyme involved further upstream in the same pathway. The hope was that the two agents would, by their possible synergistic effects, reduce the development of resistance (88–90). However, resistance to the combination became significant, and the serious potential adverse effects of the sulfonamide resulted in the single agent proving to be more popular in the long-term. Drug resistance is still a big problem for trimethoprim (91).

The quinolones are a good example of drugs invented and gradually refined over this period and still in widespread use across the world despite encountering antimicrobial resistance. Useful advances also comprised new formulations and many of that generation of injectables are also still in use (92–94).

Thus, these four decades, although responsible for significant incremental improvement of antimicrobial drugs in existing classes, saw little by way of fundamental innovation. It is hardly surprising that when microbes are attacked in similar ways to those which have already been circumvented, they rapidly manage to develop resistance to similar "me-too" agents. However, since 1962, only two new classes of antimicrobials have been developed (50, 95–97). Of these new classes of antimicrobials, only three were marketed for human infectious diseases, and one class was restricted just for topical administration (98).

Historical antimicrobials development is depicted in **Table 1**, which lists the year in which the first drug of a class was developed.

TABLE 1 | Novel classes of antibiotics developed between 1935 and 2003 (99, 100).

Year of development	Antimicrobial classes
1935	Sulphonamides
1941	Penicillins
1944	Aminoglycosides
1945	Cephalosporins
1949	Chloramphenicol
1950	Tetracyclines
1952	Macrolides/Lincosamides/Streptogramins
1956	Glycopeptides
1957	Rifamycins
1959	Nitroimidazoles
1962	Quinolones
1968	Trimethoprim
2000	Oxazolidinones
2003	Lipopeptides

Drug Development in This Century

The early part of the 21st century saw the development of relatively few antimicrobial drugs, (26, 101, 102), and most newly introduced drugs had limited application.

Some antimicrobials were developed from natural resources. Healthcare in developing countries benefitted from economical, often soil-derived, medicines. When their potential had been exploited to the point of exhaustion, there was a need to synthesize new antimicrobial molecules (37, 103–105). However, research into developing synthetic antimicrobial molecules from existing natural medicines had poor success rates (103, 106).

Global research endeavor focused on developing new approaches to overcome MDR. Early this century, infection caused by antibiotic-resistant microbes, both by gram-negative bacilli (GNB) and gram-positive pathogens such as *Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter species* had significantly increased human morbidity, mortality, hospitalization, and augmented hospital stay and healthcare costs throughout the globe (107–113). Subsequent research used highly advanced technology to explore "genomics and combinational chemistry" but was often unsuccessful in finding new molecules with the necessary efficient antimicrobial activity (114). **Box 1** lists some antimicrobials introduced in the last 20 years.

New Combinations of Antimicrobials

Some promising new combination drugs have been introduced since 2015, They are mostly expensive and their restricted indications have the effect of limiting their prescription to a small number of specialists in developed countries.

Ceftazidime-Avibactam combination was first licensed by the FDA in 2015 (127). Ceftazidime, a third-generation, antipseudomonal cephalosporin antimicrobial with an advantageous pharmacokinetic profile, and avibactam, a next-generation, β-lactamase inhibitor. This combination was approved for the treatment of complicated intra-abdominal infections, complicated urinary tract infections, hospital-acquired bacterial pneumonia, and ventilator-associated bacterial pneumonia (128, 129). Ceftazidime has an advantageous pharmacokinetic profile (130–132) and Avibactam is a microbial enzyme inhibitor designed to overcome the key issue of cephalosporin resistance. The clinical importance of avibactam is its ability to inhibit some carbapenemases, thereby giving a therapeutic option for some infections caused by MDR organisms when there are no other options (133, 134). Sadly, although this combination offers major advantages in the management of complex infections, multiple studies have described the emergence of resistance among

BOX 1 | Antimicrobials introduced 2003 to 2013.

Daptomycin is a lipopeptide antibiotic introduced in 2003 for the treatment of systemic and life-threatening infections caused by Gram-positive organisms. It is a naturally occurring compound found in the soil saprotroph *Streptomyces roseosporus* (115).

Tigecycline, introduced in 2005, is an intravenous glycylcycline (tetracycline derivative) antibiotic. Active against both Gram-positive and Gram-negative organisms, it was intruded to combat MDR organisms, but has since encountered drug resistance (116, 117).

Retapamulin is a topical antibiotic introduced in 2007. It is used in the treatment of bacterial skin infections such as impetigo, and it is the first drug in the new class of pleuromutilin antibiotics to be approved for human use (118, 119).

Fidaxomicin, FDA licensed in 2011, is the first member of a class of narrow spectrum macrocyclic antibiotic drugs called tiacumicins. It is a fermentation product obtained from a natural actinomycete. Currently very expensive, it is used for the treatment of *Clostridioides* (*Clostridium*) *difficile* infection (120–123).

Bedaquiline, approved by the FDA in 2012, is an oral preparation used to treat multi-drug-resistant tuberculosis (MDR-TB) in combination with other anti-tubercular medication. It is a diarylquinoline, and blocks ability of *M. tuberculosis* to make adenosine 5'-triphosphate (ATP) (124).

Televancin is a synthetic derivative of vancomycin, originally used in skin infections. Subsequently it has been found useful in hospital acquired *Staphylococcus Aureus* pneumonia, for which it was licensed in 2013 (125, 126).

carbapenemase-producing *Klebsiella pneumoniae* (CPKP) pathogens (135–140).

The US FDA also approved the three-drug combination imipenem-cilastatin/relebactam for hospital-acquired bacterial pneumonia and ventilator-associated bacterial pneumonia in adults in 2019 (141). The indications for this combination agent are the treatment of complicated urinary tract infections and complicated intra-abdominal infections (142). The combination of imipenem-cilastatin has been in clinical use since 1985 (143). The addition of relebactam, a novel beta-lactamase inhibitor in the diazabicyclooctane class, was the innovation in this combination (141, 142), conferring advantage by overcoming the resistance issue of several imipenem-resistant microorganisms, including *Enterobacteriaceae* and *Pseudomonas aeruginosa* (144). Relebactam impedes bacterial synthesis of class A and C β-lactamases, consequently, lowering the minimum inhibitory concentration (MIC) and improving imipenem sensitivity activity against *P aeruginosa* (144). The approval of imipenem-cilastatin/relebactam brings new hope for enduring combat against MDR pathogenic microbes (144–146).

New Single Agents

In 2018 the FDA approved plazomicin for the management of very severe chronic urinary tract infections (CUTI) including pyelonephritis in adult patients (147). In licensing plazomicin, the regulatory authority imposed an important restriction by limiting plazomicin prescription only to those hospitals using trough-based therapeutic drug management (TDM) systems to minimize the possibility of renal adverse effects among recipient patients. This important restriction to protect highly vulnerable patients should reduce irresponsible prescription. Plazomicin is a newly developed aminoglycoside antimicrobial which inhibits microbial protein synthesis by binding with the microbial 30S ribosomal subunit in a concentration-dependent manner. Plazomicin exhibits a broad spectrum of activity against aerobic gram-negative pathogens including extended-spectrum β-lactamase–producing (ESBL) *Enterobacteriaceae*, CRE, and microorganisms capable of producing aminoglycoside-modifying enzymes (148, 149). Plazomicin resistant to those pathogens are encoded with 16S ribosomal RNA methyl-transferases (16S-RMTases) especially for *Enterobacteriaceae* spp (150–154). It has, however, been reported that the 16S-RMTase enzyme can bind with 16S rRNA target sites in the presence of plazomicin as with other aminoglycosides. So far 10 different type of acquired 16S-RMTases have been identified among gram-negative pathogenic microbes. The majority of 16S-RMTases were post- transcriptionally methylate residue G1405 of 16S rRNA; consequentially, these pathogens can already develop the same high levels of resistance to plazomicin as to other aminoglycosides (gentamicin, tobramycin, and amikacin) (154).

Cefiderocol is a parenteral siderophore (from the Greek meaning iron carrier). Low molecular weight Fe^{3+} chelating molecules are synthesized by microbes such as bacteria and fungi and serve primarily to transport iron across cell membranes (155). This novel cephalosporin, developed in Japan, (156) was FDA approved in 2019 (157). Cefiderocol is a β-lactam antimicrobial, exerting its principal mechanism of action through inhibition of the cell wall synthesis of Gram-negative pathogens (158). It possesses a similar mode of action topenicillin—the first antibiotic. The novelty of cefiderocol lies in its ability to enter the microbial periplasmic space. It is too early to tell how effective the siderophore qualities will be in countering β-lactamase drug resistance (159).

SCIENTIFIC AND ECONOMIC CHALLENGES FOR ANTIMICROBIAL DEVELOPMENT

If the flow of antimicrobials through the pipeline of development seems to have slowed, (102, 160) one suggested reason is that giant pharmaceutical companies have deprioritized funding antibiotics research, because the development of medications utilized in lifestyle-related sicknesses generates much more substantial financial gain (53, 99, 100). The invention of a new antimicrobial agent or a new class of antimicrobials in the last 35 years has been difficult, time-consuming, and problematic because of many issues (101, 161). In addition, it is taking longer for new antimicrobials to obtain approval from drug regulatory bodies, and hence new agents are coming onto the clinical market too slowly and too infrequently to combat current alarming levels of AMR (162, 163). Despite pharmaceutical industry

and academic institute sponsored research, the development of innovative antimicrobial agents for clinical use has dwindled.

The principal approaches to combating AMR remain in two significant areas, Firstly, the accurate identification of molecular targets that are not predisposed to quick development resistance mechanisms is a priority (101, 162). Secondly, in order to overcome current limitations on treatment of contagious diseases, there is an urgent need to move past the current well-known five principal core mechanisms of antimicrobial action (i.e., cell wall synthesis, protein synthesis, RNA polymerase and DNA gyrase, folate mechanism, and membrane structure).

One particular ambition is to develop novel antimicrobial molecules to overcome the ability of gram-negative microorganisms to develop efflux-mediated drug resistance, and molecular target alteration (101, 162, 164, 165). Although pharmaceutical industries have in the past benefitted considerably from developing innovative antimicrobial agents for the management of contagious diseases; nevertheless, many have discontinued their antimicrobial research investment since the late 1990s. Not only has further innovation of new antimicrobial molecules became extreme difficult, but also the profit margin for this activity turns out to be very low in proportion to the enormous investment required (106, 161, 166–168).

Profitability is affected by the speed with which microbes develop resistance to newly introduced antimicrobials, thereby severely restricting sales of the drug (161, 166, 169, 170). Additionally, the significant difference between antimicrobials and other medicines for chronic non-communicable disease (NCDs) management is that antimicrobials are taken for a short period to cure infectious diseases. In comparison, medicines for NCDs like hypertension, diabetes mellitus, bronchial asthma, hyperlipidemia, mood disorders often need to be prescribed over the patient's lifetime (161). The enormous investment required for drug development is a powerful consideration for profit-focused pharmaceutical companies (161, 171–173). Some major transnational pharmaceutical industries have lost interest in investing in antibiotic research as antimicrobials became less profitable. Dr Mahesh Patel has drawn attention to a particular problem arising from the closure of multiple antibiotic discovery programs witnessed over past twenty plus years, it has led to crippling loss of skill sets specifically required for the discovery of antibacterial drugs. Given such scenario, large pharma companies are now finding it difficult to assemble a full multidisciplinary team, such as is required for this type of productive research program. "Society wants a cheaper antibiotic, but the cost of development will be high. So, we need to manage these two conflicting needs." (174).

Multiple studies attest to the continuing low pace of development of new antimicrobials (66–80). The causes, which are not limited to corporate-driven planning of pharmaceutical industries, also include the guidelines, policies, and processes of supervisory bodies responsible for medicine approval, and regulation. Perhaps the best-known of these bodies is the USA's Food and Drug Administration (FDA),

Changes which the FDA has made to their guidelines on research protocols over the past 25 years have resulted in some restriction of the ongoing work by scientists to develop new antimicrobials (161, 175, 176). Under the FDA's current guidelines placebo-controlled clinical trials for antimicrobials are deemed to be detrimental to human rights. The current FDA protocol for antimicrobials research necessitates large sample sizes and, as a result, hugely increases the financial overheads. Thus, the commercial incentives for the pharmaceutical industry to invest in antimicrobial research, including the quest to overcome drug-resistant microorganisms, have been drastically reduced (175, 176).

Despite all the disincentives new antimicrobial drug innovation remains a significant thrust for scientists in drug-developing industries (161). The pharma-industries adopted genomics and target-based screening technologies in the 1980s to enable and accelerate the antimicrobial drug innovation procedure (161, 177–179). Undoubtedly, novel and efficient biochemical and genomic target-based techniques for screening approaches to human drug development have been a significant advance for (106), Nonetheless, little has yet emerged from the use of these modern technologies to increase optimism about development of novel antimicrobials to combat AMR infectious diseases in the near future (180–182). At the present time we can only speculate about whether the global drive to develop vaccines and antiviral compounds for the Covid-19 pandemic could have positive spin-offs for antimicrobials.

ANTIMICROBIAL RESISTANCE AROUND THE GLOBE

Microbial resistance to antibiotics has been a predictable to the point of certainty. The inescapable emergence of the resistance has been observed from the initial days of the antibiotic research and clinical utilization. Nevertheless, the advent of the most notorious resistant microbial strains in the last 25 years has transformed the situation into a life-threatening issue (168). AMR is a tremendous public health problem all over the globe. There is universal distress as the threat to human life rises (183). AMR pathogenic microorganisms have emerged, both in humans and in animals on each of the earth's continents. They have been identified in arctic regions and even on the international space station (184–186). Consequently, infectious diseases remain the most important cause of mortality (187). A brief timeline of the antimicrobials' development and resistance (81, 130–132, 188–210) is depicted in **Table 2**. Multiple research reported by the early-1940s presence penicillin inactivator enzyme among *Staphylococcus aureus;* thereby, penicillin was resistant (211–213). Abraham and Chain revealed that published in 1940 that an *Escherichia coli* was capable of inactivating penicillin by producing penicillinase enzyme (213, 214).

Currently, almost all clinical used antimicrobials, including colistin, the final weapon in the armament safeguarding humans from deadly gram-negative infections, have also developed resistance (168, 215–217). Furthermore, internationally, the threat to public health from the exponential progression of MDR, XDR, and PDR gram-negative microorganisms has become critical.

Although widespread use of any antibiotics inevitably promotes resistance in micro-organisms over time, many

TABLE 2 | Timeline of antimicrobials development and resistance (81, 130–132, 188–210).

Antimicrobials	Year		The resistant pathogen
	FIRST marketed for clinical use	First reported resistance	
Penicillin	1943	1940	*Escherichia coli*
Penicillin G	1942	1942	*Staphylococcus aureus*
Streptomycin	1945	1952	*Mycobacterium tuberculosis*
Chloramphenicol	1949	1973	*Streptococcus pneumoniae*
Tetracycline	1950	1959	*Shigella flexneri*
Erythromycin	1953	1968	*Streptococcus pyogenes*
Isoniazid	1954	1992	*Mycobacterium tuberculosis*
Colistin	1959	1999	*Acinetobacter baumannii*
Methicillin	1960	1962	*Staphylococcus aureus*
Ampicillin	1961	1972	*Haemophilus influenzae*
Gentamicin	1967	1979	*Enterococcus*
Rifampin*	1968	1985	*Mycobacterium tuberculosis*
Vancomycin	1972	1988	*Enterococcus faecium*
Ceftriaxone	1982	2009	*Neisseria gonorrhoeae*
Imipenem	1985	1998	*Enterobacteriaceae*
Ceftazidime	1985	1987	*Enterobacteriaceae*
Ciprofloxacin	1987	1993	*Salmonella typhimurium*
Imipenem	1987	2001	*Klebsiella pneumoniae*
Meropenem	1996	1998	*Acinetobacter species*
Levofloxacin	1996	1996	*Streptococcus pneumoniae*
Linezolid	2000	2000	XDR Tuberculosis
		2001	*Staphylococcus aureus*
Daptomycin	2003	2005	Methicillin-Resistant *Staphylococcus aureus*
Ceftaroline	2010	2011	*Staphylococcus aureus*

antibiotics have given good service worldwide for 25 years or more before they become redundant. After a period of disuse, sometimes brought about as much because of adverse effects as ineffectiveness due to resistance, desperate attempts have been made to bring back into use some age-old antibiotics with a new dosage schedule. These drugs had previously been dropped from clinical use because of their profound adverse effects. Unsurprisingly, resistance has also speedily arisen to these resurrected antimicrobials (218).

Besides the list shown in **Table 2**, PDR was reported in the year 2004/2005 for Acinetobacter and Pseudomonas, and in 2009 for Enterobacteriaceae. Rifampicin mono-resistant tuberculosis (RMR-TB)is rare globally. In 2014, The World Health Organization (WHO) appraised that only 1.1% of TB patients around the planet had rifampicin resistance without resistance to isoniazid (197, 198, 210).

CURRENT MOST DANGEROUS PATHOGENIC MICROBES

In 2017 WHO first published the list of antimicrobial-resistant (**Table 3**) "priority pathogens" —a directory of 12 families of microbes that pose the most extreme public health risks around the globe (219). In 2019 the Center for Disease Control and Prevention (CDC) classified 18 antimicrobial-resistant bacteria and fungi into three classes by level of public health issues of urgency, severity, morbidity, and mortality (**Table 4**) (220).

One estimate is that development of a new antimicrobials molecule takes some 15–20 years (221, 222) and financial support of over US$ 2.6 billion (223). Another study estimated this at a

TABLE 3 | WHO *priority list: infectious micro-organisms for research and development of novel antimicro*bials.

Name of the Pathogens	Name of Antimicrobial Resistance
PRIORITY 1: CRITICAL	
Acinetobacter baumannii	Carbapenem
Pseudomonas aeruginosa	Carbapenem
Enterobacteriaceae	Carbapenem [Extended Spectrum B-Lactamase (ESBL) Producing]
Priority 2: HIGH	
*Enterococcus faeciu*m	Vancomycin
Methicillin-Resistant *Staphylococcus aureus*	Vancomycin
Helicobacter pylori	Clarithromycin
*Campylobacte*r spp.	Fluoroquinolone
Salmonellae	Fluoroquinolone
Neisseria gonorrhoeae	Cephalosporin and Fluoroquinolone
Priority 3: MEDIUM	
Streptococcus pneumoniae	Penicillin
Haemophilus influenzae	Ampicillin
Shigella spp.	Fluoroquinolone

TABLE 4 | CDC threats to public health.

Urgent threats	Serious threats	Concerning threats
Carbapenem-resistant *Acinetobacter*	Drug-resistant *Campylobacter*	Erythromycin-resistant group A *Streptococcus*
Candida auris	Drug-resistant *Candida*	Clindamycin-resistant Group B *Streptococcus*
Clostridioides difficile	ESBL-producing *Enterobacteriaceae*	**Watch Lists**
Carbapenem-resistant *Enterobacteriaceae* (CRE)	Vancomycin-resistant *Enterococci* (VRE)	Azole-resistant *Aspergillus fumigatus*
Drug-resistant *Neisseria gonorrhoeae*	Multidrug-resistant *Pseudomonas aeruginosa*	Drug-resistant *Mycoplasma genitalium*
	Drug-resistant non-typhoidal *Salmonella*	Drug-resistant *Bordetella pertussis*
	Drug-resistant *Salmonella* serotype Typhi	
	Drug-resistant *Shigella*	
	Methicillin-resistant *Staphylococcus aureus* (MRSA)	
	Drug-resistant *Streptococcus pneumoniae*	
	Drug-resistant Tuberculosis	

minimum of 10-years and needs over £(GBP)1.5 billion (224). Most long-standing groups of antimicrobials have considerable resistance problems, and new approaches are needed (50).

The principal mechanisms of resistance are: restraining uptake of an antimicrobial; alteration of an antimicrobial target; degradation of an antimicrobial; and active efflux of an antimicrobial. These mechanisms can appear as innate to the micro-organism, or transferred from other micro-organisms (216, 225). Antimicrobial resistance, conferring enhanced survival for a rapidly replicating microbial species, is passed down genetically as the species evolves. Microbes employ two chief genetic plans to mitigate the antimicrobial line of attack. These are either mutations in gene(s) frequently correlated with the mode of action of the antimicrobial compound, or getting hold of foreign DNA coding for resistance factors through horizontal gene transfer (HGT) (216). Typically, microbes gain external genetic elements in one of three ways: transformation; transduction; or conjugation (216, 226).

Plasmids are extrachromosomal DNA molecules that can be found throughout the microbial population, as in other realms of life. The plasmid is considered as a means of transportation for rapid modification and adjustment of microbial populaces to altering ecological settings. Plasmid-arbitrated gene transfers act as the central task, not only in the deployment and propagation of antimicrobial resistance genes, but also in the forming of degradative pathways and pathogenicity determining factors of pathogenic micro-organisms (227, 228). Horizontal gene transfer (HGT) contributes to the rapid dissemination resistance of microbial genes. The dynamic forces of gene transmission that confer antimicrobial resistance are yet to be fully defined. There are manifold HGT mechanisms by which genes are liberated from their normal vertical microbial genetic legacy. These include conjugation by plasmids, transduction by bacteriophages, and natural alteration and conversion by extracellular DNA elements that permit genetic molecules to leap among strains and species. (Consequently, HGT enables multiple unrelated pathogenic micro-organisms to act as agents of an epidemic by transferring drug resistance conferred by an antimicrobial resistance gene (ARG) (229).

RATIONAL USE OF MEDICINE AND IRRATIONAL PRESCRIBING OF ANTIMICROBIALS

The Situation in Developed Countries

The Greek physician and earliest anatomist Herophilus [335-280 BC] mentioned that "medicines are nothing in themselves but are the very hands of God if employed with reason and prudence," indicating that the notion of the rational use of medicines is a few thousand years old (230). The judicious or rational use of medicine (RUM) was defined by WHO in 1985 as "Patients receive medications appropriate to their clinical needs, in doses that meet their requirements, for an adequate period, and at the lowest cost to them and their community" (231). The World Bank has also defined RUM in two tiers: (i) the utilization of medicines based on scientific data regarding drug efficacy, safety, and compliance; and (ii) the need to maximize the benefit of medicine in the resource-limited health system to ensure cost-efficacy (232, 233). RUM has been considered as the strategic issue in providing effective and quality healthcare (234, 235).

In the developed world antimicrobials are almost without exception legally defined as prescription-only medicines. However, a recent Norwegian study has shown how frequently travelers are able to buy antibiotics over the counter, even in EU countries (236).

Awareness of the consequences of irrational and imprudent prescriptions in raising utilization of antimicrobials with a consequential higher rate of AMR (237, 238), has led to many initiatives to make antimicrobial prescribing more careful and selective (239–241). Careful, rational prescribing, can be seen as a quality marker for healthcare (242).

However, until recently, disappointingly high rates of irrational prescribing were still seen in developed countries around the world. For example, in the USA, despite tight regulation by the FDA, rates as high as 30% and in China, where the reputable National Medical Products Administration (NMPA) is the agency responsible for strict drug strategies (243, 244) non-concordant prescribing up to 60% has been reported (237, 238, 245, 246). Even strong regulation, such as that in Europe, seems to fall short of preventing health professionals from prescribing antimicrobials imprudently (169, 247–250), which is why there have been recent initiatives in many developed countries to raise public awareness of the issues (thereby reducing pressure on prescribers) and to educate the prescribers better about AMR (251–253). Public awareness is important to tackle problems such as self-medication using leftover antibiotics from the previous prescription, and optimal duration of prescriptions is an example of health professional practice amenable to relevant education among the healthcare providers themselves (254).

The Situation in Developing Countries

Although the sale of antibiotics without prescription is illegal in all European Union (EU) countries, in practice they are available over the counter in many EU countries (255–257). This is also the case in several low and middle-income countries (LMICs), despite laws requiring that antimicrobials must only be dispensed on the prescription of registered medical practitioners (253, 258, 259). It has been reported that in the majority of LMICs, at least 19–100% of all antimicrobials are retailed without a prescription outside northern Europe and North America because of the loosely regulated and implemented private segments of healthcare (260). Furthermore, the WHO recorded that roughly 80% of all prescribed pharmaceutical products in LMICs are given out by a person who possesses almost no training or educational background in dispensing medicine (261–264).

The regulatory agencies in many LMICs failed to implement the necessary laws regarding prescription-only medicine all over the country (265, 266). Consequently, pharmacies take the opportunity to maximize their profit by selling antibiotics over the counter and over the internet (265, 267, 268). It is unsurprising that patients themselves opt to buy antibiotics and other prescription-only medicine to reduce the cost of treatment

and the hassle of obtaining treatment either through general practitioners or public and private outpatient services (269, 270).

A study conducted in Iran revealed that at least 42.7% of antibiotic prescribing was not done rationally. The authors advocated the development of new programs in collaboration with WHO to prevent the imprudent use of antimicrobials (271). Indeed, the problem is global. For example, multiple studies supported the finding that the rate of irrationally prescribed antimicrobials was even higher in Pakistan, at the rate of 60.3% (272, 273).

Even governmental attempts to improve the situation can be thwarted. For example, the Tanzanian government became highly concerned about the irrational prescribing of antibiotics and AMR (274, 275). They developed a regulatory policy that antimicrobials be limited to prescription-only medicines, sold only in drugstores with accredited drug dispensing outlets (ADDOs), and named in the local area Duka la Dawa Muhimu (DLDM). Moreover, all antibiotics are sold under the strict supervision of registered pharmacists, who are specially trained for antimicrobials dispensing. Regardless of such strict policies, the irrational utilization of these medicines remains at a very high rate of 80–85% (274–277). Additionally, 88.8% of antibiotic procurements were found to be sold over the counter for self-medication with antibiotics (278). In South Africa, more than 54% of antibiotic prescribing violates the national guidelines for prescribing antimicrobials. Ignoring guidelines results in the use of antibiotics for non-indicated diseases such as the common cold or viral infection (21.6%), inappropriate dosing (12.9%), inappropriate medicine (11.5%), and inappropriate duration of therapy (9.5%) (279). The reported use of antimicrobials in Egypt during the years 2000–2015 was extremely high—always one of the top three for per-capita antibiotic consumption worldwide. Yet multiple Egyptian studies reported a high rate of antimicrobials consumed without scientific reasons or guidelines (280–283). Additionally, antimicrobials dispensing standard in Egypt does not meet the national guideline in both qualities and quantities, which ultimately results in increasing drug resistance and the loss of healthcare budget (279, 280).

The Latin American nations, including Brazil, are troubled by irrational consumption of antimicrobials, especially self-medication with antibiotics. Even though Brazilian medicine-related law does not permit self-medication with antibiotics, around one-fifth of their antibiotic total use was self-medicated (284). Another recent report shows a much higher rate of self-medication with antibiotics at 66.2%, with around 33% of patients consumed antibiotics without any microbial diseases (284, 285). In 2010 the Brazilian Health Surveillance Agency developed a new policy for antibiotic sales over the counter without a prescription. This necessitates that pharmacists maintain a register of antibiotic sales with genuine evidence of the pharmacist's antimicrobials prescriptions to be shown to the public audit team during routine and extraordinary inspection (286, 287). This new law asserted that if any pharmacists fail to show such evidence, they face stringent civil and criminal charges. One study regarding the implementation of such laws found a decrease in the number of antimicrobials without prescription in Brazil. Consequently, studies concluded that stringent policy and planning implemented by the regulatory authority could change the overall situation of drug consumption by promoting rational and prudent utilization of antibiotics and other medicine (286, 287).

ANTIMICROBIAL PRESCRIBING: KNOWLEDGE, ATTITUDES, AND PRACTICE (KAP)

In most of the developed world and many developing countries, the prescribing of antibiotics is guided by local and national formularies (288, 289). Most of these deploy step wise guidance in terms most infections, escalating antibiotic therapy by counseling first-, second-, and third-line antibiotics for each condition. Formulary developers take into account a number of relevant issues including cost and availability; the site and severity of the infection; and the likely organisms. Severe life-threatening infections may need to be treated "blind" if the patient's life is to be saved and so "the big guns" of the antibacterial armamentarium are often reserved for these situations. Their expense, and perhaps the need for intravenous administration, are factors which often limit their use to specialist hospital units, and their relatively infrequent use may help to limit the development of microbial resistance. The more local the formulary, the easier it is to take into account local epidemiology and resistance trends, especially when these formularies are accessed on-line. It is still down to the individual prescriber to take account of factors such as the severity of infection, patient's age, co-morbidities, and immune status.

Sound principles of antibiotic stewardship are vital in guiding physicians responsible for prescribing the appropriate antibiotic at the correct dose and for the right duration. The same stewardship principles should enable prescribers to resist prescribing an antibiotic at all, if it is inappropriate to do so, but this is one of the most difficult issues. Saying "No" to a patient pressing for treatment requires advanced skills in interpersonal communication, particularly in situations where the patient is likely to go elsewhere if they do not like what the doctor is saying.

Where treatment is needed, prescribers must be mindful of the importance of achieving sustained pathogen eradication, leading to clinical cure. This is all the more important when dealing with serious infection where the objective is to minimize relapse. In hospital practice, judicious antimicrobial prescribing requires a dosing regimen which both ensures patient's safety from adverse effects and facilitates early discharge from ICU or hospital.

Prescribers are often faced with complex situations where there is a dearth of guidance. Clinical trials have often not systematically evaluated an antimicrobial for the predicament of the individual patient concerned, and it is down to the prescriber to use best judgement. For prescribers, knowledge about drugs is vital, but so too is an attitude that promotes the responsible behaviors to look after both the individual patient and the wider community, and the skills to support best practice.

Antimicrobial Prescribing KAP Among Medical Practitioners

Studies across the world demonstrate that there are serious KAP deficiencies amongst prescribers. We select here four examples: one each from Malaysia, India, China, and Baltimore USA.

The Malaysian study, conducted in a public hospital, looked primarily at knowledge. Medical officers scored moderately well on knowledge, reflecting the fact that 62.0% of the research respondents expressed confidence in prescribing antibiotics. However, despite their lack of confidence, only 18% of the respondents actually discussed the therapeutic options with a colleague before prescribing antibiotics or other medicines (290).

The Indian study conducted in tertiary hospitals revealed that was statistically significantly related to the periodic updates on bacterial resistance patterns improved medical doctors' knowledge levels, as did internal and external antibiotic-related courses. More senior doctors with 11 years' average experience were more likely to have a scientific and rational basis for antimicrobial utilization. The study also highlighted that 40% of the study respondents reported that their institute did not have a formulary or an infection control policy (291).

A recent Chinese study reported that medical doctors possessed limited knowledge and skills about prescribing antibiotics with, on average, respondents answering correctly just over half of the questions to assess their understanding (292). The study reported that medical doctors were anxious about AMR and believed that resistance is promoted by "overprescribing." They claimed to usually avoid patient pressure for antibiotic prescribing and to practice "defensive prescribing" policy, being aware of the impact of overprescribing on AMR. This study noted, however. that physicians were poorly motivated to improve and upgrade prescribing quality. The structural equation modeling (SEM) used in this study showed that poor knowledge, obliviousness to AMR, and low enthusiasm to upgrade prescribing quality all correlated with overprescribing practice for antibiotics ($p < 0.001$) (292).

The study conducted at Johns Hopkins Hospital, a 1,000-bed university teaching hospital in Baltimore, revealed that residents in medicine had a significantly higher mean score for antimicrobial prescribing than those in surgery, emergency medicine, and obstetrics and gynecology ($p = 0.04$). There were, however, no statistically significant variations in total scores between the four groups when equated for years of training, and this remained the case for sub-scores on both elementary and critical-thinking issues. At this hospital, the junior doctors were found to have less than the desired knowledge level about antibiotics, and their knowledge did not improve significantly after attending a training program (293).

Educating Medical Students About Antimicrobial Prescribing and Resistance

A study conducted in the United Arab Emirates compared KAP for medical students with their non-medical student colleagues. Unsurprisingly, this study revealed that medical students had statistically significantly higher KAP regarding antibiotic use than non-medical students with $p < 0.001$ for knowledge and attitude and $p = 0.002$ for practice (294). Medical student performance improved over time on the course, but worryingly a third of all medical students were confused about whether antibiotics were effective against bacteria or viruses.

There were some interesting findings in a Chinese study which also reported that the knowledge scores of medical students improved as they progressed across their course, and were statistically significantly higher than that of non-medical students regarding the prudent use of antibiotics ($p < 0.001$). However, the medical students' own consumption level of antibiotics was also statistically significantly higher than that of non-medical students ($p < 0.001$) (295). What this study also reported was disparity between knowledge and personal practice as regards self-medication. Senior medical students consumed antibiotics irrationally, indicating that the medical curriculum was not managing to promote prudent consumption of antibiotics in the future prescribers (295).

This appears not to be an isolated problem. Another Chinese multicenter study revealed that among medical students who had self-limiting diseases in the last month, 54% of them were self-medicated, and 27% took antibiotics. Only 21% of them consulted local medical doctors, among whom, 58% were prescribed antibiotics. Another study found that the KAP scores regarding antibiotics were significantly lower among those who practiced self-medication with antibiotics, used antibiotics for prophylaxis or requested antibiotics from their physician, compared to those with no self-medication with antibiotics (296).

Studies from India also address the relationship between what the medical student knows and what he/she does. One Indian study reported that clinical medical students were more aware of issues around self-medication with antibiotics than preclinical students. Knowledge levels reported in another Indian study were "good" but the attitude and practice scores were quite low by comparison (297). However, another Indian study reporting high scores in the antibiotics and resistance knowledge domain found that 67%, of the research respondents practiced self-medication with antibiotics, 70% stocked left-over antimicrobials, and 42% consumed these left-over medicines (298).

One Pakistani comparative study reported that medical students' knowledge scores were statistically significantly lower than the pharmacy students ($p < 0.05$). Most of the study respondents (79%) from both medical and pharmacy students reported that antimicrobials were over-prescribed in Pakistan (299).

OVERCOMING THE PROBLEMS

Undergraduate Medical Education and Training on Antimicrobials

> "*Prescribing is one of the commonest tasks expected of new doctors and is a complex process involving a mixture of knowledge, judgment, and skills* (300)."

Rational prescribing is a critically important attribute for all doctors. (301, 302). Prudent prescribing practice necessitates a comprehensive mastery of the clinical pharmacology and

therapeutics, ability to work from first principles in unfamiliar, complex, or ambiguous situations and high quality decision-making skills, honed by experience (300).

Since clinical pharmacology and therapeutics form the scientific basis of prudent prescribing (303–306), it is imperative to allocate adequate priority to these subjects in both undergraduate and postgraduate curricula, and to ensure meaningful assessment of real-life prescribing skills (300, 303, 304, 306–309).

There seems to be a strong impetus for improving undergraduate education, arising from concerns around the world about the levels of skills of newly qualified doctors to prescribe safely and effectively medicine. One British study in 2009 revealed a lack of uniformity in teaching clinical pharmacology and therapeutics and deficiencies in the teaching and assessment of prescribing skills of medical students in most British medical schools (307). Two years later, a study of newly qualified doctors, trained in very different medical schools, found that graduates entering their first postgraduate foundation year (F1) felt under-prepared for prescribing. However, there was improvement over the F1 year through practical experience and support. Participants reported that learning in an applied setting would be helpful and increase confidence in prescribing. No clear differences were found in preparedness to prescribe between graduates of the three medical schools. The authors recommended increasing the number of opportunities at medical school to develop the skill-based, applied aspects of prescribing in a controlled, "real" environment. They suggested that either simulated activity could provide this experience to undergraduates or, on clinical placements, they could write prescriptions and drug charts to be checked and signed by a doctor (310).

Another study involving 185 medical schools in 27 countries of the European Union (EU) found significant variation in clinical pharmacology and therapeutics coursework and little or no provision for medical students to be exposed to real-world clinical settings for them to develop their prescribing skills. Researchers highlighted the need for collective effort to improve undergraduate clinical pharmacology and therapeutics education congruently (308).

In a cross-sectional study of 296 medical schools in 29 EU countries, students' perception of a need for more educational interventions to support learning about rational antibiotic use varied between 20.3% (Sweden) and 94.3% (Slovakia). Lower scores in clinical pharmacology and therapeutics education and higher self-reported perception for more clinical pharmacology and therapeutics course work were associated with prescribing antibiotics for non-susceptible microbes ($p < 0.001$) (311).

Likewise, another study found that French medical students demanded more educational training in prescribing than Swedish counterparts, and the final year French medical students' self-perceived readiness to prescribe an antibiotic after graduation was lower than their Swedish counterparts (312).

A number of other studies have also supported the need for educational interventions to combat widespread findings of imprudent and irrational prescribing of antibiotics (239, 313–316).

As well as increasing the curriculum time allocated to teaching and learning about the teaching of proper selection of antibiotics (315) the emergent message from research studies is to promote educational inventions in real-life settings for undergraduate medical students (239, 310, 313).

Strategies to Improve Antibiotic Prescribing, and Reduce Self-Medication

Irrational consumption of medicines has very deleterious consequences for patients and healthcare systems, both budgetary and societal (153). WHO classifies irrational prescribing as a chronic progressive disease of any healthcare system, and as in any other chronic diseases, treatment is challenging and cure elusive, but prevention is possible (317, 318). Strategies to combat irrational prescribing include educational, managerial, regulatory, and economic interventions (153, 318, 319).

Postgraduate Educational Strategies

Undergraduate leaning has been covered above. Similar learning opportunities are needed for postgraduates. As they progress through advanced training, the science of clinical pharmacology and therapeutics needs revisiting to support doctors becoming responsible for prescribing more specialized antimicrobials. They need training to be able to assess the appropriate prescribing of new clinical entities, and it is vital that their prescribing is audited and that the doctor is given appropriate feedback. Multiple systematic reviews conclude that positive improvements in prescribing competency are most likely to be achieved with educational inventions specially tailored to local needs. (316, 320–322).

Managerial Strategies

Managerial strategies include: "Essential drug lists, kit system distribution, re-printed order forms, stock control, course-of-therapy packaging, and effective package labeling" (323). A systematic review of managerial interventions for antibiotic prescribing in LMICs improved correct dose-taking by 8.0% and adherence to the treatment plan by 54.0% as well as a 29.1% mean improvement in rational prescribing antibiotics for the treatment of resistant microbial infection and a 54.8% mean improvement in prophylactic use of antibiotics (324).

Regulatory Strategies

Poorly functioning National Medicines Regulatory Agencies (NMRAs) contribute to irrational medicine utilization and prescribing. Additionally, the absence of a national health policy on antimicrobial prescribing, the absence of drug formularies or appropriate dispensing guidance, and sagging control over how medicines are promoted to prescribers and consumers have all been found to underpin irrational medicine practice (254, 325–330). WHO estimates that only 30% of the world's NMRAs perform their principal supervisory and monitory tasks (324, 331).

WHO describes how regulatory agencies should limit the open choices to health professionals prescribing medication. NMRA approaches consist of strict rules, prioritizing generic medicines, promotion of essential medicines, and taking doubtful medications off the market (331, 332). These stringent policies are often poorly accepted by both patients and health professionals. An untoward consequence can, therefore, be the promotion of imprudent prescribing and utilization of medicine (331). Even when controls are in place, they are often circumvented or overcome by consumer pressure on prescribers and dispensers. There is a risk that people who are adamant that they want an antibiotic will desert the doctor who declines to prescribe it. The challenge for regulators is to both control the prescribing and simultaneously undertake effective public health messaging. Regulation to prevent the sale of antibiotics without prescription is essential.

Another regulatory strategy is to focus significant effort on the single most important disease area. For many countries this is acute respiratory tract infections (ARTIs). WHO estimates that <30–40% of healthcare providers issue or enforce national or international treatment guidelines on ARTI's (333). Around 60% of patients were given antimicrobials in ARTIs. Their report comprises of 679 research studies in 97 LMIC nations of (333). Other studies provide further evidence of how many NMRA's exist in LMICs, on many occasions, are not managing to control and promote rational and prudent prescribing (153, 318, 334–336), so there is scope for very significant improvement here.

Economic Strategies

Downward pressures on prescribing from regulators can have economic benefits. In Chile, a new regulatory policy, launched in 2000, successfully decreased antimicrobials sales in the private health-sector from US$37.6M 1996 to US$32M in 2000 (326).

Other economic strategies to prevent irrational prescribing are include the abolition of all commercial incentives to those involved in prescribing antibiotics and other medicines. This includes preventing direct monetary inducements or other forms of financial motivational benefits being offered to healthcare staff at any level (153, 325, 332, 337–341). Multiple studies report that the concept of "essential drugs," generic drug utilization programmes, and robust implementation of national guidelines for treatment can bring about significant benefit for overall healthcare costs (266, 340–342).

Strategies to Combat Antimicrobial Resistance

Microbes have been successfully existing on this planet for 4 billion years. The microbial community has faced and prevailed over all types of catastrophes all over the globe, and they have magnificently persisted. These microscopic creatures have efficiently proved over time that they are the survival of the fittest (343). AMR is a natural complex phenomenon, but there are several different causative influences which include the irrational use of antimicrobials (10–13, 344). The fight against AMR needs to combine a global, nationwide, and local line of attack strategy, including the promotion of rational use of antibiotics discussed above.

Less infection leads to less demand for antibiotics. Simple measures, like the cultivation and nurturing of hand hygiene routines, play a part in the effective strategies to prevent and control infections. The battle against AMR needs collective effort, multidisciplinary approaches, and ongoing supervision and monitoring policies (344). The Global Alliance for Infections in Surgery advised seven stratagems to avert hospital and community-acquired infections (345). Those policies are "patient safety; following guidelines; antibiotic stewardship; surveillance; screening patients; environmental hygiene, and hand hygiene (345)."

Some of the WHO recommended approaches include increased collaboration between governments, non-governmental organizations, professional groups, and international agencies; new networks to undertake the surveillance of antimicrobial use and AMR; a global approach to the control of counterfeit antimicrobials; incentives for the research and development of new drugs and vaccines; and forming new or reinforcing existing programs to contain AMR (344).

We have earlier in this review drawn attention to the difficulties that research scientists and pharmaceutical companies face in introducing new antimicrobial drugs to overcome resistance problems. Each endeavor requires time for researchers to overcome the scientific challenges of microbes' rapidly evolving resistance mechanisms, particularly those which involve reduced cell-wall permeability and efflux pumps with broader substrate specificity linked to their cytoplasmic membranes (162, 346, 347). It has been estimated that it takes more than 6–8 years of research effort to identify a new antibacterial active

TABLE 5 | Key findings of this review.

- The "golden age" of antibiotic discovery, produced many highly useful antimicrobials, some of which are still in use. Over time microbes have developed to all these drugs
- Antimicrobial resistance ranks amongst the world most important health problems causing misery, morbidity, and death around the globe
- The financial burden of AMR is high as both direct and indirect health costs are increased
- Innovative approaches to antimicrobial therapy will continue. However, for the foreseeable future we should not rely on any new 'magic bullet' to overcome AMR
- Shortcomings in undergraduate and postgraduate education and training significantly exacerbate the AMR problem by way of ineffective and imprudent prescribing
- Strategies to improve antibiotic prescribing and consumption require educational, managerial, regulatory, and economic approaches in combination
- Collaboration between governments, agencies, academia, pharmaceutical industry, healthcare professions, and the community is crucial in combating AMR.

against Gram negative pathogens harboring permeability and efflux pumps (348, 349). Add to this 3–4 years for completing regulatory toxicology studies, non-clinical PK/PD studies for arriving at human dose, and elucidating new drug's DMPK features, and a clinical development phase of another 4–5 years, and the residual patent life may be too short to recoup development costs, Thus, difficult-to-overcome AMR mechanisms and lack of financial incentives combine against new drug introduction and hence the WHO call for incentives for novel research.

Strategies to extend the beneficial therapeutic lifespan of antimicrobials currently available include maintaining the heterogeneity of antimicrobial agents, assuring adequate serum drug concentrations, repurposing of withdrawn and underused antimicrobial drugs, and combination therapy (350). Another possible approach to rejuvenate existing antimicrobials is to explore further combination drug therapy.

Other contemporary novel approaches include (a) bacteriophage therapy, fecal microbiota transplantation, and antimicrobial adjuvants to combat antimicrobial resistance (350, 351).

CONCLUSIONS

Antimicrobial resistance is a multifaceted problem that affects almost all communities and is driven by many interrelated factors. Single isolated attempts or interventions have a limited effect. Therefore, coordinated strategies and actions are required from various stakeholders at the global level in order to curtail the emergence and spread of antimicrobial resistance. Our key findings are summarized in **Table 5**.

RECOMMENDATIONS

- Recognition of AMR as an issue of first rank importance to each and every nation is the starting point
- The causes of AMR are multi-factorial and the approaches to combat it must be multipronged and collaborative.
- Stakeholders must work together to combat AMR, targeting different measures at international, national, community, hospital, individual, and patient levels.
- Regulatory agencies have a key role to play in abolishing the availability of antibiotics without prescription and overseeing prescribing of antibiotics that is concordant with national and local formularies.
- Prescribing doctors must be better prepared for their role by "real-world" undergraduate training in prescribing and by locally appropriate continuing professional development.
- Publicity campaigns directed at consumers must be directed at reducing their pressure for inappropriate antibiotic prescribing
- International collaboration is required to support development of the next generation of innovative antimicrobial drugs.

LIMITATIONS OF THIS STUDY

This paper has all the inherent limitations of narrative reviews. We have tried to counter subjective bias by our wide diversity of authorship from developed and developing nations. The review has benefitted from detailed and thoughtful pre-publication reviews that have strengthened the perspectives we offer.

Systematic reviews and meta-analyses offer valuable syntheses of evidence to policy makers. However, narrative reviews like this one can make an important contribution on a topic as broad as antimicrobial resistance. We have been able to combine a historical perspective on drug development with a forward-looking evaluation of prospects. We have selected evidence from across the world, including both developed and developing countries, as we tried to offer readers a chance to consider where the problems and solutions are universal, and where local factors predicate local solutions.

The literature searches were conducted in a location which offered somewhat limited access to reference sources. However, this has the benefit of making it more likely that readers from around the world will be able to access the primary references, if they so wish.

AUTHOR CONTRIBUTIONS

TI and MH: conceptualization. SD, NAAR, EP, MR, MS, MAH, TI, SI, and MH: writing—original draft preparation and supervision. SD, NAAR, EP, MR, MS, MAH, TI, SI, and MH: writing—review and editing and project administration. All authors contributed to the article and approved the submitted version.

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GENERAL COMMENTARY
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Commentary: Microbial Resistance Movements: An Overview of Global Public Health Threats Posed by Antimicrobial Resistance, and How Best to Counter

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INTRODUCTION

"Superbugs" are the antimicrobial-resistant microorganisms. Bacteria, viruses, fungi, and parasites acquire the ability to evade the antimicrobial drug effects, not only to survive but also, in some cases, become more virulent. As such, the existing antimicrobial drugs are no longer effective and useful in treating the infections (used to be treatable). Superbug-induced infections are the major worldwide health concern with higher human mortality and an increased financial burden on society. The underlying mechanism of the evolvement of drug-sensitive to drug-resistant microorganisms is an extremely complex phenomenon. It is partly related to microorganism's unique ability to modify their genetic structures and biochemical functionality to survive and keep growing even in the presence of antimicrobial drugs. Since there are multiple factors involved in developing antimicrobial drug resistance, it cannot be reversed by adopting a single prevention strategy. Of importance, certain bacterium may not require antimicrobial drug exposure to develop resistance, as surrounding environmental exposure can facilitate the resistance.

Consistent misuse and overuse of antimicrobial drugs by healthcare professionals and consumers with its extensive use in food and meat production have put human health at risk. Lack of resources for research and low interest in developing the newer generation of antimicrobial drugs are also contributing to the evolution of superbugs. Without global involvement, partnership and collaboration, superbug-induced morbidity and mortality will be unmanageable in the future. To address this impending global health crisis, in May 2015, the World Health Organization (WHO) assembly adopted a global action plan to combat the antimicrobial resistance, that include (1) to increase the awareness of antimicrobial resistance, (2) to advance research and surveillance, (3) to cut down the rate of infections through preventive measures, (4) to ensure the optimal use of antimicrobial drugs, and (5) to develop sustainable investment, taking into account the needs of the countries, to develop novel interventions. Unfortunately, implementing such WHO measures have both financial and logistic hurdles, and the rates of superbug-induced infections are alarmingly increasing.

A recently published article in "Frontiers in Public Health" has highlighted the importance of microbial resistance movements to reduce the burden of superbug-induced infections (1). The authors have elaborated on the genesis of antimicrobial drugs and listed the challenges of producing the newer generation of drugs to combat existing drug-resistant pathogens (1). Although the authors briefly touched on the irrational prescription of antimicrobial drugs in the both developed and developing countries, the review article did not discuss in depth the regulatory enforcement procedures to minimize the antimicrobial resistance (1). The opportunities and challenges of global standardization of the antimicrobial prescription processes were not explained in detail in the publication (1). Another critical area that was not emphasized enough in the article was the use of the antimicrobial drugs on animals and its potential consequences in developing antimicrobial resistance. This commentary will briefly elaborate on the cross-species transmission of resistant pathogens from animal to human. Appreciating that one single review article cannot cover all the aspects of antimicrobial resistance, the authors have fittingly highlighted the scientific and economic challenges that are hindering the novel antimicrobial drug development (1). The publication has justifiably concluded that antimicrobial resistance is a multifaced issue driven by numerous interrelated factors, and therefore, the use of any single intervention would have limited success (1). Recent publications have also emphasized why implementing an antimicrobial stewardship program is necessary to prepare the future medical professionals to enhance their awareness and knowledge of antimicrobial resistance to reduce the disease burden related to superbug-mediated infections (**Figure 1**) (2, 3).



FIGURE 1 | Schematic diagram showing the main steps needed to be implemented to minimize the antimicrobial drug resistance (2).

Antimicrobial Stewardship

Antimicrobial stewardship program is one of the most effective approaches to educate healthcare professionals to select suitable antimicrobial medications for required patients for the right period to lower the emergence of antimicrobial resistance (4). Of concern, antimicrobial drugs are commonly used in clinical practice, and around 50% of antibiotics prescribed in the hospitals are unnecessary (5). In a similar line of observation, the Centers for Disease Control and Prevention (CDC) reported that during 2010–2011, around 154 million times, antibiotics were prescribed in the ambulatory care settings in the U.S., of which ∼47 million were estimated as unnecessary or inappropriate prescriptions (6). Such an irrational use of antimicrobial drugs partly contributed to the development of resistance against the microorganisms, once treatable before the emergence of resistance (7, 8). One unfortunate example would be the treatment of gonorrhea. Azithromycin and ceftriaxone were very effective in treating gonorrhea. However, gonorrhea is no longer responsive to azithromycin and ceftriaxone treatment due to their overuse/ misuse and the subsequent development of antimicrobial resistance. The CDC categorized gonorrhea as an "urgent threat" (9, 10). Therefore, it is of utmost importance to implement antimicrobial stewardship programs to educate future healthcare professionals on the responsible use of antimicrobial drugs to improve their effectiveness and sustainability (11). As mentioned, in the U. S., the annual (2010–2011) antibiotic prescription was 506 per 1,000 population, but only 353 antibiotic prescriptions were estimated to be appropriate (6). Implementing an antimicrobial stewardship program makes it possible to reduce around 30% fewer antibiotic prescriptions yearly, which will have far-reaching impacts and benefits on human health. Although the unnecessary antimicrobial prescriptions in humans with subsequent drug exposure are among the major causes of antimicrobial resistance for specific strains, (needless) prescriptions alone are not the cause of antimicrobial resistance for all bacterial strains (12).

Antimicrobial Drug Use on Livestock

Another important area that requires intense focus to reduce antimicrobial resistance is the use of antibiotics to promote animal growth for meat consumption. In the U.S., around 70–80% of clinically important and useful antibiotics are sold and utilized for the maintenance and growth of the livestock (13). Such massive use of antibiotics on meat-producing animals is likely to promote antimicrobial resistance, although animal to the human association is not universally accepted and contested by certain groups. However, studies have shown that when foodborne pathogens (Campylobacter) were challenged with antimicrobial drugs, resistant pathogens could be isolated from the exposed animals (14). Of more concern, antimicrobial resistance remained higher for years, even after discontinuation of antibiotics (14). How quickly microorganisms can gain

resistance usually depends on the microbial strains and the drugs used (15). Even though the resistance of animal pathogens on farms can risk human health is an ongoing area of research; a U.S. study found that tetracycline-treated birds (broiler chicken) resulted in the emergence of tetracycline resistance pathogens, which were traced in the birds, and isolated from 11 members of the farms who were exposed to those housed birds (16). The study suggests the chain of events of how antimicrobial resistance can develop in the birds, and can eventually be transmitted to humans. The cross-species transmission of resistant pathogens from animal to human can be transmitted by direct contact between humans and animals by consuming contaminated food or sharing pathogen-polluted water (17). According to the CDC, more than 35,000 yearly deaths are estimated to be related to antibiotic-resistant infections in the U.S., costing more than US$50 billion (18). It is essential to realize that even if unnecessary antimicrobial prescriptions in humans are reduced, it may not necessarily eliminate the antimicrobial resistance altogether, as the use of antimicrobial drugs on animals can also initiate and propagate antimicrobial resistance. From the available evidence, it appears to be rational to advocate reducing or more preferably eliminating growth-promoting antimicrobial use in animals and birds to minimize the occurrence of antimicrobial resistance (19). Of relevance, such initiatives are partially implemented in Europe and should be executed globally. Decreasing antibiotic use reduces the prevalence of antimicrobial resistance in animals by around 15% and multidrug-resistant bacteria by ∼24–32% (19). The subsequent effect on humans is difficult to determine, but it is estimated that around a 24% reduction in the prevalence of antimicrobial resistance in humans with reduced use of antimicrobial drugs in animals (19).

CONCLUSION

Naturally occurring antimicrobial resistance is a prolonged and slow process. On the other hand, the overuse or misuse of antimicrobial drugs can rapidly induce antimicrobial resistance, and these superbugs are clinically challenging to eradicate. Through the antimicrobial stewardship program, necessary training should be provided to the healthcare professionals to reduce the unnecessary use of antimicrobial drugs to delay the occurrence of antimicrobial-resistant organisms. Also, alternatives to the existing antimicrobial drugs or supplementary agents are needed to reduce the burden of antimicrobial drug resistance. For instance, a recent publication from McGill University (in Montreal, Canada) has claimed that a cranberry extract can make the bacteria more sensitive to antibiotic treatment (20). Developing clinically viable quorum sensing inhibitors to supplement existing antimicrobial agents would be another research avenue to pursue (21, 22). Finally, the empiric antibacterial therapy during the ongoing COVID-19 pandemic is likely to enhance antibiotic-resistant microorganisms (19–21). There is an urgent need to develop more potent antibiotics and/or innovative therapeutic strategies to deal with such emerging microbial resistance (23–25). The newly developed therapeutics need to be strictly regulated to avoid the past error of overuse-antimicrobial resistance. The coordinated and collaborative efforts among the national and international governmental and private agencies are required to achieve substantial progress in reducing or delaying the occurrence of antimicrobial resistance.

AUTHOR CONTRIBUTIONS

MR: conceptualized and wrote the article.

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Interprofessional Education: Reaching Health Professionals With an Interactive Professional Virtual/Online Event on Advocacy and Policy

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Competencies in health policy and advocacy should be developed by all health professionals to effectively advance their professions but also effectively collaborate in interprofessional teams to improve public health. However, the COVID-19 epidemic presents a challenge to reaching students of health professions through face-to-face offerings. To meet this need, the University of South Florida College of Public Health developed asynchronous and synchronous online health policy and advocacy modules delivered to an interprofessional group of students pursuing health careers. After learning policy and advocacy material individually through a self-paced online curriculum, faculty gathered the students for a synchronous online event where they formed collaborative groups. In interprofessional teams, students prepared and presented advocacy briefs that were critiqued by the faculty. Post-event evaluation results showed that most students strongly agreed that the interprofessional event was very effective, and they all would recommend the program to other students. Universities and colleges educating students of health professions can take advantage of the technologies employed to keep students safe in the COVID-19 pandemic and still reach students effectively with interprofessional health policy and advocacy content.

Keywords: health professionals' education, interprofessional education, advocacy and policy education, virtual education, working in teams

INTRODUCTION

Adult learners prefer to be involved in the planning and evaluation of their instruction and to see immediate relevance of learning to their jobs or lives (1). Capturing the attention of adult learners—especially in the online environment—requires a more problem-centered approach to learning, as opposed to learning through passive reception of knowledge (2). Thus, utilization of these principles of adult education can help health professionals to be skilled in advocacy and policy development in an online environment.

However, students of health professions often lack opportunities to build effective policy and advocacy skills due to barriers in health profession education, such as competing priorities, perceived lack of time, weak support from administration, absence of expertise, and logistical impracticalities (3–5). Therefore, approaches to teaching health advocacy and policy in health profession education programs need to be further developed in the literature. There is a growing need for health professions to translate clinical and public health practice skills into design and development of health policy (3, 6). Some published pedagogical literature describing health policy education approaches exists, including descriptions of curriculum (7), case-based learning (8), practicum experiences (9), and semester-long courses (10).

In addition to basic understanding of health policy processes, there is a critical need to build advocacy skills among public health professionals (11). Recognizing that several of our greatest health achievements include clean water, passage of laws limiting toxic substances, laws removing lead from products, and use of seatbelts (12), learning public health advocacy skills is valued as a long-term investment in curricula for many types of health professions (13). Therefore, health profession students need to be taught the importance of successful advocacy of public health issues (14). Hearne (15) provides a sample advocacy course using hands-on learning with didactic and skill building exercises addressing public health areas. Other pedagogical studies reported undergraduate medical curricula that included physician advocacy components focused on population-level injury prevention (16).

PEDAGOGICAL FRAMEWORK

The Center for the Advancement of Interprofessional Education (CAIPE) defined interprofessional education as "occasions when two or more professions learn together with the object of cultivating collaborative practice" (17). More recently interprofessional education was defined as "when students from two or more professions learn about, from, and with each other to enable effective collaboration and improve health outcomes" (18). The Council on Education for Public Health (CEPH) clarifies the Master of Public Health (MPH) competency with "interprofessional" referring to the "engagement with professionals (either students in other professions or practicing professionals) outside of public health (e.g., architects, nurses), rather than engaging with individuals from other public health disciplines (e.g., biostatisticians, health promotion specialists)" [(19), p.18].

The Institute of Medicine Committee first spoke of the importance of interdisciplinary education in the 1970s. In 2003 the Institute of Medicine Committee on Health Professions Education wrote a report indicating that all health professionals should be educated as members of an interdisciplinary team. The World Health Organization (WHO) (18) issued a call to action for all health and education systems to use interprofessional education and collaborative practice to improve health outcomes. The WHO proposed that through interprofessional education the health workforce would become a collaborative practice-ready workforce and through collaborative practice there would be optimal health services. They analyzed research that found numerous benefits to collaborative practice including improved health outcomes for people with chronic diseases, improved access to care, decreased length of hospital stay and mortality rates, and increased patient satisfaction (18).

The Interprofessional Education Collaborative (IPEC) was formed in 2009 when six associations of schools of health professions joined to encourage and advance interprofessional learning experiences in the preparation and education of health-professional students for team-based care and improvements in population-based health outcomes. The Association of Schools and Programs of Public Health was one of the founding associations. In 2011, the collaborative released the *Core Competencies for Interprofessional Collaborative Practice* which is widely used as the framework for interprofessional education within the health sciences. In 2016 an update was written to organize the competencies (values and ethics, roles and responsibilities, interprofessional communication, and teamwork) into a single domain of Interprofessional Collaboration. The document also includes sub-competencies under each competency (20). In 2016, the Council on Education for Public Health updated their MPH Competencies and included a new competency in support of interprofessional teamwork (19).

Consistent with ASPPH *Core Competencies for Interprofessional Collaborative Practice* (20), the University of South Florida (USF) College of Public Health is a contributing supporter of USF Health's Interprofessional Education and Practice programming, a collaboration that includes the Morsani College of Medicine, College of Nursing, Taneja College of Pharmacy, School of Biomedical Sciences, and School of Physical Therapy and Rehabilitation Sciences. USF Health has offered interprofessional educational programming for over 10 years structured around IPEC's core competencies and each programs' specific competencies. The majority of the interprofessional education programs is offered through in-person modules. However, the need for online opportunities became more pronounced due to the COVID-19 pandemic, resulting in the development of a fully online Health Policy and Advocacy interprofessional education (IPE) module that could be piloted with students from various health professions.

LEARNING ENVIRONMENT

For this IPE, three 45-min asynchronous competency-based modules were created on advocacy and policy development. Students completed the asynchronous modules prior to the IPE session. Objectives of the two health policy modules were: (1) understand the relationship of federal and state/local governments in public health law, (2) recognize the dichotomy of common good vs. individual freedoms in public health law, (3) summarize the steps involved in the development of policy, and (4) explain the phases of health policymaking. In the first of the two health policy modules, the fundamentals

of public health law are provided to students, including an in-depth discussion of legal powers and duties of the state to protect or promote community health and the limitations on those powers (21). Topics covered in the health law module were federalism, police power, home rule, public good vs. individual autonomy, the difference between laws and regulations, and the levels and roles of government in the United States. In the second health policy module, the policy development and implementation process was outlined in detail, including the formulation, implementation, modification phases (22). Students were provided examples of how public health policy problems are identified and how these problems get placed on the health policy agenda (i.e., the "window of opportunity") (23). Also, the basics of how regulators, such as the Centers for Disease Control and Prevention, implement legislation in order to achieve the public health aims within the context of examples. Finally, students consider how to determine the outcomes of existing policy (including the unintended consequences caused by bad policy) lead to policy modification.

Objectives for the advocacy and coalition building module were: (1) define the similarities and differences between advocacy and lobbying for public health issues; (2) explain best practices for effective advocacy including communication and meeting skills with legislators; and (3) describe steps that will build effective coalitions for advocacy efforts. Topics covered in the advocacy module were definitions of advocacy which can be any person or group who advocates, supports, and argues for a cause and lobbying such that a lobbyist is generally a paid representative of a group, organization, or industry who communicates with legislators about specific legislation and expresses the view or opinion of their organization; effective tips for performing successful advocacy including, knowing the difference between regular advocacy and media advocacy such that in media advocacy the target audience are those individuals who can make policy changes; and steps in building a successful coalition. These steps focus on making sure your coalition is broad-based in participation, has a mission, goals and objectives, and stays focused on the advocacy issue during meetings and in-between meetings. Also in the advocacy module students were asked to rank areas of advocacy of which they had the most interest. These areas included: (1) universal motorcycle helmet laws, all ages, all riders; (2) increase funding for human trafficking programs; and (3) ban assault weapons. These public health areas were chosen based on relevance for the geographic area and a long history of difficulties in the passage of related legislation.

For the 3-h online synchronous activity session, 30 students participated through Microsoft Teams videoconferencing application. At the start, a brief review of major components of the modules was delivered by program faculty (1.5 h). Then, students were put into groups based on their interest of topics, as reflected in the results of the modules, for ∼60 to 70 min. During this time, the groups of students prepared an advocacy brief to be presented to all IPE participants.

Following the group break-out sessions, the groups reported out to all participants on the following components:

What is the issue?

- Why is it important?

Magnitude of the problem (data)

- How many people does this impact?
- Have current data to substantiate your position

Best practices available anywhere

- Who is doing what about your issue?
- How has it worked?
- How might it affect constituencies?

Recommendations

- What are you recommending (beside more money!)?
- Be specific, refer to elements of where this has worked

Impact/Consequences statement

- What is the impact of doing nothing?
- What is the main point you need to convey?

Summary

- Summarize why your group's issue is important and what you want change-agents to do.

A student representing each group orally presented the group's brief for the course faculty to critique. All student participants also provided feedback to the presenters. Suggestions made by the faculty included the importance of cost information related to interventions, how to reach the broadest audience possible, and connecting with lawmakers through personal accounts or stories.

After the event concluded, an evaluation of the IPE was assessed through an online survey with five largely Likert-type items and one text-based feedback question of the event. The survey questions included:

1. How effective were the Canvas modules in preparing you for the IPE event?
2. The goal of the IPE event was to engage students in a team approach to address a current healthcare issue that could be solved with health policy changes and/or a health advocacy approach. Did this event accomplish its intended goal?
3. Teamwork is one of the four core competencies of interprofessional practice. Did the breakout sessions increase your ability to perform effectively on an interprofessional team?
4. After participating in this IPE event, I am knowledgeable about the foundations of health policy and advocacy.
5. Would you recommend this program to other students in your program?

RESULTS

Thirty graduate students from the Colleges of Public Health, Nursing, Pharmacy, and Physician Assistant programs participated in the IPE session. Seventeen students were

from the College of Public Health (40%), seven students were from the College of Nursing (23%), five students (16.7%) were from the College of Pharmacy, and one student (3.3%) was enrolled in the Physician Assistant Program. Of the 30 participants, 13 responded (43%) to our program evaluation. Of these respondents, four (31%) were from the College of Nursing and nine (69%) were from the College of Public Health. The respondents found the modules very effective (23%) or effective (77%) in preparation for the event. They also agreed (77% responded definitely yes, and 23% responded yes) that the modules met the goal of the session which was to use a team approach to address a current healthcare issue that could be solved with health policy changes and/or health advocacy. For the breakout sessions strengthening teamwork ability, the majority responded affirmatively, with 77% strongly agreeing and 23% somewhat agreeing to this item. Over three-quarters of the respondents (77%) strongly agreed that the event increased their knowledge of policy and advocacy, while 23% somewhat agreed. Finally, all respondents (100%) reported they would recommend the program to other students. In terms of open-ended responses, students remarked that it would be beneficial if they had more time to work on their position paper. This could be accomplished by decreasing the time devoted to the review of concepts at the start of the event since the students were responsible for learning the modules beforehand.

DISCUSSION

The COVID-19 pandemic has interrupted more traditional IPE educational delivery; however, use of asynchronous modules and a synchronous session proved to be a feasible educational strategy. In concert with the tenants of adult education, this educational experience allowed adult learners to partake in curricula that was problem-centered and for students to be involved with the direction of the course through their teamwork discussions. It also allowed for prior and present occupational and life experiences to be built into the program and discussion, and for the learners to see immediate relevance to their fields. We encourage health programs and disciplines to pursue IPEs with their students and incorporate adult education strategies. Also, IPEs may be helpful for professional nursing, medical, public health, and allied health associations to incorporate into their education efforts.

We plan to develop additional IPEs based on advocacy and policy as a follow-up to this pilot endeavor and will continue to offer these programs as asynchronous modules followed by synchronous activities. We also will continue to evaluate the curricula for efficacy and to focus on increasing the numbers of those individuals who evaluate the program. These methods may include having the evaluation available immediately after the synchronous section or utilizing incentives for completion. While our results may not be generalizable to other interprofessional learning environments, we believe that the foundations of this approach can be translated to various topics in the health professions and tailored for program efforts.

DATA AVAILABILITY STATEMENT

All datasets presented in this study are included in the article/supplementary material.

AUTHOR CONTRIBUTIONS

KL and ZP conceptualized the content of the paper, wrote major sections, and reviewed all versions before submission. SB wrote the IPE history section of the paper and reviewed all revised versions. KL and ZP led the synchronous event and developed the asynchronous modules and activities. SB provided all administrative support. All authors contributed to the article and approved the submitted version.

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Gynecologic Oncology Sub-Specialty Training in Ghana: A Model for Sustainable Impact on Gynecologic Cancer Care in Sub-Saharan Africa

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African women have double the risk of dying from cancer than women in high-income countries. In Ghana, most women with gynecological malignancies present with advanced-stage disease when treatment is less effective. Barriers to improved cancer outcomes include the availability of cancer screening, affordability of treatment, and access to gynecologic oncology specialists. In response to a paucity of gynecologic oncology providers, an in-country fellowship training program was established at Komfo Anokye Teaching Hospital (KATH) in 2013. Historically, Ghanaian resident physicians were sent to other countries for fellowship training and were unlikely to repatriate. The establishment of an in-country training program not only addresses the challenge of "brain drain," but also builds local capacity in gynecologic oncology education and emphasizes culturally relevant and accessible healthcare. The four-years gynecologic oncology fellowship program at KATH was developed as part of a longitudinal multi-decade partnership between the University of Michigan and academic medical centers in Ghana. The fellowship trains obstetricians and gynecologists to provide subspecialist clinical and surgical care to patients with gynecologic malignancies. Fellows collaborate with the radiation, oncology and pathology departments, participate in monthly inter-institutional tumor board meetings, conduct research, advise on health policy issues, and train subsequent cohorts. This fellowship is representative of emerging twenty-first-century trends in which subspecialty training programs in low-income countries are strengthened by international collaborations. Providing specialized training in gynecologic oncology can help develop and maintain resources that will improve clinical outcomes for women in low-resources settings.

Keywords: medical education, trends and challenges, twenty-first century, gynecologic oncology fellowship, Ghana

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INTRODUCTION

Across Sub-Saharan Africa (SSA), the prevalence of gynecological malignancies is high, and subsequent morbidity and mortality are significant. In particular, cervical cancer is uniquely problematic in low-resource settings where access to routine screening is minimal. Gynecologic malignancies disproportionately affect reproductive age women, resulting in economic and social consequences for women, their families, and their communities. Due to the complexities of medical and surgical management of gynecologic malignancies, routine medical training is not sufficient to provide this specialized care. A lack of trained gynecologic oncology specialists contributes to poor patient outcomes, with a critical need for specialists to lead diagnosis, imaging, and surgical and oncologic care. Local training programs in gynecologic oncology also contribute to cancer screening initiatives, capacity for chemotherapy and radiation, and locally driven research.

We stress the importance of global partnerships in high-impact subspecialized care like gynecologic oncology. These partnerships utilize existing infrastructure and relationships to access funding and build healthcare and research capacity in low-resource settings. We explore the structure and commonalities of existing gynecologic oncology training programs across Africa, including South Africa, Zambia, Uganda, Kenya, Ethiopia, Mozambique, and Ghana.

We discuss in detail a gynecologic oncology fellowship program at the Komfo Anokye Teaching Hospital (KATH) in Ghana established in 2013 through a partnership between the University of Michigan and the Ghana College of Physicians and Surgeons (GCPS). We outline the structure of the gynecologic oncology fellowship program, including goals, entrance requirements, didactics, research requirements, evaluation processes, and local and external faculty support. Finally, to gain a personal perspective on gynecologic oncology fellowship training, we explore responses to semi-structured interviews completed by Ghanaian fellows.

PREVALENCE OF GYNECOLOGICAL MALIGNANCIES IN SUB-SAHARAN AFRICA AND GHANA

In Sub-Saharan Africa (SSA), cancer has historically taken a back seat to communicable diseases. Now that treatment of communicable diseases has improved, and life expectancies have increased, a large focus of healthcare has shifted to treatment of chronic diseases, including cancer (1). In 2018, cervical cancer was the leading cancer in half of the countries in SSA and responsible for 21.7% of all cancer deaths in SSA women (2). While the probability of developing cancer for a woman living in Uganda or Zimbabwe is 30% lower than a Western European woman, her probability of death is almost twice as high (3). In low- and middle-income (LMIC) families, women play many essential roles, including providing food, and contributing to economic support (4–6). Thus, morbidity and mortality secondary to gynecologic malignancies is especially devastating.

Demographic and health infrastructure factors unique to SSA drive the epidemiology of gynecologic cancer in the region. In SSA, higher parity and lower incidence of obesity are protective against endometrial cancer (7). However, recent trends in industrialization and urbanization, changes in smoking and alcohol consumption, increasing obesity rates, and decreased parity may increase cancer risk (8, 9). In SSA, factors contributing to the delays in diagnosis and treatment of gynecological cancers include a lack of knowledge among women, lack of confidence in a cure, fear of the cost of treatment, travel time to a treatment center, and concern over being outcast by their family (10).

Unlike high-income countries, cervical cancer is a leading cause of cancer burden and death in LMIC (11, 12), including in the West African country of Ghana (8). The annualized age-standardized incidence rate of cervical cancer in Ghana is 32.9 per 100,000 people, four times the incidence seen in high-income countries (13). Barriers to cervical cancer screening, low health literacy, and limited capacity for treatment contribute to higher incidence and morbidity of cervical cancer in Ghana. A review of the cancer registry at Korle Bu Teaching Hospital, a major cancer referral center in Ghana, found that the majority of cervical cancers were diagnosed at a late stage, and more than fifty percent of the cancers were not resectable at diagnosis (8). More than half of Ghanaian women with significant risk factors, including multiple partners and early age at first intercourse, were unaware that they were at risk for cervical cancer (14).

RELEVANCE OF ONCOLOGICAL SPECIALTIES IN SUB-SAHARAN AFRICA

One of the essential components of gynecological cancer diagnoses and management is healthcare staff specially trained in gynecologic cancer care, including gynecologic surgeons, medical oncologists, and radiation oncologists (10). Several studies indicate that the outcomes of patients with gynecologic cancers in high-income countries are improved when they receive treatment from a gynecologic oncologist (15–18). In LMICs, poor patient outcomes and low cure rates are partially attributed to the scarcity of trained gynecologic oncology surgeons (6). In SSA, local healthcare providers and medical facilities capable of managing cancer are woefully insufficient. The number of oncologists per country in Africa ranges from zero in Togo, Chad, and Burundi, to 1,500 in Egypt (19). Ghana has only four clinical oncologists (19). The workload is daunting with 25 countries in Africa reporting an incidence of cancer $>$1,000 per oncologist (19).

Gynecologists with subspecialty training in oncology can perform complex pelvic surgeries, allowing for surgical resection and debulking, with improvement in prognosis (6). Also key in the delivery of care for women with gynecological cancers in SSA is access to radiation oncologists and radiation facilities. Radiation therapy is an essential mode of therapy of at least half of all cancers in Africa (20). The International Atomic Energy Commission recommends a radiotherapy facility for every 250,000–500,000 people, but in SSA there are 140 facilities for a population of over 1.2 billion (21). Ghana, a country with

a population of 30 million people, has only three radiotherapy facilities, 12 radiation oncologists, and ten resident radiation oncologists in training (22). A study of Ghanaian women with cervical cancer reported an increase in five-years survival rate from 41% among all patients to 86.7% in women treated with radical radiotherapy as compared to palliative radiotherapy (23).

In SSA, the opportunities for specialty training in gynecologic oncology are rare. There are few trained local specialists who are qualified to train medical residents and fellows. At present, by our count, there are only seven SSA countries (including Ghana) in which a gynecologic fellowship training is currently offered. Most of these programs are very recent, with the oldest program, in South Africa, only dating back to 2008. Brain drain further depletes local human capacity as foreign-trained physicians remain in high-income countries to practice (24). Existing facilities are over-utilized, and because patient care is prioritized, the time allotted to education and training programs is sometimes cut short. LMICs are also limited by surgical supplies, imaging, anesthesia capacity, radiation equipment, and chemotherapeutics.

IMPORTANCE OF GLOBAL PARTNERSHIPS IN HEALTHCARE CAPACITY BUILDING IN SUB-SAHARAN AFRICA

Strengthening global health in Africa, in many cases, makes use of partnerships that were originally established to battle communicable diseases such as tuberculosis and HIV. Global collaborations are based on many motivations, including the link between health and economic development, the belief in a humanitarian agenda, and the recognition that healthcare developments can improve well-being globally (25).

Partnerships between institutions in LMICs and high-income countries can utilize infrastructure and relationships to access funding and build healthcare and research capacity in a part of the world that is disproportionately burdened with gynecological cancers and has limited access to resources and care (21, 26). Examples of partnerships in LMICs include the development of a training curriculum for OBGYN resident physicians in Central America based on guidelines from the Council for Resident Education in Obstetrics and Gynecology (27) and a collaboration between Health Volunteers Overseas (HVO), the Society of Gynecologic Oncology (SGO), and the American Society of Clinical Oncology to provide surgical training in Vietnam and Honduras (28). Similar programs have been established in Africa, including a partnership between the Botswana Harvard AIDS Initiative Partnership and the Beth Israel Deaconess Medical Center to provide eight weeks of gynecologic oncology services in Botswana (26), and a partnership between the University of Toronto and the Academic Model To Provide Healthcare to develop cervical cancer screening and gynecologic oncology programs at Moi University in Kenya. Technology and virtual relationships have been utilized by the University of Birmingham and Nigerian pathologists, who are providing training over Skype (29).

Many existing partnerships in gynecologic oncology care are based on a model of providing periodic assistance and training. Most are relatively new, utilize already established teaching hospitals and medical schools, require outside funding, and rely on external mentorship. Chuang et al. outlines 11 international professional organizations that are well-suited to provide training and education for healthcare providers that care for women with gynecological malignancies in LMICs. One such association is the International Gynecologic Cancer Society, which seeks to improve the quality of care women with gynecological cancers receive through education and training. The Gynecologic Oncology Global Curriculum & Mentorship Program is designed to facilitate connections between high-income country resources and LMICs seeking gynecologic oncology training. There is significant room for additional collaborations based on existing resources. In particular, academic institutions are ideal global partners given their expertise in clinical training, research infrastructure, and commitment to education.

Gynecologic Oncology Training Programs Across Sub-Saharan Africa

Several gynecologic oncology fellowships have been established across the African continent. These programs share qualities such as global collaboration with international mentors, research components, and association with a teaching hospital (**Table 1**) (30). Several of the fellowship programs arose from cervical cancer screening initiatives that leveraged international collaborations and funding (**Table 1**).

GYNECOLOGIC ONCOLOGY FELLOWSHIP AT THE KOMFO ANOKYE TEACHING HOSPITAL, GHANA

History

An OBGYN residency program was established in Ghana in 1989 through collaboration between Ghanaian academic hospitals and the University of Michigan, with funding from the Carnegie Corporation. To date, 246 OBGYN resident physicians have been trained, of which 236 (95.9%) certified specialists have remained in-country (24, 37–39). Subsequently, the University of Michigan has continued long-standing relationships with Ghanaian medical schools (40–42) and has been committed to an ongoing exchange of faculty and trainees (43). Building upon the successful OBGYN residency programs, the GCPS developed subspecialty training programs to further improve clinical care and promote research in certain specialized areas. These include fellowships in Maternal-Fetal Medicine, Reproductive Health and Family Planning, Urogynecology, and Gynecologic Oncology.

Goals

The gynecologic oncology fellowship was designed to produce well-rounded gynecologic oncology subspecialists. Graduates of the fellowship are expected to provide clinical care, conduct research, train future fellows, and provide advice, leadership, and policy guidance related to gynecologic oncology (44).

TABLE 1 | Gynecological oncology fellowship and training programs in Sub-Saharan Africa.

Gynecological oncology fellowship programs					
Country / facility	**Year start / stop**	**Global partnerships**	**Fellowship structure**	**Certifying body**	**Currently training /graduated**
Ethiopia / Black Lion Hospital (BLH)	2013	Initial HIC Partnership with Emory University and University of Toronto Subsequent HIC Partnership with Emory University and University of Michigan, joined by Martin Luther University*, subsequently joined by International Gynecologic Cancer Society (IGCS) in 2017	3 yr. program, local mentorship from practicing gynecologic oncologists (30–32)	Addis Ababa University The Association of Gynecological Oncology, Germany (AGO)—2019	1 / 6 (BLH Program) 4 graduated in 2017 2 graduated in 2019 with AGO certification
Ethiopia / St. Paul's Hospital Millennium Medical College (SPHMMC)	2015	University of Minnesota, University of Michigan, The Association of Gynecological Oncology, Germany (AGO)*, subsequently joined by IGCS in 2017	2 yr. program, mentorship from HIC programs (30–32)	St. Paul's Hospital Millennium Medical College	2/ 3 (SPHMMC Program)
Ethiopia / BLH & SPHMMC	2017	IGCS, (International Mentorship provided directly through IGCS) +	2- 3 yr. program, mentorship provided directly from HIC oncologists, 1 local supervisor	IGCS independently certifies its graduates	5/0
Ghana/ Komfo Anokye Teaching Hospital	2013	University of Michigan	4 yr. program, mentorship from HIC program and local mentorship from 1 practicing gyn-oncologist	Ghana College of Physicians and Surgeons	2 /3
Kenya / Moi University Medical School and Moi Teaching & Referral Hospital	2012	Academic Model Providing Access to Healthcare (AMPATH), University of Toronto, Society of Gynecologic Oncology of Canada, subsequently joined by IGCS in 2017	2 yr. program, HIC mentorship support for first 2 years, then local mentors took over (30, 33)	Moi University	0/ 7**
	2017	IGCS (International Mentorship provided directly through IGCS) +	2–3 yr. program, 2 HIC mentor from HIC programs, 2 local supervisors	IGCS independently certifies its graduates	3 / 1
Mozambique / Hospital Central de Maputo	2017	IGCS (International Mentorship provided directly through IGCS) +	2–3 yr. program, 2 local gynecology mentors, 5 HIC mentors, away rotations in Brazil for trainees (34)	IGCS independently certifies its graduates	3 / 0
South Africa / University of Cape Town, University of Pretoria (UP), University of Stellenbosch	2008	The South African Society of Gynaecologic Oncology joined with IGCS as part of strategic alliance partnership in 2020 ***	2 yr. program, local mentorship from practicing gyn-oncologists (30)	Health Professions Council of South Africa, Medical and Dental Professions Board	4 / NA (UP)
Uganda / Uganda Cancer Institute (UCI) and Mulago National Referral Hospital	2018	IGCS (International Mentorship provided directly through IGCS) +	2–3 yr. program, 2 HIC mentors and 1 local supervisor (30, 34)	IGCS independently certifies its graduates	5 / 2
Zambia / University Teaching Hospital—Women and Newborn	2018	IGCS (International Mentorship provided directly through IGCS) +	2–3 yr. program, 3 HIC mentors and 2 local supervisors (30, 35)	IGCS independently certifies its graduates	1/ 0
Gynecological oncology training programs					
Botswana / Scottish Livingstone Hospital	2017	Botswana Harvard AIDS Initiative Partnership, Beth Israel Deaconess Medical Center	2-weeks pilot+, HIC mentorship support (26) ++	NA	NA

(Continued)

TABLE 1 | Continued

Gynecological oncology fellowship programs					
Country / facility	**Year start / stop**	**Global partnerships**	**Fellowship structure**	**Certifying body**	**Currently training /graduated**
Malawi / Kamuzu Central Hospital	2015	University of North Carolina Project Melawi	1-week pilot project, surgical oncology, HIC mentorship support (36)	NA	NA / 1

**Information regarding Ethiopia programs verified by Dr. Dawit Worku, MD, OBGYN, Assistant Professor Gynecologic Oncologist, Addis Ababa University.*
*** Kenya program information verified by Barry P Rosen, MD, Gynecologic Oncologist, Beaumont Gynecologic Oncology Associates.*
+ IGCS program information verified by Susan Ralph, IGCS Mentorship and Training Program Manager via conference call.
****Information from https://igcs.org/welcome-sasgo/.*
++ Botswana program information verified by Rebecca Luckett MD, MPH, OBGYN, Associated Physicians of Harvard Medical Faculty Physicians at Beth Israel Deaconess Medical Center, Inc.

Entrance Requirements

Entrance requirements include passing a selection interview, completion of a residency in obstetrics and gynecology, membership or fellowship in the GCPS, the West Africa College of Surgeons, or other accredited or recognized colleges. Applicants who hold a membership in the GCPS will complete a total of four years of clinical training (two years for general gynecology and other rotations, and two years of gynecologic oncology). Those who hold fellowship will do two years of clinical training in gynecologic oncology (44).

Program Structure

The fellowship lasts a total of four years. Clinical training is composed of rotations within gynecologic oncology and related specialties. The 1st and 2nd year of training focus on core medical and surgical training on gynecologic oncology. Fellows also manage some general gynecology patients, particularly those who need complex pelvic surgery. The third year of training includes one- to two-months rotations in various related subfields, including radiation and medical oncology, pathology, general surgery, urology, plastic surgery, and wound care. During this time, fellows continue their core gynecologic oncology training, while spending several days a week on these related rotations. Days spent on related rotations are focused on inpatient management, surgical care, and emergency care. Time spent with medical oncology and radiation oncology is focused on management of patients in clinic. The fourth and final year of training consists of a six-months external rotation in a department of gynecologic oncology in a training center outside of Ghana. During the final six months of the program, fellows complete and defend their dissertation and take their certifying board exam. To supplement training conducted in Ghana and the six-months external rotation, the fellowship program also has a designated outside faculty mentor from the University of Michigan who periodically comes to do hands-on teaching in Ghana each year.

Training Sites

All clinical training in Ghana is done at the Komfo Anokye Teaching Hospital (KATH), a tertiary hospital in Ghana's second largest city, Kumasi (44). Trainees can elect to undergo a six-months external rotation in another country in order to have exposure to additional diagnostic and therapeutic training.

Education

Fellows gain experience observing and performing a wide range of surgical procedures and post-operative care. In addition to hands-on clinical training, fellows attend and present at teaching sessions and monthly tumor boards, conduct research, write reports, and attend clinical rounds, meetings, and journal clubs.

Syllabus/Curriculum

The curriculum was developed in collaboration with Ghanaian and University of Michigan faculty. The structure was adapted from gynecologist oncology training conducted in Ethiopia. The curriculum was approved by the Ghana College of Physicians and Surgeons.

The fellowship includes comprehensive training in a wide variety of topics (**Table 2**). Fellows are trained to diagnose and provide pre- and post-operative care associated with the management of a wide range of gynecologic oncologic diseases. Surgical training involves not only procedures related to female reproductive organs but also the gastrointestinal tract and urinary tract. Related procedures, including cystoscopy, thoracentesis, bowel resection, and lymph node dissection, are also learned. Development of these clinical and surgical skills is the central focus of each year of fellowship training. Daily rounds are conducted with faculty, fellows, and residents. Weekly schedules consist of the following: Monday: clinic; Tuesday: procedures including exam under anesthesia, biopsies, colposcopy, and pap smears; Wednesday: inpatient management with expanded rounds; Thursday: major surgeries; Friday: didactics.

A key part of oncology training for gynecologists is better understanding of radiation therapy and chemotherapy. A rotation in radiation oncology covers the mechanisms of radiobiology, building a treatment plan that includes radiation treatments, and managing subsequent complications. Spending time in the clinic with medical oncologists gives fellows the opportunity to better understand the basic biology of chemotherapeutic agents as well as the clinical uses and side effects. These rotations occur in the third year of the fellowship.

TABLE 2 | Syllabus content for Ghana gynecologic oncology fellowship training program.

Syllabus content
• Basic gynecologic oncology
• General surgery techniques
• Cancer of the ovary
• Cancer of the uterus
• Cancer of the cervix
• Cancer of the vulva
• Cancer of the vagina
• Gestational trophoblastic diseases
• Medical oncology
• Radiation oncology
• Imaging in gynecological oncology
• Pathology in gynecological oncology
• Urology
• Bowel surgery
• Plastic surgery
• Wound care

While fellows do not need to be able to work completely independently in these areas, they should become comfortable with consulting and working with radiation and medical oncologists (44).

Didactic instruction is provided on the basic biology of carcinogenesis, tumor genetics, and cancer immunology. Fellows will gain understanding in the pharmacological characteristics of drugs used for the treatment of various disease states, and how to manage complications that may arise from treatment. Additional instruction is provided on the basics of pathology, imaging, epidemiology, biostatistics, and palliative care. This didactic education is provided through several forums. Monthly journal clubs are held with fellows and Ghanaian faculty. Weekly virtual teaching sessions are held with fellows and a University of Michigan faculty member. Monthly virtual tumor boards are conducted with involvement from fellows, pathologists, and gynecologic oncology faculty from KATH and the University of Michigan.

Research Requirements

Fellows choose research topics within the first six months of the program and can work on their projects over the course of their training. Fellows consult with the department's statisticians, and research proposals are approved by their faculty mentor (44). The fellows are required to submit their dissertation six months prior to taking their final exams and are encouraged to publish after their exams. Submission and successful defense of a dissertation on a locally relevant gynecologic oncology topic is a requirement for graduation. In addition, fellows collaborate with Ghanaian and University of Michigan mentors to conduct and publish research. To date, the graduated fellow and three current fellows have a total of 31 publications in peer-reviewed journals, one-quarter of which were in collaboration with University of Michigan faculty. Research goals include both the generation of data that improves local and regional clinical care, as well as the development of fellows' careers in academic medicine.

Evaluation

Fellows record their surgical procedures in a logbook, which is assessed regularly by their mentor to ensure that each fellow is adequately progressing in skills development. Fellows undergo quarterly assessments to ensure they are meeting milestones. Final examinations consist of an oral exam, written exam, and a defense of their research dissertation. During the oral exam, fellows are quizzed for one h on gynecologic oncology topics. The written exam is comprised of 100 multiple-choice questions. The defense consists of a 15-minute PowerPoint presentation by the fellow, followed by a 45-minute defense. Once a fellow passes this examination, they are awarded the fellowship (44).

Local and External Faculty Support

Primary mentors for the fellows are specialists within the Department of Obstetrics and Gynecology at KATH. Additionally, radiation oncologists, medical oncologists, and pathologists are made available for fellows to consult and train with throughout the program. Furthermore, fellows benefit from instruction from external faculty. Annual surgical teaching on advanced techniques is done in Ghana by a visiting University of Michigan faculty member, Dr. Carolyn Johnston. Weekly teaching, review of readings, and presentations of case records is carried out virtually with Dr. Carolyn Johnston. A multidisciplinary tumor board is held monthly by gynecologic oncologists, pathologists, and radiation oncologists from both Ghana and Michigan. Drs. Richard Lieberman and Shruti Jolly, of Michigan Medicine Pathology and Radiation Oncology departments respectively, have not only participated regularly in monthly tumor boards but also taught at KATH and provided ad lib remote consultations.

Regarding local sustainability of the fellowship, the graduation of a fellow in 2016 was a key step in ensuring capacity for continued local training. This first graduate of the fellowship remains at KATH as a gynecologic oncology faculty member, and he oversees clinical and surgical training of current fellows. The University of Michigan has decades of partnership with academic medical institutions in Ghana, and is committed to continuing partnerships in gynecologic oncology. Collaborations in research and through the monthly inter-institution tumor board are beneficial to trainees at both KATH and the University of Michigan.

The COVID-19 pandemic has challenged traditional models of global partnerships, with safety concerns about international visits from partners to provide local surgical training. With continued advancement in surgical techniques, including laparoscopy and new methods of lymph node sampling, there is continued benefit from University of Michigan faculty providing periodic surgical training when international travel is safe. Virtual engagement between the KATH fellows and University of Michigan faculty, including virtual weekly teaching sessions, monthly tumor boards, and virtual collaboration on research, serve as important models of sustainable collaboration.

TABLE 3 | Representative quotations from qualitative interviews with past and current fellows.

Motivation	
	"When I was doing OBGYN, I also realized that for a certain group of women with cancer, there were very few people taking care of them."
	"There are not a lot of gyn-oncologists, in Ghana. So, I think that there are a lot of patients here that will need me. I will be [more] use in Ghana than going elsewhere, where there are lots of doctors and all those fancy things. I think that when I when I'm in Ghana, then I'll be able to help the people who need me most."
	"I see the cases that she [Dr. Carolyn Johnston, University of Michigan] does and there are some cases that previously we would have done and said this is not operable. But when she comes to take four or five hours and it becomes operable. I realized that we needed to do more."
Strengths of the Program	
	"We have every kind of gynecology oncology case you can think of in Ghana."
	"In fact, we have too many [cases]. The problem we have now is time to operate."
Challenges of the Program	
	"We don't have a lot of instruments for surgeries. …You have to improvise, especially with retraction. We really are in need of those retractors."
	"We had a lot of backlog, even before COVID. So as soon as we start operating, some of the backlogged patients will have been dead already."
	"I need more people to be interested in gynecology oncology. We need more fellows."
	"Laparoscopic surgeries…That is what we lack most. And that is one area that if I get any opportunity, I will gladly grab it. Because, it is the way the world is moving."
	"Screening for cervical cancer is <5% in Ghana."
	"The [radiation] machines are broken down. Also,… the chemotherapy drugs are expensive. Some of them are not on the national health insurance. So, at times, the patients have to buy and because patient cannot buy, the patient tends to default. And that's also causing a lot of problems for us."
Value of Global Partnerships	
	"I think the University of Michigan has been so much of a help to Ghana, to my hospital, and to me personally. They've been so fantastic to us and [what] I want to tell the University of Michigan is that they are really, really saving lives in Ghana and that they should keep it up. They are really helping humanity."
	"Because we can train fellows in Ghana, women with cancers are going to have quality care in Ghana. Instead of having to rely on people coming from outside to take care of them… It is because of this fellowship that was a collaboration with the University of Michigan and the Ghana College."

REFLECTIONS FROM GYNECOLOGIC ONCOLOGY FELLOWS IN GHANA

To gain a personal perspective on gynecologic oncology fellowship training, two physicians involved currently and previously involved in the KATH gynecologic oncology fellowship completed in-depth semi-structured interviews. The first interviewee is a current fellow scheduled to graduate in 2020. The second interviewee graduated from the fellowship in 2016 and is now a local mentor for current fellows in the program. Questions focused on their perspectives about the program; its strengths and its weaknesses, and challenges in the delivery of gynecological oncology care in Ghana. See **Table 3** for representative quotations.

Primary motivations for applying for the gynecologic oncology fellowship were a genuine desire to help improve care for Ghanaian women, a personal connection with gynecological cancers, and strong local and international mentors in gynecologic oncology. Fellows felt that strengths of their training program were wide exposure to various gynecologic cancers, as well as a high volume of surgical cases. Challenges of the fellowship include limitations in surgical equipment and operating room time in Ghana, a lack of access to frozen section pathology, long waiting times for pathology results, and limited capacity for radiation and chemotherapy. Looking forward to the future of gynecologic oncology training in Ghana, concern was expressed about low numbers of future fellowship candidates and the desire for exposure to laparoscopic techniques. Fellows' concerns regarding the challenges in delivery of gynecologic oncology care to women in Ghana include lack of screening and early prevention programs, poor patient education, and lack of financial resources.

Fellows recognize the strength of the Michigan-Ghana partnership and its impact on training and OBGYN care in Ghana. Benefits include surgical and didactic mentoring, research partnerships formed with faculty and trainees, and involvement in a collaborative tumor board. Room for improvement includes regulations that preclude hands-on surgical training during elective time in Michigan.

CONCLUSIONS

Gynecological malignancies are important contributors to morbidity and mortality worldwide and have a disproportionate burden in LMIC. The availability of trained gynecological oncologists is essential to provide screening, diagnosis,

surgical care, and coordinate chemotherapy and radiotherapy. Gynecological oncology fellowship/training programs in sub-Saharan Africa, many developed as part of sustained global partnerships, are relatively new but are already having a positive impact. The gynecological oncology fellowship at KATH in Ghana is a four-years program developed in collaboration with the University of Michigan. The fellowship involves weekly virtual mentorship sessions, monthly tumor board meetings, in-country surgical training, an away observership and opportunities for research. Challenges of the fellowship include limited availability of surgical instruments, advanced technology including laparoscopy, affordable imaging, and timely pathology diagnoses. Among the program's successes, however, are the increasing number of patients managed for gynecologic malignancies, and an increasing number of complex pelvic surgical procedures that can be done in-country. Fellows are also advocates for patient education and screening in medical associations and the local media. The first gynecologic oncologist graduated from the KATH fellowship, and now serves as a mentor to future trainees.

The manuscript contributes to the literature by outlining the importance of global partnerships in high-impact subspecialized care like gynecologic oncology, describing the structure and commonalities of existing gynecologic oncology training programs across Africa, and discussing a gynecologic oncology fellowship program at KATH in Ghana. Details about the structure and content of the fellowship program at KATH can be utilized by other academic institutions to adopt similar fellowship programs. Limitations include the in-depth focus on a single fellowship, and the newness of the fellowship, which limits evaluation of longer-term impact. Further research is needed to evaluate quality improvements in clinical practice as a result of fellowship graduates, and to evaluate the sustainability and changes in the fellowship over time. In conclusion, by using the KATH fellowship as a model, the expansion of gynecological oncology training programs in LMICs is essential to improve access to life-saving gynecological oncology care.

AUTHOR CONTRIBUTIONS

AE was responsible for the literature search, drafting the original manuscript, and conducting interviews. AA-K and TK provided guidance, reviewed, and edited the manuscript. SB reviewed and edited the manuscript. TJ reviewed the manuscript. CJ reviewed and edited the manuscript. EL provided guidance, edited, and wrote portions of the manuscript. KA-A and AT proofread and edited the manuscript. All authors contributed to the article and approved the submitted version.

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Student Volunteering as a Solution for Undergraduate Health Professions Education: Lessons From the COVID-19 Pandemic

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In response to the COVID-19 pandemic, many medical universities worldwide, including the Poznan University of Medical Sciences, launched student volunteering projects (SVPs). We examined our student volunteers' perceptions on the conditions, safety, costs and benefits of their participation in the SVP. Using this information, we attempted to assess the viability of SVPs as a solution for health professions education during and after the pandemic. The main research tool was a questionnaire on students' perceptions of their participation in the SVP. As a complementary qualitative method, we used semi-structured interviews with the volunteers. Our respondents (n = 158) perceived conditions and safety generally positively: most reported having personal protective equipment (89.24%), technical support (88.61%), and induction training (79.11%). Only 38.61% said they had access to psychological support. In our view, benefits (e.g., an opportunity to make new contacts or receiving positive reactions from patients and staff) seemed to outweigh costs. 65.82% of the respondents agreed that they learnt new interesting things. A majority noticed the development of their soft skills (social 86.08%; organisational 78.48%; stress management 68.99%), while 40.51% – the development of their medical skills. The interviews pointed to additional benefits for students such as gaining insight of the healthcare system, and costs such as distress caused by some patient interactions. We conclude that student volunteering could become a viable solution for health professions education. To maximise its educational potential, volunteers' needs must be explored, psychological support ensured, and opportunities for mentoring and reflection provided. The organisational framework of a SVP should be culturally sensitive.

Keywords: health professions education, undergraduate medical education, student volunteering, service-learning, community service, emergency response, COVID-19

INTRODUCTION

In many parts of the world, student volunteering (SV) as a form of community engagement is not only an important part of the mission of higher education, but also a curricular activity forming an important part of experiential learning (1). What distinguishes SV from other forms of student engagement such as service-learning or internships is the focus and intended beneficiary of the engagement. In volunteering, the focus is on the service provided and the beneficiary is the service recipient (e.g., the patient receiving care). In internships, the main focus is learning, and the primary beneficiary is the student who learns. Service-learning, in turn, attempts to strike a balance between the service and the learning components (2).

In Poland, as well as in most Central and Eastern European countries, SV is not an element of university curricula (3). Under the Polish law, volunteering is distinct from mandatory forms of experiential learning such as internships (4, 5). While Polish medical universities widely endorse various SV initiatives, they do not treat them as a teaching tool that could support student learning.

The situation changed with the outbreak of the coronavirus disease (COVID-19), declared a pandemic by the World Health Organization on 11 March 2020 (6). It presented itself not only as a global public health emergency, but also as a challenge to health professions education. Lockdowns, restrictions on gatherings, shortages of healthcare personnel, and withdrawal of students from clinical settings forced medical schools worldwide to come up with a number of educational innovations. One of them was using SV to support health systems overburdened by responding to COVID-19 (7, 8). It turned out to be a good solution to staff shortages during the crisis (9–22).

In Poland, the incidence of COVID-19 in mid March 2020 was still relatively low at 3.3 total cases per 1 million population (23), but the pandemic-related preparedness procedures contributed to healthcare workforce shortages. They had already been evident before: in 2017, Poland had 2.4 doctors (OECD mean 3.5) and 5.1. nurses (OECD mean 8.8) per 1,000 population (24). In 2019, 54% of Polish doctors were employed at more than one health facility (25). In 2020, faced with the challenges caused by the pandemic, the government obligated health professionals working with COVID-19 patients to do it at only one facility (26). On 12 March, medical universities were asked to invite students to take part in the pandemic response by supporting epidemiological institutions (27). The shutdown of in-person teaching imposed on the same day (28) banned students from practical learning.

In response to that difficult situation, the Poznan University of Medical Sciences (PUMS), in close collaboration with student organisations, launched a COVID-19 student volunteering project (SVP). The first beneficiary institutions were PUMS teaching hospitals, but soon other institutions joined, including city hospitals, Sanitary and Epidemiological Inspection offices, outpatient clinics, laboratories, pharmacies, as well as the local Chamber of Physicians, which coordinated various field activities. PUMS offered three incentives to attract student volunteers: [1] gaining a credit for a compulsory internship; [2] postponed and more flexible assessment of e-learning outcomes; [3] concessionary prices for PUMS accommodation. The project, widely promoted through official university channels and student-led campaigns, soon became very popular: 1,126 students (19.19% of all students) of 16 (out of 19) fields of study taught at PUMS took part between 12 March and 30 June. Consequently, the SVP replaced practical learning for about a fifth of PUMS students during the first wave of the pandemic.

Such a wide involvement might indicate that SV has a potential not only to support the health system during emergencies, but also, under some conditions, to become a solution for improved health professions education in post-pandemic times. It is then the role of medical universities to initiate and develop such SVPs which might complement and reinforce educational outcomes. In this article, we take a closer look at the Poznań SVP and similar projects to see what lessons towards achieving this aim they can offer to countries such as Poland – countries without traditions of incorporating SV in university curricula. As a starting point for these considerations, we use perspectives obtained from our student volunteers.

There are multiple theoretical approaches to volunteering (29, 30). We chose a cost-benefit approach as our theoretical framework. It sees volunteering as an activity undertaken by an individual when the perceived benefits of volunteering outweigh its costs (31, 32). Some of the benefits of volunteering quoted in literature include personal (e.g., learning, career opportunities, self-development), social (e.g., respect from others), and normative ones (e.g., fulfilling the civic duty, following the need to help others). Volunteering may also involve similar categories of costs: personal (e.g., time, effort, stress), social (e.g., negative social reaction), and normative ones (e.g., frustration from lack of progress towards intended goals) (31, 33). Thus, one of the aspects we explored in our study was volunteers' perceptions on selected costs and benefits of SVP participation.

The main objective of our study was to examine volunteers' perceptions on the conditions, safety, costs and benefits of their participation in the SVP. We wanted to find out which benefits incentivised our volunteers more: the internship credit or the normative benefits of volunteering. We also intended to check if volunteers noticed any educational benefits of participation. Using this information, we attempted to assess the viability of SV as a solution for health professions education during and after the current COVID-19 pandemic.

MATERIALS AND METHODS

Our main research tool was an anonymous web-based survey designed by means of Webankieta.pl (Get Feedback Racino, Sadowski, Skowronek s.j., Poland) and advertised by PUMS e-mail service, on intranet and social media. Survey completion was voluntary. Ethical review and approval was not required

Abbreviations: PPE, personal protective equipment; PUMS, Poznan University of Medical Sciences; SIs, student interviewees; SV, student volunteering; SVP, student volunteering project.

for the study in accordance with the local legislation and institutional requirements.

We used a self-developed questionnaire (see English translation in **Supplementary File 1**) with 35 questions of various types (open-ended, yes/no, multiple choice, 5-point Likert scale of attitude). There were 3 questions about students' demographic details, 3 about their previous volunteering experiences, and 29 about their COVID-19 voluntary service: volunteering placement and responsibilities, safety and conditions of the service (contact with COVID-19 patients, training, equipment, technical support, etc.), costs of volunteering (time spent, clash with educational responsibilities), benefits of volunteering (skill development, feeling needed, meeting new people, increased self-esteem, etc.), as well as the importance of helping others and receiving an internship credit as incentives to participate. In the final question we asked if volunteering confirmed the student's choice of the field of study.

The survey was available online from 4 May to 30 June 2020. After the survey closing date, we divided the study sample into groups according to the answers provided. The undecided answers to scaled questions were not included in the analyses. The groups were compared using the chi-squared test (Statistica, version 13, TIBCO Software Inc., USA) to determine significant differences between group pairs. *P* values below 0.05 were considered statistically significant.

To gain a wider view of the SVP, we used semi-structured telephoned interviews with four volunteers, including one representative of the Student Union. We asked open-ended questions about SVP benefits, costs, safety and organisation, reasons for participation, opinions on the internship credit as an incentive, and opinions on making SV a curricular activity in the future (see English translation of the topic areas in **Supplementary File 2**). We also asked follow-up questions whenever a topic needed elaboration. This allowed us to obtain more detailed information on those aspects which had been explored by means of closed-ended questions in the survey.

RESULTS

Until 30 June 2020, 161 student volunteers submitted the questionnaire. Three responses were incomplete. The remaining 158 responses were included in data analysis. The characteristics of the respondents and details of their volunteering service are presented in **Table 1**.

Conditions and Safety

With reference to the conditions and safety of their service, most of the respondents reported that they had necessary equipment/tools (93.04%; $n = 147$) and PPE (personal protective equipment; 89.24%; $n = 141$), were able to take rest breaks while working (92.41%; $n = 146$), had access to technical support (88.61%; $n = 140$), and had received induction training (79.11%; $n = 125$). However, only 38.61% ($n = 61$) said they had access to psychological support when needed. We checked if there were any differences regarding SVP conditions between those volunteers who declared that they had direct contact with patients and those who did not. The respondents who had such contact more often reported having access to PPE, but less often – having access to psychological support and being able to take a rest (see **Table 2**).

Our student interviewees (SIs) expressed generally positive opinions on the safety of the project. One interviewee (SI.1) particularly appreciated expert support from the personnel of the beneficiary institution, who were "very friendly, very helpful." Another (SI.4) said, "we were well-looked after."

Costs and Benefits

Time and the resulting learning-volunteering tensions were the only costs we asked about in the survey. The mean time of service among our participants was 39.5 days and the mean time spent volunteering was 22.04 h per week. 60.76% ($n = 96$) of the respondents stated that SV did not clash with the remote learning at the university. Two out of four student interviewees (SIs) said that lecturers respected the rule of postponing assessment for student volunteers (SI.1, SI.2), but the other two (SI.3, SI.4) noticed that violations, although rare, did happen. Three SIs (SI.3, SI.1, SI.2) said that participation was not too much of a burden in terms of time thanks to flexible volunteering schedules. One SI (SI.4) noticed that the beginnings were hard, with "too few people to fill the roster." Three SIs (SI.1, SI.2, SI.4) remarked that the SVP was associated with a different kind of cost: stress. Its primary source was contacts with "misinformed" (SI.1, SI.2), "demanding" (SI.1) or even "aggressive" (SI.4) patients. Two SIs (SI.1, SI.4) felt stressed by the overburdened health system and the resulting shortages of human resources.

We were also interested if the volunteers noticed any project benefits, and educational benefits in particular. Generally speaking, 65.82% ($n = 104$) of the respondents agreed or strongly agreed with the statement *Volunteering allows me to learn new interesting things*. A majority noticed learning primarily soft skills: social (86.08%; $n = 136$), organisational (78.48%; $n = 124$) and stress management ones (68.99%; $n = 109$). Also 3 in 4 of our SIs (SI.1, SI.2, SI.4) said that volunteering honed their skills of communicating under stress. They emphasised that opportunities of learning communication during authentic patient – health professional contacts were scarce in regular university education. On the other hand, only 40.51% ($n = 64$) of the survey respondents noticed the development of their medical skills, even though 72.78% ($n = 115$) agreed or strongly agreed with the statement that volunteering was good for their future professional development. The interviews indicate a possible reason for that: 3 out of 4 of the SIs mentioned that the service provided them with an inside view of the health system and of the difficulties connected with pandemic response. They said how eye-opening it was to see "how the system really works, how much time and effort everything takes" (SI.3), "how the system responds to the pandemic" (SI.4), and that "there are so many shortages in the system" (SI.1). One person "worked like a regular employee" (SI.1). Another felt "as if we were sent to war" and admitted that "patients didn't go easy on us" (SI.4).

TABLE 1 | Characteristics of the survey respondents and details of their volunteering service ($n = 158$).

Age (in years)	Mean	23.3
	Median	23
Sex	Female	72.78% ($n = 115$)
	Male	27.22% ($n = 43$)
Field of study	Medicine	70.89% ($n = 112$)
	Nursing	6.33% ($n = 10$)
	Medical laboratory science	6.33% ($n = 10$)
	Dentistry	3.80% ($n = 6$)
	Public health	3.16% ($n = 5$)
	Midwifery	2.53% ($n = 4$)
	Other fields	6.96% ($n = 11$)
Prior volunteering experience	YES	74.05% ($n = 117$)
	NO	25.95% ($n = 41$)
Volunteering placement	Inpatient health facility (hospital/nursing home/quarantine facility)	42.40% ($n = 67$)
(more than one answer allowed)	Hospital checkpoint	31.65% ($n = 50$)
	Home, student hostel, Chamber of Physicians or other field work not directly at health facility	20.25% ($n = 32$)
	Outpatient clinic	13.92% ($n = 22$)
	Emergency service	13.29% ($n = 21$)
	Laboratory or drive thru	12.02% ($n = 19$)
	Sanitary and Epidemiological Inspection office	6.96% ($n = 11$)
	Pharmacy	1.90% ($n = 3$)
Patient contact	YES	65.19% ($n = 103$)
	NO	34.81% ($n = 55$)
Volunteering responsibilities	Taking patients' temperature	51.27% ($n = 81$)
(more than one answer allowed)	Taking patients' medical history face to face	46.84% ($n = 74$)
	Transport or logistics of patients, equipment or supplies	36.07% ($n = 57$)
	Patient triage	35.44% ($n = 56$)
	Patient care or support	29.75% ($n = 47$)
	Documentation (reports, analyses, contact tracing)	27.85% ($n = 44$)
	Taking patients' medical history on the phone	19.62% ($n = 31$)
	Informational and educational activities	16.45% ($n = 26$)
	Supporting healthcare workers with everyday tasks or helping to provide them with personal protective equipment	10.13% ($n = 16$)
	Helping at laboratories	8.86% ($n = 14$)
	Operating diagnostic equipment	3.80% ($n = 6$)

According to SI.1, volunteering required more self-reliance than a regular internship.

Another area where the SVP proved beneficial was community links it created: making new contacts was among the most frequently observed benefits (82.28%; $n = 130$). One of our interviewees (SI.3) stressed that the project was one of the few opportunities for interprofessional collaboration offered by PUMS, and a unique chance for the students of different health professions to "leave their own castes" and appreciate skills of other specialties.

One more aspect of the positive impact of the Poznań project on volunteers was the fact that it made them feel useful for the community: they felt needed (75.31%; $n = 119$) and believed that skills might be of use to the community (77.85%; $n = 123$). Moreover, they received positive reactions from colleagues (91.77%; $n = 145$) and beneficiaries (86.71%; $n = 137$). When we asked our interviewees, they said, "we were there when people needed us" (SI.3), "we were a real help, indispensable" (SI.4), "when we didn't know what to do with ourselves, we were able to help, in an organised way" (SI.2). Please see **Figure 1** for details of the reported benefits of volunteering (**Figure 1**).

Next, we compared the importance of the tangible personal benefit (internship credit) and the intangible normative benefits among the survey respondents. 95.57% ($n = 151$) of them agreed or strongly agreed with the statement *I think it is important to help others*, and 77.85% ($n = 123$) – with *I believe that my skills may be of use to the community at this difficult time*. In contrast, only 26.58% ($n = 42$) of the respondents agreed or strongly agreed with the statement *I have decided to volunteer mostly to receive a credit for internship*. The

TABLE 2 | Reported conditions and safety of volunteering among the survey respondents with and without contact with patients ($n = 158$).

	Had contact with patients 65.19% ($n = 103$)			Did not have contact with patients 34.81% ($n = 55$)			p
I have received induction training to help me perform my tasks	YES	78.64%	($n = 81$)	YES	80.00%	($n = 44$)	$p = 0.84131$
	NO	21.36%	($n = 22$)	NO	20.00%	($n = 11$)	
I have the equipment and tools that are necessary for my work	YES	93.20%	($n = 96$)	YES	92.73%	($n = 51$)	$p = 0.91072$
	NO	6.80%	($n = 7$)	NO	7.27%	($n = 4$)	
I have the necessary personal protective equipment (face masks, gloves)	YES	93.20%	($n = 96$)	YES	81.82%	($n = 45$)	$p = 0.02780$
	NO	6.80%	($n = 7$)	NO	18.18%	($n = 10$)	
When necessary, I receive technical support (training, information materials, expert advice)	YES	86.41%	($n = 89$)	YES	92.73%	($n = 51$)	$p = 0.23365$
	NO	13.59%	($n = 14$)	NO	7.27%	($n = 4$)	
I have access to psychological support, when needed	YES	32.04%	($n = 33$)	YES	50.91%	($n = 28$)	$p = 0.02029$
	NO	67.96%	($n = 70$)	NO	49.09%	($n = 27$)	
I can take a rest break (to have a drink or meal)	YES	89.32%	($n = 92$)	YES	98.18%	($n = 54$)	$p = 0.04519$
	NO	10.68%	($n = 11$)	NO	1.82%	($n = 1$)	

TABLE 3 | Reported influence of volunteering on skills among the survey respondents grouped by attitude to internship credit as incentive ($n = 158$).

	I have decided to volunteer mostly to receive a credit for internship									
I am learning new…	AGREE 26.58% ($n = 42$)			DISAGREE 62.66% ($n = 99$)			NEUTRAL 10.76% ($n = 17$)			p
Medical skills	YES	68.18%	($n = 15$)	YES	42.42%	($n = 42$)	YES	41.18%	($n = 7$)	0.45779
	NO	31.82%	($n = 27$)	NO	57.58%	($n = 57$)	NO	58.82%	($n = 10$)	
Social skills	YES	69.05%	($n = 29$)	YES	91.92%	($n = 91$)	YES	94.12%	($n = 16$)	0.00049
	NO	30.95%	($n = 13$)	NO	8.08%	($n = 8$)	NO	5.88%	($n = 1$)	
Organisational skills	YES	61.90%	($n = 26$)	YES	85.86%	($n = 85$)	YES	76.47%	($n = 13$)	0.00148
	NO	38.10%	($n = 16$)	NO	14.14%	($n = 14$)	NO	23.53%	($n = 4$)	
Skills of dealing with stressful/difficult situations	YES	50.00%	($n = 21$)	YES	77.78%	($n = 77$)	YES	64.71%	($n = 11$)	0.00105
	NO	50.00%	($n = 21$)	NO	22.22%	($n = 22$)	NO	35.29%	($n = 6$)	

latter group significantly less often reported learning new social skills ($p = 0.00049$), organisational skills ($p = 0.00148$), and skills of dealing with stressful/difficult situations ($p = 0.00105$) than those respondents who disagreed or strongly disagreed (see **Table 3**).

While only a fourth of the survey respondents seem driven by the academic credit, two of our interviewees reported a noticeably bigger influx of new SVs after the decision to grant the credit was announced. According to SI.3, "the idea of SVP was spoiled by adding the internship credit." Another interviewee (SI.4) stated that the internship-motivated students "can't be called real volunteers" and that the decision "distorted the idea of volunteering." Both said that the students who were motivated by gaining a credit "botched up their service hours." At the same time, SI.4 and SI.2 pointed out that the decision was necessary because it partly ameliorated the suspension of practical classes and did not place additional burden on volunteers by requiring them to take internships on top of their service. Three SIs (SI.3, SI.2, and SI.4) said that replacing internships with volunteering was an emergency solution, and that volunteering in general was unfeasible as a required curricular activity but perhaps workable as an elective or selective course. SI.1's volunteering experience was "actually better than internships," but "not all volunteers were so lucky."

Finally, there was one benefit we analysed in more detail: the impact of the SVP on students' feelings about their study choices. It turned out that for 60.76% ($n = 96$) of the survey respondents, it was volunteering that helped them to make sure that they had made the right choice of the field of study. This group also significantly more often noticed some intangible benefits of volunteering (see **Table 4**).

DISCUSSION

Main Findings and Comparison With Other Studies

The first area we analysed was the volunteers' perceptions on the conditions and safety of the project. Among similar projects carried out globally in response to the COVID-19 pandemic, we found one whose participants were asked to assess safety of their service. 74.6% of the 65 medical students who were involved in testing healthcare employees through the Johannes Gutenberg-University in Mainz, Germany, felt well-protected

TABLE 4 | Reported benefits of volunteering among the survey respondents who found that volunteering confirmed their study choices compared with those who did not find that ($n = 158$).

	I have found that I made the right choice of the field of study						
	YES 60.76% ($n = 96$)			NO 39.24% ($n = 62$)			p
Volunteering allows me to learn new interesting things	YES	80.21%	($n = 77$)	YES	43.55%	($n = 27$)	<0.00001
	NO	12.50%	($n = 12$)	NO	43.55%	($n = 27$)	
	UNDECIDED	7.29%	($n = 7$)	UNDECIDED	12.90%	($n = 8$)	
Volunteering makes me feel needed	YES	89.58%	($n = 86$)	YES	53.23%	($n = 33$)	0.00001
	NO	6.25%	($n = 6$)	NO	29.03%	($n = 18$)	
	UNDECIDED	4.17%	($n = 4$)	UNDECIDED	17.74%	($n = 11$)	
I believe that my skills may be of use to the community at this difficult time	YES	87.50%	($n = 84$)	YES	62.90%	($n = 39$)	0.00016
	NO	4.17%	($n = 4$)	NO	22.58%	($n = 14$)	
	UNDECIDED	8.33%	($n = 8$)	UNDECIDED	14.52%	($n = 9$)	
Volunteering gives me an opportunity to meet new friends	YES	70.83%	($n = 68$)	YES	66.13%	($n = 41$)	0.18598
	NO	12.50%	($n = 12$)	NO	20.97%	($n = 13$)	
	UNDECIDED	16.67%	($n = 16$)	UNDECIDED	12.90%	($n = 8$)	
I think it is important to help other people	YES	95.83%	($n = 92$	YES	95.16%	($n = 59$)	0.75319
	NO	1.04%	($n = 1$)	NO	1.61%	($n = 1$)	
	UNDECIDED	3.13%	($n = 3$)	UNDECIDED	3.23%	($n = 2$)	
Volunteering is good for my future professional development	YES	87.50%	($n = 84$)	YES	50.00%	($n = 31$)	<0.00001
	NO	5.21%	($n = 5$)	NO	33.87%	($n = 21$)	
	UNDECIDED	7.29%	($n = 7$)	UNDECIDED	16.13%	($n = 10$)	
Volunteering increases my self-esteem	YES	64.58%	($n = 62$)	YES	33.87%	($n = 21$)	0.00001
	NO	11.46%	($n = 11$)	NO	38.71%	($n = 24$)	
	UNDECIDED	23.96%	($n = 23$)	UNDECIDED	27.42%	($n = 17$)	
I am learning new medical skills	YES	51.04%	($n = 49$)	YES	24.19%	($n = 15$)	0.00079
	NO	48.96%	($n = 47$)	NO	75.81%	($n = 47$)	
I am learning new social skills	YES	90.63%	($n = 87$)	YES	79.03%	($n = 49$)	0.03985
	NO	9.38%	($n = 9$)	NO	20.97%	($n = 13$)	
I am learning new organisational skills	YES	87.50%	($n = 84$)	YES	64.52%	($n = 40$)	0.0006
	NO	12.50%	($n = 12$)	NO	35.48%	($n = 22$)	
I am learning new skills of dealing with stressful or difficult situations	YES	79.17%	($n = 76$)	YES	53.23%	($n = 33$)	0.00058
	NO	20.83%	($n = 20$)	NO	46.77%	($n = 29$)	
I am making new contacts	YES	87.50%	($n = 84$)	YES	74.19%	($n = 46$)	0.03245
	NO	12.50%	($n = 12$)	NO	25.81%	($n = 16$)	
I am receiving positive reactions from the people I help	YES	91.67%	($n = 88$)	YES	79.03%	($n = 49$)	0.02236
	NO	8.33%	($n = 8$)	NO	20.97%	($n = 13$)	
I am receiving positive reactions from the people I work with during my voluntary service	YES	94.79%	($n = 91$)	YES	87.10%	($n = 54$)	0.08566
	NO	5.21%	($n = 5$)	NO	12.90%	($n = 8$)	
I am receiving a positive response from the community/gaining social esteem	YES	76.04%	($n = 73$)	YES	58.06%	($n = 36$)	0.01706
	NO	23.96%	($n = 23$)	NO	41.94%	($n = 26$)	

during service, although only 12.19% felt well-prepared for their tasks (16). In our study, students' perceptions on safety sometimes differed from what was guaranteed to them under their contracts with beneficiary institutions. Alarmingly, nearly 7% of the respondents who had contact with patients reported that they did not have the necessary PPE. It is also worrying that over 20% of the respondents said they had not received induction training, and around 11% did not have technical support (including training, information materials, and expert advice). On the one hand, these numbers reveal the weakness of the health system during the crisis. On the other hand, they may result from the fact that the project was organised *ad-hoc*, without sufficient material and human resources to guarantee proper safety and arrange a training and mentoring framework. A solution to that could be using fast-track remote preparatory courses: either tailored ones developed by universities for their

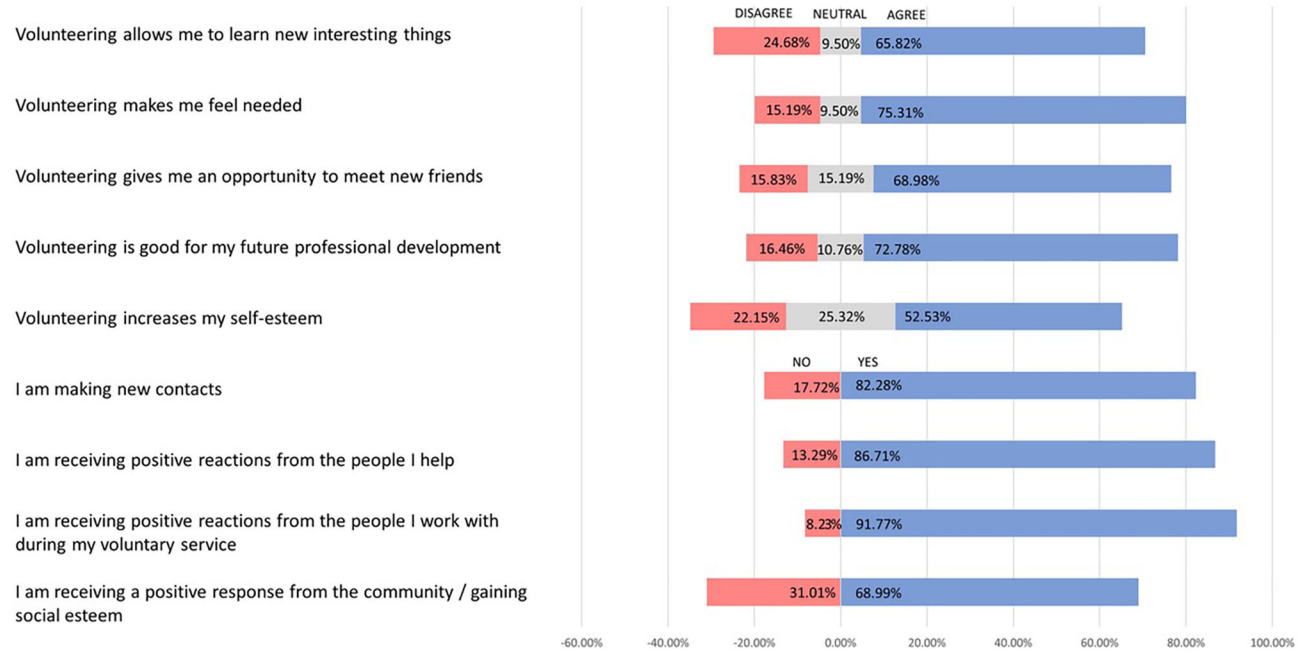


FIGURE 1 | Reported benefits of volunteering among the survey respondents ($n = 158$).

own students, as it happened at universities in the USA (20), Denmark (17), and Switzerland (13), or courses already prepared at different universities and made available to other medical schools, as was the case with Harvard Medical School, USA (19). Our findings also suggest that it is crucial to ask student volunteers about the safety and conditions of volunteering in order to discover and resolve any discrepancies between policy and practice.

In the area of costs related to SVP participation, we found that nearly 40% of the survey respondents felt that the service clashed with their learning responsibilities, and 2 out of 4 SIs reported (though infrequent) difficulties arranging postponed assessment with individual lecturers. This indicates that the university authorities failed to properly explain or communicate the new assessment rule to the faculty, or just failed to enforce it rigorously enough. Another cost, which we did not ask about in the survey but which was mentioned during the interviews, was stress. Coupled with the absence of psychological support reported by over 60% of the respondents, this indicates that insufficient care was taken to ensure volunteers' well-being. Well-being assistance does not always require substantial institutional outlays: it can be provided by volunteers themselves, as it happened at the Columbia University in the USA (11, 18).

When analysing benefits connected with the service, we were particularly interested in the educational benefits. The majority of our participants reported learning new skills, and so did participants of other COVID-19 SVPs. The participants of the Mainz study noticed the positive impact of volunteering: 68.3% said they had learned new skills, and 81.0% said they had improved their existing skills due to the commitment (16). More specific questions about skills were asked to medical student volunteers from the Reno School of Medicine, USA, who staffed a COVID-19 hotline for rural communities. The students reported 75 to 366.67% improvement in comfort with various tasks connected with audio-only patient contact (20). Another detailed account of educational benefits of volunteering was collected in an open-text survey among students from the University of Nebraska College of Public Health, USA, supporting COVID-19 public education and efforts of a local epidemiology team. The benefits listed by the students included such valuable skills as real-time data collection, social media monitoring, and effective communication with communities and public health organisations (22). Since our student volunteers performed a wide range of tasks, we asked them only about broad categories of skills. The survey results suggest that volunteering positively influenced students' soft skills (especially social ones). In addition, our respondents widely recognised social benefits of volunteering: feeling useful to and being appreciated by the community. The importance of this aspect was also highlighted at the Paulista School of Medicine in São Paulo, Brasil. Its SVP, inspired by medical students, generated enthusiasm, a sense of purpose and gratitude from beneficiaries. As the authors put it, "the project's main outcome is the moment of solidarity it has started, involving more and more participants and impacting far beyond the hospital walls" (10).

The interviews with our students indicated that volunteering also enhanced their understanding of how the health system works as a multidisciplinary whole. In fact, the Poznań project seems to be among the few interprofessional COVID-19 SVPs described in the latest literature, partly due to the fact that some

medical schools offer only medical programmes. A large-scale multidisciplinary SVP was initiated by the Columbia University Irving Medical Center in New York, USA; it soon turned into a national initiative (11, 18). The project website stresses that collaboration should be interprofessional "to promote students learning with, from, and about each other through their service" (34). Another multidisciplinary project was launched at the University of Nebraska Medical Center in Omaha, USA, where a number of student-led volunteering initiatives were integrated with the activities of an emergency preparedness and response institution. The result was a "campus-wide, interprofessional effort with a diverse volunteer pool," which replaced "siloed volunteer structures designed by and for specific health professions" (14).

It should be noted that the area where our students noticed the least improvement thanks to the SVP was learning new medical skills (40.51%). It is hardly surprising. The decision to treat the SVP as an equivalent of regular internships was understandable, but problematic. Understandable, because it meant that student volunteers thus gained a chance to hone at least some practical skills during the lockdown. And problematic, because volunteering did not always teach them the skills required by the curriculum and did not offer many opportunities for mentoring, feedback and reflection. It was caused by the *ad-hoc* character of the initiative and the resulting absence of a pre-existing conceptual model and organisational framework.

For example, the concept of our SVP was largely determined by the fact that student volunteers were initially treated as emergency workforce rather than stakeholders in their own right and with their own needs. This might have been caused by the fact that representatives of particular beneficiary institutions did not participate in the works of the SVP coordinating team. Closer collaboration of all the stakeholders might have enabled the university authorities and the students themselves to promote a more balanced project concept, with a bigger focus on students' learning needs.

The available literature suggests that the pandemic SVPs which offered the most to students in terms of educational benefits were those organised at universities using well-tried models of experiential learning and having long-standing traditions of doing so. Such models are often based on community-campus partnerships and incorporate appropriate mentoring and reflection mechanisms to support student learning. One example was the SVP at Columbia, USA, where a service-learning model was used to ensure close collaboration between students and faculty members and to bridge community needs with student learning objectives (11, 18). The university required its student volunteers to take part in reflection and debriefing sessions (18). Aalborg University, Denmark, also decided to match the pandemic emergency with the learning objectives of undergraduate medical curriculum. As the university had relied on problem-based learning since 1974 (35), it managed to make its COVID-19 SVP operational within 2 weeks thanks to close collaboration between the hospital, the university, and students' organisations. A new portfolio was constructed for student volunteers for assessment purposes (17). At British Columbia, Canada, volunteering was partly incorporated into FLEX, the university's flexible programme of individual scholarly projects (12). The projects are guided by supervisors, who help students develop project activities, provide direction and mentorship during students' engagement, and assess their performance (36). It can be concluded that volunteer service is easier to incorporate also into curricula which include individual learning opportunities.

All the three models described above assumed granting academic credits to student volunteers and treating SVPs as curricular activities. Such a practice is well-grounded and seems to work well at universities around the world (3, 37). It should be noted, however, that formalising and mandating voluntary activities is a sensitive issue. A formal incentive or requirement to volunteer may encourage participation (38, 39), but might sometimes be perceived as an imposition taking away students' time and may consequently reduce their internal motivation to volunteer, satisfaction levels, university commitment, and future intentions to volunteer (40–42). Some of these consequences might have arisen in the Poznań SVP. Although the internship credit proved to be a powerful magnet to our volunteers, some student interviews suggest that the volunteers it attracted were not as conscientious as the others. Those survey respondents who were incentivised by the internship credit also significantly less often reported learning new soft skills while volunteering. The reasons would require more in-depth research, but one possible explanation could be decreased motivation and satisfaction due to the presence of an academic credit perceived as a form of external constraint. If this is the case, the experiences from educational systems with mandatory volunteering show that it is possible to mitigate the negative effect of requirements by increasing volunteers' perceptions of intrinsic motivation (e.g., by demonstrating how volunteering fits with students' own goals) and autonomy (e.g., by allowing volunteers to choose placements matching their primary motivations) (43, 44).

Finally, turning volunteering into a curricular activity in post-communist countries of Eastern and Central Europe may be hindered by specific cultural and social factors. According to Preradović and Mažeikienė, these societies have deeply embedded mistrust of volunteering through public organisations, which were highly regulated in the communist times. At the same time, they have well-developed informal social networks which tend to be favoured over formal structures (45). This is corroborated by the latest survey by Statistics Poland, which found that 30.9% of the respondents had been involved in informal volunteering within 4 weeks prior to the survey, while only 8.5% had engaged in formal volunteering (46). This means that building trust in formal volunteering within these societies may take time and may require paying special attention to organisational and procedural transparency. As Preradović and Mažeikienė pointed out, the faculty in these countries are often underpaid and overworked compared to their peers at universities in Western Europe and the USA. Consequently, they may not have enough time and motivation to seek innovations in curricular design (45). Therefore, it would be wise to use the experiences of predecessors and build partnerships with universities with longer traditions

of experiential learning. It must be stressed, however, that such solutions are culture-sensitive and should not be simply transplanted from the countries where they originated and whose civic cultures they match. While foreign models should be explored to avoid reinventing the wheel and duplicating efforts, local challenges and determinants must be identified. Thus, to guide future practice, in-depth research is required to determine the expectations and preferences with regard to SV among different stakeholders: students, faculty members, and beneficiary institutions.

Strengths and Limitations

The strength of our study is the fact that it presents SV experiences in a country without traditions of infusing volunteering into university curricula. On the one hand, volunteering of health professions students in Poland meant more than just filling the gaps in the understaffed health system, which seemed to be the case in some African countries (15). On the other hand, it fell short of being an effective educational tool, which was the case in the countries where formalised SV has longer traditions. As such, the Polish SVP can be quite instructive to medical schools in communities with similar characteristics.

A limitation of this study was the use of a non-standardised questionnaire as our primary research tool. We asked the questions that, in our opinion, best suited the circumstances. Next, the study did not investigate the impact of the SVP on the community and the perspectives of all the stakeholders: patients, faculty members, and staff of beneficiary institutions. Finally, we did not fully explore volunteers' satisfaction with the project, their views on its weaknesses, and opinions on the viability of volunteering projects as future curricular activities.

CONCLUSIONS

The 2020 COVID-19 pandemic taught us a few important lessons. Although it caused a serious disruption of health professions education, it also gave rise to a number of valuable SV initiatives around the world. It suggests that SV is a viable solution for such disruptions and that the patient contact opportunities it offers may well complement remote or simulated learning. However, if SV is to effectively support health professions education, it requires a systemic approach which includes:

(1) promoting the idea of SV by presenting its benefits in order to tap and fuel volunteers' enthusiasm;
(2) using a well-thought-out and transparent organisational framework to balance the needs and channel the efforts of multiple players;
(3) maximising the educational benefits of SV by introducing opportunities for mentoring and reflection;
(4) maximising volunteers' safety by ensuring induction training, sufficient equipment and psychological support;
(5) exploring expectations of all stakeholders in order to develop and implement culture-sensitive solutions.

Our SV experiences showed that health professions students are willing to volunteer in large numbers and appreciate the practicality of volunteering, which often helps to confirm their career choices. We believe that such initiatives can become an impulse for implementing SV as a complementary element of health professions education in Poland and other countries of Central and Eastern Europe, where formal volunteering is still approached with reserve. Our findings as well as the available literature lead us to conclude that such countries could use the best practices from more experienced educational systems to build a strong SV organisational framework, but at the same time should make sure that formalisation of volunteering does not reduce the perceived value of volunteering in the eyes of the participants.

To achieve the first goal, a university should consider setting up a permanent student volunteering committee that would develop appropriate procedures for launching and running SVPs during and between emergencies such as epidemics. In non-emergency periods, a small number of SVPs could be made available to students on a regular basis. In emergency times, the procedures would allow for a swift and smooth launch of additional SVPs to support the understaffed healthcare system. The committee, acting as a liaison between different stakeholders, would determine, record and match the personnel needs of healthcare facilities with students' educational needs defined in curricula.

To achieve the second goal, a university should try to maximise and capitalise on the voluntary nature of SV so as to increase the intrinsic motivation for participation. One way to accomplish that is to build and emphasise the educational potential of SV, for instance through feedback and debriefing sessions with peers and mentors, or through official and informal communications presenting educational benefits of volunteering. Another way is to devise a model of volunteering based on student autonomy, with as many points of choice as possible. For example, an undergraduate health professions student could choose from the following forms of participation in volunteering:

(1) **internship SVPs as an alternative to regular internships**. In times of emergency, students could choose to participate in internship SVPs or wait until regular internships are resumed. Since each course and year has specific learning outcomes to be achieved during internships, this form of participation would probably be the most suitable for first- or second-year students required to develop non-specialist competencies or soft skills. Placements might involve registering patients, managing patient flow, doing administrative jobs or epidemiological tasks. A student would be granted a credit after completing the required number of hours and reflecting on them in an internship report, and given a mark based on performance assessments made jointly by a supervisor from a host facility and an internship coordinator from the university;

(2) **elective SVPs**. Each student is required to choose one or more elective courses to gain a specific number of credits in a given year, but electives are not as strictly regulated as internships in terms of learning outcomes. As such, elective SVPs would be available to a wide group of students provided that they meet entry requirements set by healthcare facilities. Taking an elective SVP would give a student an opportunity to choose from a number of different placements, some of them offering insights into unfamiliar settings or novel tasks. A credit would be granted after completing a pre-defined number of hours and submitting an assignment required by an elective coordinator;

(3) **non-credit SVPs**. This form of participation could be offered to all students willing to volunteer just for the sake of volunteering. It could also be open to the students who completed the required number of hours as part of their credited volunteering but wish to keep helping others. The participants would be free to choose the length of their service as well as their placement on condition that they met entry requirements.

The implementation of such a model may present a big organisational challenge. However, with the first steps already taken by numerous universities during the COVID-19 pandemic, continuing along this road could soon pay off and benefit students and patients alike.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

EC, RS, AL, and JW: conceptualization. EC, MK, and MC: methodology. DB, RS, AL, and EC: acquisition of data. EC, MC, MN, BG, and AL: analysis of data. EC, RS, AL, BG, MK, DB, MN, MC, and JW: writing, review, and editing. RS and AL: project administration. EC and JW: supervision. All authors gave final approval of the paper and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2020.633888/full#supplementary-material

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Addressing Challenges in Humanistic Communication During COVID-19 Through Medical Education

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The current global pandemic due to COVID-19 has resulted in widespread lockdowns, social distancing, and other protective guidelines; these infectious control and mitigation measures challenge the medical system and create anxiety among all populations. In hospitals and healthcare facilities, patient interaction and shared decision making are sacrificed for fear of COVID-19 nosocomial spread. The intangible effects of human interaction with COVID-19 patients, whether of a physician or a patient's family, are replaced with isolation amid ventilators. Medical professionals must find a way to practice life-saving medical care while maintaining humanistic and professional interactions. This article provides insight into the necessity and challenges of humanistic communication during COVID-19 across various institutions and offers both short- and long-term solutions and reforms through medical education.

Keywords: medical education, COVID-19, humanism, pandemic, humanistic

INTRODUCTION

In March 2020, the Coronavirus disease 2019 (COVID-19) rapidly transitioned to a worldwide pandemic, significantly affecting both the general population and the medical community (Adams and Walls, 2020). As the virus spread, physicians were confronted with caring for infected patients, who were not only critically ill but also fearful of their potential mortality. In order to control nosocomial spread, infection precautions were implemented, such as isolating patients to confined rooms without family or friends and maintaining physical distancing by communicating with medical staff via phone or video (Sonis et al., 2020). For healthcare providers required to enter the room for assessment and delivery of care, the utilization of personal protective equipment (PPE), including but not limited to masks, shields, gowns, and gloves, was essential for safety (Adams and Walls, 2020). From an institutional standpoint, these precautions were necessary to limit spread of the virus within the facility. To patients and providers, these restrictions caused a significant emotional toll (Sonis et al., 2020). Patients' anxiety and fear of the virus heightened when unable to recognize providers covered head-to-toe in protective gear. Physicians were exhausted under layers of PPE, overworked due to increased demand in critical care and infected patients, and worried about how they were to take care of their patients in this unfamiliar setting (Sonis et al., 2020).

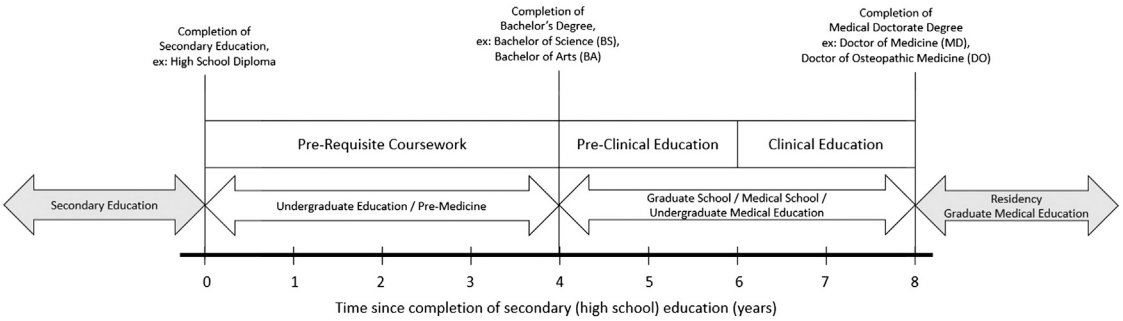


FIGURE 1 | Medical Education Framework—In the United States, traditionally, completion of high school (secondary school) education and the awarding of the high school diploma or equivalent is followed by four years of education at an undergraduate school; this is commonly known as "pre-medicine," as it requires pre-requisite coursework for education at a graduate school, specifically "medical school" for those whose intent is to become a physician, and ends with the completion of a bachelor's degree or equivalent. Subsequently, medical school, also known as undergraduate medical education, is divided into two years of pre-clinical education followed by two years of clinical education, totaling four years, and culminating in the earning of the medical doctorate degree, either the doctor of medicine (MD) or doctor of osteopathic medicine (DO) degree. In most instances, one must continue to residency, also known as graduate medical education, after the completion of medical school, varying in length based on specialty, to meet qualifications for a license to practice medicine.

MEDICAL EDUCATION

Medical Education Framework

It is important to focus on medical education in the midst of a pandemic because of its direct influence on the training of future physicians; progressive and innovative curricular modifications can positively impact the development of future healthcare heroes while disruptions could lead to drastic effects on patients and the communities which physicians serve. In the United States, the traditional four-year medical education curriculum (medical school, or "med school") begins after completion of a bachelor's degree and necessary pre-requisite coursework (pre-medicine, or "pre-med"), with the first two years in the classroom or lecture hall to acquire fundamental basic science and clinical knowledge, designated as "pre-clinical" education, and the last two years spent in hospitals and various clinical training sites, transitioning every two to eight weeks to a different specialty, known as "rotations" within "clinical" education (**Figure 1**). Pre-clinical students accustomed to instruction in large lectures or peer interaction in smaller classrooms are now taught virtually through live-streamed or recorded lectures to decrease risk of infection spread and to safely practice social distancing (Samarasekera et al., 2020; Singh et al., 2020); this led to a direct impact in medical schools utilizing laboratories and cadavers for dissection in first-year anatomy and introductory history and physical examination courses, requiring a shift to a digital platform. Clinical students were removed from in-person rotations and provided an online curriculum, due to the risks of contracting the virus and either becoming ill or remaining asymptomatic and acting as carriers, or spreaders, of the disease (Rose, 2020). Adaptations were rapidly made for the delivery of medical education.

The clinical years are typically thought of as the formative years of a medical student's journey (Holden et al., 2012; Gaufberg et al., 2017). Rotations allow students to physically immerse themselves in different medical specialties and discover their professional identity. Their experiences in hospitals and healthcare centers, being part of a patient's care team, learning clinical skills, and collaborating directly with physicians is not something that can be entirely reproduced online (Rose, 2020). Yet, in late Spring 2020, medical schools had no choice given the severity of the pandemic. Medical students were also challenged with the cancellations of licensure examinations, required for continuing to graduate medical education, or residency, after medical school. While these adjustments in medical education may seem minor compared to the worldwide effect of the pandemic, their implications on the training of medical students is yet to be measured. With limited time to provide a substitute online curriculum, it is still unknown whether the lack of clinical experience, as well as lack of patient interaction during times of uncertainty, could affect the student's future humanistic performance in residency and beyond (Ferrel and Ryan, 2020).

Humanism in Medical Education and Practice

Medicine was founded on the responsibility of establishing a strong physician-patient relationship, through verbal and non-verbal communication. The physician's role was simple: to benefit the patient by bringing science and humanism together (Schwenk, 2020). Humanism is defined as actions and attitudes of physicians which address not only concerns but also values of patients, showing both respect for and interest in patients (Branch et al., 2001). Similar to professionalism, humanism is considered an essential component in medical education. A physician embodies humanistic values when the patients' social, cultural, spiritual, and emotional experiences are taken into consideration when providing care (Lomiguen et al., 2020). With humanistic care, there is respect and dignity toward both parties as well as compassion and communication (Cohen and Sherif, 2014). Modern medicine and the public health system have challenged humanism by giving physicians more responsibility and more commitments, making it difficult to prioritize the patient. With the rise of scholarly activity

requirements, lab orders, and dependence on technology, medicine has shifted toward "dehumanization in care" with resultant patient dissatisfaction (Gorlin and Zucker, 1983). Physicians now spend more than half their time documenting, or "charting," on computers rather than using that time engaging and enhancing patient care (Schwenk, 2020). Despite technology emerging as a way to help physicians provide greater and more efficient care for their patients, it has turned into a distraction from patient interaction (Gorlin and Zucker, 1983). Before the pandemic, physicians were burdened with increasing tasks and demands and facing burnout (West et al., 2018; Thuma et al., 2020). Challenges and pressures led physicians to diminish humanistic practices to compensate for the amount of time required for additional responsibilities (Cohen and Sherif, 2014). It took a worldwide pandemic to remind healthcare workers of the necessity of humanism and professionalism through the "nature of suffering and the fragility of life" (Benatar and Daneman, 2020).

While humanism is taught in medical schools, its current emphasis is insufficient. Past studies have provided some evidence that suggests adding professional and humanistic aspects of medicine is effective in medical school (Cohen, 2007); however, medical students are critical of how they are taught (Haidet et al., 2001; Lypson and Hauser, 2002). In recent years, a contributing factor in teaching medical students humanism is for high pass rates on medical licensure examinations, or "board exams," in addition to learning to foster patient relationships. In 2005, the National Board of Osteopathic Medical Examiners (NBOME) established the Comprehensive Osteopathic Medical Licensing Examination of the United States Level 2 Physical Examination, abbreviated COMLEX-United States Level 2 PE, a practical examination in which fundamental clinical skills assessed are categorized into one of two domains: the Biomedical/Biomechanical Domain and the Humanistic Domain. The Humanistic Domain is inclusive of physician-patient communication, interpersonal skills, and professionalism (National Board of Osteopathic Medical Examiners, 2020). Achieving humanistic competency is essential, as poor communication between physicians and patients is a detriment to healthcare, decreasing quality and increasing costs of care (Institute of Medicine, 2001; Frankel, 2006). However, medical students may face a disconnect in humanism when they enter clinical years through exposure to poor professional behavior by other members of the healthcare team (Jones et al., 2004; Huggett et al., 2008). The result is that many medical students view humanism as a requirement to pass their board exams, but not a requirement for a practicing physician. Moreover, the humanistic ideals are further lost as medical students transition to residents because residency programs may not emphasize humanism. Therefore, it is necessary to have proper humanistic curricula in the preclinical and clinical years of undergraduate medical education as well as in graduate medical education to foster change that can lead to life-long practice changes in healthcare.

The pandemic revealed the need for interpersonal skills for the healing process and positive patient outcomes. As students, residents, and physicians begin to embrace humanism in practice, the future of health care will greatly improve (Benatar and Daneman, 2020). This paper offers three short-term strategies to include in medical education to encourage humanism in medical practice during the pandemic: effective physician-patient communication, telemedicine, and empathetic techniques. Long-term strategies include suggested requirements in humanism for institutional assessment and evaluation as well as for continuing medical education, board certification, and licensing renewal.

DISCUSSION

Encouraging Humanism During the Pandemic

First, effective physician-patient communication is of the utmost importance during the pandemic. Therefore, it is important to teach medical students the humanistic ideal of presence, which refers to "aspects of awareness, acceptance, availability, and expressiveness" (Hoffman, 2020). Presence involves the physician and patient recognizing the role of one another and building a trusting relationship. During times of uncertainty, such as a pandemic, it is crucial that this step not be diminished. Establishing a meaningful relationship is significant because it gives the patient a sense of safety and commitment for long-term follow-up care (Hoffman, 2020). Additionally, the physical presence of healthcare workers, much like gloves, masks, hand sanitizers, and ventilators, was of increased value and demand, as healthcare worker shortages were pronounced during the pandemic (Adams and Walls, 2020). This was further exacerbated at the height of the COVID-19 pandemic when medical students assisting in hospitals were removed from in-person rotations for safety and placed under stay-at-home orders with the rest of the general population. Students felt the chaos in the general population but were unable to witness the emotional trauma felt by patients as well as the gravity of meaningful physician presence and patient communication. As medical students can feel overwhelmed with the vast amount of factual basic science and clinical knowledge they must learn, it is important for curricula to include coursework and lessons on effective physician-patient communication, ideally with the use of live practice patients, also known as standardized patients. Assessments should also serve to evaluate effective communication, rather than the mere regurgitation of facts. Teaching students the importance of presence in everyday medicine will create more humanistic physicians.

Second, training on telemedicine practices is imperative. During the COVID-19 pandemic, practicing social distancing and keeping safe from contracting the virus has meant only seeing patients in-person when necessary (Jnr, 2020). To continue seeing patients, physicians began to rely on telehealth. Although telehealth is a technology-based patient encounter, its use throughout the pandemic has demonstrated advancement of technology does not necessarily require medicine to be dehumanized (Stimell-Rauch et al., 2020). Despite telehealth seeming distant and removing the traditional history, physical examination, and other entities of the physician-patient in-

person interaction, the connections established virtually can feel intimate in that it is unrushed and without external distractions. Telehealth can have a meaningful impact on a patient's life, especially during times of isolation. The physician's role in telehealth remains the same: to establish a physician-patient relationship and to guide patients through their care (Stimell-Rauch et al., 2020). While technology and humanism are separate entities for consideration, there exists a relationship, where one needs the other to function properly. In both undergraduate and graduate medical education, medical students and residents, respectively, should practice forging relationships via telehealth by occasionally scheduling virtual encounters with their outpatient follow up visits. As students are re-integrated in the clinical field, they should also attempt to view or participate in virtual encounters. Pre-clinical students are taught how to conduct a proper in-person history and physical examination prior to beginning rotations. In the future, it will be necessary to simultaneously teach students how to perform a virtual patient encounter. As the use of telehealth continues to increase, residents and medical students should become familiar with virtual patient encounters.

Third, an emphasis on empathic communication techniques are especially needed to comfort patients in-person or in virtual patient encounters during the pandemic. For example, a useful humanistic mnemonic to use in both settings is ICARE, which stands for Introduction, Collaboration, Acknowledgment, Reflection, Expectations. All members of the care team should introduce themselves and their role in care to the patient, and this may need to be done every time they interact with the patient. The physician should also remember to acknowledge the emotions surrounding the situation and engage in reflective listening. Lastly, the physician should convey the plan and expectations for the patient throughout their time together (Sonis et al., 2020). Previous studies have shown the effectiveness of role-playing and improvisation exercises in teaching medical students clear and empathetic communication (Kaplan-Liss et al., 2018). Thus, medical education at all levels should aim to modify existing curricula and training to include an emphasis on humanism. Medical schools should consider teaching the ICARE mnemonic and similar tools for humanistic communication to students during their pre-clinical years, possibly as part of their clinical skills curriculum and/or in small group settings, and students should continue practicing its use during their clinical rotations. Practicing physicians should be taught, during in-house training sessions and other continuing medical education opportunities, and reminded to incorporate the ICARE mnemonic in their practice. Use of the ICARE mnemonic in daily practice has the potential to increase compassionate communication with patients.

Empathy and other components of humanistic communication has been recently reported as beneficial for both physicians and patients (Pohontsch et al., 2018; Abrams et al., 2020). Medical student interviews resulted in the identification of hands-on experiences and highlighting the importance of empathy as major influences in the professional development and empathetic communication and expression (Pohontsch et al., 2018). Thus, the aforementioned small group activities, role-playing and improvisation exercises, and inclusion of techniques for improved physician-patient humanistic communication within graded and/or required coursework to emphasize its importance can be incorporated into curriculum for focused training.

Though short-term strategies with emphasis on effective physician-patient communication, telemedicine, and empathetic techniques are encouraged, long-term strategies also must be considered for the development of humanistic communication in medical practice. While introductory lessons in undergraduate medical education are important, humanistic communication should be emphasized as a necessity, not an option, for clinical practice, at all times, not solely for implementation during a global health pandemic due to increased physical distance, addition of barriers for infectious control, and scarcity of resources. Suggested long-term strategies include humanistic requirements for 1) institutional assessment and evaluation, for example, as included criteria in quarterly or yearly departmental reviews by supervisors or organizational human resources, 2) continuing medical education, and 3) board certification and licensure, for physicians obtaining them initially or for renewal of credentials.

CONCLUSION

As physicians provide medical care to patients during the COVID-19 pandemic, emphasizing compassion and humanism is needed more than ever. Adding humanism to patient care is not burdensome or time consuming, and may improve patient care and personal satisfaction, especially during challenging times. By highlighting humanism in everyday practice, physicians may be more resilient when facing stressors, such as those imposed by a global health pandemic (Sonis et al., 2020). The earlier humanism is introduced in a person's medical career, such as medical school and residency, the more natural, habitual, and automatic its implementation will be in physicians. High quality medical care lies in providing both clinical skills and representing humanistic ideals (Benatar and Daneman, 2020). Though unexpected, the pandemic brought about changes in humanism and these proposed curriculum additions for undergraduate medical education for students, graduate medical education for residents, and even continuing medical education for practicing physicians that will benefit patients forever (Sonis et al., 2020).

Behaviors linked to humanistic care include: demonstrating respect, enhancing personal connections, invoking and responding to emotional expressions, identifying humanistic behaviors, and illustrating self-awareness in practicing humanistic care. The COVID-19 pandemic calls for new innovations in curricular delivery, including bedside teaching, improvements in empathy, and improved patient communication, both at the undergraduate and graduate medical education levels. Limitations include the challenges of implementing and assessing humanistic communication with pandemic precautions in place. Future studies can consider measuring the effectiveness of implementing humanistic curricular components with qualitative analysis of written evaluations or quantitative analysis of grades, constituents of licensure examination scores, or with the utilization of various scales developed to assess empathy, such as the Basic Empathy

Scale in Adults (BES-A), the Hogan Empathy Scale, or the Jefferson Scale of Physician Empathy (Jolliffe and Farrington, 2006; Cross and Sharpley, 1982; Hojat et al., 2001), which previously have been used in recent, small-scale studies in medical education prior to the COVID-19 pandemic (Newton et al., 2000; Evans et al., 1993; Batt-Rawden et al., 2013).

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The "Plan-Do-Check-Action" Plan Helps Improve the Quality of the "Standardized Training of Resident Physicians": An Analysis of the Results of the First Pass Rate

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Background: Medical education is a demanding lifelong learning process, which includes three tightly connected stages: college education, post-graduate education, and continuous education. Residency, the first several years after a college education, is a pivotal time in the development of a qualified doctor. Additionally, residents are the main force that undertakes much of the clinical work in hospitals. Therefore, guaranteeing and improving residents' clinical skills and abilities through the standardized training of resident physicians (STRP) is important. However, compared with other hospitals in the Zhejiang Province, the STRP assessment results of residents in our hospital were not satisfactory in recent years. Therefore, the objective of this study was to find the problems causing the unsatisfactory performance and identify the role of the "Plan-Do-Check-Action" (PDCA) plan in providing a valuable framework for future training.

Methods: Relevant studies of STRP in China and abroad were investigated by the literature review. According to published data by the Health Commision of Zhejiang Province, we collected the STRP assessment rsults of a total number of 12,036 residents. The inclusion cretria of these residents include: (1) 3rd-year residents. (2) taking STRP in the Zhejiang Province during 2016–2018 or 2017–2019. (3) the first time taking the clinical practice ability examination (CPAE) in 2018 or 2019. The results of 634 3rd-year residents from The Second Affiliated Hospital of Zhejiang University (SAHZU) were provided by the Department of Medical Education and were analyzed in depth. Three hundred and eight residents from SAHZU received normal training and took the CPAE in 2018, whereas 326 resident received PDCA and took the CPAE in 2019. PDCA is a program designed to improve the performance of residency in SAHZU. It includes the formulation and implementation of specific training plans, the check of effects, and continuous improvements. There was no change in the STRP assessment in these 2 years and the indicator of performance in the STRP assessment was the first pass rate (FPR). Statistical analyses were performed using Pearson's *chi-squared* test, Yates-corrected

chi-square test, or Fisher's exact test (SPSS Statistics, version 25). A *P*-value of < 0.05 was considered significant.

Results: A total number of 6,180 and 5,856 examinees in the Zhejiang Province took the clinical practice ability examination in 2018 and 2019, respectively. In 2018, a total of 308 residents from 20 departments of the SAHZU took the STRP assessment. In 2019, a total of 326 residents from 22 departments of the SAHZU underwent the PDCA plan and took the STRP assessment. Compared with the results in 2018, the average FPR in the Zhejiang Province increased by 2.92% from 87.87 to 90.79% ($P < 0.001$). The FPR of the SAHZU increased by 7.88% from 85.06 to 92.94% ($P = 0.001$). In the SAHZU, the FPRs of the Department of Emergency and Department of Anesthesiology improved 34.51% ($P = 0.024$) and 20.36% ($P = 0.004$), respectively. There were no significant differences between the performances in the 2 years of the other 20 departments. There were improved results in the "Clinical Thinking and Decision-Making" and "Operation of Basic Skills" assessment stations with increases of 3.01% ($P = 0.002$) and 3.94% ($P = 0.002$), respectively. No statistically significant differences in the FPRs of the other six stations were found. The performances in all the stations in the final tests were better than in the stimulation tests ($P < 0.001$).

Conclusions: Although our sample size was relatively small, our results showed a small success of the PDCA plan in improving the quality of the STRP, especially for the residents in the Departments of Emergency and Anesthesiology. The PDCA plan also contributed to enhancing residents' abilities in the "Clinical Thinking and Decision-Making" and "Operation of Basic Skills" stations. Taken together, the PDCA plan may provide a practical framework for developing future training plans.

Keywords: the standardized training of resident physicians, assessment results, PDCA plan, first pass rate, education

INTRODUCTION

In the fight against disease, humans have established medicine and passed their long-term accumulated medical experience on to the next generation. The transfer of this knowledge and experience is typically through the continuous and unified process of medical education. After completing basic medical education, medical students are required to receive specialized training to deepen their knowledge and clinical skills in their specialization before becoming qualified junior doctors. Therefore, this training period, known as residency, plays an important role in medical education (1). Additionally, residents are the main force who undertake large amounts of basic medical work, such as collecting medical histories, recording the courses, and performing clinical operations under the guidance of superior doctors. Residents are first-line doctors who participate in the whole process of treating patients and thus should perform at high levels. Therefore, the standardized training of resident physicians (STRP) is designed to help improve the quality of residents (2, 3).

Some of the earliest countries to start STRP, including the United States (US) (3, 4), Germany (5, 6), and the United Kingdom (UK) (7, 8)), now have well-established and relatively complete STRP systems. Currently, different countries use different assessments for the STRP; however, the core competencies in the assessments are similar. In the US, medical students are required to pass the United States Medical Licensing Examination (USMLE)[1] which is composed of Step 1, Step 2 Clinical Skills, Step 2 Clinical Knowledge, and Step 3 to get medical licensure. Step 1 assess the examinees' abilities to apply concepts from the basic sciences to medical practice. Step 2 Clinical Skills uses standardized patients (SP) to test examinees' ability to gather information from patients, perform physical examinations (PE), and communicate their findings to patients and colleagues. Step 2 Clinical Knowledge assesses the examinee's ability to apply medical knowledge, and understanding of clinical science essential for the provision of patient care under supervision, with an emphasis on health promotion and disease prevention. Step 3 assesses the examinee's ability to apply medical knowledge and understanding of biomedical and clinical

Abbreviations: CPAE, clinical practice ability examination; DME, the Department of Medical Education; FPR, first pass rate; PDCA, Plan-Do-Check-Action; PLAB, Professional and Linguistic Assessments Board; QIT, quality improvement team; SAHZU, The Second Affiliated Hospital of Zhejiang University; SP, standardized patient; STRP, the standardized training of resident physicians; USMLE, the United States Medical Licensing Examination.

[1] https://www.usmle.org/pdfs/bulletin/2020bulletin.pdf

TABLE 1 | Clinical practice ability examination.

Station name		Assessment content	Assessment method	Numbers of examiners	Time	Total score	Pass	Comment
Interpretation of clinical results		X-ray, CT, MRI, ultrasound, ECG, other laboratory tests	Man-machine dialogue exam	–	60 min	100	60	Automatic computer scoring
Patient consultation	Medical history collection	Medical history collection; doctor-patient communication skills	Clinical simulation	2	20 min	100	80	Selecting a disease recommended by the assessment regulations; gather information from patient and performing physical examinations; taking the average score of two points as the final score of this station, and any one of the scores below 80 considered to be unqualified.
	Physical examination	Special physical examination		2		100	80	
Medical document writing	First course record	1 First course record	Writing a record of the first course based on the patient's case at the examination station	2	15 min	100	80	Scoring based on assessment requirements
	Medical record	1 Medical record	1 Random medical record	2	–	100	80	
Clinical thinking and decision-making		Giving answers based on questions	Interviewing	2	20 min	100	80	Preparing corresponding questions and assessments according to the requirements of training standards and examination outlines for each subject
Operation of basic skills	CPR	CPR	Clinical simulation	2	10 min	100	80	Scoring based on assessment requirements
	Tracheal intubation	Tracheal intubation	Clinical simulation	2	10 min	100	80	
Operation of specialized skills		Performing operations based on cases	Clinical simulation	2	15 min	100	80	Preparing corresponding questions and assessments according to the training standards

science essential for the unsupervised practice of medicine, with emphasis on patient management in ambulatory settings. Analogous to the USMLE, there is a Professional and Linguistic Assessments Board (PLAB)[2] test in the UK. The PLAB test[3] focuses on professional knowledge and skills, patient safety, good partnerships with others and maintaining trust.

In China, the 3-year STRP has been continuously improved since 1993, and STRP has been vigorously carried out nationwide in recent years. Although the training standards vary among provinces and the training levels are different among hospitals, all residents are required to participate in provincial unified assessments in order to complete their training. Due to a lack of data from other provinces, this paper only describes the situation of STRP in the Zhejiang Province[4] where the STRP assessment includes process assessment and graduation assessment. The former is a dynamic evaluation of the clinical competences and abilities of residents during the training, and the latter is a comprehensive evaluation of the overall effect of training. The graduation assessment is divided into two parts: the professional theory examination and the clinical practice ability examination (CPAE). The CPAE assesses the examinees' abilities to conduct standardized clinical operations and independently handle multiple common diseases in their major (**Table 1**). The first pass rate (FPR) of the CPAE is an indicator of the performance of the training program on the development of residents. Because of limited data, we only analyzed the results of 634 3rd-year residents from the SAHZU through studying the FPR of the CPAE in 2018 and 2019.

[2]https://www.gmc-uk.org/registration-and-licensing/join-the-register/plab/a-guide-to-the-plab-test

[3]https://www.gmc-uk.org/-/media/documents/good-medical-practice---english-20200128_pdf-51527435.pdf?la=en&hash=DA1263358CCA88F298785FE2BD7610EB4EE9A530

[4]http://zjyxjy.zjwjw.gov.cn/Home/Content?news_id=ED09CC5C-AF20-40EE-8905-AB8A00F38A3D

METHODS

The Compliance Statement

All research methods comprised in the study protocol were pursued/implemented in full compliance with pertinent guidelines, regulations, and applicable legislation in place.

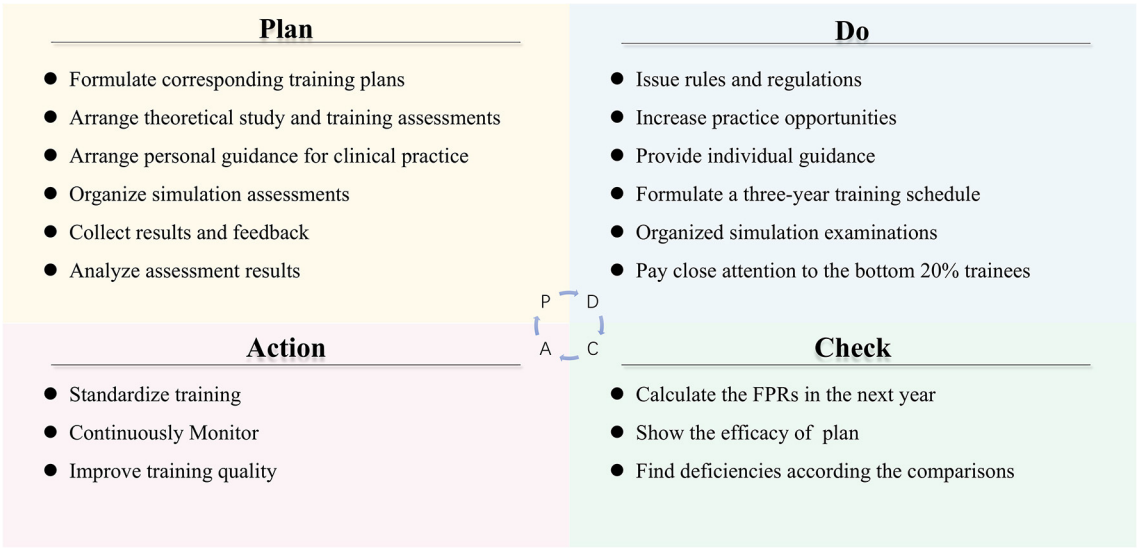


FIGURE 1 | The PDCA plan.

Ethical Approval

All participants provided written informed consent, and the study was conducted with the approval of the ethics committee of The Second Affiliated Hospital, School of Medicine, Zhejiang University.

Inclusion Criteria

1) 3rd-year residents;
2) Taking STRP in SAHZU and other hospitals in the Zhejiang Province during 2016–2018 or 2017–2019;
3) The first time taking the CPAE in 2018 or 2019.

Exclusion Criteria

1) Not 3rd-year residents;
2) Not taking STRP in the Zhejiang Province during 2016–2018 or 2017–2019;
3) Residents taking the make-up examination of the CPAE in 2018 or 2019.

Information Collection

The information of all residents meeting the above inclusion and exclusion criteria was collected. Detailed information about the performance of residents from our hospital was provided by the relevant Departments and the FPR-associated data from the Zhejiang Province was collected online. There were 6,180 and 5,856 examinees that took the CPAE in 2018 and 2019, respectively. The number of examinees from our hospital was 308 and 326 in 2018 and 2019, respectively.

The "Plan-Do-Check-Action" Plan

The "Plan-Do-Check-Action" Plan (PDCA) (**Figure 1**) whose purpose was to comprehensively improve the quality of the STRP program and the FPR. PDCA included formulating plans, implementing the specific training plans, checking the effects by FPR and improving training quality.

Plan

A quality improvement team (QIT) composed of the Training Center and the Department of Medical Education (DME) was set up. The work of the QIT included: (1) formulate tailored training plans for residents in different departments; (2) arrange theoretical studies and training assessments; (3) arrange personal guidance for clinical practice in the training center; (4) organize simulation assessments before the final examination; (5) make trainees participate in the simulated examinations; (6) collect results and feedback; and (7) analyze the factors that contributed to the poor performance of trainees whose rank was in the bottom 20%. Subsequently, the QIT analyzed the results of examinees with an emphasis on the FPR before making further plans. There were constant adjustments in this step until a complete and practical solution was determined.

Do

Although time was always tight, the QIT tried to take several measures, such as increasing residents' attention, providing training venues and personal guidance, to improve the quality of residency training. In order to increase the attention of residents and supervisors on the STRP program, the DME issued rules and regulations for both residents and supervisors. For example, the assessment results of residents were factored into the supervisors' promotions, award applications, and annual evaluation by the department director. This measure helped to stimulate the enthusiasm of both the trainees and the supervisors. In addition, the Training Center provided more specialized training venues and extended training time to increase the number of practice opportunities for residents who were engaged in clinical work. Another measure was that residents who had problems in operating could ask for individual guidance from supervisors that were senior doctors from the corresponding department. For example, when residents were

practicing tracheal intubation, anesthesiologists were arranged to provide individual guidance to residents to ensure that trainees have correctly mastered this skill. With the help of the Training Center and increased personal supervision, most trainees greatly improved. The fourth important measure was the formulation of a 3-year training schedule for 12 specialized skills (e.g., abdominal puncture, arteriovenous puncture, and defibrillation) training, which helped to strengthen clinical practice skills. Although this study focused on the performance of the 3rd-year residents (**Appendix 1** showed a detailed timetable), all 1st-year residents were required to conduct the 12 specialized skills correctly. The assessments for the 3rd-year trainees emphasized "Medical History Collection," "Physical Examination," "Clinical Thinking," and "Specialized Skills."

In addition, the QIT organized a simulation residency examination to test all trainees' abilities during the last period (about 20 days) prior to the final examination. After obtaining the results of the simulation test, the QIT conducted a careful analysis of the trainees' performances and then retrained the bottom 20% of trainees with an emphasis on problematic stations. For stations like "Medical History Collection" and PE, the QIT used standardized patients (SP) (9), who were trained to consistently portray a wide variety of clinical cases, to provide a better understanding of the poor performances of the examinees. At the same time, the QIT invited excellent residents and SPs to take instructional videos on medical history collection and PE so that these referenced videos could provide standardized guidelines for those failed trainees. In all stations, examinees who failed in any station of the simulation examination received feedback from SP or supervisors before being re-evaluated. In addition, the QIT held a symposium for the bottom 20% of trainees so that they could figure out where their problems were arising from through face-to-face talks. Furthermore, the QIT informed the department to pay close attention to those trainees' performances. These steps enabled residents to have more opportunities to practice and resulted in significant progress.

Check and Action

In this step, the QIT calculated the FPR in the next year to find the efficacy of the PDCA plan and find deficiencies according to the comparisons with the results of previous years. The last step was "Action," which primarily included training standardization, continuous monitoring, and quality improvements. In this stage, it was proposed to standardize the 3-year training by formulating the "Layered Training Program for Clinical Practice Competence of Residents" according to the national requirements and standards as well as to conduct more specific training outlines in the different departments. Detailed clinical practice ability grading tables (**Appendix 2**) were provided. It was also suggested to formulate the "Master Plan for the Training of Residents' Skills" to annually test the trainees' clinical abilities. Continuous monitoring was associated with extending the time of the PDCA plan and continued data collection. Some deficiencies were taken into consideration for quality improvements. First, residents were engaged in clinical work and they probably missed some of the training time. In regards to time constraints, the QIT extended the practice training time. Second, there was an increasing number of trainees, which brought difficult to supervision. To solve this problem, the QIT created a useful information system to make comprehensive records to track the training process of trainees and implemented a staggered, centralized training to reduce the burden on the trainers.

Statistical Analysis

Statistical analyses were performed using Pearson's *chi-squared* test, Yates-corrected *chi-square* test, or Fisher's exact test (IBM SPSS Statistics, version 25). A P-value level of < 0.05 was considered significant.

RESULTS

The First Pass Rate in 2018

In 2018[5], 5,430 examinees out of a total of 6,180 examinees that took the CPAE passed, which resulted in an FPR of 87.87%. Of the 6,180 total examinees, 308 of them were from our hospital, and 262 examinees passed. The FPR of examinees from our hospital was 85.06%, which was lower than the average FPR in the Zhejiang Province. When the performance on the CPAE was examined at the station level, the two highest FPRs from our hospital were in "Medical Records" and "Medical History Collection." Both FPRs were higher than the average FPR in the Zhejiang Province. However, the FPRs of the other four stations, including "Operation of Specialized Skills," "Medical Document Writing," "Clinical Thinking and Decision-Making," and "Operation of Basic Skills," were below the corresponding average FPRs in the Zhejiang Province (**Table 2**). Examinees from our hospital did the worst in the "Operation of Basic Skills" station out of the eight stations, with the lowest FPR of 95.45%. Additionally, FPRs for the complete CPAE varied among departments. The Department of Rehabilitation, Department of General Medicine, Department of Neurosurgery, and Department of Obstetrics and Gynecology all performed well with FPRs of 100%; however, the Department of Orthopedics performed the worst with an FPR of 50%. In addition, the Department of Ultrasound Medicine and Department of Ophthalmology had FPRs of over 90% (**Figure 2**).

The First Pass Rate in 2019 and Improvements

In 2019, 5,317 examinees out of a total of 5,856[6] examinees that took the CPAE in the Zhejiang Province passed. There were a total of 326 examinees from our hospital. Compared with the results in 2018, the average FPR in the Zhejiang Province increased by 2.92% from 87.87 to 90.79% ($P < 0.001$). The FPR of examinees from the SAHZU increased by 7.88% from 85.06% in 2018 to 92.94% in 2019 ($P = 0.001$) (**Figure 3**). In the SAHZU, the FPRs of the Department of Emergency and Department of Anesthesiology improved 34.51% ($P = 0.024$) and 20.36% ($P = 0.004$), respectively. There were no other significant differences between the FPRs in 2018

[5]http://www.med66.com/zhuyuanyishi/zhejiang/cd1809097926.shtml
[6]http://www.zjyxjl.org.cn/detail.aspx?newsId=1354

and 2019 in the other 20 Departments (**Table 3**). When the performance on the CPAE was broken down by assessment stations, the FPRs for "Clinical Thinking and Decision-Making" and "Operation of Basic Skills" increased 3.01% ($P = 0.002$) and 3.94% ($P = 0.002$), respectively, from 2018 to 2019. No significant differences in the FPRs for the other six stations were found (**Table 4**). In the process of "Plan-Do-Check-Action" (PDCA) plan, it was observed that the FPR of the final examination in all stations was higher than that in the stimulation examination ($P < 0.001$), particularly in the "Medical History Collection" assessment where the FPR improved 28.63% (**Figure 4**).

TABLE 2 | Results of first pass rate in different stations in 2018.

Station name	Numbers of total examinees	Numbers of qualified examinees	FPR	Average FPR in Zhejiang Province
Medical record	302	0	100.00%	99.98%
Medical history collection	302	3	99.01%	98.93%
Operation of specialized skills	302	3	99.01%	98.99%
Physical examination	302	7	97.68%	97.91%
Medical document writing	254	6	97.64%	98.15%
Clinical thinking and decision-making	299	9	96.99%	97.45%
Interpretation of clinical results	308	12	96.10%	96.99%
Operation of basic skills	308	14	95.45%	97.85%

DISCUSSION

To better understand the current implementation of STRP and find the reasons for the unsatisfactory performance, DME took a series of measures, such as organizing meetings for in-depth discussion and conducting regular face-to-face conversations with resident representatives from all departments in our study. The primary factors were vague training plans, time constraints, lack of teaching resources, and lack of practice opportunities.

Vague Training Plan

Because our hospital is a large comprehensive teaching hospital, there is a lot of teaching and training work that is needed for residents. However, STRP was not complete in China at the time and there were no specific training plans for residents from different departments in our hospital. In fact, the training of medical personnel, such as interns, residents, and fellows, in the hospitals of China was vague and untargeted. During the STRP process, the residents did not know the clear requirements for themselves. When they were working and getting trained in different departments, they have no clear goals or plannings. This may have resulted in some residents not having significant improvements after 3 years. Therefore, a clearer training plan for personnel in different disciplines or types was required.

Time Constraints and Burnout

In medical school, students are focused on studying. However, during the residency stage, residents not only need to complete countless amounts of paperwork and practice professional skills to improve their ability, but they also need to complete many

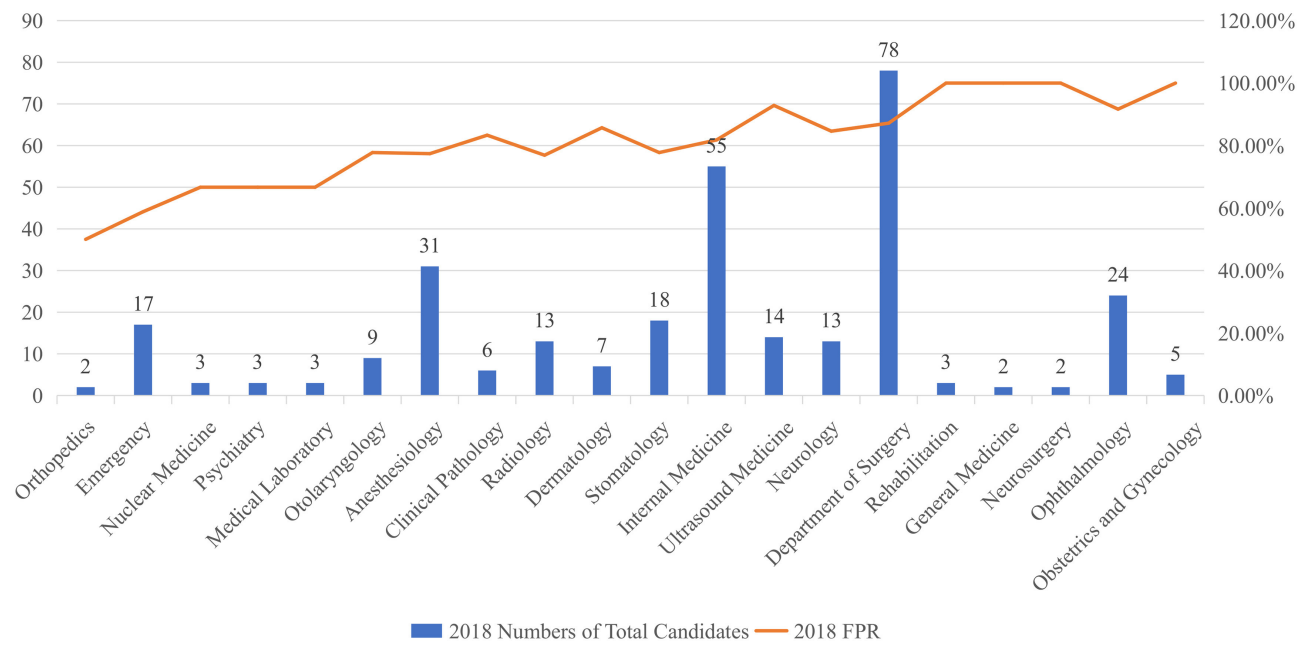


FIGURE 2 | Results of first pass rate in different departments in 2018.

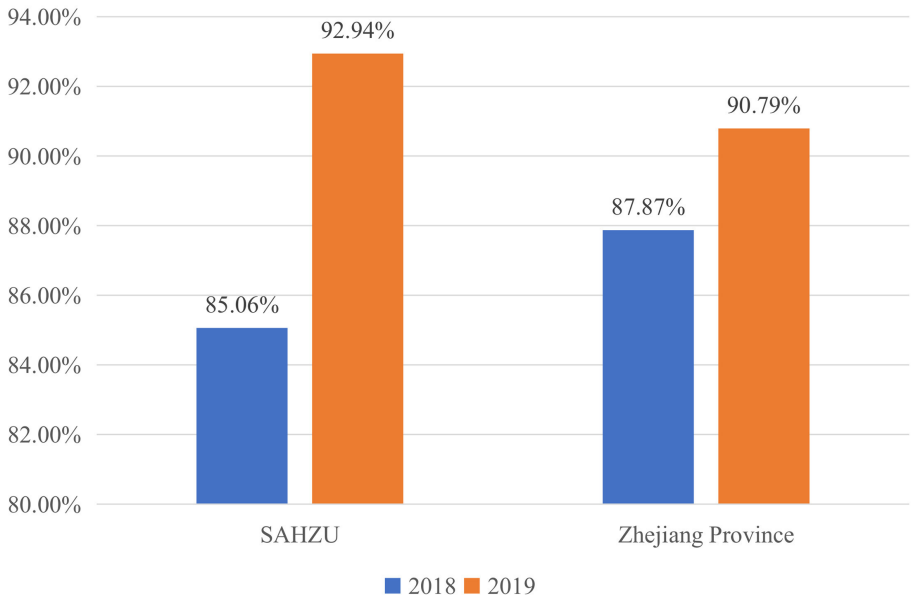


FIGURE 3 | The first pass rate in 2018 and 2019.

TABLE 3 | The first pass rate associated with Departments in 2018 and 2019.

Department	FPR in 2018 *n* (%)	FPR in 2019 *n* (%)	χ^2	*P*-Value
Pediatrics	/	1 (100)	/	/
Radiation oncology	/	1 (100)	/	/
Orthopedics	2 (50)	7 (85.71)	0.417	0.284
Emergency	17 (58.82)	15 (93.33)	0.041	0.024
Nuclear medicine	3 (66.67)	2 (100)	1	0.361
Psychiatry	3 (66.67)	2 (100)	1	0.361
Medical laboratory	3 (66.67)	2 (100)	1	0.361
Otolaryngology	9 (77.78)	8 (100)	0.471	0.156
Anesthesiology	31 (77.42)	45 (97.78)	6.061	0.004
Clinical pathology	6 (83.33)	11 (100)	0.353	0.163
Radiology	13 (76.92)	12 (91.67)	0.593	0.315
Dermatology	7 (85.71)	8 (100)	0.467	0.268
Stomatology	18 (77.78)	32 (90.63)	0.692	0.209
Internal medicine	55 (81.82)	56 (92.86)	2.148	0.08
Ultrasound medicine	14 (92.86)	15 (100)	0.483	0.292
Neurology	13 (84.62)	11 (90.91)	1	0.642
Department of surgery	78 (87.18)	55 (87.27)	0	0.987
Rehabilitation	3 (100)	4 (100)	/	/
General medicine	2 (100)	3 (100)	/	/
Neurosurgery	2 (100)	4 (100)	/	/
Ophthalmology	24 (91.67)	23 (82.61)	0.416	0.352
Obstetrics and gynecology	5 (100)	9 (88.89)	1	0.439

TABLE 4 | The first pass rate associated with stations in 2018 and 2019.

Station name	FPR in 2018 *n* (%)	FPR in 2019 *n* (%)	χ^2	*P*-Value
Medical record	302 (100)	315 (100)	/	/
Medical history collection	302 (99.01)	315 (99.68)	0.299	0.294
Operation of specialized skills	302 (99.01)	315 (99.68)	0.299	0.294
Physical examination	302 (97.68)	315 (99.37)	1.98	0.081
Medical document writing	254 (97.64)	315 (99.21)	1.143	0.154
Clinical thinking and decision-making	299 (96.99)	254 (100)	0.001	0.002
Interpretation of clinical results	308 (96.10)	313 (95.09)	0.384	0.535
Operation of basic skills	308 (95.45)	326 (99.39)	8.419	0.002

other tasks (e.g., participating in scientific research or academic forums) to keep them up-to-date on the latest developments. In addition, heavy clinical burdens and tough academic studying make it difficult for residents to balance time and energy to perform well in all aspects, which drives them to pay the most attention to completing work rather than extending clinical knowledge or improving clinical skills. Thus, all of these demands lead to burnout being a common problem for residents, especially those in surgical residency training programs. Hu et al. did a cross-sectional national survey of 7,409 residents and found that 38.5% of these residents reported burnout symptoms weekly (10). In addition, Lichstein et al. conducted an orthopedic educational survey study that showed that 52% (342 of 661) of residents reported burnout and that the factors causing burnout included unmanageable work volume (OR 3.13; 95% CI, 1.45–6.67; $P < 0.01$) and lack of exercise (OR 1.69; 95% CI, 1.08-2.70; $P = 0.02$) (11). In our hospital, there was a large volume of work as there were 92,553 inpatient operations and 186,102 discharges

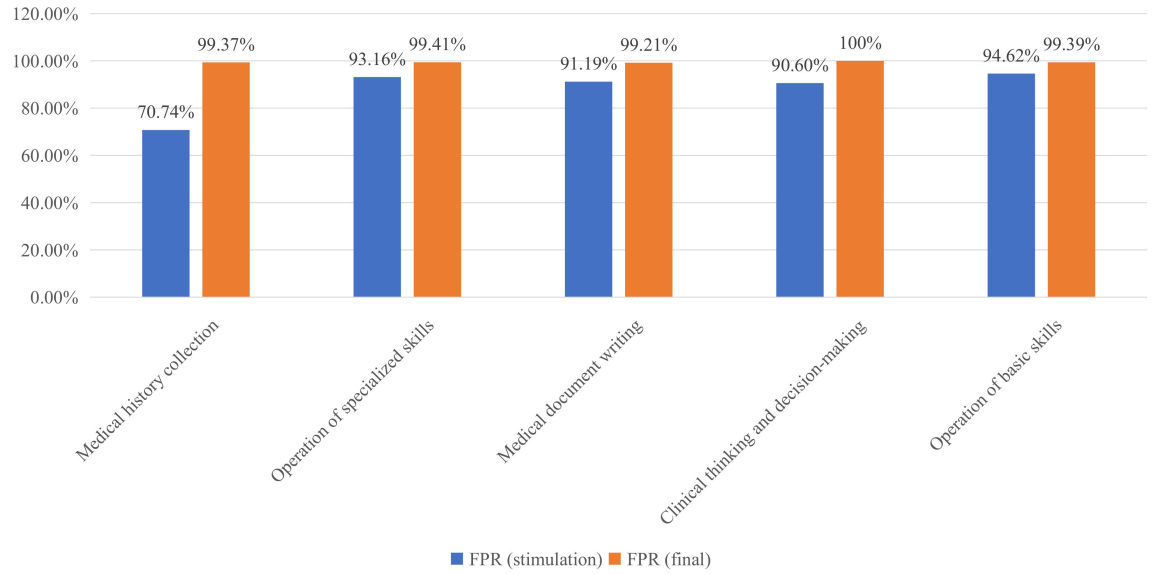


FIGURE 4 | Results of stations in stimulation and final examinations in 2019.

in 2019. In addition, the average hospital stay was 6.09 days. Even though there was no detailed data about the wellness of the residents in our hospital, most residents had complained about time constraints. Furthermore, time spent on clinical improvement was greatly compressed and residents' operation time was limited, which may have made it hard for residents to meet the training requirements. Therefore, residents should have good time management plans and the departments should have reasonable divisions of labor.

Lack of Teaching Resources and Practice Opportunities

There were many factors that resulted in the deficiency of teaching resources. First, the rapid growth in the number of residents who were required to have STRP and the lack of available teaching resources created a demand that was higher than supply. Second, senior doctors devoted themselves to heavy clinical workloads and they might not have had extra time to focus on clinical teaching, which may have resulted in them ignoring residents. Consequently, the trainees were inactive in raising or analyzing problems resulting in making their clinical thinking and emergency response ability rather weak. Third, due to the uneven levels of teachers' professional skills and clinical teaching skills, it was hard to achieve homogeneity in the training process. Fourth, although the training program was characterized by "learning in practice," the obtained training in practice was not satisfactory due to the lack of guidance from experienced doctors. Fifth, many of the departments had adopted the strategy of "one size fits all" in the arrangement of training time in order to save time and manpower, which led to poor quality of training. Under the combined influence of these factors, residents became indifferent to department rotations and gradually lost initiative and enthusiasm toward the STRP program. Herein, a reasonable allocation of teacher resources and an increase of examination practice time in daily work were worth discussing.

Yet, there are no complete and specific training plans for the different departments and this deserves our continued efforts. In addition, the lack of wellness among residents is troubling. Therefore, educational leaders of the STPR program should pay attention to residents' burnout and mental health as well as provide access for health maintenance in order to foster a positive and comfortable environment for trainees.

Despite factors such as time constraints and heavy clinical workloads, the PDCA plan still needs to be improved as follows: (1) develop separate training plans for each department; (2) provide better models for training; (3) cooperate with clinical departments to improve trainees' clinical abilities rather than just work hard to pass the STRP examination; (4) pay attention to trainees' physical and mental health because they are too busy; (5) reward departments for excellent performance to keep their enthusiasm in teaching and training. Taken together, we propose that the PDCA plan will become more and more useful in the future and it may contribute to the development of medical education in China or other countries.

CONCLUSION

STRP has become an important part of medical education and the FPR is considered as an indicator that shows the effect of STRP implementation in Chinese hospitals. With an increasing number of medical students and trainees, how to improve the FPR and cultivate outstanding clinicians using limited teaching resources is a question that requires constant thinking. Here, we used a practical approach to this problem, which is the PDCA

plan. Although the sample size was small and the observation time was short, we witnessed success of the PDCA plan through an increased FPR (**Table 3**). Additionally, the simulation examination of the PDCA plan helped to figure out the reasons for poor performance. As residents were busy working and many of them may miss the stimulation emanation, it was difficult to make this examination the same as the final one. As the "Medical Records" and "Interpretation of Clinical Results" were evaluated on their performance in daily work, assessments of five stations ("Medical History Collection," "Operation of Specialized Skills," "Medical Document Writing," "Clinical Thinking and Decision-Making," and "Operation of Basic Skills") were organized. In fact, the number of participants in the stimulation examination was less than the number in the final examination because residents were too busy to attend it. However, based on collected information from stimulation examination we were able to identify problems and poor performances in some stations, including "Medical History Collection" and "Clinical Thinking and Decision-Making" (**Figure 4**). After taking several measures (e.g., inviting SPs, watching videos, and holding seminars), trainees performed better on the final examination (**Figure 4**).

LIMITATION

The most conspicuous limitation is the small sample size. Due to data confidentiality and the lack of open database for SRTP examination in China, we did not have access to the detailed results of residents' performances at other hospitals. Therefore, we collected data from our own center through the simulation and actual SRTP examinations, which resulted in small sample size. In future, we hope that teaching hospitals can cooperate with others and strengthen data sharing to achieve better medical training performances. In addition, there were different numbers of residents, ranging from 1 to 78, in different departments because of the Chinese department setting system and the strength of the hospital. This brings statistical errors and makes the results unconvincing. However, an evaluation of these departments (e.g., Pediatrics, Nuclear Medicine, and Psychiatry) was necessary because there were a number of residents in those departments. In the future, multicenter and provincial or national studies involving a greater number of examinees and detailed data are required to better understand the situation of the STPR program across China. The second limitation is the data collected from the simulation examination. The missing data on "Medical Records" and "Interpretation of Clinical Results" may influence identifying the efficacy of the PDCA plan. Furthermore, due to busy and uncontrollable work schedules, the number of participants in the simulation examination was less than that in the final one. In the following year, we will find a better time to schedule the simulation so that more residents can participate. The third limitation of this study is the short observation time. In this study, we observed results from 2 years and saw a slight increase of FPR. However, in some exceptional circumstances (i.e., the pandemic of COVID-19), cultivating high-quality juniors in a short time is important for the society. A slight improvement in STRP may be of great significance to regions or countries. In fact, we will conduct the PDCA plan in the following years with an enrollment of the 1st-, 2nd- and 3rd-year residents, and collect more comprehensive data. We will continue to develop STRP and improve it to make the STRP more objective and reliable. Last but not least, we hope that our educational experience can bring benefits to other hospitals though STRP is still under exploration.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Second Affiliated Hospital, School of Medicine, Zhejiang University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

BT and AS conceptualized the research project. DL wrote the paper and made the original figure and tables. AS, MY, FZ, and BT critically revised the texts and figures. AS and BT supervised the research and led the discussion. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2020.598774/full#supplementary-material

Appendix 1 | Arrangements of 12 operation trainings.

Appendix 2 | Layered training program for clinical practice competence of residents.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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REVIEW
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Pandemic Opens Opportunities to Solve Pathology Manpower Challenges Worldwide

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Conventional processes of pathology education have been disrupted by the pandemic of 2020, forcing a re-evaluation of the means of teacher-learner interactions. Digital and remote teaching methods have become the standard, spearheaded by several national and international organizations and enforced by a need to social distance during a pandemic. At the same time, the public health predictions regarding the impact of non-communicable diseases on the developing world, and the resultant increased demand for pathology services to help cope with that tidal wave of disease, presents a challenge to a declining population of pathologists in North America. However, the shift in teaching methods has produced a wealth of on-line training resources. This offers for the first time a leveraging effect on the teaching value of pathology expertise, largely concentrated in the developed world, and an opportunity to both enhance and equitize training internationally, potentially sufficient to meet the rising wave of non-communicable diseases ahead in the next 20 years. We propose four next steps to take advantage of the current opportunity to meet this challenge: Curate and organize digital training materials; Invest in the digital pathology infrastructure for education and clinical care; Expand student exposure to pathology through virtual or in person electives; Develop further competency-based rather than time-based certification and board eligibility.

Keywords: virtual pathology education, pathology manpower, low-resource settings, cancer prevalence, digital pathology

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BACKGROUND

The graduate pathology education pathway for the vast extent of the 20th Century rested on a traditional model relying upon several fundamental methods and assumptions. Among these were that learning was enhanced by personal exposure to experts and to significant quantities of real and varied clinical materials. Thus learning pathology could then only happen in fairly intimate mentor-mentee relationships with sufficient long-term exposure to ensure adequate transmission of knowledge, habits and methods. Inasmuch as it was improved by extensive exposure to sufficient quantities of clinical materials (cases) the volume and scope of cases became a relative advantage or disadvantage in the allure of various training programs or settings. Large volume, referral centers with a diversity of case types were optimal to ensure that trainees had sufficient exposure. While the adage "see one, do one, teach one" repeated often in some disciples implied a fairly limited requisite range of exposure, in pathology the nuances of individual variation seemed to require a far broader exposure to diseases and variations to ensure an adequate core of diagnostic

competency. The 10,000 h rule described and espoused in Malcolm Gladwell's book *Outliers: The Story of Success* seemed apt to pathology's breadth and diversity, and could even apply to individual disciplines among the progressive sub-specialization trend that occurred in the latter half of the century (Gladwell, 2009).

Likewise, undergraduate pathology education had for many decades been riveted to basic science lecture courses within the foundational years of medical school. These were commonly supplemented by gross and microscopy-focused laboratory sessions intended to teach foundational principles like wound repair, inflammation and neoplasia that had broad application in medical practice. The barriers to learning were primarily time and resource based, such as the amount of time required to surmount the learning curve of operating a microscope, and the limitations imposed by glass slide sets that were subject to age, damage and inconsistencies of content. Adequate instructional attention by professors and laboratory assistants could also be a relative barrier in some programs. In many resource-limited settings, access to quality, functional microscopes and high quality (or even any) glass slides imposed additional impediments for learners. Access to current texts, up to date scientific journals and experienced specialists were also problems not easily overcome in these settings.

But then the world suddenly became flat, or at least flatter (Friedman, 2005). Undersea fiber optic cables linked the continents; data transmission costs dropped, software for file sharing and crowdsourcing of content, disrupted normal channels of content distribution and quite quickly it became easy and inexpensive to search for answers, collaborate with peers or teams, make social and educational connections, attend massive on-line courses, or even to sit at the virtual microscope with a professor many time-zones or continents away. This tectonic shift in how we interact has changed the assumptions about the global supply chain of goods and services in many if not all disciplines, but perhaps none more profoundly than the content-intensive, and image-rich field of pathology practice, and thereby also pathology education. This paper intends to map some of the changes to date, and to project forward how some of the problems in medical education and public health ahead may be impacted by these changes in pathology in particular.

THE PROBLEM(S) AHEAD

The WHO and other public health organizations worldwide have been successful in turning the tide on many of the world's great nemeses, the communicable diseases, even if we are currently dealing with yet another new threat from that front. But this advance has rolled away the barriers to a potentially more devastating tidal wave of non-communicable diseases. Conservative estimates from the International Agency for Research on Cancer (IARC) place the worldwide cancer incidence in the year 2040 at over 27 million new cases per year, an increase of 62% over 2018 (not accounting for aging, tobacco use and other pro-carcinogenic factors). The distribution of these cases will moreover be very unevenly divided in the world, tending heavily toward the developing world. Since the capacity to diagnose, treat and manage the care of this tidal wave of patients is currently very limited, the potential for dire economic, social and political devastation on world populations is enormous. Foundational to any ability to confront and cope with this deluge of new cancer cases (or for that matter, diabetes and heart disease) is the ability to render an accurate and timely diagnosis and provide accurate, actionable follow-up data. However, we are yet a long way from having capable and adequately trained pathologists manning the front lines to cope with either the current needs much less any wave of cancer that may be ahead.

Efforts to build regional and thus "global" capacity in laboratory diagnosis have been undertaken in many countries (Olmsted et al., 2010). For example, the US President's Emergency Plan for AIDS Relief (PEPFAR), a program providing assistance to develop capacity to manage and diagnose HIV-related diseases in the African sub-continent, has returned favorable results and is now working to expand on that to deal with a broader range of diseases, including cancer. Many of these programs, however, suffer from the problems recounted in *The Prosperity Paradox* such as brain-drain, non-sustainability, and insufficient infrastructure (Christensen et al., 2019). Less ambitious projects often struggle with resources, human and otherwise, as well as funding. A sister-country collaboration between Vietnam and Laos to develop capacity in the Lao Cancer Center has seen the exchange of expertise and training, but struggles to gain traction due to an overall lack of trained physicians and a sustainable economic model that can attract (and retain) physicians, both oncologists and pathologists, to the fray (Tran Van Vinh, MD, Hospital 108, Hanoi, personal communication).

This brings us to a second feeder current for the potentially disastrous storm ahead--diagnostic manpower, particularly when it comes to the subspecialty expertise needed to optimally guide the personalized care paradigm we'll discuss below. A study published by the College of American Pathologists (CAP) in 2013 illustrates this nicely (Robboy et al., 2013). That work evaluated the demographics of the current US pathologist workforce using predictive methods based on prior history to project the number of pathologists who were likely to leave practice over the ensuing decades and project similarly the number of new pathologists who would enter the workforce. The projected deficits resulted in a significant predicted decline in available pathologists that would progressively worsen over the decade beginning in 2015. Although some other factors in pathologist workforce, such as the influence of economic shifts on retirements, the improved efficiencies from digital pathology or other technologies, or from shifts in techniques for monitoring and detecting disease (such as liquid biopsies for example) were not taken into account, the predicted increase in vacant positions has largely proven to be true (Metter et al., 2019).

Worldwide, less is known about the demographics and replacement or growth capabilities of training programs. It is evident that subspecialty trained pathologists are heavily concentrated in the US, and that the supply of capable

pathologists is enormously deficient in broad swaths of the world. The majority of the low or middle-income countries have a ratio of pathologists: population that is orders of magnitude less than that in the United States or United Kingdom. This dilemma underscores the need to dramatically ramp-up the training capabilities while ensuring that the working environments are similarly prepared to employ and hold onto these trainees. But as illustrated in many countries by the enlistment of public health workers to do contact tracing and quarantine related tasks, such development and training of a workforce once the need is upon us is fraught with challenges (WHO, 2020; Hassell et al., 2021).

Hence the situation may be described as another "perfect storm" — a dramatic rising tide of diseases requiring the expertise of pathologists, a stagnant or even falling population of suitably trained pathologists who can offer training, facing off with an education model based on time-based multifaceted, fixed resource-intensive training in largely face to face settings with frequent mentoring direct interactions.

TRENDS IN EDUCATION AND PATIENT CARE

Several key trends have been gaining speed in pathology education, both at the undergraduate and graduate levels over the past few decades. These have been accompanied by several key trends in patient care that also dramatically impact the need for, and the demands upon pathology education (Christensen et al., 2009; Hassell et al., 2011).

The first of the educational trends (accompanied in a lagging manner on the diagnostic side) has been a move toward digitalization of images and data (Yin et al., 2016; Hassell, 2019). One hallmark of this trend is the dismantling of fixed microscopy labs and glass slide sets for undergraduate medical students, enabled initially by the digital slide box project piloted by Fred Dee at the University of Iowa and replicated in dental, veterinary, and numerous other health science settings (Dee, 2009; Rodrigues-Fernandes et al., 2020). A parallel trend is the creation of digital textbooks and image or slide galleries available through the World Wide Web, now typified by resources such as PathPresenter and the Digital Anatomic Pathology Academy from the Digital Pathology Association (DPA). Whereas a visitor to a pathology lab in Vietnam in 1995 might be welcomed if offering as a gift a cast-off, out-of-date edition of Anderson's Textbook of Pathology, a visitor to the same lab 15 years later would be astounded to find colleagues and students there bringing up quickly on their tablets or smartphone the latest journal article on a topic or pertinent illustrations from the WHO classification just published. Having all the world's library materials essentially in one's pocket flattens and shrinks the world immensely (Rodrigues-Fernandes et al., 2020).

This same microchip and related technology megatrend has fostered the migration of many previously highly complex laboratory tests to seemingly simple bedside devices that minimally trained personnel can perform and interpret. This has leveled much of the playing field in clinical laboratory sciences in some ways, though such devices have not come with the benefit of lower costs per test that might have completely disrupted care paradigms. However, simultaneously, we have witnessed the drive to highly individualized treatment for many diseases such as cancer, requiring ever increasing levels of genetic and epigenetic profiling, testing which has also migrated away from many traditional clinical laboratories into esoteric centralized high volume settings, often away from the training programs providing pathology training.

For a student on the medical education track or the pathology specialty path in 2020, it has been a roller coaster ride to obtain a comprehensive educational experience. Starting with conventional on-site and hands-on methods and then experiencing an accelerated shift almost entirely to on-line virtual settings due to sudden response to a pandemic has been unsettling for many. Just as clinical encounters migrated to telemedical settings quite dramatically, often leaving medical students or trainees out of the loop, pathology training programs had to navigate carrying out case review with residents, a core component of training, almost entirely in a virtual setting or not at all (PathElective, 2020). And while most undergraduate digital slide lab sessions could continue without restrictions, any live lectures and many group, seated-round-the-microscope sessions had to migrate to being in front of the computer screen remotely connected. While both in-person and online/virtual options have their own benefits the lack of a coherent roadmap between the two has been challenging. Fortunately a robust response of educators and organizations, quickly created many opportunities online with few or no boundaries as to how much and how fast one could learn (Mukhopadhyay et al., 2020; PathElective, 2020). This developing digital world of training has enormous potential if we learn to organize and utilize it properly. That is still a big if when it comes to attaining competency to practice and certifying such to licensing boards or credentialing institutions.

For medical students, and to a certain degree trainees in disciplines such as orthopedic surgery, neurology and otorhinolaryngology where deeper knowledge of pathology is highly valued, the limitations on patient and faculty attending contact of the recent pandemic experience, highlights the value in pathology of virtual clerkships. With the creation of some of the first of these (pathelective.com) not only students locked out of hospital contact by the pandemic, but also students restricted from access due to distance, finances, or other barriers could deepen their knowledge in a variety of areas of pathology and laboratory practice (PathElective, 2020). Thus equipped, they can make better decisions on laboratory utilization, consultation, patient care, and specialty choice. Making such virtual electives widely available at low or no cost could also blunt some of the winds of the storm brewing as noted above by helping more students become familiar with the work of pathologists and amenable to following that career choice. This is also a key "re-branding" opportunity for pathology to raise awareness generally of a core, vibrant discipline that has been somewhat marginalized by systems-based medical curricula focused on clinical content.

As more remote platforms are becoming available such as these elective opportunities, videotaped didactic lectures, pathology Twitter feeds, pathology-oriented FaceBook groups and online teaching slide sessions, the critical need becomes how to organize and promote these platforms such that the very limited boundary restrictions they offer (no or low tuition, no geographic restrictions, etc.) can work to solve meaningfully the challenges ahead, rather than just be a stop-gap filler for this current crisis (Mukhopadhyay et al., 2020; Weinstein et al., 2009; PathElective, 2020; Rodrigues-Fernandes et al., 2020). While examples of self-organizing educational teams exist, as described by Sugata Mitra in his TedTalk about the children who organized themselves to learn English and coding in order to use the free computer terminals left in their low-income neighborhood (Mitra 2010), to expect a potential physician or pathologist to scour the myriad resources and selectively find those that can fill the sufficiency of their current and future needs online seems an unreasonable ask. And to expect that self-directed study to lead to any functional sort of degree or certificate is imprudent. But a medical school or residency training program "in the cloud" without walls, might not be such a pipe dream given what we are learning from the pandemic.

We will discuss below more of the particulars and action steps that may enable these established trends, and the catalyzing impact of the COVID19 pandemic to truly transform medical and pathology education in a manner that will empower the people of the world to meet the challenges we have already described and which loom ahead.

But one other trend in patient care deserves mention before we move on to the next section. The personalization of medical diagnosis and treatment has devolved upon an increasing array of highly complex testing, which by necessity can only be performed in specialized reference laboratories. This has made it difficult for trainees in sites without direct access to such a lab to learn key features about the development, quality control, management and performance of those tests, skills and knowledge that may be required for competency as a practicing pathologist. Currently there is little in the way of virtual training that can bridge the gap in those areas either by video conferences, problem simulations, case studies or other materials. In parallel, but opposite manner, less complex testing has moved out of the laboratory to the patient bedside as point of care devices have proliferated allowing shorter information loops and fostering or accelerating care, as we have noted above. But this testing may not always be within the purview of laboratory direction and hence within the curriculum of trainees, again creating a potential gap. It therefore becomes more and more important to digitize and standardize the training options to bridge all these deficits smoothly. To make great future professionals, it is necessary to prepare current trainees according to the dynamic nature of medicine or pathology. Some fine examples of solutions to similar curriculum gap issues are programs such as the "Laboratory Management University" (LMU) produced by the American Society of Clinical Pathology (ASCP) and American Pathology Foundation (APF), and the "University of Pathology Informatics" a joint effort of the ASCP and the Association for Pathology Informatics (API), both of which have been developed and deployed over the past 10 years in a virtual format. In the case of LMU, over 50% of pathology training programs in the US have made its contents available to their trainees, while laboratory technologists have also made use of its contents. The wave of first "graduates" of the core content came in 2013, prompting the developers to develop an advanced level curriculum including significant thesis-type projects incorporating their learnings and helping to polish management skills (Ronald Weiss MD, personal communication.) More such collaborations are needed to fill other gaps.

The challenges imposed upon pathology due to a pandemic forced adaptation so as not to compromise education and training. For the trainees, this was a whole new experience with little or no access to hands-on training, relying solely on a digital world and virtual techniques for learning purposes. For many of these "digital natives", this hasn't been bad as they quickly adapted to the new virtual "reality" of their educational world. For some the changes may have even accelerated their learning due to a reduction in non-learning activities. To the educators however, the abrupt transition to virtual teaching using digital tools was fraught with challenges and an immediate sense of their teaching effectiveness and quality being diminished-results derived from a survey of faculty and program directors reported elsewhere, and detailed in **Table 1** (Hassell et al., 2021).

PUBLIC HEALTH TRENDS AND CHALLENGES

In turning the corner into the decade of the 2020s, many agencies and health-concerned entities paused to reflect on goals and accomplishments in promoting health. The WHO identified 13 areas of urgent action for the next decade to improve health, among which was "investing in the people who defend our health" a move to target the underfunding of human resources in the health care sector (WHO, 2020). Similarly, the US Department of Health and Human Services in the Healthy People 2030 initiative has established numerous target goals in a wide array of components of and contributors to health (Healthy People 2030, 2020). Needless to say, numerous goals within the Healthy People 2030 framework have implications for laboratories and pathologists. Additionally, the payment systems within healthcare in the United States are undergoing flux, shifting emphasis from volume of testing to value in outcomes. While one might assume that this shift of rewards would reduce demand on pathologists, in reality, the demand may be increased, as in addition to their current workload under the volume paradigm, they will increasingly see demands for their expertise in rendering population health assistance and management. This is directly due to their proximity to and often stewardship for the vast trove of patient testing information that will drive effective outcomes management and improvements within the public health initiatives such as Healthy People 2030.

Implicit in this public health shift toward rewarding value- and outcomes-driven care is the dependence upon large streams of

TABLE 1 | Potential long term pros and cons of virtual learning for pathology.

Potential benefits of virtual training for students and trainees	Disadvantages, unexpected, or unintended adverse outcomes
More student autonomy (choice of where, when, how and what to study)	Technological breakdowns create a vulnerability
Increased variety of curriculum options and modalities available to choose from	Sham attendance or other forms of non-engagement become common; "multitasking" during educational sessions becomes much easier potentially creating bad habits
Short-segment learning enabled via social media platforms like FaceBook, Twitter and Youtube	Assessments and competency forced into the digital/virtual realm become more difficult to validate
Performance and time spent on cases can be tracked digitally.	Transfer of live, hands-on experience to virtual training in areas like blood bank, microbiology and chemistry where benchwork is necessary to learn becomes problematic.
Exposure to multiple institutes and a global community of teachers and learners fosters seeing differing approaches to different cases.	Immersion in a virtual learning environment may make students and residents reluctant to perform on-site tasks which pose risk or seem "non-essential" to training.
Lower costs due to reduced travel, reduced physical facilities space and equipment, and leveraged instructional effort spread over many learners.	Excess screen time and reduced physical activity can be bad for vision, posture and overall health, potentially leading to problems like obesity, backaches etc.
Low-volume, rare event situations can be made available to a wider audience for extended educational impact	Clinical encounters and practical experience like communicating with patients, surgeons and laboratory colleagues is reduced and interpersonal skills thus not honed.
Searchable database of instructional options can further extend learning	

patient data. There is little mystery to the moguls of modern information technology (be they Google, Amazon or others) that there is power in the data streams gathered from even seemingly trivial choices like searches for COVID-19 symptoms (Stephens-Davidowitz, 2020), or purchases of anti-inflammatory medications. Harnessing this information for the public good may be one of the coming century's great challenges. But it is clear that early responses to detectable shifts in such data, either from individuals or populations, will become a key tool in our ability to reach ambitious public health goals, whether that is reduction in obesity and diabetes, early detection of cancer or heart disease, or tracking an emerging infection.

Informatics has become an increasingly important component of pathology education and training. Recognized as a distinct subspecialty with its own certifying examination (offered to candidates completing core materials from several disciplines including pathology) in 2015, the understanding and management of data, computer technology, data sets, and other digital tools have also become a core area of competency required of every pathology trainee. This imperative coincides well with the trends noted above. But again, not all training settings are ideally equipped to provide these kinds of training experiences. The COVID-19 pandemic exposed this weakness as many institutions struggled to adapt to remote sign-out options using digital pathology (Hassell et al., 2021).

Telehealth has taken a dramatic leap forward during the pandemic, and continues to hold great potential to flatten the world in terms of access to care for remote populations. This trend holds true for pathology as well. Telepathology refers to the practice of pathology from a distance via image or data-sharing systems (Tran and Hassell, 2020). Primary diagnosis as well as quality control, peer review or secondary consultation can readily be performed in this mode. Several of the projects around the world aimed at improving capacity and quality of care have exploited telepathology in a variety of forms. The ASCP focus on African laboratory capacity has provided telepathology support for example (Fleming et al., 2016). Even before that, streaming video consultation has been used effectively by individuals such as Dr. Thuy Phung of Texas Children's Hospital, in teaching and supporting dermatopathology in Ho Chi Minh City, or by Dr. Matt Zarka of the Mayo Clinic in cytopathology in several locations, and by others. Fixed image telepathology has been used by the author to provide diagnostic support to a referral laboratory in Hanoi since 1995.

Digital pathology is now increasingly viewed as an enabling technology (Weinstein et al., 1987). Just as digitization of radiologic materials in the late 1990s opened the door for development and deployment of computer-assisted diagnostic tools, a host of similar efforts are underway in pathology.

Automated, FDA-approved algorithms already exist for evaluation of quantitation of staining characteristics for breast prognostic markers, and some other applications (Lloyd et al., 2010). Several venture-funded companies as well as many individuals and institutions are working on additional tools to augment the capability of pathologists to do their work using the various deep learning, artificial intelligence capabilities of fast computers and digitized images. Specific strengths of such tools can include rare-event detection, quantitation, quality control verification, and potentially image/pattern comparison to expand or narrow differential diagnostic considerations, again mirroring the path of such tools in radiology. Stand-alone functionality to replace human interaction or decision will probably face a very stiff path to approval, whereas adjunctive functions to enhance pathologist performance should be readily adopted and more easily approved. While use of these kinds of tools does not require in-depth understanding of coding or computer hardware necessarily, any more than a nurse needs to understand the solid-state chemistry on a urine dip-stick test used in an outpatient setting, nevertheless, the greater the complexity of the situation encountered mandates quality and safety controls that arise out of individuals with deeper understanding of the diseases, the technology and the various potential pitfalls involved.

These trends underline the importance of on-going training for faculty and current practitioners as well as trainees to enable

them to teach and practice in the world today and the world ahead.

Finally, it is important to mention the regulatory and social environment in which all of these changes are happening. In almost all political domains, the practice of medicine is governed by a licensing process that requires educational credentials. Such licensing boards operate within a legal construct that specifies a scope of practice. Additional credentialing scrutiny is often performed by hospitals, practices or laboratories, accrediting agencies, specialty certifying boards and insurers or other payment systems. In most settings these processes are transparent, perhaps even public information, and intended to protect the health of the population. However, in some circumstances, they may also operate out of other interests, as a proprietary guild, to impose barriers to entry for economic or other reasons more than public safety. Disruptions to the status quo, even if safe to the public and effective for greater health, may not easily overcome these barriers (Christensen et al., 2009).

One major and truly public health challenge lies in the decision to invest in the infrastructure to implement costly new technologies such as digital pathology. Often with digital pathology, if one is to convince professionals to make practice changes and to convince the management and administration of a hospital or clinic to fund the needed purchases, the evaluation of costs expended relative to benefits obtained must be widened to the system or society level. This is due to the great asymmetry in those costs and benefits. In other words, costs tend to be local and immediate, while the benefits are often delayed or long term and more widely spread across stakeholders. If digital pathology is to be an enabling shift for pathology education and practice, and thus an enabling solution to the problems noted above, health systems, government agencies, and broad-perspective individuals will be needed to guide the strategic decisions that will open that door.

One of the lessons from COVID-19 is that things can always be done by alternative means if we don't have the choice to continue conventional methods (Wobker et al., 2020). The stress imposed upon one component of the system creates an opportunity in another. The innovation and removal of barriers required by the pandemic has created a unique opportunity for pathology education and practice not likely to be repeated, but with great potential value to future generations if they can be directed to solve the even greater problems ahead. Although there are always opportunities to improve the medical and pathology education systems, the unique circumstances of the current situation would seem to allow us to change the education dynamics forever in a positive way.

OPPORTUNITIES AND SOLUTIONS

Based on our assessment of this current and anticipated future state, we have several recommendations for action that can move us closer to a solution for the vexing public health challenges noted above, and avoidance of the storm brewing that would make them worse.

First, take advantage of the sudden deluge of on-line learning activities for pathology postgraduate medical education to not only fill a temporary gap, but to systematically enhance and standardize conventional training. Organizing these materials into a systematic structure could readily be undertaken by existing leadership in pathology training such as within the Association of Pathology Chairs Program Directors group, or other entities like the American Board of Pathology, or International Academy of Pathology. These should then be coupled with competency assessments to both affirm to the learner their progress, but also to attest to training programs and certifying boards the capacity and competency. Maintaining a low cost structure for all these activities is especially desirable to expand the reach and impact of these programs into the developing world, where quality of post-graduate training is even more uneven. Integration of such materials into on-line courses, interactive platforms, or into a structure such as the Khan Academy could then become the "Pathology Residency in the Cloud" offering some form of certification that could lead to a degree of functionality. Ideally, this could be linked to willing physical sites to provide polishing of manual skills, interpersonal skills not otherwise well assessed, and validation of the on-line assessments. It would be especially helpful if this process were directed toward potential trainees in the most underserved regions of the world. Organizations or institutions can foster this kind of mentoring, to the benefit of both mentors and mentees. This flattening effect will help prepare the world for the deluge of non-communicable diseases ahead that will require competent pathologists to be in place ahead of time.

Of course, such a change in diagnostic resources cannot occur in a vacuum. As Christensen's work has nicely demonstrated with several historical examples, endeavors that "pull" supporting resources into underserved areas, the consequences of innovation, consistently work better than efforts to "push" them in from above or outside (Christensen et al., 2019). However, one means that can facilitate this concept of pulling in resources are effective health communications on key priorities like cancer prevention (Best et al., 2017). The means of using public health messaging, or a health literacy effort to enhance the training and retention of providers in a low resource setting is a worthy topic for further publications.

Second, public health oriented non-governmental organizations, as well as health systems, academic institutions and other stakeholders should prioritize funding to invest in digital pathology infrastructure that can link areas of need with areas of capacity, and support the enhancement of digital educational and practice tools such as telemedicine, that can help to flatten the misdistribution of specialty expertise and disease distribution. Such investment may yield additional benefits to society in the form of digital data streams that can assist with disease tracking, diagnosis, prevention and optimal management.

Thirdly, existing medical schools could inform and encourage students to use one or more of the virtual pathology resources to increase their understanding of the optimal use of laboratories, and gain insight into the role of pathologists in the healthcare team by participating in one or more virtual electives during their training (Mukhopadhyay et al., 2020; PathElective, 2020). This would have the impact of directing suited students into this specialty more

efficiently, rather than as a belated discovery after a year or more in other training programs. It would also help raise the profile of pathology as a viable, key clinical discipline as noted above.

Fourthly, the move toward the full use of competency assessments to certify candidates for board examination (and hence independent practice) should continue, with a relaxation on the time-based stipulations that currently are in place in the US and other jurisdictions. This would open the door for suitably virtually certified individuals to enter training programs for a shorter, but appropriately intense, on-site training period, and thus potentially produce more certified trained pathologists, without expanding the number of funded residency positions.

These are not trivial suggestions, we acknowledge. But neither are the problems looming ahead. Creative thinking and a willingness to seize the opportunities presented by both our technologic capabilities and our social circumstances are required at such a moment as this if we are to avoid the storms ahead which may wreak even worse havoc economically and socially than the most recent COVID-19 pandemic.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Gender Differences and Influencing Factors in Specialty Choices: Findings From One Medical School in China

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Background: Gender plays a significant role in the selection of medical specialty. Few studies have been conducted to explore the impact of gender differences on specialty choosing among Chinese medical students.

Methods: The specialty choices of 648 students from six consecutive classes in an 8-year MD program were collected and compared between male and female students. A total of 110 students from one graduating class were surveyed by a questionnaire covering 22 career influencing factors. Each factor has a scale of zero to three (zero = no influence, one = mild influence, two = moderate influence, and three = strong influence).

Results: Statistically significant gender differences were observed in 10 out of 16 specialties. Most male students limited their specialty choices to surgery (64%), internal medicine (12%), and orthopedics (12%), compared with a relatively diversified pattern in female students. For male students, the top three influencing factors were personal interest, future job prospects for the chosen specialty, and job opportunity in academic medicine. The strongest influencing factors of females were personal interest, specialty-specific knowledge and skills, and the sense of achievement. The expected salary was ranked among the top 10 influencing factors in male but not in females, while the work-life balance was ranked among the top 10 factors in females but not in males.

Conclusion: There is a significant gender difference regarding specialty choices among Chinese medical students. Career coaching is needed to help students in their specialty choosing process.

Keywords: medical education, specialty choices, medical student, gender differences, China

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INTRODUCTION

Around the world, the selection of a medical specialty as a career choice has important implications for both medical students and their healthcare system. Medical students' specialty choice is associated with income, prestige, work hours, and lifestyle. For the healthcare system, the distribution of medical specialties has a profound impact on the ability to deliver health care to high need groups. For students, the process of medical specialty decision-making is influenced

by many factors, including the mission of the specific school or program, exposure to influential mentors, cultural background, personal characteristics, and social needs (1–7). Having a better understanding of this process can not only guide the medical educators to provide effective career coaching but also help policymakers to correct the maldistribution of healthcare providers.

Numerous studies conducted in both Western and Eastern societies have demonstrated that gender differences impact medical students' specialty choices and are associated with many factors such as external (e.g., parental) perceptions of specialty characteristics, perceived prestige of the specialty, work-life balance, job-related tasks or responsibilities, and personal interest (3, 8–13). While there is an increasing number of women in medical schools and clinical practice areas worldwide (9, 14), gender inequality still exists in many medical specialties, especially in traditionally male-dominated specialties (15, 16).

China faces both an allopathic physician shortage and a physician maldistribution (both geographic- and specialty-related) (17, 18). In order for medical educators and policymakers to intervene, it is critical to understand medical students' specialty preferences and the driving forces behind specialty selection. However, only a handful of studies have been conducted targeting this topic. For example, by surveying 190 Chinese medical students from three medical schools in Fujian, a province in Southeast China, Liang et al. showed that general surgery and internal medicine are the two most preferred specialties. In contrast, geriatric medicine and psychiatry were the least selected specialties (19). Also, the influencing factors in medical students' specialty choices were evaluated by several prior studies, using both qualitative and quantitative methods (20–22). Personal interest, clinical rotation experience, specialty development prospective, and future income were identified as important decision-making factors. In addition, Chinese medical students' attitudes toward one particular medical specialty or non-traditional medical careers were also evaluated (23, 24). However, none of these studies focuses on the potential gender difference in medical students' specialty choices, and most of these studies were small-scale analyses with <300 students enrolled. In the current study, by analyzing a sizeable cohort of medical students (>600 students), we aimed to examine gender differences in medical students' specialty preferences in a leading Chinese medical school and identify the motivations behind those specialty choices.

METHODS

Setting and Participants

All medical students from six successive classes (Class 2012–2017) in an 8-year MD program at Fudan University, China, were involved in this study. All students in this premier program had excellent academic credentials upon admission to medical school (National College Entrance Exam scores were ranked at top 0.1–1%). The curriculum consisted of a 2-years of general education followed by 4 years of combined basic medical science and clinical knowledge training. Students selected their career specialty at the end of their 6th year. Students then continued their training for two additional years, which included combined clinical and research experiences in their own specialties. As such, the training was a "2 + 4 + 2" model. Specialty choice at the end of the 6th year represented the students' residency selection after graduation.

Abbreviations: ENT, Eye, nose, and throat (aka: otolaryngology); GBT, Guobiao Standard (aka: Chinese National Standard); OB/GYN, obstetrics and gynecology.

TABLE 1 | Specialty choices of 648 Chinese medical students.

	Male ($n = 283$)		Female ($n = 365$)		
Specialty	**Number**	**%**	**Number**	**%**	***P*-value**
Surgery ($n = 230$)	180	63.60	50	13.70	< 0.001*
Internal medicine ($n = 164$)	35	12.37	129	35.34	< 0.001*
Neurology ($n = 39$)	11	3.89	28	7.67	0.045*
Ophthalmology ($n = 37$)	4	1.41	33	9.04	< 0.001*
Orthopedics ($n = 36$)	33	11.66	3	0.82	< 0.001*
OB/GYN ($n = 34$)	3	1.06	31	8.49	< 0.001*
Dermatology ($n = 24$)	2	0.71	22	6.03	< 0.001*
Therapeutic radiology ($n = 21$)	2	0.71	19	5.21	0.001*
Diagnostic radiology ($n = 19$)	7	2.47	12	3.29	0.542
Anesthesiology ($n = 18$)	2	0.71	16	4.38	0.006*
Pediatrics ($n = 10$)	0	0.00	10	2.74	0.003*
ENT ($n = 7$)	4	1.41	3	0.82	0.705
Pathology ($n = 4$)	0	0.00	4	1.10	0.136
Rehabilitation medicine ($n = 3$)	0	0.00	3	0.82	0.261
Psychiatry ($n = 2$)	0	0.00	2	0.55	0.507
Family medicine ($n = 0$)	0	0.00	0	0.00	–

Asterisk indicates statistical significance.

Data Collection and Survey

All students' specialty choice and gender were collected from an internal database at the Medical Education Office of Fudan University. Specialties were categorized into 16 categories according to the Chinese National Standard of Subject Classification (GBT 13745-2009): internal medicine, surgery, obstetrics and gynecology (OB/GYN), pediatrics, family medicine, neurology, orthopedics, anesthesiology, diagnostic radiology, therapeutic radiology, dermatology, ophthalmology, otolaryngology, pathology, rehabilitation medicine, and psychiatry. Of note, three oncology branches—medical, surgical, and gynecologic oncology—were classified into internal medicine, surgery, and OB/GYN, respectively.

A 34-item questionnaire was delivered to all final year students (Class of 2017) to explore factors that might have influenced their specialty choice. Using a structured focus group of 10 final-year medical students, we derived a total of 22 factors to include in the questionnaire. Students were asked to rate influencing factors: zero = no influence, one = mild influence, two = moderate influence, and three = strong influence. A factor with a mean score over 2.5 was considered a strong influence, while a score between 2.0 and 2.5 was considered a moderate influence.

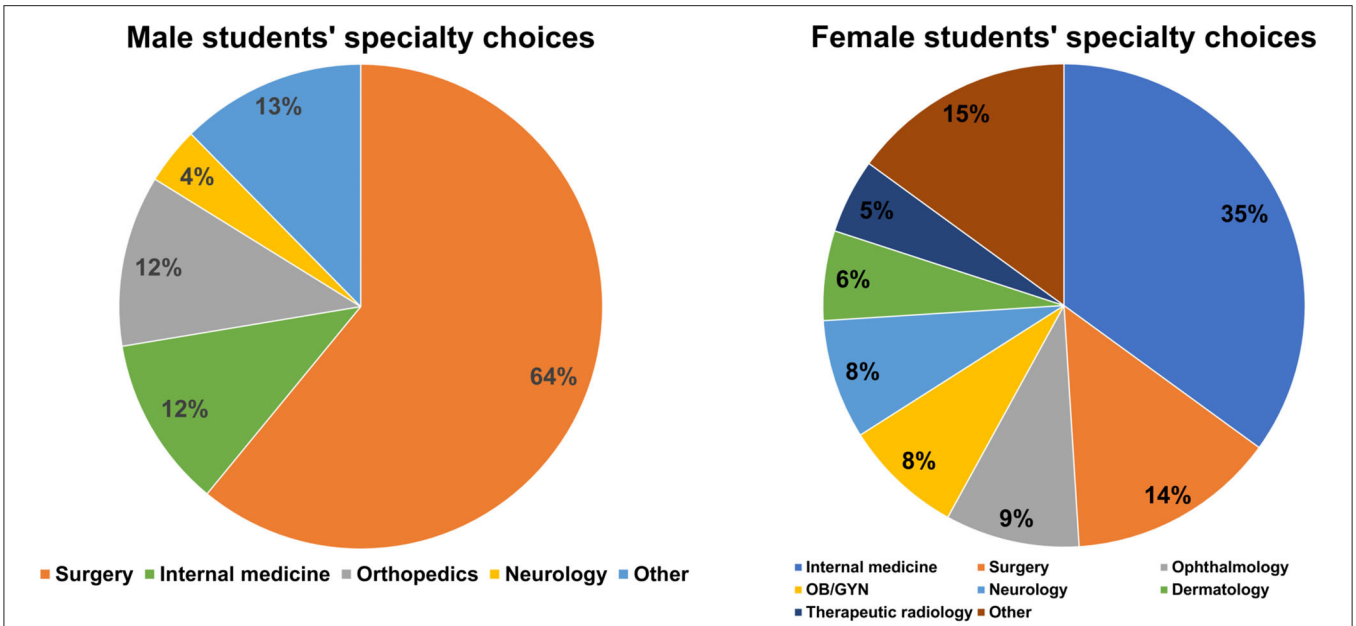


FIGURE 1 | The male and female medical students' specialty choices.

Statistical Analysis

Continuous data were expressed as mean ± standard deviation. Categorical data were compared by the Chi-square test as long as the observed cell counts were over five. Otherwise, Fisher's exact test was used. A $p < 0.05$ was considered statistically significant. All statistical analysis was performed using SPSS 19.0 (Chicago, IL, USA).

RESULTS

Specialty Choices and Gender Differences

The specialty choices of a total of 648 students (mean age 23.9 ± 1.3 years, 283 males and 365 females) from six consecutive classes were collected and are summarized in **Table 1**. The number of students per class varied from 97 to 113, and the mean sex ratio for each class was 0.78 ± 0.14 (range: 0.59–0.98).

Eighty-eight percent of male students focused their choices only on three specialties: surgery ($n = 180$, 63.6%), internal medicine ($n = 35$, 12.3%), and orthopedics ($n = 33$, 11.7%). In contrast, female students' specialty choices were more diverse (**Figure 1**). The most often selected specialties included 35% internal medicine ($n = 129$), 14% surgery ($n = 50$), 9% ophthalmology ($n = 33$), and 9% OB/GYN ($n = 31$).

Statistically significant gender differences were observed in 10 out of 16 specialties (62.5%): A significantly higher proportion of male students chose surgery and orthopedics (both $p < 0.001$); more female students chose internal medicine ($p < 0.001$), neurology ($p = 0.045$), ophthalmology ($p < 0.001$), OB/GYN ($p < 0.001$), dermatology ($p < 0.001$), therapeutic radiology ($p < 0.001$), anesthesiology ($p = 0.006$), and pediatrics ($p = 0.003$).

Six specialties [pediatrics ($n = 10$), ENT ($n = 7$), pathology ($n = 4$), rehabilitation ($n = 3$), psychiatry ($n = 2$) and family medicine ($n = 0$)] were selected by fewer than 10 students from the entire 6-year cohort. Except for ENT (where four students were male), all students selecting these less popular specialties were female.

Influencing Factors

One hundred and ten students out of 113 medical students (97%) from the Class of 2017 completed the questionnaire. This included 60 female and 50 male students. The top 10 influencing factors of both male and female students are summarized in **Table 2**. The mean scores of all these factors were above two (i.e., moderate influence).

For male students, personal interest ($x = 2.6$), future job prospects ($x = 2.6$), and opportunities in academic medicine ($x = 2.5$) were the three highest ranked influencing factors. In contrast, for female students, personal interest ($x = 2.7$), specialty-specific knowledge and skills ($x = 2.6$), sense of achievement ($x = 2.5$), and prestige or reputation of their clinical supervisor ($x = 2.5$) were the four strongest influencing factors.

Males ranked expected salary ($x = 2.5$) the fourth most important criterion, but this was not the top 10 factors for females. In contrast, work-life balance ($x = 2.2$) was ranked in the top 10 factors for female students (No. 9) but was not highly ranked in males.

DISCUSSION

This study is the first report of Chinese medical students' specialty preferences and selection factors analyzed by a gender stratification to the best of our knowledge. There are significant gender differences in specialty selection preferences among Chinese medical students. Female students had more diverse specialty choices compared with male students. Male students placed more weight on career and job prospects, salary,

TABLE 2 | Top 10 influencing factors in specialty choices.

Rank	Male	Mean score	Female	Mean score
1	Personal interest	2.6	Personal interest	2.7
2	Future job prospects	2.6	Specialty-specific knowledge and skills	2.6
3	Opportunity in academic medicine	2.5	Sense of achievement	2.5
4	Expected salary	2.5	Prestige/reputation of clinical supervisor	2.5
5	Prestige/reputation of clinical supervisor	2.5	Opportunity in academic medicine	2.4
6	Specialty is technically demanding	2.4	Future job prospect	2.4
7	Specialty-specific knowledge and skills	2.4	Working environment	2.3
8	Working environment	2.4	Job opportunity in general	2.2
9	Sense of achievement	2.3	Work-life balance	2.2
10	Job opportunity in general	2.2	Specialty is technically demanding	2.2

and technical challenges than females, while female students were more concerned about work-life balance and the sense of achievement.

Fifty-six percent of the study group were female students, which is comparable to the overall Chinese medical student population and is consistent with the global phenomenon that more females are entering medical schools and medical practice worldwide, often referred to as the "feminization" of medicine (9, 25). However, gender inequality still exists widely in both medical schools and hospitals. For example, females still represent a small minority in many surgical fields. Therefore, there are few female surgeons available to serve as role models (15). In contrast, male faculty are often a minority in fields like OB/GYN making finding male role models difficult for students (26).

In our study, statistically significant gender differences were observed in ten specialties (63%), suggesting that male and female Chinese medical students make very different specialty choices. Surgery and orthopedics were heavily male-dominated choices, while female students' selection is more diverse and gravitates toward internal medicine, ophthalmology, neurology, dermatology, radiology, anesthesiology, pathology, OB/GYN, and pediatrics. This is consistent with studies from other countries showing similar trends whereby females select OB/GYN, pediatrics, and primary care, while males select more procedure-oriented specialties (2, 5, 8–10, 13).

Understanding specialty choice is complex and multifactorial with influencing factors from internal (student-related personal factors) and external factors (family, peers, role models, potential earning power, etc.). External factors that are perceived to be "negative" such as an unfriendly working environment, scarcity of female role models, and a lack of career guidance and coaching may drive students away from certain careers. Given the heavy clinical workload required in Chinese medical practice and the extremely short time devoted to the doctor-patient relationship, career choices that devalue work-life balance, a disregard for personal wellness, and specialties that allow little time for family life seem less attractive to female medical students. Traditionally, female medical students have been exposed to few female role models in specialties like surgery. Those role models that do exist may have adopted traditional male values and work-life patterns. Without career consulting and coaching, male and female medical students often select stereotype roles and are not aware of other potentially more attractive specialties. It would be worth exploring the impact of career counselors or career advisors on specialty selection (27). Male students tend to select specialty based on the male's traditional role in Chinese society as head of household, main income earner, and a competitor. This may help explain why many female students chose the less prestigious specialties (i.e., specialties chosen by < 10 students). It is important to point out that students enrolled in this study were the products of China's "one-child policy." High family expectations, especially expectations placed on male students, may contribute to the current gender distribution.

It should be noted that only 10 students (all females) chose pediatrics, two students chose psychiatry, and no student chose family medicine over six consecutive years. However, an estimated shortage of 200,000 pediatricians' poses is a major threat to Chinese children (28). Similarly, there are only 1.2 family physicians per 10,000 population, far fewer than that in other developed countries (29). There are also significant shortages in licensed psychiatrists and allied mental health professionals in China (30). Students wrote in their surveys that long working hours, a high chance of getting involved in the doctor-patient physical conflict (mainly with patients' parents), and a relatively low salary are three main reasons that make pediatrics and psychiatry less attractive.

This study has some limitations. The results were based on a single medical school located in a large metropolitan region. The results may not represent all Chinese medical students, especially those in remote areas of the country. Moreover, as the study design is cross-sectional, it is impossible to demonstrate the causality between influencing factors and gender. Establishing and analyzing a multi-school, multi-year, longitudinal cohort covering different geographical areas and various types of degree programs may better elucidate the impact of gender on Chinese medical students' specialty choices.

CONCLUSIONS

There are significant gender differences in specialty preferences among Chinese medical students. Male students tend to hold more practical and utilitarian attitudes toward their future specialty choices, while female students are more concerned about work-life balance and sense of achievement.

DATA AVAILABILITY STATEMENT

The raw data are available on reasonable request due to privacy or ethical restrictions.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Institutional Review Board of Fudan University Shanghai Medical College. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KY, LY, MSW, and YL were involved in the conceptualization and design of this study. KY, LY, and DZ collected the data. KY, RZ, and DZ analyzed the data and interpreted the results. KY and RZ drafted the initial manuscript with critical feedback from MSW and YL. All authors read and approved the final manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Encouraging Cross-Disciplinary Collaboration and Innovation in Epidemiology in Japan

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Background: Scientific innovation is often achieved through the intersection of ideas from different fields. However, barriers prevent non-epidemiologists from cultivating interests in epidemiology or undertaking epidemiologic work. In this study, we evaluated changes in the diversity of research topics in an epidemiologic journal over time. We aimed to understand how epidemiologists and non-epidemiologists communicate about epidemiologic data and how this impacts innovation in the field.

Methods: We categorized the topics of articles published in the *Journal of Epidemiology* during the early and late 2010s based on their titles. We calculated the Shannon–Weaver diversity index (H′) to measure changes in the diversity of topics addressed by published articles.

Results: Comparing 2011–2013 with 2017–2019, there was no significant change in the diversity of article topics (H′ = 4.25 and 4.21, respectively) published in the *Journal of Epidemiology*.

Conclusion: To encourage healthcare providers and public administrators to conduct or comment on epidemiologic studies, epidemiologists should present their findings in easily understood language with appropriate and relevant statistical indicators and useful illustrations. Bringing experience from other specialties into epidemiology may yield new findings from epidemiologic data because of the exposure of non-epidemiologists to different values, workplaces, and occupations. Collaboration among professionals from varied backgrounds and with varied occupational experiences may help to promote scientific innovation by broadening perspectives. In addition, a range of professional experiences may enable individuals to solve difficult research questions more easily by themselves.

Keywords: epidemiology, variation, diversity, public officer, clinician-researcher, job change, collaboration, statistical indicator

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INTRODUCTION

Innovation in science is often achieved when new ideas and technologies come together (1). In epidemiology, this may occur when people from diverse backgrounds read or are involved in a study (2). Research results should be transparent to everyone (3). Research papers, particularly epidemiologic papers with public value (4), should be written to ensure that they can be broadly understood.

In Japan, there are many societal expectations regarding professional roles (5). The same phenomenon is observed in Western countries; as a result, the strategy for solving clinical issues is often expected to arise from a single idea (6). Communitarianism is sometimes preferred to individualism in workplaces and communities (7, 8). The attitudes of healthcare professionals in different specialties toward one another as well as toward other healthcare providers may limit the potential for collaboration and cross-disciplinary work (9). The degree of innovation in epidemiologic studies may be limited when professionals conform to cultural norms and associated values. The presentation of results may be biased toward those that fit within epidemiologists' world views (10). Epidemiologists tend to view issues at the level of large populations and summary statistics such as mean, standard deviation, and proportion.

Japan has relatively low academic job mobility because of the closed nature of the scholarly community and limited opportunities for academics in administrative agencies and private industry. Part of the closed nature of academic employment may be related to hiring based on referral rather than ability. Private companies sometimes hesitate to hire employees with doctoral degrees. Additionally, barriers exist among faculties in Japanese universities. For example, members of the faculties of medicine and of nursing value different academic cultures and qualifications. Because of these attitudes, trends in research publishing and student education can differ among faculties. Occasionally, such attitudes impede collaboration between members of different faculties (e.g., medicine and nursing or medicine and science).

Japanese administrative officers often have lifetime employment and rarely change jobs. Although they may rotate within roles in an organization, very few find academic jobs following administrative work. Hospital clinicians constantly seek scientific evidence to support their clinical practice. However, they are bound by their professional qualifications and clinical duties, and thus rarely publish scientific papers. Many non-academics (those employed outside of universities) want to implement scientific findings into practice (11). However, there are several barriers preventing this in the general population including socioeconomic status and class, obstacles related to healthcare qualifications, and the ability to understand English. Health professionals' views and knowledge are not always shared among the general population (12). Non-health professionals cannot always view study results from a clinical perspective. Epidemiologic research conducted by administrative professionals could identify new social needs and spark widespread interest. This may, in turn, lead to increased diversity in other branches of medical science. Interpretation of study results in the context of different professional perspectives is also important in disseminating results more widely.

In this study, we measured changes during the early and late 2010s in the variety of research topics published in an epidemiologic journal. We aimed to provide a perspective on how epidemiologists from diverse backgrounds can increase innovation and foster cross-discipline interactions.

METHODS

We investigated how the variety of research topics in epidemiology has changed over time. We examined the topics of research articles published in the *Journal of Epidemiology*, the official journal of The Japan Epidemiological Association. The journal accepts submissions from professionals working in the fields of medicine, odontology, pharmacology, nursing, public health administration, nutrition, sports medicine, physical therapy, occupational therapy, the humanities and social sciences, and veterinary medicine.

We assigned all articles published in the journal into categories of epidemiologic subspecialty based on their titles. Articles could be assigned to multiple categories. For example, we categorized a paper entitled "Community social capital and depressive symptoms among older people in Japan: A multilevel longitudinal study" (5) under social epidemiology, psychiatry, and geriatrics. To examine changes in the variety of topics covered in the journal over time, we examined articles published in 2011–2013 and in 2017–2019. We used Fisher's exact test to assess differences in the proportions of articles on each topic comparing 2011–2013 with 2017–2019. The goal of this analysis was to examine changes in epidemiologic research topics over the 2010s. We also calculated the Shannon–Weaver diversity index (H′) (6) to assess changes in topic diversity over time using the following formula:

$$H' = -\Sigma Pi \log Pi,$$

where Pi, representing the proportion of subset i within the entire set, is sensitive to changes in the relative abundance in a community (13). We also counted the number of categories appearing only in 2011–2013 or in 2017–2019. Using this count, we explored changes in the total number of categories addressed by published articles.

RESULTS

Table 1 summarizes the topics of epidemiologic studies published in the *Journal of Epidemiology* by epidemiologic subspecialty. Overall, the diversity of study topics did not change significantly from 2011–2013 to 2017–2019. The most common topics overall were cancer, cardiovascular disease, diabetes, physical activity and orthopedics, nutrition, tobacco, alcohol and internet addiction, and social epidemiology. **Figure 1** shows percentage of papers addressing the top seven research topics (cardiovascular disease, diabetes, cancer, physical activity, nutrition, tobacco, alcohol or internet addiction, and social epidemiology) in 2011–2013 and 2017–2019. Estimates of diversity using the Shannon–Weaver index were similar for the two periods: 4.25 for 2011–2013 and 4.21 for 2017–2019. In 2017–2019, there were greater proportions of studies on perinatal disease, pediatrics, geriatrics, oral/dental disease, disaster medicine, social epidemiology, and disability compared with 2011–2013. The increased focus on children, disaster medicine, periodontal disease, and disability may

TABLE 1 | Diversity in topics of articles published in the *Journal of Epidemiology* in 2011–2013 and 2017–2019.

Epidemiologic topic[†]	2011–13	Percentage	2017–19	Percentage	*P*-value[‡]
Clinical medicine, kidney disease	4	1.3	8	2.5	0.38
Cancer	27	8.7	32	10.0	0.59
Infectious disease	13	4.2	12	3.7	0.84
Cardiovascular disease	34	10.9	30	9.3	0.51
Digestive disease	3	1.0	6	1.9	0.51
Respiratory disease	8	2.6	4	1.2	0.26
Diabetes	29	9.3	31	9.7	0.89
Perinatal disease	12	3.9	17	5.3	0.45
Pediatrics	11	3.5	19	5.9	0.19
Geriatrics	8	2.6	13	4.0	0.38
Psychiatry	13	4.2	14	4.4	1.00
Intractable disease	7	2.3	1	0.3	0.035
Radiation	0	0.0	1	0.3	1.00
Oral/dental disease	3	1.0	6	1.9	0.51
Nutrition	24	7.7	24	7.5	0.16
Physical activity	27	8.7	25	7.8	0.77
Air pollution	5	1.6	5	1.6	1.00
Occupational medicine	4	1.3	6	1.9	0.75
Disaster medicine	5	1.6	9	2.8	0.42
Social epidemiology, deprivation, income or house	17	5.5	20	6.2	0.74
Genetic epidemiology	13	4.2	4	1.2	0.29
Molecular epidemiology	5	1.6	2	0.6	0.28
Tobacco, alcohol or internet addiction	22	7.1	23	7.2	1.00
Disability and hearing or visual ability	2	0.6	6	1.9	0.29
Methodology	13	4.2	3	0.9	0.011
Pharmacoepidemiology	2	0.6	0	0.0	0.24
Total	311	100	321	100	
Shannon-Weaver's diversity index H′		4.25		4.21	

[†] *A single study could be categorized under multiple topics.*
[‡] *From Fisher's exact test.*

reflect greater interest in these topics in recent years. The proportions of articles on intractable diseases (rare diseases with unknown etiology requiring long-term treatment) and methodology decreased significantly from 2011–2013 to 2017–2019. Very few topics were observed only in the earlier or the later data set. Only one topic (radiation) appeared in 2017–2019 but not the earlier period, and only one topic (pharmacoepidemiology) appeared in 2011–2013 but not the later period.

Following our exploratory Shannon–Weiner analysis, we applied Fisher's exact tests of proportion to assess differences in the frequencies of individual topics from 2011–2013 to 2017–2019. We found no significant difference in any topic after adjusting for multiplicity. Overall, topics of epidemiologic studies did not significantly change over the 2010s. This suggests that in Japan, at least, innovation in epidemiologic research may be limited. Therefore, we asked what could be done to bring together diverse professions and translate research results across disciplines.

DISCUSSION

Interpretation and Limitations of the Results

The total number of different topics of studies published in the *Journal of Epidemiology* was 311 in 2011–2013 compared with 321 in 2017–2019. In the 2010s, the diversity of topics addressed by published epidemiologic studies did not change significantly. This analysis was based on an overview of trends in study topics in a single journal. We anticipated that the diversity of topics would have changed over time. However, the diversity index and total number of topics addressed by published articles were similar in the two periods, suggesting no significant change.

Our analysis was limited in several ways. First, we assessed the topics of epidemiologic studies published in a single journal. The aim of this analysis was to explore the diversity of topics addressed in epidemiology and to assess how rapidly these topics were changing. Second, we could not evaluate the

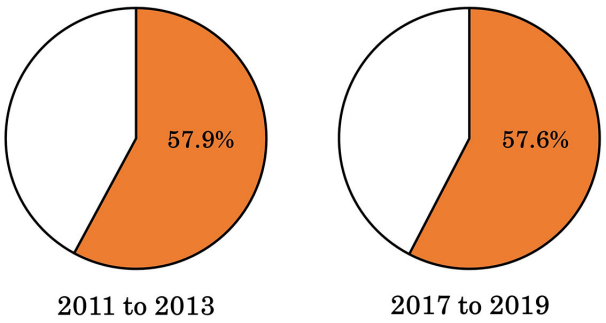


FIGURE 1 | Percentage of papers published in the *Journal of Epidemiology* addressing the top seven research topics (cardiovascular disease, diabetes, cancer, physical activity, nutrition, tobacco, alcohol or internet addiction, and social epidemiology) in 2011–2013 and 2017–2019.

statistical significance of changes over time in the Shannon–Weaver diversity index. Trends in epidemiologic research depend on the needs of clinical practice and the interests of the general population. Further investigation of academic trends in the publication of epidemiologic research may illuminate social opinions in the medical field. Third, the journal we investigated (the *Journal of Epidemiology*) was the official journal of an academic association, and thus authors were relatively biased toward members of the association. Thus, trends in the diversity of research topics were biased to deflect the interests of Japanese academics and members of The Japan Epidemiological Association.

The results in **Table 1** indicate that the topics addressed by epidemiologic studies and the authors' backgrounds cover diverse fields of medical science. The subjects of studies ranged from children to older adults. Papers covered clinical medicine, odontology, nutrition, exercise medicine, and environmental science. Thus, almost all qualified professionals contributed to articles published in the journal.

Most studies covered multiple specialties. This is a typical feature of epidemiologic studies. When publishing the results of an epidemiologic study, researchers need to collaborate with other epidemiologists, clinicians, administrative officers, and laypeople from different backgrounds.

Research Environments in Japan

Recently in Japan, the profession of epidemiology has become famous because of the ongoing coronavirus disease 2019 (COVID-19) pandemic. Formerly, epidemiologists were almost unknown among the general public. This is potentially because for over 200 years, the Japanese medical community has placed high value on basic science to understand physiological or biochemical causal associations. Conversely, epidemiology, a pragmatic data science based on correlation, was not highly weighed in policymaking or defining clinical guidelines. Recently, epidemiology has achieved enhanced influence in administration, clinical practice, and industry. Although academic, administrative, and clinical employment is highly coveted, the profession of epidemiology needs to be open to everyone to facilitate the use of epidemiologic data.

Current Roles of Epidemiologists

Epidemiologists in Japan may currently have several roles, whether they are clinicians or informed observers and laypeople. These roles include translation of epidemiologic results, analyzing data to help drive changes in clinical practice, improving medication plans, and developing new techniques for clinical epidemiologic studies. The diversity of these roles means that studies supported by epidemiologists can sometimes achieve innovative results (14).

It has become commonplace for scientific journals to request that authors ask an epidemiologist or biostatistician to assess the statistical methods of submitted manuscripts (15). Advising on statistical methods is an important role of epidemiologists. Biostatisticians can check manuscripts from a mathematical perspective, but epidemiologists can also check the statistical appropriateness of the study and statistical design. Therefore, epidemiologists fit between clinicians and biostatisticians and must understand both clinical needs and mathematics. Careers in epidemiology, therefore, should be open to professionals from different backgrounds, including clinicians and biostatisticians.

Conveying Epidemiologic Study Results to the General Population

It is common for clinicians and epidemiologists to work together as a team to design clinical epidemiologic studies, collect and analyze data, and report findings. These findings, expressed in non-technical terms, may appear in mainstream newspapers and magazines, as well as in media aimed at clinicians. Specialist media may provide detailed information on exposures, outcomes, and interpretations in the context of previous studies. Newspapers tend to provide more general information that is not particularly useful in clinical practice. This means that epidemiologists need to seek a balance between value for clinicians and the public.

In presenting epidemiologic work, illustrations may help to make data more understandable. Tables and figures should be designed so that they are comprehensible to both researchers in similar fields and to other professionals working in diverse areas. We believe that findings should be understandable by high school-level students (16) and be openly accessible online (17) to reach the broadest possible audience. The word "publish," after all, means to make findings available publicly.

Interpreting Research Results to Reflect Different Values and Cultures

To make their findings clear to individuals with different cultures and values, epidemiologists need to learn how to convey technical concepts to non-academics. In Japan, there is rarely a need to communicate with people who hold different cultural values in the workplace because there has been limited social mobility. However, this has begun to change because of the end of career-long employment in an era when intellectual labor and creative

thinking are required rather than factory work with industry-specific experience. Companies that produce information (e.g., Google, Amazon, Facebook, and Apple) have become dominant in place of those producing machines (e.g., Toyota or Honda). Instead of skilled labor, creativity and idea-driven thinking that understands the needs of public health and the general population is now needed for life-long employment. This means that epidemiologists may need to work with colleagues with different values and even change workplace several times over their lives. For example, epidemiologists may learn about public health values in administrative agencies and about commercial values in companies. Administrative and commercial values are often related to clinical values because both administrative agencies and commercial companies often focus on helping people remain healthy (6). In general, scholars work toward ideals, public administrators aim to provide social benefit within a given budget, and businesspeople strive for commercial gain and social contribution. However, the aims of the work conducted by these three groups often overlap; all of them pursue the public interest. The differences between them may lie primarily in terminology.

Epidemiologists may have difficulty in creating illustrations that are understandable to non-academics. For example, when presenting an odds ratio of two for mortality among cigarette smokers, journalists may understand this to mean that smoking doubles the mortality rate. This is not entirely correct in a mathematical sense (18) but may be considered good enough for interpretation by non-academics. Another example is the use of hazard ratios with adjustment of covariates. Here, academics might maintain that the hazard ratio needs to be interpreted using assumptions of proportional hazard (19) and appropriate covariate selection. However, it may be acceptable for non-academic purposes to ignore these assumptions.

Researchers must select the most appropriate strategies for conveying research findings to those in other professions. The optimal approach differs by specialty. For example, in reporting the impact of seasonal influenza infection on hospitalization within a region, local clinicians may use the number of hospitalizations (20). However, government officials may find it more informative to see the monthly hospitalization rate displayed as a graph, and it may therefore be necessary to provide both forms of information.

Exchanging Ideas on Clinical Issues and Data Analysis

Unlike clinicians, epidemiologists do not necessarily have intimate knowledge of patients' needs. Similarly, clinicians may not know how to analyze data to drive changing practice. It can therefore be helpful for clinicians and epidemiologists to collaborate to explore a particular issue. This may also help clinical epidemiology to survive as a career in the era of big data.

In Japan, there may be barriers between clinicians and epidemiologists in the conduct of clinical epidemiologic studies. These barriers could include different values and cultures arising from departmental priorities, duty hours, primary needs, career course, and criteria for performance evaluation.

From 2015 to 2017, we undertook a case-control study to investigate the risk of immune thrombocytopenic purpura risk associated with simultaneous vaccinations (21). This was a successful example of collaboration between clinicians, administrative officers, and epidemiologists. We sparked useful discussions spanning clinical interests, administrative needs, and the validity of epidemiological methods. These clinical interests, administrative needs and methodological priorities sometimes conflicted. However, after several discussions, all parties agreed. Finally, the results were reported to the Ministry of Health, Labor and Welfare and subsequently published. We consider it essential for individuals of different professional backgrounds in a study group to discuss and exchange their needs and cultural values.

Lessons From the COVID-19 Pandemic

Historically, collaborations among politicians, government administrators, administrative officers, clinicians, epidemiologists, data scientists, economists, commercial companies, and citizens has been required to control the spread of pandemics. Collaborations were simplified because the issue was evident and urgent to all parties; technology aided their communication and assisted the development of countermeasures. The COVID-19 pandemic may teach us valuable lessons in how to ask assistance from other professionals at remote sites as well as in how to efficiently share information. Although different professional cultures can sometimes prevent mutual understanding, new scientific innovations might be generated by the admixture of values from different cultures (1, 2).

Collaborations Among Individuals From Diverse Backgrounds

Combining different academic specialties can produce new disciplines (1). For example, cross-disciplinary work between medicine and evolutionary biology created the field of evolutionary medicine (22), which has provided new interpretations of why humans develop disease. Cross-disciplinary research on circadian rhythms and psychiatry produced the field of sleep science. The field of psychology has also provided "nudge" interventions to help prevent disease (23). Throughout history, academic fields have intersected, converged, and diffused. Collaboration has been at the departmental, institutional, or national level and has been aided by development of technologies and communication tools.

Collaboration can be achieved by bringing together people from different backgrounds. However, the experience of different roles and organizations can also encourage individuals to produce new ideas themselves. Collaboration between individuals may be made difficult by physical distance and psychological issues. However, friction of ideas within an individual can also lead to innovation. In solving a complex issue, bringing together different ideas within a single brain can often be extremely powerful, including in the field of epidemiology.

There is very low job mobility in Japan (24). Working for a single company was considered ideal in the period of high economic growth after the Second World War. However, Japan has now entered an era in which many people change jobs several times during their lives. In the future, epidemiologists will have much more diverse backgrounds and skills, which may be crucial in exploring new ideas and innovations in the field.

CONCLUSION

Our analysis of changes in article titles published in an epidemiologic journal suggested little change in the diversity of research topics in the 2010s. However, topics over this decade covered all clinical qualifications and specialties. Thus, in epidemiologic studies, communication with individuals with diverse backgrounds is essential. The intersection between clinicians, administrators and epidemiologists has the potential to foster scientific innovation. This could be important both in situations in which each role is taken by a different person and in which an individual has worked in several fields and brings these distinct experiences together. Research results can be most easily tailored to an audience by researchers who are also part of that audience. Scientific progress has been a challenge for researchers for many years. Changing attitudes by encouraging movement between workplaces and bringing together professionals from different backgrounds has the potential to create new and innovative results, catalyze innovation, and drive scientific progress.

DATA AVAILABILITY STATEMENT

The original contributions generated for the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

HY: original draft preparation, conceptualization, methodology, analysis, investigation and review, and editing. MM: original draft preparation, investigation and review, results interpretation, and editing. ZY: resources, results interpretation, and editing. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Perioperative Exercise Intention and Influencing Factors: A Multi-Centered Cross-Sectional Study

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Objectives: This study aimed to evaluate the level and factors affecting the perioperative exercise intention in China.

Design: This study was a cross-sectional survey in Southwest China.

Methods: Four hundred and ninety nine participants were randomly sampled in eight medical centers from November 23, 2020 to November 27, 2020. The survey included sociodemographic information and a 24-item modified questionnaire, which aimed to evaluate the attitude toward daily exercise, perception of perioperative exercise, social support and the perioperative exercise intention. A multivariable linear regression model was used to evaluate the effect of different items on the patients' intention for perioperative exercise.

Results: A total of 523 responses (95.09%) were collected and 499 (95.41%) were analyzed. The level of exercise intention of the patients during the perioperative period was: 14.83% planned to exercise every day in the hospital, 21.04% planned to exercise every other day, and 35.87% planned to exercise every week. Intensity of daily exercise ($P = 0.016$), positive attitude of daily exercise ($P < 0.001$), positive attitude of perioperative exercise ($P < 0.001$) and social support ($P < 0.001$) were positively associated with the intention for perioperative exercise. Female ($P = 0.012$), non-tertiary center ($P = 0.011$), and preoperative anxiety ($P = 0.023$) was negatively associated with it.

Conclusions: The intention for perioperative exercise was low in Southwest China. The authors aimed to relieve preoperative anxiety, promote the education of perioperative exercise, design perioperative exercise programs, and provide more social support from medical staff and family for inpatients undergoing elective surgery.

Keywords: physical activity, perioperative exercise, intention, China, inpatient

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INTRODUCTION

Physical activity (PA) is a major contributor to prevent non-communicable diseases. Strong evidence supports that PA can generate positive clinical outcomes such as reducing blood pressure, glycosylated hemoglobin, cholesterol and important positive effects on mental health. It not only provides survival benefits both in primary and secondary cardiovascular disease prevention, but also increases lung function with higher FEV_1 and FVC (1). The World Health Organization (WHO) and American College of sports medicine PA guidelines recommend that all adults should undertake 150–300 min of moderateintensity, or 75–150 min of vigorous-intensity physical activity, or some equivalent combination of moderateintensity and vigorous-intensity aerobic physical activity, per week (2, 3). In the UK, the National Institute of Health and Care Excellence (NICE) encourages people to be physically active, and there should be referral schemes for sedentary or inactive adults (4). WHO has identified physical inactivity as the fourth leading risk factor for overall morbidity and mortality, and has adopted a new voluntary global target to reduce global levels of physical inactivity in adults and adolescents by 15% by 2030. Despite this, few adults regularly participate in PA to promote health; 31.1% of adults were physically inactive worldwide (5). It is closely related to age, gender, education, income and area (5, 6).

Temporary functional decline as a result of decreased PA is a common side-effect during the perioperative period. Surgical stress is also a physiological contributor to functional decline. A poorer preoperative physical condition could hamper post-operative recovery, increase hospitalization times and operative mortality. Our previous study and those of other researchers both show that preoperative exercise-based training can improve preoperative lung function, reduce post-operative hospital stay and post-operative complications (7–9). Early physical exercise after surgery significantly improves functional and aerobic capacity following cardiac surgery (10). Therefore, in the case of elective surgery, patients should begin physical exercise before surgery and continue to exercise early and late after surgery until the maximum recovery of physical function and social participation is achieved (11). Some recommendations on perioperative exercise training have been offered in guidelines (12, 13). In patients awaiting major non-cardiac surgery, it is recommended 30–60 min of moderate exercise, or 20–60 of vigorous exercise, or a combination of moderate and vigorous exercise per day (13).

Unlike leisure-physical exercise, perioperative exercise is affected by surgical disease, pain, mental status at the same time. However, there is a complete lack of primary data describing on the perioperative exercise intention (PEI) in surgical patients and influencing factors in China. In this paper, we report on the current profile, opinion, and factors affecting perioperative exercise in Southwest China.

METHODS

Participants

This study was approved by the institutional Ethics Board of the First Affiliated Hospital of Chongqing Medical University (the organizing center) on November 19, 2020 (approval number: 2020-666). The study was registered before patient enrolment at http://www.chictr.org.cn (registration number: ChiCTR2000040078). A stratified random sampling survey was carried out in 8 medical centers (2 university-affiliated hospitals, 3 hospitals at provincial level, 3 secondary hospitals for adult in Southwest China) depending on geological distribution.

The study protocol was conducted according to the principles of survey research (14). Informed consent was obtained from all participants. Then inpatients undergoing elective surgery were surveyed with face-to-face on the first day of hospitalization, from November 23, 2020 to November 27, 2020. All 21 investigators were trained with the questionnaire and communication skills.

Inpatients undergoing elective surgery ranged from 18 to 90 years old. Emergency surgery, patients with cognitive dysfunction, acoustic dysfunction, visual impairment and completely self-care functional disability were not included, which was based on the patient's history; and other conditions that made it impossible for hospitalized patients to be interviewed.

Measures and Materials

The questionnaire included eight domains with 39 items in Chinese (**Appendix 1**). Three experts' consensus on the suitability of the 39 items on the questionnaire set were obtained. The basic characteristics of patients included age, gender, height, weight, educational background, social and economic status, marital and children status, medical payment, self-care ability (11 items), and disease characteristics included comorbidity, preoperative pain, emotional state, surgical types (4 items). Preoperative exercise characteristics included length and intensity of daily exercise based on the Global Physical Activity Questionnaire (2 items).

The scale for measuring attitude toward daily exercise was prepared by partially modifying attitudes toward exercise scale used in older adults (15). The scale comprised 3 items (Cronbach's alpha = 0.699) with each item assessed on a 5-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Uncertain, 4 = Agree, 5 = Strongly agree).

A scale for measuring perception of perioperative exercise was prepared by modifying and supplementing attitudes toward exercise scale used by Park (16). The scale comprised 10 items pertaining to perception of rehabilitation (Cronbach's alpha = 0.697), negative attitude of preoperative exercise (Cronbach's alpha = 0.699), and positive attitude of preoperative exercise (Cronbach's alpha = 0.740).

The scale to measure social support was prepared by modifying the 5 items from the study by Hankonen et al. (Cronbach's alpha = 0.850 at baseline, 0.836 in the current

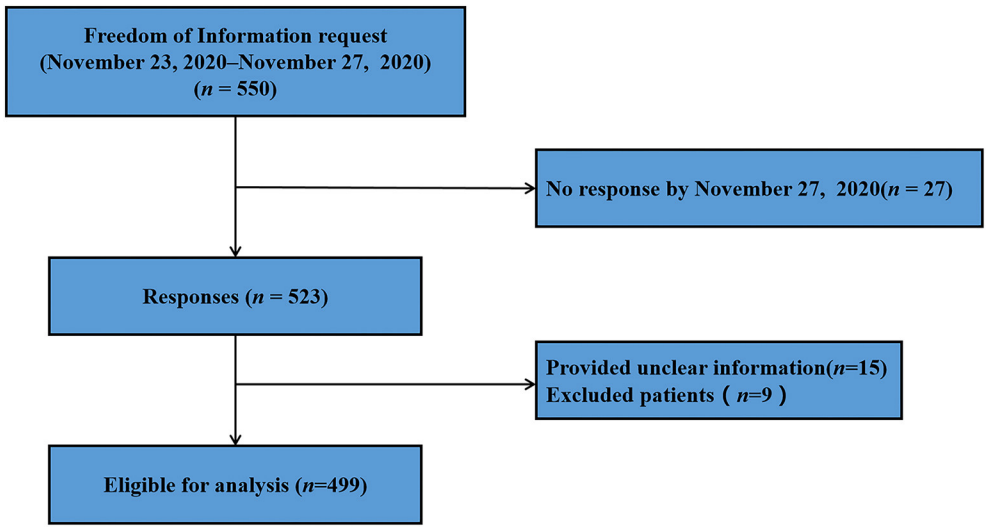


FIGURE 1 | Flowchart of the study population selection.

study) (17). To assessing PEI, authors used the scale by modifying 4 items scale from the stage models of physical activity developed by Duan (18). Cronbach's alpha was 0.677 as reported in Liu's study, and was 0.916 in this study (19).

Reliability analysis yielded a Cronbach coefficient alpha of 0.873 for the total sample.

Sample Size Calculation

A previous study reported that percentage of persons with low physical activity was ∼50% in China (20). The requirement of minimum sample size in this study was 402 participants to reach the statistical significance at two-sided 95% confidence interval with a width equal to 0.100 when the sample proportion is 0.500. In addition, the total sample size was 503 by assuming a 20% attrition during follow-up. Finally, the scheduled sample was decided to be 550. The sample size calculation was performed PASS 15.0 analysis program.

Statistical Strategies

The responses to the questions were summarized and analyzed via SPSS 21.0. Baseline characteristics were described by descriptive statistics. The continuous variables were compared by *T*-test (parametric)/Mann–Whitney U test (non-parametric) between two independent samples, and compared by One-Way ANOVA (parametric)/Kruskall-Wallis (non-parametric) tests between more than two independent samples. Pearson's (parametric)/Spearman's (non-parametric) tests were used to assess the correlation between continuous variables. The internal reliability of the training satisfaction questionnaire was assessed by Cronbach's alpha. A multivariable linear regression model was used to evaluate the effect of different items on PEI. The graphs were created by Graphpad prism 8. A value of $P < 0.05$ was considered statistically significant.

RESULT

A total of 550 questionnaires were send to different medical centers, 523 patients had been completed by November 27, 2020, with a response rate of 95.09%. Of these, we excluded 15 patients and 9 patients did not meet the inclusion criteria, therefore, a total of 499 patients were included in this analysis (**Figure 1**). The face-to-face interview for patients took 278.00 (interquartile range, IQR, 288) s to complete the questionnaire in this survey.

The baseline characteristics of patients are described in **Table 1**. The range of age were 18–90 years, the median age was 53 years (IQR, 20). 46.89% of the patients were male and 53.11% were female. Overall, 4.61% of the patients had a body mass index (BMI) < 18.5 kg/m^2, and 42.28% had a BMI > 24.0 kg/m^2. The education level of the patients was mainly primary and middle school (64.53%), undergraduate and graduate students accounted for only 15.83%, and working patients accounted for 72.34%. 10.82% of the patients had a monthly income of more than 10,000 yuan. A majority of the patients complained of mild pain before surgery (43.29%), and 15.43% reported moderate or severe pain. Most patients (69.74%) could meet the WHO PA recommendation (moderate intensity PA of 150 min, or 75 min vigorous-intensity PA per week). 83.57% of the patients took exercise at a moderate-vigorous intensity in daily life. The majority of the patients felt anxiety before surgery (79.16%).

The scores in PEI items were from 5 to 20, the median was 11.00 (IQR, 4). Only 74 (14.83%) of the patients planned to take exercise every day in hospital, 105(21.04%) once every 2 days and 179 (35.87%) per week (**Figure 2**). A comparison of PEI scores between these various factors found that they differed significantly in educational background ($P = 0.047$), social status ($P = 0.001$), monthly incomes ($P = 0.001$), self-care ability

TABLE 1 | Baseline characteristics of survey respondents and factors affecting overall perioperative exercise intention ($N = 499$).

Characteristics	*n*	(%)	Perioperative exercise intention Median (IQR)	Statistical methods	*P*-value
Gender					
Male	234	(46.89%)	11.00 (4)	Mann–Whitney U test	0.068
Female	265	(53.11%)	10.00 (4)		
Age (yr)					
18–35	77	(15.43%)	11.00 (5)	Kruskall-Wallis test	0.331
36–49	115	(23.05%)	12.00 (4)		
50–59	141	(28.25%)	10.00 (5)		
≥60	166	(33.27%)	11.00 (4)		
BMI (kg/m^2)					
<18.5	23	(4.61%)	12.00 (3)	Kruskall-Wallis test	0.066
18.5–23.9	255	(51.10%)	10.00 (3)		
≥24.0	221	(42.28%)	11.00 (5)		
Educational background					
Primary school	165	(33.07%)	10.00 (3)	Kruskall-Wallis test	0.047
Middle school	157	(31.46%)	10.00 (4)		
High school	101	(20.24%)	12.00 (5)		
Bachelor or post-graduate	76	(15.83%)	11.00 (4)		
Social status					
Employed	361	(72.34%)	10.00 (3)	Mann–Whitney U test	0.001
Retried or unemployed	138	(27.66%)	12.00 (6)		
Monthly incomes(RMB, Yuan)					
≤1,000	100	(20.04%)	9.00 (4)	Kruskall-Wallis test	0.001
1,001–3,449	182	(36.47%)	11.00 (4)		
3,500–9,999	163	(32.67%)	11.00 (4)		
≥10,000	54	(10.82%)	12.50 (7)		
Marital status					
Married	453	(90.78%)	11.00 (4)	Mann–Whitney U test	0.122
Single or divorced	46	(9.22%)	10.00 (4)		
Children status					
Have children	461	(92.38%)	11.00 (4)	Mann–Whitney U test	0.852
No children	38	(7.62%)	10.50 (4)		
Medical payment					
Medical insurance	462	(92.59%)	11.00 (4)	Mann–Whitney U test	0.970
Self-paying	37	(7.41%)	11.00 (5)		
Self-care ability					
Partly capable	116	(23.25%)	10.00 (3)	Mann–Whitney U test	0.041
Completely capable	383	(76.75%)	11.00 (4)		
Comorbidity					
Yes	243	(48.70%)	11.00 (3)	Mann–Whitney U test	0.933
No	256	(51.30%)	11.00 (4)		
Preoperative pain					
No pain	206	(41.28%)	11.00 (4)	Kruskall-Wallis test	0.813
Mild	216	(43.29%)	11.00 (4)		
Moderate	63	(12.62%)	11.00 (5)		
Severe	14	(2.81%)	12.00 (4)		
Surgical types					
Head or neck surgery	62	(12.42%)	12.00 (7)	Kruskall-Wallis test	0.061
Thoracic surgery	36	(7.21%)	12.00 (5)		
Abdominal surgery	273	(54.71%)	11.00 (4)		
Limb surgery	99	(19.84%)	10.00 (5)		

(Continued)

TABLE 1 | Continued

Characteristics	*n*	(%)	Perioperative exercise intention Median (IQR)	Statistical methods	*P*-value
Spinal or brain surgery	29	(5.81%)	9.00 (4)		
75 min of vigorous or 150 min of moderate intensity per week					
Yes	348	(69.74%)	11.00 (4)	Mann–Whitney U test	0.742
No	151	(30.26%)	11.00 (3)		
Intensity of daily exercise					
Light	82	(16.43%)	10.50 (4)	Kruskall-Wallis test	0.224
Moderate	266	(53.31%)	11.00 (4)		
Vigorous	151	(30.26%)	11.00 (6)		
Preoperative anxiety					
Yes	395	(79.16%)	10.00 (4)	Mann–Whitney U test	0.000
No	104	(20.84%)	12.00 (5)		
Hospital grade					
Tertiary hospital	370	(74.15%)	12.00 (5)	Mann–Whitney U test	0.000
Non-tertiary center	129	(25.85%)	9.00 (2)		

BMI, body mass index; IQR, interquartile range.

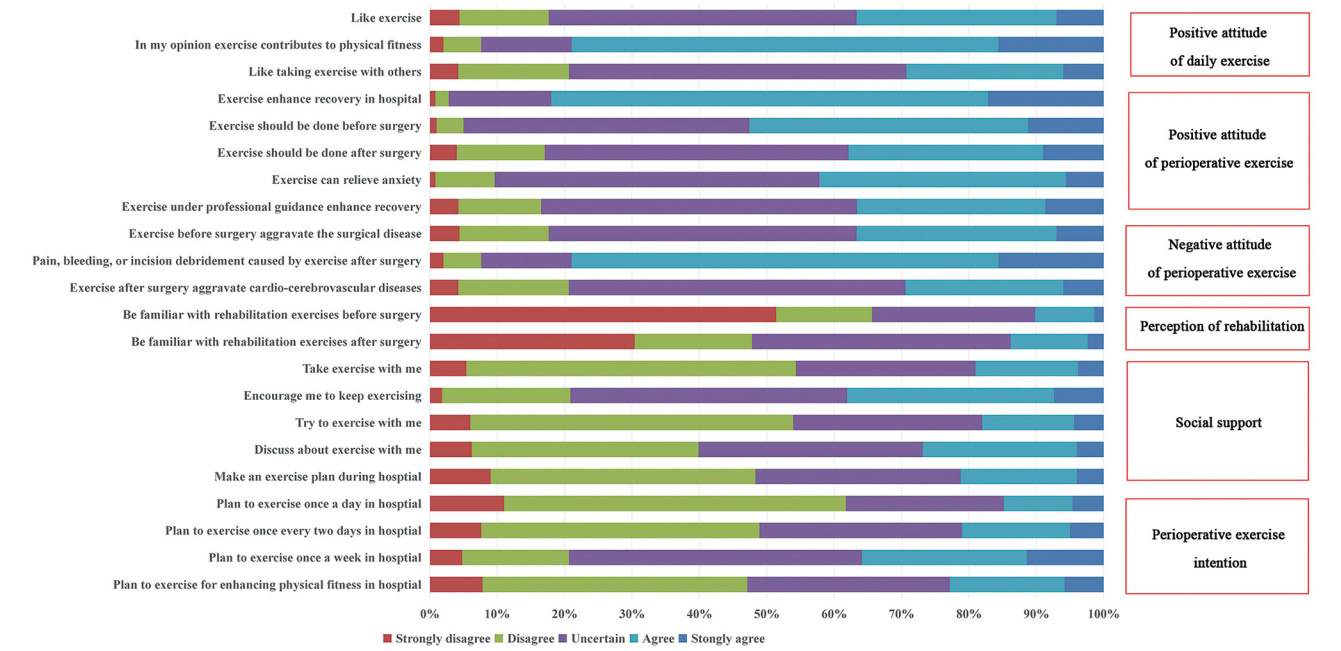


FIGURE 2 | Respondents' perioperative exercise intention (scores from 4 to 20), positive attitude of daily exercise (scores from 3 to 15), positive attitude of perioperative exercise (scores from 5 to 25), negative attitude of perioperative exercis (scores from 3 to 15), perception of rehabilitation (scores from 2 to 10), and social support (scores from 5 to 25).

($P = 0.041$), preoperative anxiety ($P < 0.001$), and hospital grade ($P < 0.001$) (**Table 1**).

In terms of their attitude toward daily sports, 394 people (78.96%) believed that daily sports were beneficial to their health, only 183 people (36.67%) liked sports, and 146 people (29.26%) were willing to do sports with others. Most of the patients believed that exercise could enhance the recovery in hospital (82.16%), and exercise should be done before (52.70%) or after (37.88%) surgery. 42.28% of the patients thought exercise could relieve anxiety, and 36.47% of the patients thought exercise under professional guidance could promote recovery. More than three quarters of the patients

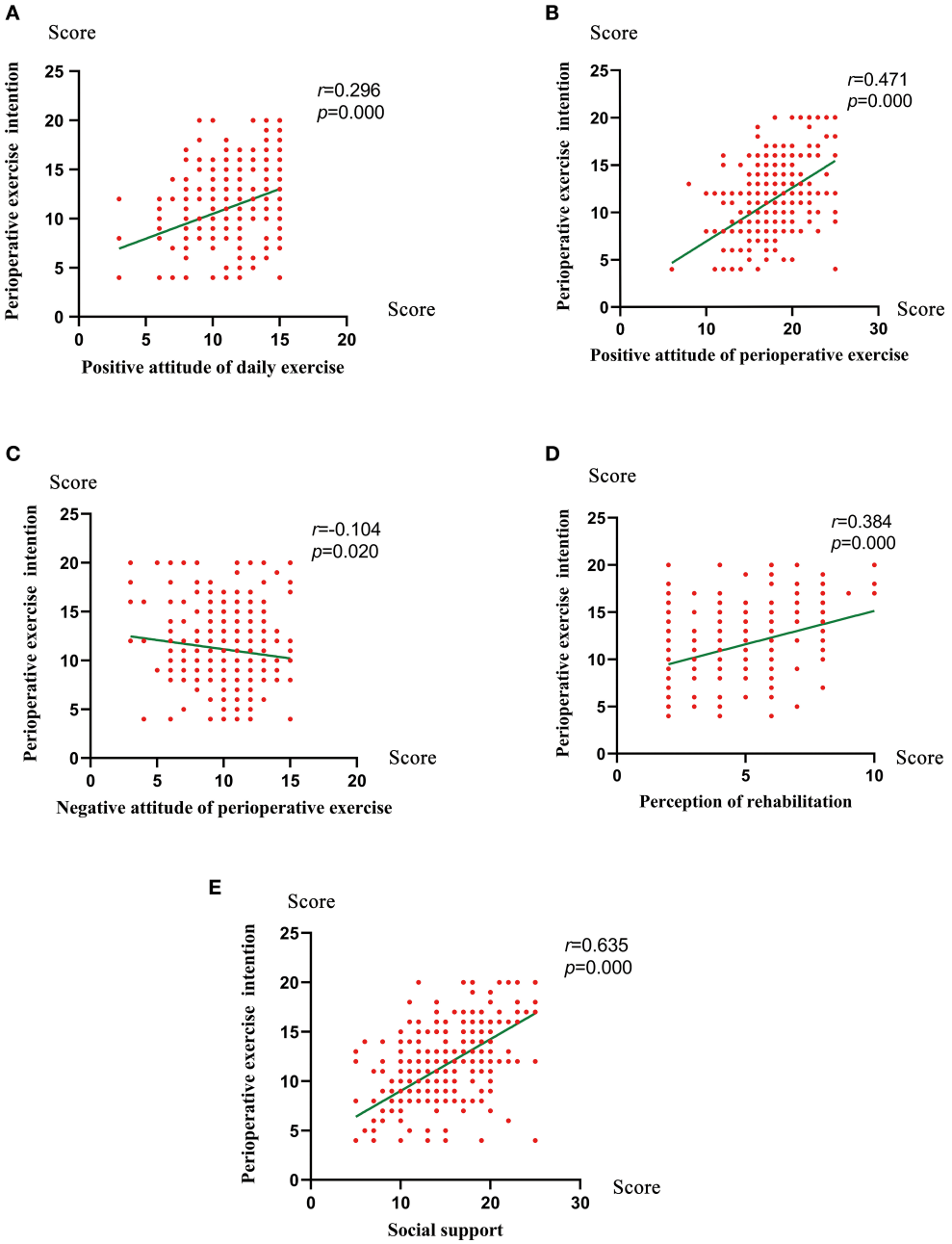


FIGURE 3 | The correlation between the perioperative exercise intention and positive attitude of daily exercise **(A)**, positive attitude of perioperative exercise **(B)**, negative attitude of perioperative exercise **(C)**, perception of rehabilitation **(D)**, and social support **(E)** used by Spearman's tests.

were concerned that exercise would increase the risk of post-operative pain, bleeding, or wound debridement (78.96%), as well as exacerbate preoperative surgical disease (36.67%) and post-operative cardiovascular and cerebrovascular disease (29.46%). The patients were unfamiliar with rehabilitation exercises before (10.22%) and after (13.83%) surgery. In this survey, social support from family or medical staff movements was low (**Figure 2**).

Figure 3 showed a higher PEI was associated with positive attitude of daily exercise ($r = 0.296$, $P < 0.001$),positive attitude of perioperative exercise ($r = 0.471$, $P < 0.001$), perception of rehabilitation ($r = 0.284$, $P < 0.001$), social support ($r = 0.635$, $P < 0.001$) and was negatively correlated with negative attitude of perioperative exercise ($r = -0.104$, $P = 0.020$). The variables which remained significantly associated with PEI on multivariable regression analysis included gender ($P = 0.012$),

TABLE 2 | Multivariate liner regression analysis for perioperative exercise intention ($N = 499$).

Model	β	*SE*	β'	*t*	*P*-value	95% confidence interval for β	
						Lower bound	Upper bound
Female	−0.598	0.237	−0.088	−2.521	0.012	−1.064	−0.132
Intensity of daily exercise	0.446	0.186	0.088	2.425	0.016	0.085	0.808
Non-tertiary center	−0.808	0.315	−0.104	−2.568	0.011	−1.426	−0.190
Positive attitude of daily exercise	0.232	0.061	0.142	3.782	0.000	0.111	0.352
Preoperative anxiety	−0.659	0.289	−0.079	−2.285	0.023	−1.226	−0.092
Positive attitude of preoperative exercise	0.200	0.047	0.170	4.276	0.000	0.108	0.292
Social support	0.388	0.033	0.470	11.653	0.000	0.323	0.454

intensity of daily exercise ($P = 0.016$), hospital grade ($P = 0.011$), positive attitude of daily exercise ($P < 0.001$), preoperative anxiety ($P = 0.023$), positive attitude of perioperative exercise ($P < 0.001$), and social support ($P < 0.001$) (**Table 2**).

DISCUSSION

This is the first survey on PEI of surgical inpatients and influencing factors in China. Our results demonstrated that there is a low level perioperative exercise intention Chinese people, which is affected by multiple factors including biological and social environment. An overall Cronbach's alpha = 0.86 of inpatient responses shows that the items on PEI have a high internal consistency.

Regular physical activity helps to improve physical and mental functions and helps individuals to maintain a healthy weight as well as reverse some effects of chronic disease. Globally, 81.0% of students aged 11–17 years were insufficiently physically active, (21) while 31.1% of adults were physically inactive (5) and 35% of older adults did not reach the global physical activity recommendations (22). Perioperative exercise could improve physical fitness and health status and reduce the risk of perioperative morbidity and mortality. The percentage of planning to exercise every day in hospital was just 14.83% in this study.

According to the findings of this study, women are less likely to exercise in hospital than men. Studies conducted in many countries have reported less PA among women than men (23, 24). PA levels gradually decline with age, and the decline is greater in women (25). The standard of living, work status, smoking status and social support contribute to the gender difference (17, 26). So we should be more concerned and give much support for women exercise.

Among older adults, an age related decrease in the intensity of physical activity was associated with a higher risk of depressive symptoms (27). Among adults and older adults, those who met WHO guidelines for moderate and vigorous exercise, but also used both, reported significantly higher levels of happiness (28). Our findings documented that moderate-intensity activity was the most beneficial activity level for improving PEI.

There is a significant association between socioeconomic position and physical activity (6, 29). Compared with rural areas and commuters, urban, educated and affluent people are more active in physical activity in their leisure time, but less active at work (6). In a study of twins over a 35-year follow-up study, the higher education was associated with lower odds of leisure-time physical inactivity (30). We did not find that the direct relationship between the socioeconomic position and PEI, but the patients in tertiary hospital had higher intention to PEI in this study. The reason may be that patients with high income and education background are easier to have their surgeries in tertiary hospitals with more social and medical resources in China.

Attitudes and beliefs about PA and health have been reported to correlate with PA levels (31). According to our findings, the patients with positive attitude of daily and perioperative exercise were more likely to take exercise during hospital. Inpatients appear to have a negative attitude toward physical activity, mainly due to the lack of counseling provided by medical staff (32). Social support from family and medical staff significantly impact the PEI in this study. Among patients with coronary artery disease, social support from medical staff plays a key role in promoting physical activity and concern by families and physicians about the relative risk of kidney disease was inversely associated with patient inactivity (32). Therefore, it could be recommended that family and medical staff should spend more time and put more effort in informing and counseling the patients toward increased perioperative exercise.

A perspective from the world health survey demonstrates that anxiety is associated with less physical activity, 33.1% of 24,850 people with anxiety symptoms were at low PA (33). Anxiety is one of the most common psychological reactions observed in patients waiting for various types of surgery, even occurring in up to 80% of patients (34). Our data showed that the prevalence of preoperative anxiety was 79.16%, which reduced the PEI. The risk factors of preoperative anxiety included female, having a higher American Society of Anesthesiologists (ASA) grading, psychiatric illness, high baseline anxiety levels, previous adverse clinical experiences, and undergoing specific types of operation. Preoperative anxiety could be reduced by reading a procedural information leaflet and receiving preoperative behavioral training (35).

To the best of our knowledge, this is the first cross-sectional study to examine perioperative motor intention and its influencing factors. Despite a high response rate in this survey, some limitations and avenues for future research

should be noted. Firstly, investigated the perioperative exercise intention by questionnaire responses, and further observation and randomized controlled studies will be useful in future. Secondly, due to the particularity of perioperative exercise, although many scales have been used in the investigation of daily exercise, the development and validation of perioperative exercise scale still needs more research support. Thirdly, the influencing factors of perioperative movement need to be further observed and analyzed.

CONCLUSION

This survey provides a contemporary assessment of the current intention for perioperative exercise of patients undergoing elective surgery in Southwest China. The intention for perioperative exercise should consider the importance of gender, intensity of daily exercise, hospital grade, positive attitude of daily exercise, preoperative anxiety, positive attitude of perioperative exercise and social support. Therefore, this study is a call to action to relieve preoperative anxiety, promote the education of perioperative exercise, design perioperative exercise programs and provide more social support from medical staff and family. In the future research and clinical practice, in-depth interviews, observational studies and clinical trials should be conducted to further explore the patients' intention for perioperative exercise and its influencing factors.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the institutional Ethics Board of the First Affiliated Hospital of Chongqing Medical University (approval number: 2020-666). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SM, FLv, YZ, and LR: study design. YS, ST, JJ, BWa, XLu, JingC, YC, YL, JinC, XZ, FLu, QX, LZ, LP, YG, JCa, QC, BWu, GC, XLi, and BX: data collection. FLv, YZ, LR, JY, and YS: statistical analysis. FLv, YZ, LR, and JY: drafting of the manuscript. SM, FLv, YZ, LR, PL, LP, and BWa: manuscript preparation. All authors edited, read, and approved the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.653055/full#supplementary-material

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BRIEF RESEARCH REPORT
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Health Communication and Inter-professional Care in Context of Multimorbidity Management: Assessment of Health Professional Curricular Focus in India

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To meet the long term care demands of chronic diseases as well as multimorbidity, healthcare providers from different disciplines need to work collaboratively in practice. This requires healthcare providers to be appropriately trained on delivery of inter-professional care (IPC) and health communication aspects during formative professional years. In this study, we have looked at the prevailing undergraduate and postgraduate healthcare professional curricula to understand the focus on health communication and on IPC for the delivery of multidisciplinary care for multimorbidity management. We observe that while there are exclusive courses on health communication being delivered at different levels, the focus on IPC is still in stages of infancy. The IPC component is just beginning to be woven into the health professional curricula through elements like competency-based curriculum, rotational posting, inter-departmental engagements. At the same time, the need to put curricular attention on multimorbidity is also highlighted here. There remains wider scope for strengthening learning on health communication and IPC among different disciplines within the curricula in the context of multimorbidity. We expect our findings to provide key inputs to academic planners and policy makers towards the introduction of adequate curricular components for addressing multimorbidity along with necessary prescriptions for health communication and IPC in India.

Keywords: multimorbidity, multiple comorbidities, patient-centred care, primary care, inter-professional care, health communicaiton, health promotion, health education

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Abbreviations: AETCOM, Attitude, Ethics and Communication; AIIMS, All India Institute of Medical Sciences; BDS, Bachelor of Dental Surgery; BPT, Bachelor of Physiotherapy; BSc, Bachelor of Science; CMC, Christian Medical College; HIV/AIDS, Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome; HWC, Health and Wellness Centre; IPC, Inter-professional care; JIPMER, Jawaharlal Institute of Postgraduate Medical Education and Research; MBBS, Bachelor of Medicine and Bachelor of Surgery; MD and MS, Doctor of Medicine and Surgery; MPT, Master of Physiotherapy; MSc, Master of Science; MCI, Medical Council of India; MoHFW, Ministry of Health and Family Welfare; NMC, National Medical Commission; NIRTAR, National Institute of Rehabilitation Training and Research; PGIMER, Postgraduate Institute of Medical Education and Research.

INTRODUCTION

With improvement in living condition, health care efficacy and better management of infectious diseases, the world is now transitioning to an ageing population. Corresponding with this is the growing magnitude of both chronic diseases as well as multiple chronic diseases, which is gradually taking shape of a daunting public health care challenge. This problem is more acute in low- and middle-income countries (LMICs) experiencing colliding epidemics of long-standing infectious and chronic non-communicable diseases (NCDs) (Bigna and Noubiap, 2019; Kassa and Grace, 2019).

The concurrent prevalence of multiple chronic conditions, known as multimorbidity, is a frequently observed norm in LMICs. Apart from the risk attributable to individual diseases, patients with multimorbidity have lower functional capacity, exhibit inferior physical and mental health related quality of life, incur higher healthcare expenditure, increased levels of polypharmacy, and heightened risk of hospital admissions and mortality rates (Pati et al., 2015a; Pati et al., 2019a). Though initially thought to be confined to elder age, multimorbidity is now found to have pervaded across younger population and all geographic and socio-economic strata in the country. This is undoubtedly an additional concern posed for health systems, professionals and patients alike.

India, the second largest demography is also witnessing an unprecedented rise in chronic diseases over the past 2 decades (Arokiasamy, 2018). Primary care being integral part of India's public health system has to absorb the major brunt since individuals with multimorbidity are mostly seen by primary care physicians although many of the issues are likely to be of similar importance in secondary care (Sinha and Pati, 2017). Our own study has found the prevalence to be around 1/3rd in primary care patient population (Pati et al., 2015b). There is even significant multimorbidity among patients attending secondary and higher levels of health care, as well as specialized settings like psychiatry or antenatal clinics (Pati et al., 2021a; Pati et al., 2021b).

The management of both chronic diseases and multimorbidity requires a holistic care approach, wherein multiple health professionals from different disciplines work together as a team in the healthcare settings. The harmony and effectiveness of such team-based care delivery would depend on synergy and synchrony across multiple healthcare professionals. With the universal health coverage being implemented in India, the organization of primary care as 'health and wellness centers' (HWC) is one of the critical goals (Lahariya, 2018). These HWCs are expected to deliver comprehensive primary care through an expanded range of services and a multidisciplinary team.

This is linked to the appropriate training of healthcare professionals in their respective formative years on inter-professional care (IPC). The role of better health communication within and beyond health professionals through collaboration between different health care disciplines is equally important. Healthcare professionals are to get first familiarized with these newer dimensions from their very stage of professional curating. One of the ways to achieve the above is that the prescriptions in the curriculum are commensurate as well.

It is therefore necessary to have adequate understanding and evidence on the current situation through a mix of approaches encompassing–curriculum review, primary data from key informants and policy analysis prior to co-creating any intervention. We therefore intended to have an inquiry into the status of health communication in general and IPC in particular within the context of multidisciplinary care for multimorbidity in India. Given the exploratory nature of our inquiry, we decided to undertake only curricular assessment to garner a preliminary understanding to start with. Our objective was 1) to map the extant undergraduate and post graduate health professional curricula (medical, nursing, dentistry, and physiotherapy) in India to see if they directly address multimorbidity and IPC for multimorbidity management, and 2) to identify the elements of health communication dwelling on these aspects. We expect the findings of the curricular assessment would provide key inputs to academic planners and policy makers towards the introduction of adequate curricular components for addressing multimorbidity along with necessary prescriptions for IPC in India. Moreover, it would help provide insights towards designing research tools for primary data collection from multiple stakeholders.

METHODOLOGY

The present study was carried out from January–December 2019 with a two-fold objective. One was to map the extant health professional curricula in India to identify the elements pertaining health communication, followed by analysis of the curricula with focus on IPC towards delivery of multidisciplinary care for multiple chronic conditions.

A systematic strategy based on our previously used approach was followed for extracting the required information (Pati et al., 2017a; Pati et al., 2019b). First, a thorough internet search was carried out to collect information available in the public domain regarding courses offered in health communication, health education and health promotion. The search was carried out using search engines such as Google, Dogpile wherein a set of keywords such as health communication, health education and health promotion, public health education in India, health communication courses offered in India etc. were used for the search. It was restricted to courses offered in India only. The websites of Medical Council of India (MCI) (now known as the National Medical Commission [NMC]), Ministry of Health and Family Welfare (MoHFW), Indira Gandhi National Open University (IGNOU), All India Institute of Medical Sciences (AIIMS), World Health Organization (WHO) were also looked up. Information related to the courses were collected from the websites of respective institutions. Modules on health communication being delivered as part of journalism or mass communication programmes have been excluded.

The second part of the research involved a similar strategy. Amongst undergraduate curricula, we included Bachelor of Medicine and Bachelor of Surgery (MBBS), Bachelor of

TABLE 1 | Overview of courses related to health communication, promotion and education offered in India[a].

Institution/University	Course/Curriculum	Duration	Type of course	Mode
Symbiosis School of Open and Distance Learning, Maharashtra	Diploma programme in health communication	1 year	Diploma	On-site
Banaras Hindu University, Uttar Pradesh	Post graduate diploma in health communication	1 year	Post graduate diploma	On-site
National Institute of Health and Family Welfare, New Delhi	Diploma in health communication, diploma in heath promotion	1 year	Diploma	Distance learning
Family Welfare Training and Research Centre, Mumbai (recognized by International Institute of Population Sciences (IIPS), a deemed University under the Ministry of Health & Family Welfare)	Diploma in health promotion education	1 year	Residential diploma	On site
Indira Gandhi National Open University	Diploma in nutrition and health education	1 year	Diploma	Distance learning
All India Institute of Hygiene and Public Health, Kolkata (Affiliated to: West Bengal University of Health Science)	Diploma in health promotion and education	1 year	Diploma	On-site
The Gandhigram Institute of Rural Health & Family Welfare Trust, Tamil Nadu (affiliated to Dr.MGR Medical University)	P.G. Diploma in health promotion and education course	1 year	Diploma	On-site
Baba Farid University of Health Sciences	Post graduate diploma in health promotion and education	1 year	Diploma	On-site
Central Health Education Bureau	PG diploma in health education	2 years	Diploma	On-site
SNDT Women's University, Maharashtra	Master of science– nutrition and health communication	2 years	Master of Science	On-site
All India Institute of Medical Sciences	Health education as a module	5 years	MBBS	On-site
SRM Institute of Science and Technology	Health promotion and behaviour change communication as a module	2 years	Master of public health	On-site
Indian Institute of Public Health Gandhinagar (Public Health Foundation of India)	Health education and promotion as a module	2 years	Master of public health	On-site
Manipal Academy of Higher Education, Karnataka	Health communication as a module	2 years	Master of public health	On-site
Indian Institute of Healthcare Communication	Communication skills enhancement program for the clinicians, nurses and healthcare support staff; clinical communication skills training for medical/dental students	—	Healthcare communication training programs	—
Lippincott Gurukul, an eLearning platform, Wolters Kluwer India	Healthcare communication	—	—	Online

[a]*Table provides few examples; may not be exhaustive.*

Science (BSc) in Nursing, Bachelor of Dental Surgery (BDS), and Bachelor of Physiotherapy (BPT). We additionally reviewed post graduate curricula namely Doctor of Medicine and Surgery (MD & MS), Master of Dental Surgery (MDS), Master of Science (MSc) in Nursing, Master of Physiotherapy (MPT) to garner a better understanding. Since, institution-level curriculum w.r.t. IPC towards delivery of multimorbidity care was not yet incorporated during the time of the research period, we reviewed the curricula/syllabi prescribed by the NMC, Indian Nursing Council, Dental Council of India and Rehabilitation Council of India. The keywords used for the search in this case included terms like MBBS, BSc Nursing, BDS, BPT, MD, MS, MSc Nursing, MDS, MPT, Bachelor of Science in Nursing, Bachelor of Dental Surgery, Bachelor of Physiotherapy, Master of Science in Nursing, Master of Dental Surgery, Master of Physiotherapy, nursing, dentistry, physiotherapy, medicine, medical education, syllabus, comorbidity, multiple morbidity, multiple chronic diseases, multiple chronic conditions, disease cluster, shared care, chronic care model, team based care, long term care, holistic care, integrated care, and patient-centred care. The designated syllabi were carefully examined for class room teaching, practical and patient ward duties or hours and details were noted. In parallel, websites of MoHFW, and few key universities and autonomous institutions offering any or all of the MBBS, BSc Nursing, BDS and BPT courses (e.g., AIIMS Delhi, JIPMER, PGIMER, CMC, and NIRTAR) were browsed to gather necessary information. The curricula were assessed to ascertain whether it has focus on multimorbidity or on IPC and understand if there was any scope of learning other disciplines as part of the patient care teaching or during resident duty. The searches were restricted to full-time courses offered only in India, while short-term courses offered by various institutions were not considered. The relevant observations captured were further analysed.

RESULTS

Assessment of Extant Health Professional Curricula With Focus on Health Communication, Promotion and Education

Table 1 gives an overview of the courses related to health communication/promotion/education which are offered in India. Select institutions are providing these courses in India. We see that of the programmes offered, a number of them are one-year diploma courses imparted as full time or distance learning programmes. In some cases, health communication or education is included as part of a Master of Science (MSc) or

Master of Public Health or MBBS degree programme, where duration of study is beyond one year. In a similar exercise conducted by us in 2012, we had reported that these aspects are also being taught as modules in Master of Public Health degrees, or in an integrated manner in the community medicine component of undergraduate and postgraduate medical curriculum (Pati et al., 2012). In addition to this, there are also trainings and online courses with focus on health communication.

Assessment of Extant Health Professional Curricula With Focus on IPC Towards Delivery of Multidisciplinary Care for Multiple Chronic Conditions

A review of the extant undergraduate and postgraduate curricula in India within disciplines of medicine, dentistry, nursing and physiotherapy available in public domain was carried out from the perspective of IPC towards delivery of multidisciplinary care for multiple chronic conditions. Since these elements have not yet been specifically included at the institutional level curricula, our observations from the overarching prescribed curriculum in the fields of medicine, dentistry, nursing and physiotherapy are discussed here.

Undergraduate Curriculum

The MCI (now known as the National Medical Commission since September 2020), recommends the Competency Based Undergraduate Curriculum for the Indian Medical Graduates (National Medical Commission). The curriculum aims to promote the practice of holistic medicine and prepare the student to be able to work in an inter-professional healthcare team, respecting the diversities of roles, responsibilities and competencies of other professionals. A new and longitudinal programme based on attitude, ethics and communication (AETCOM) competencies that can help train students on competencies such as collaboration, working in interdisciplinary teams has been included within this curriculum. The curriculum also refers to understanding of aetiology, epidemiology, pathogenesis, complications, health risks etc. of specific chronic conditions like cardiovascular diseases, hypertension, obesity, diabetes, blindness, and mental illness etc., but there is limited focus on specific concepts of multimorbidity. There is however focus on developing the graduate's skill to elicit, document and present medical history on comorbidities linked to diabetes, hypertension, and obesity.

The curriculum for BSc Nursing also embraces a competency-based approach (Indian Nursing Council) It is designed to prepare a graduate nurse to deliver patient-centred holistic care, functioning effectively among interdisciplinary and inter-professional teams. It promotes the idea of team based and collaborative learning through inter-professional education by allotting specific study hours to two subjects, namely 1) Educational Technology in Nursing Education and 2) Nursing Management and Leadership. This includes time allotted for both theory and practical classes. Under the Educational Technology in Nursing Education, active learning strategies such as peer sharing, problem based learning are also encouraged. Similar observations were made in case of the MBBS and BSc Nursing curriculum of AIIMS Delhi, which is autonomous institution.

The BDS Course Regulations 2007 (with Amendments) identifies that one of the components of the undergraduate dental course is training on general medicine and general surgery in order to provide the graduate sufficient knowledge on human diseases and its manifestations w.r.t. practice of dentistry (Dental Council of India). It also recognizes the need for the dental graduate to understand the relationship between oral and other systematic diseases. The syllabus of study mentions that training in behavioural sciences should be integrated with all departments of Dentistry, Medicine, Pharmacology, Physiology. and Biochemistry. It touches upon management of dental problems in case of medically compromised patients such as with hypertension or diabetes. The dental internship curriculum provides scope of providing exposure to the student to a functioning healthcare team including multipurpose workers, health educators, and others.

The MOHFW in 2017 released a Model Curriculum Handbook of Physiotherapy with an aim to reduce variations across different courses of physiotherapy study, and to provide a national standard which can be followed (Ministry of Health and Family Welfare, Government of India). Like in cases of other disciplines, the MoHFW also recognizes the development of skill and competency based curriculum for physiotherapy education. It prioritizes team-based provision of healthcare services where healthcare workers work in collaborations within and across settings.

Postgraduate Curriculum

We also assessed the post graduate syllabi offered in disciplines of medicine, nursing, dentistry and physiotherapy. In the medicine discipline, curricula for 29 subjects under MD, six subjects under MS were analysed (National Medical Commission). Some of the common features that were found to encourage inter-professional engagement under these subjects are discussed below:

- **Rotational posting of postgraduate student in various specialties or sub-specialties.** The curriculum mentions that students are to be attached to appropriate, related allied departments on a rotation basis for designated amount of time within the post graduate training programme. As part of this attachment, students should take part in all routine activities of the department. In some cases, rotation is encouraged for all departments. Apart from clinical departments, exposure of working in wards, intensive care units, emergency, specialty operation theatres, laboratories, sub-centres and primary healthcare centres, hospitals, clinics etc., is also recommended as part of rotation. Training in clinical departments and support service areas of the hospital is also given consideration in certain cases. There is also provision for post graduate students to attend hospital grand rounds.
- **Integrated teaching of undergraduates.** Postgraduate students, as per the curricula, are required to participate in the teaching and training programme of undergraduate

students and interns. They are encouraged to take part in integrated teaching of undergraduates by participation in joint teaching sessions and seminars with different departments, participation in clinical rounds for discussing cases of interest and by small group discussions of case-based problems

- **Intra and interdepartmental engagements.** The analysed curricula also emphasizes on carrying out intradepartmental and interdepartmental meetings on a regular basis related to discussions on a particular case or interesting medical problems. Interdepartmental learning is also a component of the assessment of the postgraduate curriculum. In some subjects, additional sessions or lectures in allied disciplines are also undertaken.

The MDS course also lays similar stress on rotation and posting in other departments, interdepartmental seminars, lectures taken for undergraduates (Dental Council of India). Across various specialties under the MDS course, there is a component of applied basic sciences which covers teaching on allied topics such as applied anatomy, biochemistry, microbiology, physiology, pathology, pharmacology etc., to enable the candidate to have knowledge of applied basic and systemic medical sciences. This also includes rotation or posting of the postgraduate student in the concerned department for relevant training. The MPT curriculum is along similar lines of the MDS curriculum. The MSc Nursing syllabus has a specific component on practical or hands-on training, wherein the post graduate nursing students are designated specific hours of practical training in appropriate and relevant wards (Indian Nursing Council).

Overall, the analysis of the current undergraduate and postgraduate curricula under disciplines of medicine, dentistry, nursing and physiotherapy indicate that concepts related to IPC in India are slowly beginning to be woven into the health professional curricula. It is encouraging to note that efforts to promote collaborative working across interdisciplinary settings is being reflected at various levels such as inclusion of competency based curriculum, or enabling rotational or interdepartmental exposure across departments of different disciplines. Common topics such as human anatomy, physiology, biochemistry, microbiology, pathology, and pharmacology are being taught across all four different professional curricula. This nevertheless heralds the first step towards promoting shared learning. There remains a huge scope for strengthening this component further so as to enable cross-learning across different disciplines. We additionally observed that there is a need to bring greater focus on addressing coexisting multiple diseases and multimorbidity issues in healthcare, in the curricula of both undergraduate and postgraduate healthcare professionals in India.

It may be noted that the above observations pertain to those obtained from syllabi mapping based on availability in public domain. Discussions regarding multimorbidity or IPC which may get transacted in class are not captured in the syllabus may have been omitted in our observations.

DISCUSSION

Considering its incidence and socioeconomic impact, multimorbidity constitutes a challenge to healthcare services in the 21st century (Abebe et al., 2020). Studies in different countries have shown that it is not chronic conditions by themselves that increase the resource cost; rather, it is the number of types of conditions, that is, multimorbidity which is responsible (Kowal et al., 2015). In India, various studies have indicated the prevalence to be ranging from 8 to 33% in adults with primary care being frequently confronted with these individuals (Pati et al., 2017b; Swain et al., 2017; Kshatri et al., 2020; Pati et al., 2020; Vargese et al., 2020). Multimorbidity with its composition of multiple illnesses poses complex challenges for patients and providers alike in primary care. Ironically, majority of our medical research and education has focused on single diseases till date. Existing models of care for chronically ill patients are mostly configured around the management of each disease separately and the clinical practice guidelines on which such models are based also focus on single diseases. Further, the traditional focus of India's healthcare systems has been inclined towards treating infections and delivery of acute episodic care than chronic continuous care and thus not optimally suited to address the needs of individuals with multimorbidity.

To cater to the above, delivery of holistic and integrated care becomes crucial. This entails healthcare professionals from multiple disciplines to come together and work in a team to provide comprehensive and quality health services within and across settings. It can only happen when these professionals have received adequate training in their education on IPC related aspects. Moreover, this is achieved even better when health professionals not only learn to effectively communicate with each other, but also with patients, their families, and the community in a collaborative and responsible way. A recent systematic review that discusses challenges faced by general physicians (GP) in ensuring quality patient care in case of multimorbidity management, highlighted concerns around poor communication with patients and with healthcare professionals (Damarell et al., 2020). This led to limitations in GP's sharing of care for multimorbidity patients with health professionals from outside primary care, resulting in a sense of "professional isolation" among them.

Against this background, we undertook this study to assess the curricular elements in the context of health communication in general, with a particular focus on IPC for delivery of multidisciplinary care for multimorbidity management in India. We found that there were exclusive courses on health communication being delivered at different levels. However, many of these courses continue to be offered outside the realm of medical education and at curricular level. As such, there is limited integration of these courses into the current curriculum of medication education and training in India. Moreover, the focus on IPC is still in stages of infancy. We did not find any specific institution or organization offering courses designed around IPC or multimorbidity. Moreover, most of the curricula focused on single non-communicable

disease and did not chart or clearly articulate the management guidelines for multimorbidity. Similar inferences have also been highlighted in an earlier survey wherein majority of students across all disciplines accepted the lack of knowledge, training and confidence in comorbidity care and were unable to identify specific teaching on comorbidities (Lawson et al., 2017). Additionally, the health education institution representatives also had found no specific references to comorbidity in current health education curricula. Therefore, it is essential that the IPC for multimorbidity is built into to current health professional curricula, along with emphasis on the need for appropriate health communication.

At the primary care level, there is an unmet need for delivery of integrated care for multimorbid patients, which is more challenging due to limited availability of primary care providers trained in multimorbidity management. Unlike chronic diseases, there are no widely accepted care models for multimorbidity at present. So far these have been based on general models for integrated care for chronic diseases such as the Chronic Care Model or the Guided Care Model (Struckmann et al., 2018). The constructs for the implementation of the multimorbiditiy aspect in such models have been shown to be absent so far (Boehmer et al., 2018). In view of this existing gap, a comprehensive conceptual SELFIE (Sustainable intEgrated chronic care modeLs for multi-morbidity: delivery, FInancing, and performancE) framework of integrated care in multimorbidity has been recently proposed, which is expected to guide development and delivery of integrated care for multimorbidity (Leijten et al., 2018).

In addition, there are other challenges. Most of the available medical research, guidelines or treatments are designed to address single diseases. Vertical and disease specific healthcare programmes, inclined more towards infectious diseases, are functioning towards rendering acute care services. The multimorbidity component is also excluded from clinical trials, thus making it difficult to generalize the results.

Unless health systems do not invest in integrating IPC into health communication/promotion/education components in the formative phase, there cannot be sustainable gains in population health outcomes (Iroku-Malize et al., 2013; Oeseburg et al., 2013; van der Gulden et al., 2020). Going forward, primary health care in the shape of HWC should steer the journey for patient-centred care by taking along all professionals in this journey. Strong evidence based advocacy at the academic and policy level could catalyse the operationalization.

In 'Multimorbidity: Technical Series on Safer Primary Care', the World Health Organization recognizes that one of the reason that multimorbidity patients are at higher risk of safety issues is the need for clear communication and patient-centred care due to complex patient needs. It stresses on the need for improved communication with patients, increased communication and coordination across different types of care including primary, secondary and also social care, strengthening workforce capacity through inter-professional education, with particular reference to multimorbidity (World Health Organization, 2016). There lies a high level of interdependence among healthcare professionals from multiple services who are responsible for taking care of patients with multimorbidity at the primary care level. These professionals need to be trained in a way such that they are able to cater to the multiple needs and problems of multimorbidity patients (Lawson et al., 2017). In view of this, we suggest the following:

- There is a need to integrate the health communication, health education and health promotion aspects into the current medical education and training system. Healthcare professionals, in their formatting stages should be trained in these aspects to be able to better yield to the needs of IPC.
- Health communication and IPC aspects in the health professional curricula should be further strengthened. This can be initiated with a series of small steps such as teaching on common topics, joint course-work, joint seminars, joint internships. However, in the long run, measures to introduce significant changes in the curriculum must be undertaken. For example, a summer attachment for the undergraduate medical students at the HWCs could be considered as a curricular intervention. Efforts should be directed to a *trans*-disciplinary learning collaborative team-oriented approach in the health professional curricula.
- The capacity of faculty members with different disciplinary background and inter-professional teaching expertise to supervise students and conduct research should be built upon. Senior leadership and administrators in academic institutions should support such capacity building and must be key partners in this process. At the department and college/school level, faculty members must take the lead in developing the curricular frameworks and time frames needed to provide opportunities for various types of inter-professional interactions for students across all health professions. In parallel, the desire and preparedness among students of various disciplines to work together in order to facilitate teamwork skills should also be assessed and enhanced.
- It is to be impressed upon that each patient with multimorbidity is recognized as an individual with unique multicomponent care aspects, rather than focusing on primary morbidity alone or singular morbidity in silo. Management of multimorbidity in primary care should now be acknowledged as a priority for health policymakers and healthcare providers. Necessary research and curricular interventions required for enabling the delivery of quality and efficient health services to patients with multimorbidity needs to be introduced (The Academy of Medical Sciences, 2018).
- Future studies to have a better understanding of the status of IPC in India, and also their linkages and relevance in the context of multimorbidity needs to be conducted. This could be done through a mixed-method study that involves 1) primary data collection from all medical universities/institutes through specifically designed questionnaires or 2) in-depth interviews with range of stakeholders (faculty, students, curriculum planners, academic administrators, and practitioners) across different disciplines of medicine, dentistry, nursing, allied health services, and physiotherapy.

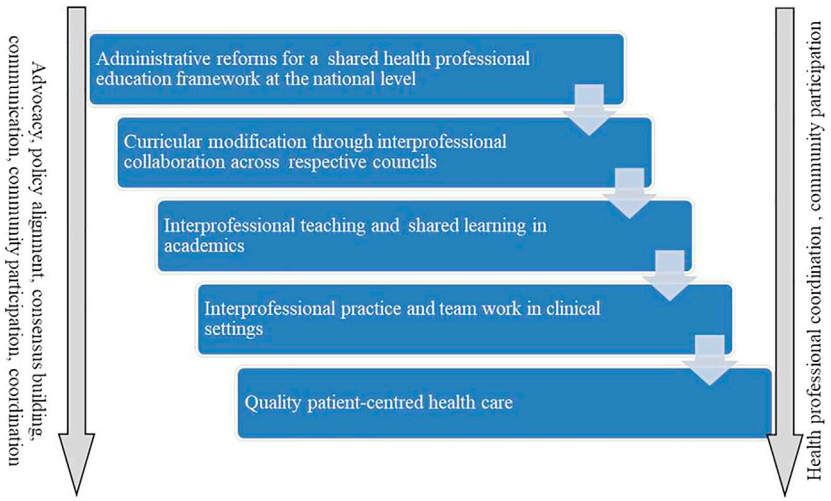


FIGURE 1 | Roadmap to the development of inter-professional care education in India.

Figure 1 provides a roadmap towards inclusion of the concept of IPC and multimorbidity in health professional education in India. Through necessary advocacy and informed decision making, academic consensus for a shared health professional education framework could be explored. This is in congruence with the newly formulated New Education Policy which promulgates cross-disciplinary and inter-disciplinary learning (Ministry of Human Resource Development, Government of India). The policy revision may then be followed by appropriate curricular modifications through fostering necessary collaboration across respective Councils. Once necessary modifications are made, inter-professional teaching and shared learning should be encouraged in academia, and delivery of IPC through team work configured around multimorbidity may be practiced in clinical settings.

FUTURE IMPLICATIONS AND CONCLUSION

In the present study, we assessed the prevailing undergraduate and postgraduate healthcare professional curricula to understand the focus on health communication and on IPC aimed to deliver multidisciplinary care for managing multimorbidity. These entities pose stronger relevance in the context of delivering collaborative team-based care for patients with multimorbidity, more so in case of primary care settings. Our curricular assessment shows that while there are some ongoing efforts around delivery of health communication education, there is still initial focus on IPC among healthcare trainees, leaving a huge scope remains for strengthening this aspect. Further, the need for curricular focus on recognizing multimorbidity as a health care challenge for patients is still to be emphasized. This would not only prepare the future healthcare professionals to ably manage the intricate care demands of multimorbidity through fostering team work, but create scope for cross dialogue and transdisciplinary learning among students. Since our findings were limited to the secondary analysis of syllabi only, future studies exploring factual learning from classroom sessions through primary study and interviews with students, faculty and academicians should be undertaken to garner a better understanding of the present scenario and provide insights for future curricular roadmap.

DATA AVAILABILITY STATEMENT

Data supporting the results reported in this article may be made available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

SP conceptualized the study. RS and SP designed the study methodology and developed the data extraction plan. RS prepared the first draft of the article which was then refined and finalized by PM and SP. The article has been read and approved by all the authors.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Bibliometric Review to Explore Emerging High-Intensity Interval Training in Health Promotion: A New Century Picture

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Background: High-intensity interval training (HIIT) is an emerging exercise strategy and is considered to be a recipe for health promotion. This study aimed to systematically identify collaboration networks, track research trends, highlight current hotspots, and predict future frontiers in HIIT and its applications in health promotion since the start of the new century.

Methods: Relevant original publications were obtained from the Science Citation Index Expanded of the Web of Science Core Collection (WoSCC) database between 2001 and 2020. CiteSpace and VOSviewer software were used to perform bibliometric visualization and comparative analysis of involved indexes that included countries, institutions, journals, authors, references, and keywords.

Results: A total of 572 papers were included, and the trend of annual publications showed a remarkable growth. The United States and the University of Exeter were the most productive country and institutions, respectively, with 107 and 18 publications, respectively. *European Journal of Applied Physiology* took the lead in the number of published articles, and *Medicine and Science in Sports and Exercise* ranked first in the cocitation counts. Barker AR and Gibala MJ were considered as the most productive and the most highly-cited authors.

Conclusions: "Health risks," "adolescent," and "aging" are the three noteworthy topics during the evolution of HIIT-health promotion (HIIT-HP) research. The current research hotspots of HIIT and its practices in the health promotion domain lies in "metabolic diseases," "cardiovascular diseases," "neurological diseases," and "musculoskeletal diseases." The authors summarize that "prevention and rehabilitation," "micro and molecular level," and "cognition and mental health" are becoming frontiers and focus on the health topics related to HIIT in the upcoming years, which are worthy of further exploration.

Keywords: high intensity interval training, health promotion, bibliometric analysis, CiteSpace, VOSviewer

INTRODUCTION

The rising prevalence of several chronic diseases (1–5) [e.g., obesity, type 2 diabetes (T2D), and hypertension] worldwide has been described as global puzzles and public health problems (6–8). The relationship between exercise and health promotion has been gradually explored and studied. In 2007, the American College of Sports Medicine and the American Medical Association colaunched a health promotion program named "exercise is medicine" (9). High-intensity interval training (HIIT), in various forms, is an emerging training method that generally refers to repeated sessions of relatively brief intermittent exercise, often performed with an "all-out" effort or at an intensity close to VO_2 peak (10–12). Billat defined HIIT as a method that involves repeated short-to-long bouts of high-intensity exercise interspersed with recovery periods (13). With the transition and development of the basic science of physiology, a series of major advancements in exercise training has spurred in the field of sports science, and among them, HIIT is one of the most effective training methods. Many studies have shown that HIIT can enhance cardiorespiratory and metabolic function and, in turn, the fitness of the athletes (13–15). Prior evidence also showed that a sufficient volume of HIIT can increase peak oxygen uptake (VO_2 peak) and the maximal activity of mitochondrial enzymes in skeletal muscles (16, 17). In contrast to other training techniques, such as moderate-intensity continuous training (MICT) and resistance training (RT), HIIT is a time-efficient, universally applicable, and enjoyable strategy. In recent years, HIIT is not only used for elite athletes training but is also considered as an exercise prescription or complementary therapy for the rehabilitation of related chronic diseases. Therefore, it has been significantly developed and widely applied to the field of exercise science and health promotion over the last 20 years.

Scholars have conducted a number of reviews (18–22) on various aspects of HIIT in different contexts, but some defects still needed to be improved: (i) most reviews used the meta-based methodology, although it can support the effects of HIIT from the evidence-based medicine level, while this type of review cannot provide an overview of all applications of HIIT in the fields of health promotion; (ii) the samples in some systematic reviews were mainly based on subjective screening, and the sample size was rather small; (iii) the included research objects were not comprehensive (such as only a review of randomized controlled trials) or were concentrated only on specific and limited aspects.

Bibliometric is a quantitative analysis strategy that involves mathematics and statistics to identify publications on a particular topic (23, 24). Based on comprehensive indexes like journals, authors, countries, and institutions, it can conduct an in-depth evaluation of the research trends and the focus of a certain field (25–27). Previous studies have shown that tracing knowledge diffusions and using cluster analysis can provide a rounded overview in several interdisciplinary research (28–30). Moreover, the results of the bibliometric evaluation can provide suggestions for future research and decision-making. CiteSpace is a java-based scientific mapping software developed by Chen (Drexel University, Philadelphia, PA, USA) for bibliometric and comparative analysis (31). VOSviewer is another scientometric tool for creating maps based on network data and for visualizing and exploring these maps. By presenting numerous data in the form of knowledge maps, the productivity of authors and institutions, geographic distributions, and cooperative relations can reflect the development of a discipline and research tendency. CiteSpace and VOSviewer have been recently applied in various fields, such as medical treatment, cognitive function, and pain management (32–34).

To the best of our knowledge, studies on the health benefits of HIIT have sprung up over the past two decades, whereas a few of them are engaged in collecting global data, evaluating the emerging trends, and conducting reviews of HIIT–health promotion (HIIT-HP) fields from the perspective of visualization and bibliometric analysis. Hence, the cooperative network, research trend, current status, and future frontier in this field are unknown and urgently need to be explored. This is the first study that pioneers the use of bibliometric strategy into the investigation of the HIIT-HP domain. This study is anticipated to help researchers extract hidden information for further studies in exercise and health-related fields and provide them with valuable guidance in selecting frontier topics by answering the following central questions:

(i) Which countries, institutions, journals, authors, and references lead the research trend in global HIIT-HP fields?
(ii) What are the current hotspots and major domains that HIIT can be used in health promotion nowadays?
(iii) Where are the frontiers and perspectives of related health topics in the future of HIIT?

MATERIALS AND METHODS

Data Acquisition and Search Strategy

All research materials were retrieved from the Science Citation Index Expanded (SCI-E) of the WoSCC database on May 15, 2021. We completed the search within the same day to avoid any bias caused by database updates. The reason for using this database is that SCI-Expanded in WoSCC contains comprehensive citation index records, which includes numerous influential and high-quality journals all over the world. Additionally, a previous study indicated that Web of Science had better accuracy than Scopus and some other databases (35). Therefore, it is a comprehensive and authoritative database for literature mining, especially in the field of natural science (36).

The following methods were conducted for search publications: topic words = [("high intensity interval training" OR "high-intensity interval training" OR "high intensity intermittent training" OR "high-intensity intermittent training" OR "high intensity interval exercise" OR "high-intensity interval exercise" OR "high intensity intermittent exercise" OR "high-intensity intermittent exercise" OR "HIIT" OR "HIIE") AND ("health" OR "public health" OR "health promotion" OR "health management")], time span = 2001–2020. Referring to the previous bibliometric studies (37, 38), we only selected "articles or reviews" for analysis, and the language was limited to "English"; other document types and non-English articles were excluded. Basic information for each research was gathered

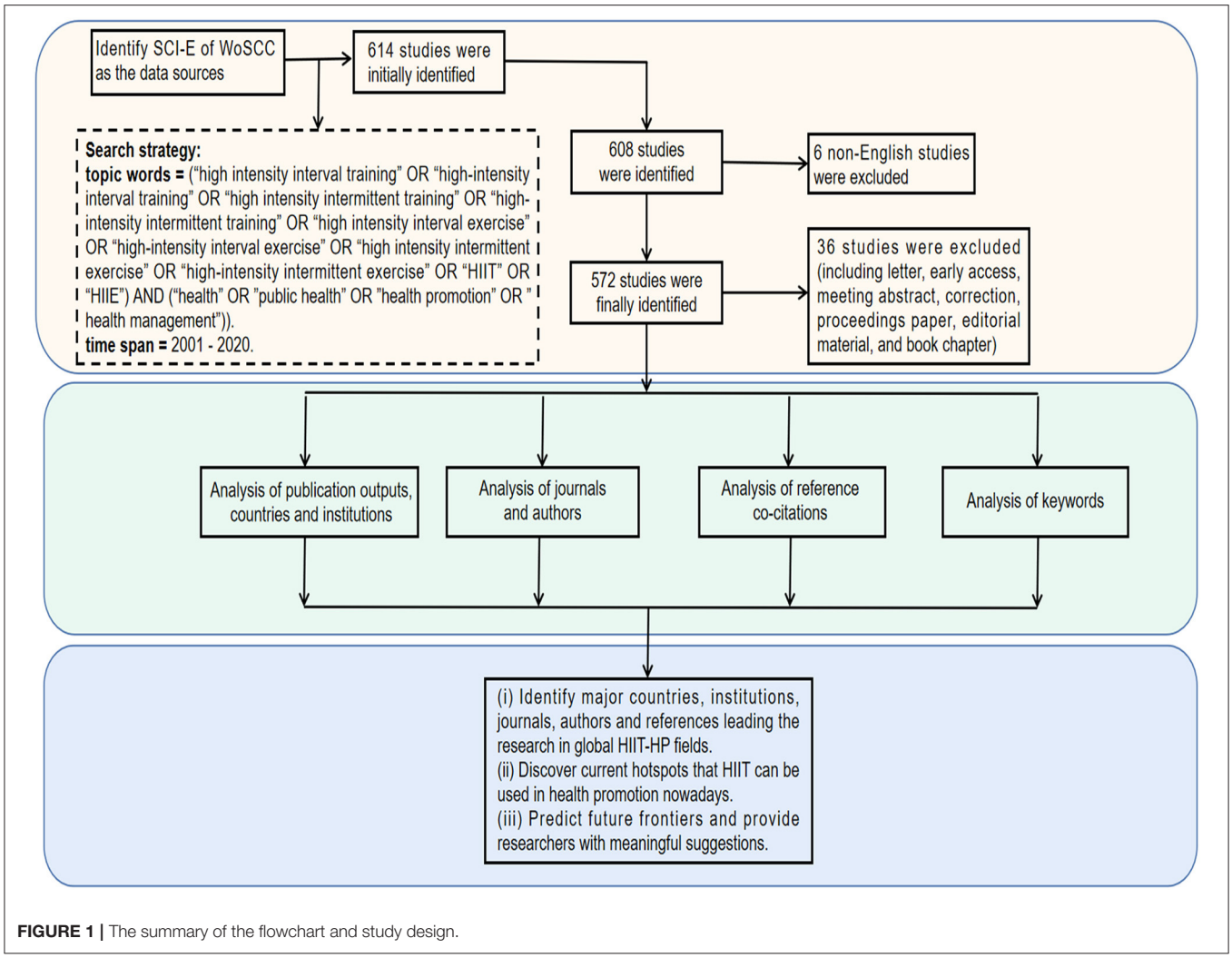


FIGURE 1 | The summary of the flowchart and study design.

into text documents, such as countries, institutions, journal sources, authors, and references. The detailed search strategy and inclusion criteria in this study are summarized in **Figure 1**.

Analysis Tool

CiteSpace and VOSviewer were used to conduct statistical analyses on the literature. This analysis drew a series of progressive visualization knowledge domains to detect emerging trends, hidden implications, and landmark literature. Parameters consisting of publication amount, impact factor, centrality, and occurrence/citation burst were applied. Impact factor (IF) is recognized as an international standard criterion for evaluating the impact of a journal (39), and the impact factors in this review are based on the Journal Citation Reports (2019). Centrality is an index for measuring the importance of a node in a network, and a node with a large size typically indicates high occurrence or citation frequency as a pivotal point (31, 40, 41). Occurrence burst denotes a term that frequently occurs over a given period, which can be considered as research hotspots (41, 42). Microsoft Excel 2016 software was applied to describe and predict the publication trend of HIIT researches. The function model was set as follows: $f(x) = ax^3 + bx^2 + cx + d$, in which x represented the year of publication and $f(x)$ demonstrated the cumulative amount of publications. The reason for using a cubic polynomial function instead of linear, logarithmic, or other functions was that it can effectively and accurately capture information about publication trends (43). The reason for not applying the exponential function was to prevent the occurrence of no publication in potential years. Through the methods mentioned above, we can have a profound understanding of the research history, current status, and future prediction of HIIT studies in the health promotion field.

RESULTS

Analysis of Publication Outputs

Since there was no publication before 2004, we started the calculation at the beginning of 2005. A total of 572 records (including 494 articles and 78 reviews) satisfied the search criteria and were used for further analysis. The relationship between the

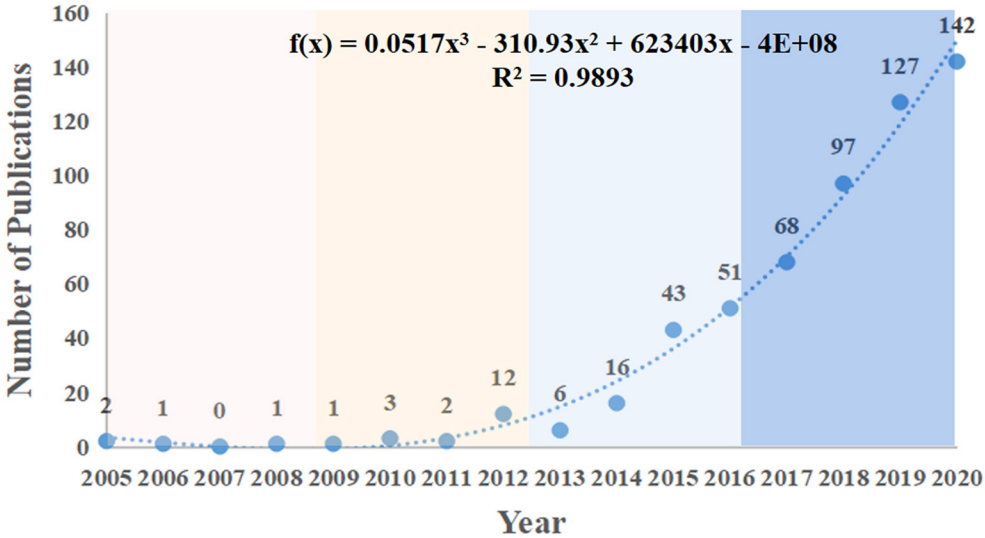


FIGURE 2 | The output of publications and growth trends of HIIT in health promotion fields.

TABLE 1 | Ranking of top 10 countries and institutions involved in the HIIT-HP domain.

Rank	Country	Publications	Centrality	Institution	Publications	Centrality
1	United States	107	0.51	University of Exeter	18	0.03
2	United Kingdom	106	0.68	Norwegian University of Science and Technology	16	0.08
3	Australia	88	0.20	University of British Columbia	15	0.06
4	Canada	63	0.02	University of Copenhagen	15	0.06
5	Spain	51	0.14	University of Newcastle	15	0.02
6	Brazil	43	0.11	McMaster University	14	0.01
7	China	35	0.11	University of Queensland	14	0.04
8	Norway	33	0.04	University of Saõ Paulo	14	0.06
9	Germany	26	0.08	University of Granada	11	0.01
10	France	24	0.25	University of Oslo	11	0.01

number of articles per year and the development tendency on HIIT research in the health promotion field is shown in **Figure 2**. The overall trend of publications increased from 2 in 2005 to 142 in 2020. The number of publications on HIIT has increased remarkably within the last two decades, and the growth trend model (R^2 = 0.9893) demonstrates that more research on the applications of HIIT in the health promotion domain is ongoing and that this field seems to be progressive and promising.

Publications on HIIT can be divided into three stages: the initial stage (2005–2012), the second stage (2012–2016), and the third stage (2016–2020). Before 2012, the annual publication remained at a low level, while it exceeded 10 for the first time in 2012. After that, the amount of literature published gradually showed a continuous upward trend and broke through 50 for the first time in 2016. From the perspective of annual publications, we consider the years 2012 and 2016 to be the critical turning points. In terms of the development of HIIT, in 1920, a famous runner named Paavo Nurmi had already used HIIT in his training routines (12). After that, many scholars contributed to the popularization of this specific training format in the previous century. However, their publications were not widely recognized and promoted. In the early 2000s, Laursen and Jenkins (16) reviewed the scientific basis for HIIT and suggested that the optimal HIIT program intensity, duration, and recovery needed further exploration, which pointed out the direction for future HIIT research. In 2012, Gibala et al. (44) indicated that HIIT can not only be applied to train athletes but can also served as an effective alternative way to traditional endurance-based training in preventing health burdens associated with a couple of chronic diseases. This discovery prompted the application of HIIT intervention in the prevention and rehabilitation of chronic diseases, which also contributed to the advancement and application of HIIT technology.

Analysis of Countries and Institutions

A total of 56 countries/regions were involved in HIIT and its applications in the health promotion domain. The details of the top 10 countries and institutions are presented in **Table 1**. The

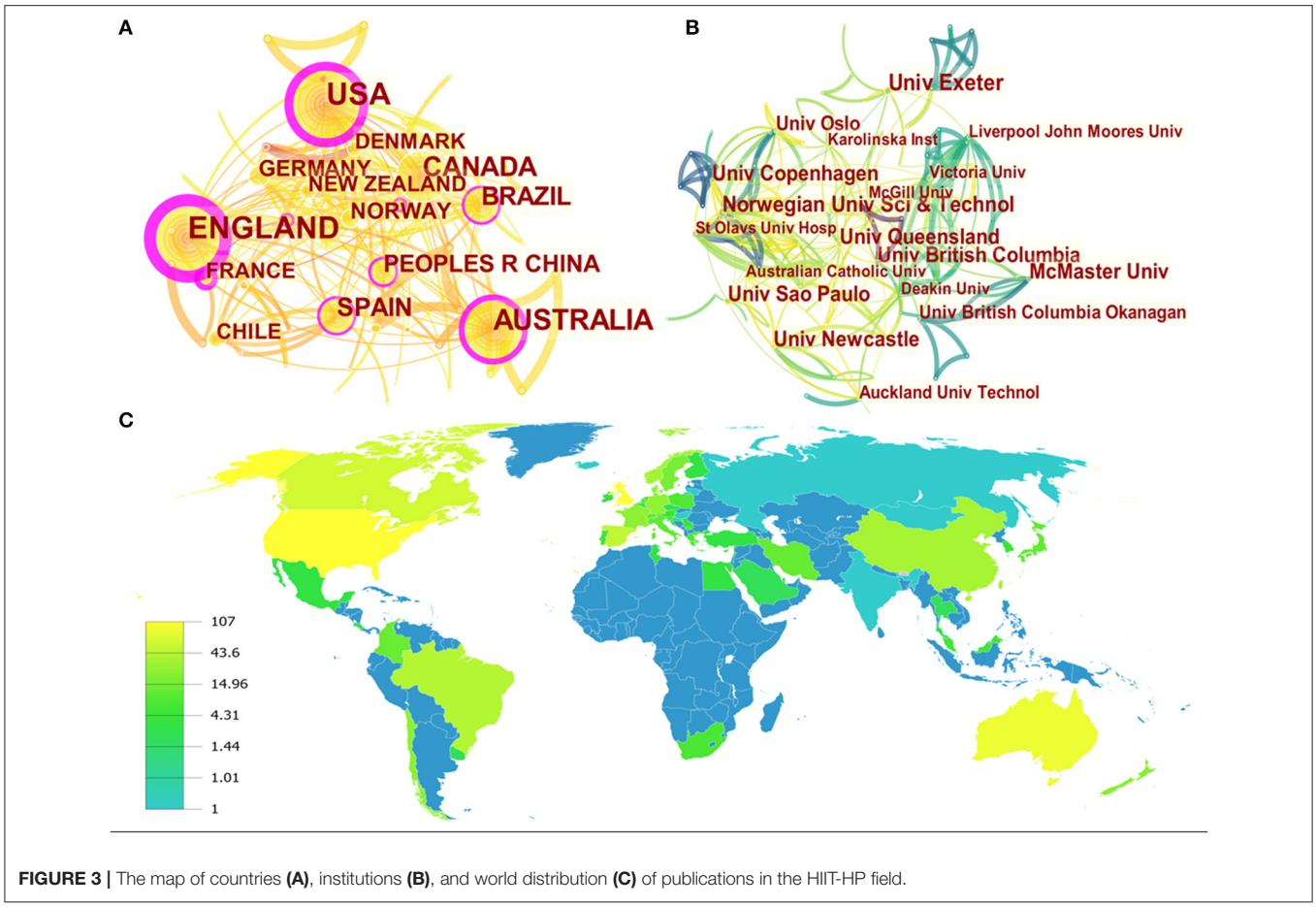


FIGURE 3 | The map of countries **(A)**, institutions **(B)**, and world distribution **(C)** of publications in the HIIT-HP field.

United States and the United Kingdom were in the dominant positions, with 107 and 106 publications, respectively. Australia was the third productive country and published 88 literatures totally, followed by Canada (63 publications) and Spain (51 publications). The contributions by the top four countries were all above 50, which indicated that they made major contributions in research achievements. As shown in **Figure 3A**, the collaborations among these countries were generated by CiteSpace. In the matter of centrality (the purple outer ring of the circle), the wider the circle, the higher is the centrality. According to the definition of centrality (31), the countries shown on the map had close collaborations with each other and produced tremendous academic influence.

A total of 270 institutions participated in the application of HIIT in the health promotion field. As listed in **Table 1**, the University of Exeter was the leading institution in the quantity of published works (18 publications), followed by the Norwegian University of Science and Technology (16 publications), the University of British Columbia (15 publications), the University of Copenhagen (15 publications), and the University of Newcastle (15 publications). The network map of institution cooperation was generated using CiteSpace (**Figure 3B**). In terms of centrality, the Norwegian University of Science and Technology (0.08) was the first-tier institution. Besides that, the University of British Columbia, the University of Copenhagen, and the University of Saõ Paulo shared the same centrality (0.06) and took the lead in cooperation as well. Additionally, the distribution of the countries and regions participating in HIIT-HP research all over the world is displayed in **Figure 3C**, and the scholars of this field were mainly distributed in North America, Europe, and Asia.

Analysis of Journals and Co-cited Journals

A total of 234 scholarly journals published articles on the application of HIIT in the health fields. As shown in **Table 2**, the top 10 journals accounted for almost a third of the total publications, *European Journal of Applied Physiology* (IF 2019 = 2.580) published the highest amount of articles (26 publications, 4.55%), followed by *Frontiers in Physiology* and *Medicine and Science in Sports and Exercise*. Compared with other journals, the contributions of the top three journals were all above 20 publications and 4% proportions, thus signifying that they had a special position in HIIT-HP fields. Among the 10 journals with the largest amount of literature published, the average IF of these 10 journals was 2.718, whereas the impact factors from only three journals exceeded 3.0. It seemed that publishing HIIT-related topics in a high-impact-factor journal could not be an easy task.

TABLE 2 | Ranking of top 10 journals and co-cited journals involved in the HIIT-HP domain.

Rank	Journal	Publications	Percentage (%)	IF (2019)	Cited journal	Co-citation counts
1	European Journal of Applied Physiology	26	4.55	2.580	Medicine and Science in Sports and Exercise	464
2	Frontiers in Physiology	24	4.20	3.367	Sports Medicine	364
3	Medicine and Science in Sports and Exercise	24	4.20	4.029	Plos One	346
4	International Journal of Environmental Research and Public Health	19	3.32	2.849	Journal of Applied Physiology	333
5	Plos One	18	3.15	2.740	Journal of Physiology-London	290
6	Journal of Sports Sciences	17	2.97	2.597	Circulation	283
7	Applied Physiology Nutrition and Metabolism	16	2.80	2.522	European Journal of Applied Physiology	272
8	Scandinavian Journal of Medicine Science in Sports	16	2.80	3.255	British Journal of Sports Medicine	252
9	Journal of Sports Medicine and Physical Fitness	12	2.10	1.432	Applied Physiology Nutrition and Metabolism	204
10	Journal of Sports Science and Medicine	11	1.92	1.806	JAMA-Journal of the American Medical Association	175

In cited journal list, *Medicine and Science in Sports and Exercise* ranked first with 464 co-citation counts, *Sports Medicine* and *PLOS ONE* also contributed 364 and 346, respectively. The high citation counts, to some extent, can illustrate that these journals had academic competitiveness and were considered mainstreams in the HIIT-HP field. The network map of cited journals was plotted by CiteSpace with 538 nodes and 3,724 links. **Figure 4A** presents that the distribution of the focus of the periodical publication is extremely extensive, including sports science, physiology, rehabilitation medicine, public health, and several comprehensive interdisciplinary research. As the cited journals offer a theoretical basis for the citing journals, these diverse trajectories indicate that the disciplinary center of the journals moved from a single subject to multidisciplinary clusters.

Figure 4B shows a dual-map overlay of journals that published literature related to HIIT-HP fields. This approach uses two graphs at the same time. On the left are the categories of citing journals, and on the right are the disciplines of cited journals. Citation links can display the ins and outs of citations data sets. As the citing journals put forward views on the basis of the cited journals, this map can reflect the citation relationship between disciplines to some extent. In general, there are mainly two citation paths, the light orange path presents that literature published in "Molecular, Biology, Immunology" journals preferred to quote journals mostly in the fields of "Health, Nursing, Medicine." The grass green path shows that articles published in "Medicine, Medical, Clinical" and "Neurology, Sports, Ophthalmology" journals tended to cite journals primarily in the "Sports, Rehabilitation, Sport" domain.

Analysis of Authors and Co-cited Authors

Three hundred and sixty-six authors contributed to the total number of papers. The top 10 authors involved in HIIT-HP research are shown in **Table 3**. These authors have published a total of 81 papers, accounting for 14.16% of all published papers on HIIT-HP research. Barker AR and Williams CA ranked first concerning publication output (12 publications), followed by Jung ME and Little JP with 9 publications. The top five co-cited authors were Gibala MJ, Wisloff U, Tjonna AE, Little JP, and Gillen JB. These authors were active authors in the field of HIIT-HP research.

Table 3 presents the top 10 most co-cited references as well. These references prepared the ground and accelerated the development of research in the HIIT-HP field. The top co-cited reference was authored by Weston KS and was published in *the British Journal of Sports Medicine* (one of the most influential journals in sports medicine), which reported the effects of HIIT in patients with lifestyle-induced cardio-metabolic disease (45). The co-cited count of articles ranked 2–8 also exceeds 40, which to some extent hints that the achievements of these research studies in this field are highly recognized. Cooperation between authors and co-cited authors is analyzed for the identification of potential partnerships. Connections represent cooperation relationships among nodes, and the thickness of the connection represents the closeness of cooperation. The merged network of authors in **Figure 5A** is composed of 366 nodes and 696 links. In this figure, the cooperation network of the author is further divided into three smaller clusters, which are scattered and led by several superstar authors. **Figure 5B** illustrates the connections between co-cited authors (nodes = 558, links = 3,288). The knowledge maps of the authors of these papers and co-cited authors can offer crucial information on influential research groups and potential partners, enabling researchers to establish cooperation.

Analysis of Reference Co-citation

Reference co-citation analysis is one of the significant indices in bibliometric studies, which is usually applied to explore research focuses in a given academic field (46). Articles and their co-citation relevant data were used to create major clusters, and

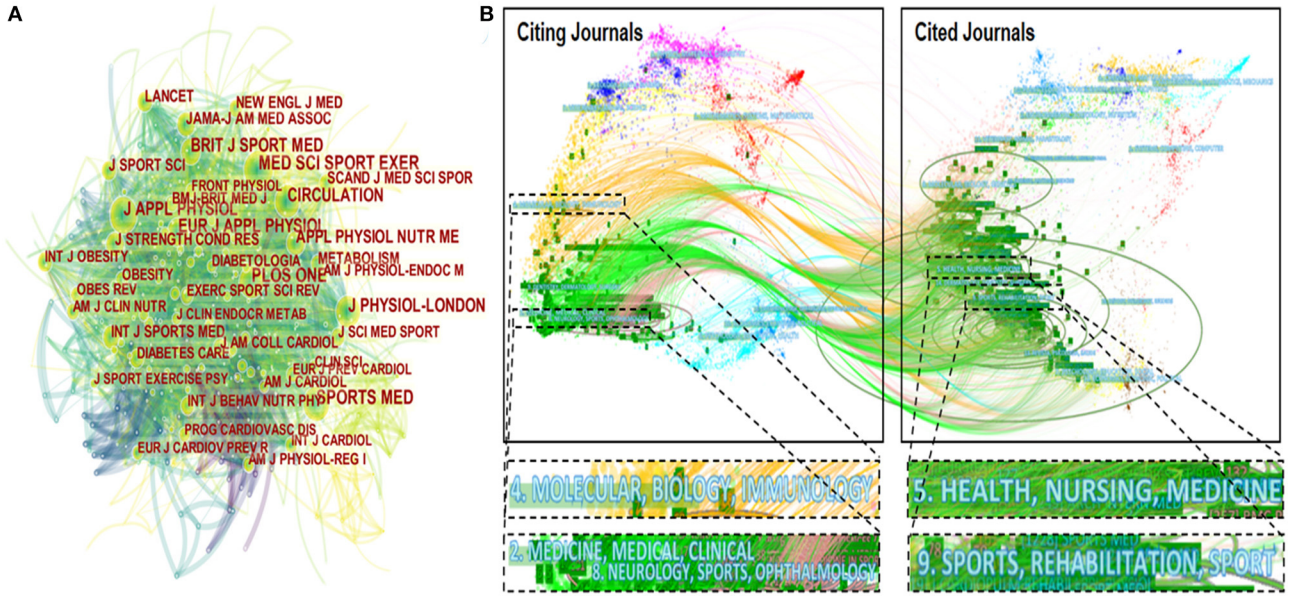


FIGURE 4 | The map of co-cited journals **(A)**; a dual-map overlay of journals that published literature in the HIIT-HP field **(B)**.

TABLE 3 | Ranking of top 10 authors, co-cited authors, and co-cited references in the HIIT-HP domain.

Rank	Author	Counts	Co-cited author	Counts	Co-cited reference	Counts
1	Barker AR	12	Gibala MJ	206	Weston KS, 2014, BRIT J SPORT MED, V48, P1227	75
2	Williams CA	12	Wisloff U	131	Gibala MJ, 2012, J PHYSIOL-LONDON, V590, P1077	62
3	Jung ME	9	Tjonna AE	113	Biddle SJH, 2015, INT J BEHAV NUTR PHY, V12, P0	56
4	Little JP	9	Little JP	110	Ramos JS, 2015, SPORTS MED, V45, P679	50
5	Eather N	8	Gillen JB	110	Costigan SA, 2015, BRIT J SPORT MED, V49, P0	47
6	Lubans DR	7	Weston KS	103	Milanovic Z, 2015, SPORTS MED, V45, P1339	47
7	Castillo MJ	6	Burgomaster KA	88	Weston M, 2014, SPORTS MED, V44, P1005	45
8	Delao A	6	Cohen J	74	Batacan RB, 2017, BRIT J SPORT MED, V51, P0	45
9	Ramirezcampillo R	6	Jung ME	68	Gillen JB, 2014, APPL PHYSIOL NUTR ME, V39, P409	38
10	Amarogahete FJ	6	Garber CE	66	Jung ME, 2014, PLOS ONE, V9, P0	37

then knowledge domains of these clusters were constructed by analyzing reference co-citation. All kinds of research related to the HIIT-HP field between 2000 and 2020 were grouped into a number of major clusters. Each cluster was associated with the citation index, achievement field, and critical literature series within a period, making a grand spectacle of distinct specialty or thematic concentration. The timeline view for the major clusters, which illustrates the time interval and research advance in the progress and evolution of the subdomain of each cluster, is shown in **Figure 6A**. In CiteSpace, the modularity value (Q-value) and the weighted mean silhouette value (S-value) are regarded as the evaluation strategies to assess the standard of clustering, and a mean of $Q > 0.5$ and $S > 0.7$ implies that the cluster is convincing. In **Figure 6A**, the value of Q equals 0.6382 and that of S equals 0.8141, which further verifies the rationality of this clustering strategy.

We used the log-likelihood ratio (LLR) strategy to generate reference co-citation clustering, with the type of selection using "Keywords Option," since the creator of CiteSpace software suggested that the LLR algorithm performed best for covering the "uniqueness and coverage" of labels and keywords detection and can accurately present the classification of all clusters. Here, we introduced the following three noteworthy topics, "Health Risks," "Adolescent," and "Aging," which have been of wide concern recently and would be discussed in depth in the discussion part.

References with the strongest citation burst are considered as the research basics of frontiers in the upcoming years (47, 48). As shown in **Figure 6B**, the top 50 references were identified in terms of their strongest citation bursts. Among these references, Gibala et al. (44) provided insights on the utility of HIIT for improving physiological adaptations in health and disease and highlighted suggestions for future research. Little et al. (49) focused on investigating the role of HIIT in reducing hyperglycemia and increasing muscle mitochondrial volume in patients with T2D. Burgomaster et al. (50) analyzed and compared the similar metabolic adaptations of humans

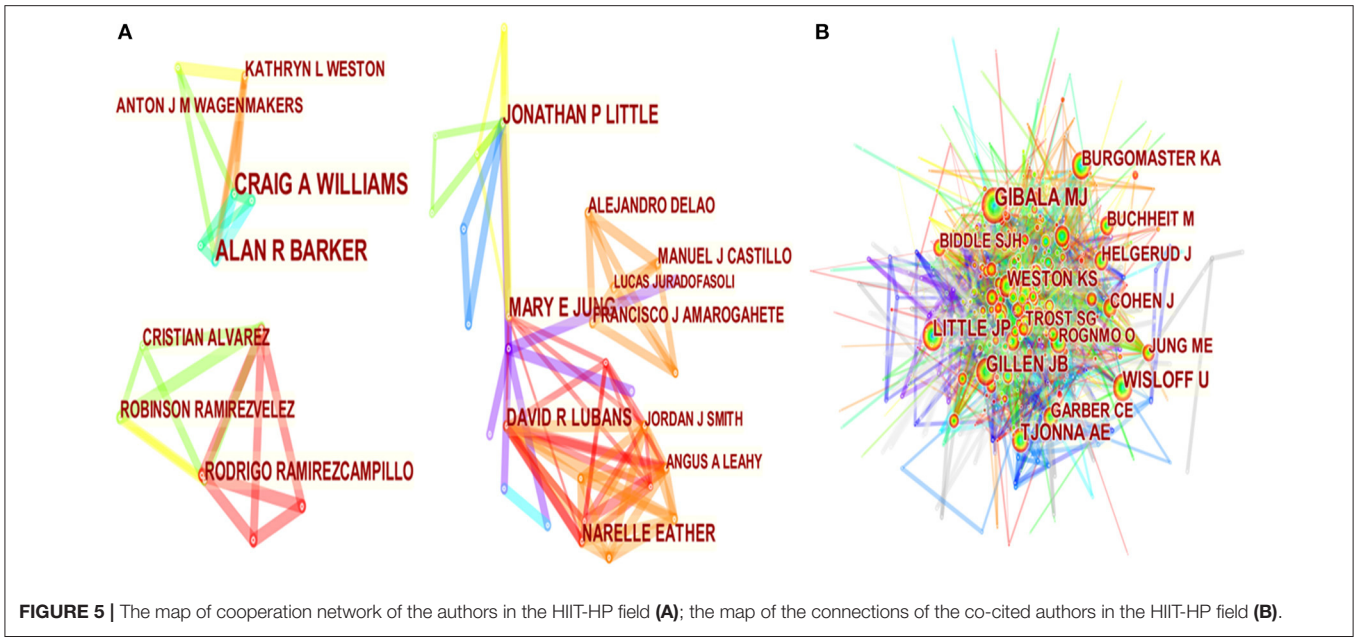


FIGURE 5 | The map of cooperation network of the authors in the HIIT-HP field **(A)**; the map of the connections of the co-cited authors in the HIIT-HP field **(B)**.



FIGURE 6 | The timeline view map based on the reference co-citation analysis in the HIIT-HP field **(A)**; top 50 references with the strongest citation burst in the HIIT-HP field **(B)**.

during the low-volume sprint interval and traditional endurance training from a physiological point of view. In recent years, high burst articles showed that HIIT had a positive role in treating chronic diseases caused by an unhealthy lifestyle. Two reviews focusing on the effectiveness of HIIT in the treatment of cardiovascular-related disease published in *the British Journal of Sports Medicine* by Batacan et al. (51) and Weston et al. (45) with burst strength as 7.02 and 5.33 represented a strong research hotspot.

Analysis of Keywords

A map of keywords can present major objects and hot topics of research. VOSviewer software was applied to conduct the co-occurrence network of keywords in this study. We created the map on the basis of bibliographic data with a full counting strategy, setting the minimum number of occurrences of a keyword as four. By using a thesaurus to clean and purify the data, 85 keywords out of the total 1,163 keywords met the threshold and are presented in **Figure 7**. According to the

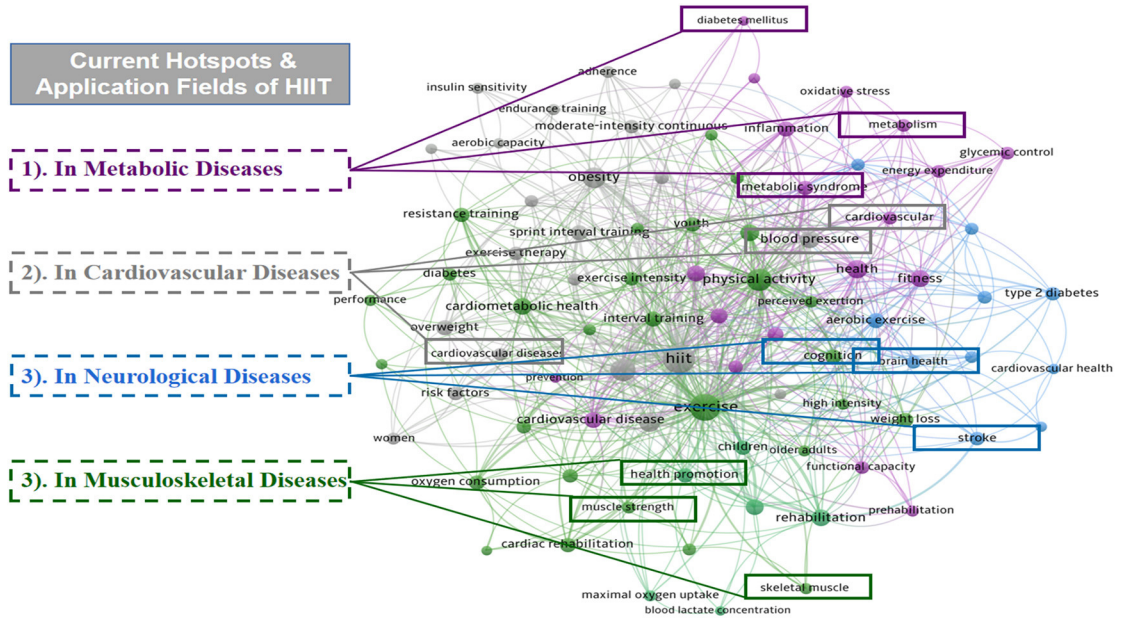


FIGURE 7 | The distribution of the co-occurrence network of keywords in the HIIT-HP field.

research categories of keywords, we integrated the classification generated by VOSviewer algorithm and further divided all these keywords into several major clusters with four different colors. In this figure, violet purple, light gray, photo blue, and grass green are represented for the applications of HIIT in "Metabolic Diseases," "Cardiovascular Diseases," "Neurological Diseases," and "Musculoskeletal Diseases," respectively. These application domains would be further discussed in the next part.

The top five keywords with the highest citation burst in HIIT-HP research were low volume (6.14), human skeletal muscle (5.83), sprint interval (5.58), HIIT (5.22), and aerobic fitness (4.48). The values in brackets reflect the strength of burst. Occurrence burst, which indicates the steep increment of a keyword in appearance over a period of time, can reflect development in frontier topics and dynamics in a research field (41, 42, 52). The top 50 keywords with the strongest occurrence burst are shown in **Figure 8**. In the first decade of the twenty-first century, critical physiological indexes such as skeletal muscle, cardiovascular capacity, respiratory function, and other physical performances induced by HIIT were widely mentioned and studied. Around the year 2015, with the physiological mechanisms of HIIT gradually been recognized, it seemed to be a research trend to apply HIIT to the rehabilitation of chronic diseases. Burst keywords like "heart disease," "cardiovascular disease," "obesity," and other health-related problems were dominant in this period. From 2018 to 2020, keywords with the strongest citation bursts were focusing on the molecular level and mental benefits of HIIT recently, including "gene expression" and "mental health." This result verifies that "prevention and rehabilitation," "micro and molecular level," and "cognition and mental health" are becoming frontiers and focuses in HIIT-HP fields, which are worthy of further exploration.

DISCUSSION

High-intensity interval training has become one of the most popular training methods for different groups of people to keep fit all over the world. In country and institution analysis, information about regional distribution presented that HIIT-HP researches are currently ongoing worldwide. Among the top 10 prolific countries, eight are developed countries and only two are developing countries. This implies that developed countries may invest more resources in the field of sports science and medicine. People living in developed regions usually pay more attention to fitness and wellness, so they also have a relatively high quality of life and a longer life span. However, developing countries, such as China, tended to catch up in the field of exercise and health science, especially in the HIIT-HP domain. Moreover, a previous study reported that the United States, China, and Brazil were also among the most productive countries in diabetes-related publications (53). We suppose that a large population base and aging tendency may lead to an increase in health risks, which tends to be an important driving force for these countries to invest resources in health researches.

Discovery and exploration of remarkable authors, references, and journals were carried out in this study. Authors from different regions and institutions who participated in the HIIT research made noteworthy contributions to studies in this field. **Figures 5A,B** show that the relationship between

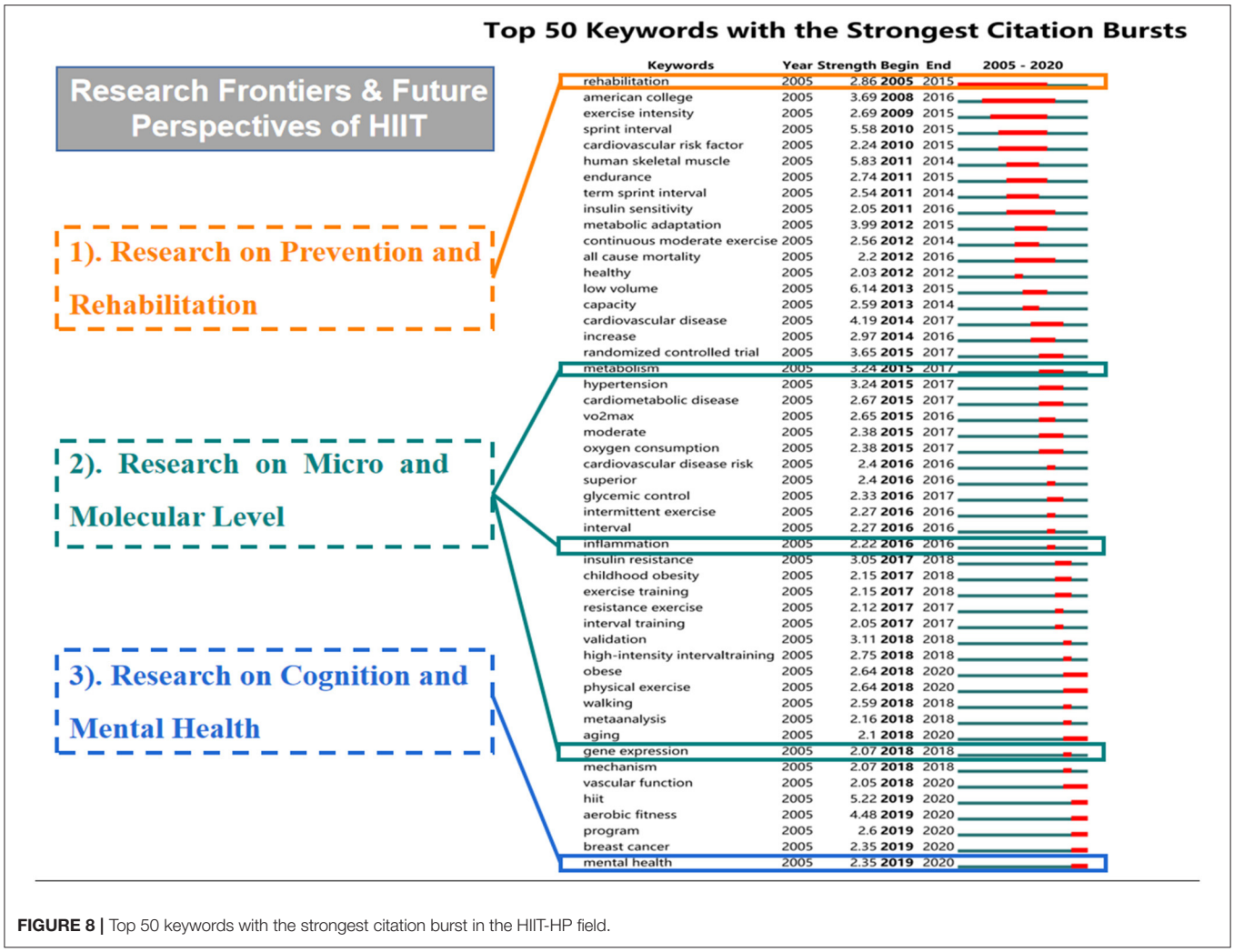


FIGURE 8 | Top 50 keywords with the strongest citation burst in the HIIT-HP field.

co-cited authors seems stronger, while the authors have cooperation only in part and lack communication and contact in general. Under the background of interdisciplinary integration, more scholars from different fields should strengthen mutual communication and cooperation and jointly promote the research progress and application of the HIIT method. As shown in **Figures 4A,B**, the network map and dual-map overlay of journals demonstrate several relevant publishing sources in the HIIT-HP field. Sports science-related journals were still the primary source to publish HIIT research. Physiology, rehabilitation or preventive medicine, and public health journals had a certain interest in this field as well. In addition, comprehensive journals also played an important role in publishing HIIT articles.

On the basis of the timeline view map of reference co-citation analysis, we could disclose research evolution trends. From **Figures 6A,B**, three high-frequency topics and clusters were summarized and analyzed. "Health Risks," "Adolescent," and "Aging" are three noteworthy topics during the development of HIIT-HP research:

(i) For health risks and factors: In the early stage of HIIT-HP study, scholars mostly focused on the risk factors of health-related problems. The two main factors that cause health risks are excessive energy intake and physical inactivity (54–57). The former gives rise to overweight or obesity risks, and the latter often leads to a sedentary lifestyle. It is almost universally acknowledged that obesity leads to multiple health risks (55, 57). Member states of the WHO appealed for a voluntary target to stop the rise in obesity by 2025, and exercise has been considered as widespread call to counteract overweight in all populations. Compared with MICT or other training methods, HIIT has its unique advantages in treating overweight people. A number of recent research have already proved that HIIT favored better body composition improvements and expended less time to achieve similar effects than MICT in curing obesity (58, 59). When it comes to problems related to a sedentary lifestyle, converging epidemiological evidence demonstrates that a sedentary lifestyle may lead to incompatible chronic diseases (54, 56). From an evolutionary point of view, the adaptation that HIIT-related exercise brings to the body is

an excellent strategy against the lifestyle-induced evolutionary mismatch (45, 51).

(ii) For youth and adolescent groups: In the initial development of HIIT, its applications were mostly promoted among young athletes (16, 60). With the development of exercise-training theory, HIIT is no longer a unique recipe for elite athletes, and children and teenagers also have access to this method to keep healthy. Adolescence is a critical period for physical growth and development. In view of the fact that teenagers are still in the growth stage, all-extremity HIIT will have a long-term impact on shaping their cardiopulmonary endurance, skeletal muscle, and circulatory system. The most common model used in HIIT research is the Wingate Test, which asks teenagers to complete an "all out" cycling session of 30 s against high-resistance on a specialized cycle ergometer. After a typical training session with four to six repeats interspersed by 4 min of recovery, the oxidative capacity of skeletal muscle of the youth groups and the maximum enzyme activity or protein content of mitochondria can be improved (61). In addition, metabolic abnormalities and obesity-related problems caused by academic stress, lack of sleep, and a sedentary lifestyle are concerning points in the development of teenagers. Some emerging researches have supported that HIIT can efficiently improve cardio-metabolic capacity in overweight teenagers compared with traditional endurance training (62–64). While HIIT has already been praised in teenagers for its beneficial effects on body composition and cardio-metabolic health, its application to improve cognitive and mental health also has great research potential. One study using neuroimaging methods like functional near-IR spectroscopy detected that acute HIIT can strengthen the cognitive and executive functions of teenagers by increasing the activation of the task-related area of the brain prefrontal cortex (65). In summary, it is promising to promote the application of HIIT in the mind–body shaping of teenagers.

(iii) For elderly groups: The sharp increase of the aging population has become a public issue currently (66, 67). Aging is associated with decreased aerobic fitness, cardiac remodeling, and bone-density loss, which may lead to an increased risk of chronic diseases. It is well-acknowledged that exercise may have the potential to delay the aging process, while weight-bearing activities are frequently limited due to musculoskeletal and balancing problems in the elderly groups. HIIT can be considered as a suitable supplement of strength training method in the elderly, and studies have shown that HIIT can improve the physical performance of the elderly group (68–70). In particular, when referring to the specific practicing strategy, the elderly are recommended to perform HIIT step by step. For example, when first using this method, one can practice for 20 s and rest for 30 s, and several weeks later, one can elevate the HIIT mode to an upgraded level (e.g., vigorous training for 30 s and resting for 15 s). It is better to avoid fatigue of the same muscle group (e.g., high resistance dumbbell bending), and the effective method is to combine HIIT with low-impact movements to reduce the impact on the joints and soft tissues. Additionally, it is worth noting that HIIT plays an important role in the health promotion of post-menopausal women who are more special in the elderly group. Numerous studies focusing on women suggested an increased risk of metabolic diseases in midlife (71, 72), and the management of fitness and weight at the menopause stage is becoming another public health concern (73). Several research studies (74–76) indicated that HIIT can improve health indicators, including inflammatory and adipokine profiles, in post-menopausal women. A recent meta-analysis (77) also showed that cycling HIIT seemed to be better than running in post-menopausal women, and interventions over 8 weeks with three sessions per week should be recognized as a promoted method.

On the basis of the co-occurrence map of keywords, we could not only explore current hotspots but also explore the applications of HIIT in several health promotion fields. From **Figure 7**, a number of prevalent keywords and noteworthy domains of HIIT-HP research were concluded and analyzed. Here, we further analyzed the following four categories based on the application fields of the HIIT program:

(i) Metabolic diseases: Diabetes, especially T2D and hyperglycemia, is regarded as one of the most common metabolic illnesses (78, 79). In 2014, Francois and his colleagues (80) tried to examine the effects of brief bouts of exercise performed before meals ("exercise snacks") in the treatment of post-prandial hyperglycemia in individuals with T2D. It did appear that HIIT may lead to greater reductions in post-prandial hyperglycemia when compared with moderate-intensity continuous exercise (80–82). Besides, different studies targeting multiple groups also indicated that HIIT is beneficial for the rehabilitation of T2D problems in a number of perspectives (83–85). One recent review using meta-regression concluded that the mechanism of HIIT for treating T2D lied in reducing both insulin resistance and body weight (86). However, the application of HIIT in the treatment of type 1 diabetes seems less, and the metabolism in preventing and managing other associated cardiovascular complications are still worthy of further study.

(ii) Cardiovascular diseases: Blood pressure is closely correlated with cardiovascular health, and hypertension has led to high cardiovascular morbidity and mortality worldwide (87–89). Current guidelines (90, 91) recommend a moderate-intensity approach for most inactive adults with pre-hypertension to established hypertension. However, several studies have found that HIIT provided comparable reductions in resting blood pressure and was associated with greater improvements in dealing with hypertension when compared to MICT (92, 93). More specifically, in lifestyle-induced cardio-metabolic diseases, the mechanism of the benefits of HIIT may due to its central and peripheral adaptations to the body (45). To summarize, exercise prescriptions like HIIT, as well as other health care methods, play a crucial role in achieving blood pressure control in patients with circulation disorders by reinforcing their cardiorespiratory fitness and cultivating healthy lifestyle habits.

(iii) Neurological diseases: Based on the neuromuscular and proprioceptive benefits, HIIT can also be used as counter

measures for some neurological diseases. Taking stroke as an example, it has been ranked as the second most common cause of death worldwide from the global burden of diseases, injuries, and risk factors study (94). Previous guidelines suggested that MICT in aerobics can be used as the strategy for improving mobility, aerobic capacity, and cardiovascular health in stroke groups (95, 96). However, recent evidence indicated that HIIT might be more effective than MICT for both aerobic and motor outcomes in these patients (97–99). Furthermore, it was reported that the innate ability of the nervous system to repair itself from damage through neuroplasticity formed the basis of stroke rehabilitation (100, 101). The rationality of using HIIT may be due to its strength to enhance cognitive functions, including upregulating the neuroplasticity markers in the hippocampus and cortex (102–104). HIIT has been proved as a feasible and promising strategy in individuals with stroke symptoms, and further HIIT studies are ongoing in patients with other brain diseases such as Alzheimer's disease and multiple sclerosis.

(iv) Musculoskeletal diseases: Skeletal muscles account for almost half of the human body mass and play essential roles in maintaining health. HIIT program can also be used to prevent sarcopenia, a more common syndrome in middle-aged and elderly patients, which is often combined with muscle mass loss, oxidative stress, chronic low-grade inflammatory status, and adipocytokine dysfunction (105, 106). Both animal and human experiments (106–108) showed that HIIT could modulate changes in inflammatory parameters, adipose tissues, and serum, as well as insulin-like growth factor 1 (IGF-1) levels in the skeletal muscle tissue. One recent research (109) also proved that HIIT was an effective training strategy to improve sarcopenia and skeletal muscle vascularization compared with traditional resistance training.

The detection of the burst keywords, referred to currently, can be used to explore the future development tendency. Hence, by analyzing these burst keywords (**Figure 8**) in the HIIT-HP field, we summarized the following three topics, which are considered as frontiers and expected to frequently occur over the coming years and signify research trends:

(i) Research on the prevention and rehabilitation: Based on our discussion of current hotspots and applications mentioned above, we can preliminarily find that HIIT can help to prevent or treat health burdens associated with many chronic diseases. Considering that preventive medicine is increasingly emphasized and valued nowadays, exercise intervention plays an important and irreplaceable role in this area. As a highly efficient, multi-stimulated and cost-saving means of exercise intervention, HIIT will possess broad prospects in the field of medicine and rehabilitation under the fast-paced and time-insufficient social background. Moreover, HIIT is characterized by short bursts or vigorous activity, interspersed by periods of rest or low-intensity exercise for recovery (110). So it has almost infinite forms and variables, and the specific physiological performance induced by this form of training is determined by multiple factors, including intensity, duration time, quantity of intervals performed, and activity patterns during recovery. The training performance of different modes and exercise stimuli in diverse subjects is still worthy of investigation in the future.

(ii) Research on micro-level and molecular level: With the development of life science technology, the current literature can further explain the healthy improvements conducted by HIIT from the molecular level. Previous studies revealed that aerobic-related adaptations of HIIT can include an incremental capacity for musculoskeletal lipid oxidation and rising metabolic transport proteins (50, 61, 111), which are beneficial to the mitigation and rehabilitation of specific diseases. The imbalance between pro- and anti-inflammatory cytokines can lead to diseases related to immunity and metabolism disorders (112, 113). Exercise can influence the immune system by changing the phenotype of leukocytes and producing more skeletal muscle-derived interleukin (IL)-6 and IL-10 (114–116). Studies have suggested longer duration exercises can make these improvements, but what about a short but intensive training program? New findings showed that short-term training like HIIT can also reduce the ability of IL-10 to LPS-induced TNF-α production (117). Furthermore, the metabolic crosstalk between these tissues and the molecular mechanism of these changes are still unclear, and more gene expressions, regulatory factors, and circulatory pathways need to be discovered to prove the systemic adaptations induced by HIIT.

(iii) Research on cognition and mental health: Recently, some researches on psychology and mental health have made further elaboration on the advantages of HIIT from the spiritual level. The increase in awareness of "active health" of people and the change in their attitudes toward HIIT are reinfluencing their perception of this fitness model. As terrible mental health conditions of modern people (such as anxiety, depression, and even suicidal tendencies) increase, research using HIIT strategy to counter depressive symptoms or other mood disorders are explored (118–121). Exercise can trigger the secretion of multiple hormones in the brain, such as brain-derived neurotrophic factor (BDNF, related to memory and information transmission), dopamine (DA, related to attention and satisfaction), norepinephrine (NE, related to complex emotions and motivational awakening), and serotonin (5-HT, which is related to depression, anxiety, impulsivity, and other emotions). Therefore, HIIT can enhance focus and reduce impulsive thoughts, which can mitigate a number of mental and emotional disorders. While HIIT seems to be difficult for beginners, it could evoke experiences of incompetence, failure, and lower self-esteem. Thus, the optimal HIIT regimen and the novel training mode aimed at solving such mental puzzles remain undefined and need more exploration.

Noticeably, under the context of the coronavirus disease 2019 (COVID-19) pandemic (122), isolation may lead to less exercise and more health-related problems. Although outdoor games are typically more available, varied, and usually have more infrastructures, HIIT has its unique advantage that can be

performed and completed independently at home in such a special period. With the COVID-19 pandemic, the world faced unprecedented medical challenges. Many of the infected patients suffered from severe respiratory impairment, neurasthenia, and cardiac disability due to the virus. However, evidence has suggested that HIIT may be a potential strategy for cardiac rehabilitation therapy in patients with the COVID-19 infection, which would be beneficial to improving the quality of life and long-term prognosis (123). Moreover, HIIT has similar or even superior effects on a range of physiological performance, immune system, and health-related markers of both healthy individuals and diseased populations.

This review has some limitations. First, in order to meet the data format standard of visualization tools like CiteSpace and VOSviewer, we only extracted data from the WoSCC. However, the SCI-E of the WoSCC database is one of the most extensive and well-recognized global resources, which has been used in several previous high-quality bibliometric studies. Second, this study generated a language- and article-type bias since we only considered "English" literature published as "articles or reviews," although "English" remains the most common language for publishing academic documents worldwide, and "articles or reviews" are the mainstream types of publications. Last, but not least, the greater amount of publications or cooperation networks are not always more important or inspired. Readers are recommended to focus on both the quality of researches and their citation status if they want to follow certain topics or hotspots.

There are multiple strengths of this research. It is one of the pioneering studies to tackle the specific HIIT topic in health science. Visualization software is used in analyzing the data, which allowed for a more holistic exploration of the literature with appropriate figures and tables. Moreover, the study is closely relevant to the scope of the journal, and it would be beneficial to an audience of freshmen, professional scholars, fitness coaches, doctors, rehabilitation therapists, and any other targeted readers. We sincerely hope that this bibliometric review of global publications can provide an in-depth and broad perspective to advance and expand the applications of HIIT in numerous public health promotion affairs.

CONCLUSION

This study applied a bibliometric and comparative analysis and provided a new century picture for HIIT and its applications in the health promotions field. We offered both a historical and a prospective insight into HIIT strategy and provided information for researchers regarding potential cooperative relationships, popular issues, development trends, and frontier topics. The number of published articles, crucial countries and institutions, published journals, authors and co-cited authors, and cooperative networks were systematically analyzed using hybrid analysis and visualization technologies (Q1). As an emerging exercise intervention to help people maintain health, HIIT has received increasing attention. During the development of HIIT-HP project, "health risks," "adolescent," and "aging" are three noteworthy research objects. We suggest that the current research hotspots of HIIT and its practices in the health promotion domain are "metabolic diseases," "cardiovascular diseases," "neurological diseases," and "musculoskeletal diseases" (Q2). In addition, "prevention and rehabilitation," "micro and molecular level," and "cognition and mental health" are becoming frontiers and hotspots (Q3), which should receive more attention in the future.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

YY, WL, and JL: conceptualization and writing—review and editing. YY, XL, and YF: methodology. YY and JL: validation and data curation. YY, JL, XL, and YF: formal analysis. YY: writing—original draft preparation. XM: supervision, project administration, and funding acquisition. All authors have read and agreed to the published version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.697633/full#supplementary-material

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A Virtual Approach to Promote Inter-Professional Learning (IPL) Between Biomedical Science and Medicine in Higher Education for the Benefit of Patient Care

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In the clinical setting, collaboration between multidisciplinary teams is core to providing effective patient care. The delivery of traditional interprofessional education is associated with a number of logistical challenges, which were heightened by the Covid-19 pandemic. This workshop was developed to bring together Biomedical Science and Medical students using an online platform. The workshop consisted of (1) defining interprofessional education, (2) introducing the role of the Pathology laboratory, (3) Professional registration with regulatory bodies and (4) an insight into Covid-19 laboratory diagnosis. The session was supported by mixed group breakout rooms and interactive polling. Thirty four percent of students completed a post-workshop online survey which included open and closed questions. Thematic analysis revealed a better understanding the role of the pathology laboratory in diagnosing disease, an increased awareness of the similarities and differences in the roles of a Biomedical Scientist and a Medic and the importance of a multi-disciplinary team in achieving effective patient care. Quantitative analysis of survey data revealed that the majority of students reported positive experiences of interprofessional education online. Approximately 90% of students agreed that the workshop enabled them to increase their understanding of their own roles within healthcare, in addition to increasing their understanding of the roles of other healthcare professionals. 74.3% of participants reported that working with students from a different programme provided an alternative perspective. Seventy nine percent of students agreed that the online format enabled interactivity and discussion of the tasks. Of the 204 students, 85% engaged with the four polls during the workshop. This online workshop enabled discussion between degree programmes, enabled interactivity and allowed the learning outcomes to be met. Universities should embrace online platforms to provide a novel, engaging and effective interprofessional educational experience.

Keywords: interprofessional education (IPE), interprofessional learning, biomedical science, medicine, healthcare professions, virtual education, cross-discipline collaboration

INTRODUCTION

In the clinical setting, the importance of interprofessional approaches to education and practise has been highlighted, ranging from improving the quality of patient care and safety, to reducing clinical errors (1, 2). Modern patient care is reliant upon healthcare professionals from different disciplines working collaboratively. This includes understanding each other's roles and contributions to the multi-professional team using their skillsets to problem-solve and interpret medical jargon for effective patient care (1). Interprofessional Learning (IPL) within Higher Education (HE) aims to bring students enrolled on two or more undergraduate degree programmes, to learn with, from and about each other, with the goal of achieving common learning outcomes (3, 4). Together they learn about each other's roles, skills and responsibilities, and the value of effective communication across disciplines (5), in preparation for clinical practise. The World Health Organisation (WHO) recognised the importance of IPL in 1978 and highlighted if health professionals were taught collaboratively in a multi-professional education setting, they were more likely to work effectively together in the clinical setting (6).

RECOGNITION OF IPL BY REGULATORY BODIES

IPL is recognised by the Professional Statutory and Regulatory Bodies (PSRBs). The HE curriculum is underpinned by standards set by PSRBs. The General Medical Council (GMC) sets the standards and requirements for delivery of medical education, and medical school programmes must provide medical students opportunities to work and learn from students of other professional programmes to support multi-disciplinary working (7). The Health Care and Professions Council (HCPC) accredit allied healthcare professional courses within the UK and recognise the importance of Biomedical Scientists working with, and from learners of other relevant professions (8). To prepare more inclusive and dynamic healthcare teams, an understanding of and opportunities to undertake IPL is essential. This will help overcome barriers such as a lack of awareness of the roles within the healthcare system and their involvement in patient care (9, 10).

CHALLENGES IN THE IMPLEMENTATION OF IPL

In HE, there are often logistical challenges that accompany IPL due to the large number of students (face to face learning) involved in traditional IPL, these include timetabling across multiple disciplines, as well as constraints on suitable learning environments and space (11). Another challenge that universities face when delivering IPL is to ensure that the activities are relevant to all programmes involved and activities are embedded into the curriculum, rather than extra-curricular activities which typically garner the interest of only a small proportion of students (4).

OPPORTUNITIES PROVIDED BY THE USE OF AN ONLINE PLATFORM

In HE, the move to online learning platforms provides a solution to overcome these challenges and delivers an authentic opportunity for students to work together using collaborative practise and problem based learning (PBL). This creates a different learning environment and alternative approach to working in interprofessional groups. PBL has been a key feature of medicine and allied health care programmes for a number of years (12, 13). A recent study demonstrated additional value of co-constructive discussions between students from different backgrounds, with the common goal of addressing patient concerns (1).

The Covid-19 pandemic and the extraordinary stresses it placed on the National Health Service (NHS) highlighted the importance of effective interprofessional working relationships in order to collaboratively overcome the many urgent, complex and unique demands that arose (14). IPL has been trialled virtually between healthcare focused courses and studies have reported improved teamwork, interprofessional knowledge and attitudes (15–17). Whilst a number of studies have evaluated the effectiveness of IPL programmes delivered through traditional on-campus workshops, there are relatively few studies which assess the delivery of IPL using online virtual platforms. Due to the impact of Covid-19 most UK universities moved to online delivery of learning and teaching to protect both staff and students. The aim of this study was to evaluate the effectiveness of an IPL activity designed to improve awareness and understanding of the roles of Biomedical Scientists (BMS) and Medics within healthcare, using PBL and an online platform for delivery.

MATERIALS AND METHODS

Creation of an Online IPL Workshop

The IPL workshop was created and co-delivered by academics from the School of Biosciences, the Medical School and Pharmacy School, Aston University, UK. The workshop was scheduled for 3 h and consisted of academic-led material and breakout rooms using the Blackboard Collaborate platform (Blackboard, Washington DC). Taught topics were delivered to the entire student cohort of final year Biomedical Science and second year medical students and included (1) defining IPL, (2) introducing the role of the Pathology laboratory, (3) Professional registration with regulatory bodies and (4) an insight into Covid-19 laboratory diagnosis. The workshop included a series of breakout sessions where students worked in small mixed discipline groups (6 students per group) for 20 min to complete three activities. In total there were 34 breakout rooms, which were supervised by 4 members of staff. At the end of each breakout session, students were brought back to the main virtual room to discuss the activity and share answers from each perspective. Students were able to interact with academics throughout the entire workshop using the chat function. An activity booklet was designed and completed by one member of each group, prior to being uploaded onto the virtual learning

environment (VLE). The five page booklet was designed to motivate students to participate within the study and to promote engagement with the activities within the breakout rooms. Students completed three activities which required input from both Biomedical Science and Medical students.

Activities in the Breakout Groups Included

1. Assign key skills and roles to the following healthcare professions: Medical Doctor, BMS and a Pharmacist.
2. Explain the purpose of a range of different blood tests along with clinical investigations e.g., measuring blood pressure and heart rate.
3. Share how Medical Doctors and BMS obtain registration with their professional body.

Four interactive polls were created based upon given scenarios presented throughout the workshop. The polls were hosted using the Blackboard Collaborate platform and assessed students application of knowledge and their understanding of processes related to patient sample collection, processing and diagnosis of disease.

Collecting Student Feedback and Analysis of Results

Final year Biomedical Science and second year Medical student experiences of IPL using an online platform were collected post-workshop through an eleven-item online questionnaire. A mixed methodology approach was adopted, which included open and close ended questions. The results were analysed both quantitatively and qualitatively. Students were invited to participate in the study during the IPL session and were provided the link to an online survey on Blackboard and through the chat function. Explanatory statement and consent was embedded within the online survey. Consent was required prior to accessing the questions. Students completed questions measuring awareness of professional roles, learning with and from one another (collaboration and knowledge gain), the role of IPL in patient care and the effectiveness of the online workshop (structure and organisation) in creating an IPL environment (**Table 1**). Questions around teamwork, roles and collaboration were influenced by Parsell and Bligh and were developed based on the expert opinion of the investigators (18).

Answers included Likert-scales, free-text options and interactive polling. The study used the Online Surveys (formerly known as Bristol Online Survey; BOS) platform (JISC, Bristol, UK). Participation was anonymous and voluntary; no demographic was collated apart from the degree programme on which the students were enrolled. The study was approved by the Life and Health Sciences Research Ethics Committee (Project #1494). The survey was available for 2 weeks (17th December 2020–31st December 2020). The survey was advertised during the IPL session and using the Blackboard announcement feature which included links to the online surveys and reminders sent via announcements and email.

To account for variations in the number of responses to a given question, the number of respondents to each question has been specified. We have included the raw data (where appropriate) as the study population was small, so there is not always statistical significance. To compare responses between Biomedical Science and Medical students, unpaired two-tailed *t*-tests were used to determine statistical significance between the two student cohorts ($p < 0.05$).

The free-text responses were analysed using Thematic Analysis (19). The procedure was as follows: the researchers individually read the data multiple times for familiarity and generated initial codes; the codes were then collated to form initial themes; the themes were then reviewed against the data set for plausibility; and finally the themes were refined. This process was repeated by two members of the research team individually for triangulation and final themes were agreed collectively to produce the thematic analysis.

RESULTS

A total of 204 students engaged with the workshop, of which 70 students (34% response rate) completed the online questionnaire, these consisted of 59% Biomedical Science students and 41% Medical students. Participants responded to a series of statements related to the importance of interprofessional education and its role in the workplace. **Table 1** shows that both student cohorts responded positively to the statements relating to the workshop: overall, 73% of Biomedical Science students and 91% of Medical students stated that they "Agree" or "Strongly Agree" with the statements.

All statements were rated highly across both cohorts, for all measures. Students "Agreed" or "Strongly agreed" they had improved awareness of the role of the other profession, their own role and limitations, with the understanding they need to know the roles of other healthcare professions in the team for future practise (statements 1, 2, 3). Within the knowledge measure, 80% of students across both cohorts "Agreed" or "Strongly agreed" that they now have a better understanding of the other students role as a result of this workshop, in particular medical students significantly ($p < 0.05$) improved their understanding of Biomedical Science students role due to the scenario discussed (statement 9). Students had an increased appreciation and alternative perspective by working with students from a different programme (statement 5). In particular, all students "Agreed" or "Strongly agreed" that collaboration across professions will benefit patients (statement 7). Where the workshop enabled discussion between the two programmes and improved their team work skills and relationships (statements 6, 10). The students from both cohorts "Agreed" or "Strongly agreed" that the structure and organisation of the session (statements, 4, 8, 11) meant they enjoyed the activity and felt the online platform enabled them to meet the learning outcomes and supported interactivity and discussion.

Prior to the IPL workshop, all students completed a Haematology module in which sample collection and pre-analytical processing was taught. An understanding of these processes were assessed using interactive polling, of which **Table 2** shows the results.

TABLE 1 | Student survey responses relating to the IPL workshop ($n = 70$).

Statements	Biomedical Science (mean ± SD)	Medicine (mean ± SD)	*P*	Percentage "Agreed" or "Strongly Agreed"
1. Working with students and staff from other programmes improved my awareness of the role of other professionals, in the patient pathway	4.21 ± 0.90	4.55 ± 0.57	0.09	90%
2. Working with students from other professional programmes will help me understand my own (professional) role and limitations	4.22 ± 0.85	4.38 ± 0.86	0.44	88.5%
3. I need to know about the role of other professionals for my future practise	4.39 ± 0.74	4.69 ± 0.47	0.06	94.3%
4. I feel the online platform allowed me to meet the learning outcomes of the session	3.98 ± 1.06	4.10 ± 0.98	0.61	78.5%
5. Working with students from a different programme provided an alternative perspective (which may not have been considered if working with own programme alone)	3.93 ± 1.17	4.17 ± 1.07	0.37	74.3%
6. Learning with, from and about each other (from different programmes) will improve my team work skills and working relationships	4.39 ± 0.80	4.57 ± 0.50	0.29	95.6%
7. Patients will ultimately benefit if professionals work together and learn from each other	4.73 ± 0.45	4.79 ± 0.41	0.56	100%
8. I enjoyed working with students on the other programme on this activity	4.07 ± 1.23	4.31 ± 0.93	0.39	82.9%
9. I have a better understanding of the other students role, from their contribution to the scenario discussed	3.88 ± 1.14	4.45 ± 0.78	**0.02***	80%
10. The session enabled discussion between the two programmes involved	4.12 ± 1.19	4.31 ± 0.93	0.48	84.3%
11. The online format enabled interactivity and discussion of the tasks/scenario presented	4.02 ± 1.19	3.97 ± 1.08	0.83	78.6%

The mean Likert scores for each statement are provided using a five point Likert scale with 1 = strongly disagree and 5 = strongly agree ± the standard deviation (SD). A two-tailed t-test was used to determine significance ($p<0.05$*) between the Biomedical Science and Medical student cohorts. The bold value demonstrates a statistically significant value.*

TABLE 2 | Responses to interactive polling.

Poll question	Student response rate	Number of correct responses
Q1. Which of the following shows the correct order of draw?	172/203 (85%)	70 (41%)
Q2. Which of the following statements are correct about serum?	173/204 (85%)	97 (56%)
Q3. Which two tests are performed to diagnose Covid-19?	160/197 (81%)	79 (40%)
Q4. Which antibody is a marker of past infection?	165/196 (84%)	120 (61%)

All polling questions asked within the workshop had high response rates from 81 to 85%. The questions were anonymous, therefore indication of student number responding from each programme could not be identified. Question 1 and 2 focused upon sample collection and the preparation for testing, covered prior to the workshop. Question 1 demonstrated that 41% of respondents identified the correct order of draw, and Question 2 showed that 56% identified the correct statements relating to serum. These polling results for Question 1 and 2 illustrate the need for this content to be reinforced across both student cohorts and that incorrect sample collection and preparation prior to testing can negatively impact patient care.

Within the workshop both student cohorts were taught new information about diagnostic tests used to screen for Covid-19. For Question 3, only 40% of students correctly identified the two tests used in the laboratory to diagnose coronavirus infection. The final polling question (Question 4) asked students to identify which antibody is a marker of past infection, knowledge which is relevant for both student cohorts and is taught as part of their degree programme. As shown in **Table 2**, 61% of students identified the correct answer.

Free Text Responses: Thematic Analysis

To gauge a better understanding of what students learned from and taught each other, a thematic analysis was conducted of the responses to the free-text questions: Q8 - *What did you learn from the other students on the programme?* and Q9 - *What did you feel you taught your peers when sharing your ideas and experience?* (Appendix 1 in **Supplementary Material**). In total, 80% ($n = 56$) of the students answered question 8, whilst 73% ($n = 51$) answered question 9. Responses were analysed and common themes were identified between the two questions. The three most prominent themes identified were as follows:

1. The role of a Pathology laboratory in diagnosing disease,
2. An understanding of the similarities and differences in the roles of a BMS and Medic
3. Importance of a multi-disciplinary team in achieving effective patient care.

Theme 1: The Role of the Pathology Laboratory in Diagnosing Disease

Six medical students reported that they learned of the importance of the Pathology laboratory in diagnosing disease and the majority of the responses indicated that they learned about different tests that are performed on patient samples within a diagnostic laboratory. Comments included:

> ***"The fact that they have the same goal as us medical students which is to improve patient's health but they do different tasks such as laboratory investigations on samples which is not done by doctors."***
> ***"I learned about different tests that are performed in the lab to diagnose sepsis and to identify the key markers that would be out of range from lab results."***

Similarly, ten Biomedical Science students reported that they taught the other student cohort about the role of the Pathology laboratory in diagnosing disease during the workshop. Specific comments related to the diagnostic tests and the need for medics to correctly fill out laboratory request forms in order for Biomedical Scientist's to process the samples. These results are then released to the Medic to appropriately treat the patient. Comments included:

> ***"I taught other students the purpose of the diagnostic tests and how the BMS laboratory works, along with the importance of Medics correctly filling out request forms."***
> ***"My role in the testing process and the type of work undertaken by a BMS; I shared how to interpret a full blood count and stressed that this test does not only look for anaemia, but also diagnose infection through checking the white cell count."***

Theme 2: An Understanding of the Similarities and Differences in Each Other'S Career Pathways

Twenty nine students reported that they gained an understanding of the roles of a Biomedical Scientist and a Medic. The majority of the responses indicated that students gained a deeper insight into the roles that each professional undertakes and learned how their roles are linked. Comments included:

> ***"A deeper understanding of the role of a Biomedical Scientist."***
> ***"A clear understanding of the role of a Biomedical Scientist and how it overlaps with doctors and pharmacists."***
> ***"The similarities and differences in some of the tasks performed and how their role is linked to ours."***
> ***"The "behind the scenes" whenever a doctor requests a test or prescribes drugs."***

Furthermore, students also learned about differences and similarities in professional registration and how to legally practise their profession in the UK. Comments on what they learned included:

> ***"The steps that are required to register as a Medic and the different responsibilities associated with their roles."***
> ***"The route to become a registered BMS I was not previously aware of."***

Thirty one students reported that they taught the other student cohort about their role in the patient pathway. Various students reported that they gave insights into their role and the importance of their jobs in effectively treating patients. Furthermore, students also appreciated the roles of other professionals involved in the patient pathway. Comments included:

> ***"I believe I gave Medics an insight into what a BMS is and what they do and how they are involved in patient treatment."***
> ***"I taught medics the role a BMS has in interpreting and relaying results from tests requested."***
> ***"I taught the BMS students the roles of a doctor that they may not have already been aware of and that the doctor is the centre piece connecting these specialities to patient care."***
> ***"I taught BMS the different roles of a doctor - not just talking to patients and doing a few tasks. The appreciation medical students have for other professionals (often understated)."***

Again, many students reported that they taught the other cohort how to become a registered professional in the UK and the different accrediting bodies that are involved. Examples of statements included:

> ***"More about the role of a medical doctor and how to become a registered doctor."***
> ***"Our route to practise as a registered Biomedical Scientist and the importance of the HCPC in gaining registration in order to practise."***

Theme 3: Importance of a Multi-Disciplinary Team in Achieving Effective Patient Care

Nine students reported that through the workshop they gained an appreciation of how working with other health professionals can deliver effective patient care. Students reported that they understood the importance of working collaboratively and how each professional plays an important role in treating the patient. Comments included:

> ***"It allowed me to understand how the two programmes are linked and their importance when working together."***
> ***"Learnt more about the roles and responsibilities of medics and where BMS can interact with them and work together to help diagnose patients."***
> ***"The importance of effective communication between Medics and BMS."***

Similarly, eight students reported that they taught the other cohort the importance of working together, stressing the need for a collaborative approach to provide high quality patient care. Comments included:

> ***"How many overlaps there are in our roles and how we have to work collaboratively to benefit the patient."***
> ***"The workshop allowed discussions about how we interact with***

different professionals and I stressed how we need to work together to interpret results and what they mean."
"We were able to work great as a team and listened to each other and respected each other opinions which is what we need to do when working in a hospital."

DISCUSSION

This study sought to determine the effectiveness of delivering IPL online using PBL, between Biomedical Science and Medical students. The workshop required students to collaboratively work together across degree programmes and aimed to increase awareness and understanding across professions.

The Role of IPL in Healthcare Orientated Courses

Successful interprofessional education requires all students to learn with and from one another and learning transfer occurs maximally when students are presented with relevant context in which to apply their knowledge (20). Biomedical Scientists rarely interact directly with patients but are involved in 95% of all clinical pathways (21), whereas other healthcare professionals such as Medics, Pharmacists and Nurses are all patient facing. To ensure that the requirements of both programmes were met, academics from both programmes were actively involved in the design and delivery of the workshop. The patient case studies incorporated in the workshop have created an opportunity for collaborative interprofessional practise, which are exemplar of instances where different professionals need to work together in the clinical setting. Other work has shown that collaborative working of student cohorts in a PBL setting can help to foster a positive attitude towards other professional groups, thus, improving interprofessional relations (1).

Delivering Inter-professional Education Online

The workshop was designed to address a number of different topics and ensured that the content of the three activities were familiar to both programmes but required students to work together across disciplines in order to complete the answers. The activity length was based upon previous work reporting that the average adult has a maximum attention span of 20 min (22). Over three-quarters of students (78.5%) across both programmes positively responded to all of the statements and successfully met the learning outcomes of the IPL workshop. Survey results showed that 88.5% of students agreed that the workshop enabled them to increase their understanding of their own roles within healthcare and their limitations. Furthermore, 90% of the cohort agreed that the workshop increased their understanding the roles of other healthcare professionals involved in patient care; this demonstrates improved awareness of professional roles and responsibilities within the multi-professional team. This is supported by the findings from the thematic analysis which also provide evidence that the tasks set in each of the activities allowed both cohorts to actively disseminate their discipline specific information in the workshop, as well as learn from the other cohort. Previous work has also reported that interprofessional PBL inculcates an appreciation and knowledge of other roles (1, 23, 24). Using the PBL approach to deliver interprofessional education has created an environment for cohorts of students from different backgrounds to listen to others perspectives related to their roles and construct knowledge in collaboration with one another (25, 26).

Students demonstrated knowledge gain, where 74.3% agreed that working with students from a different programme provided an alternative perspective to the case. This was particularly evident for the Medical student cohort, who reported a better understanding of the role of Biomedical Scientists post-workshop, which was identified as being statistically significant (statement nine). All students (100%) agreed that patient's will ultimately benefit from different healthcare professions working together. The activities also provided opportunities for students to identify similarities and differences across their programmes and their practise. There was a common appreciation from both cohorts of students that they each play an essential role in providing high quality care to patients, from the moment a patient first presents to a doctor, to the reporting of test results by the laboratory and collaboration being a key feature. Both the cohorts recognised the need for a multi-disciplinary approach and effective communication in treating patients.

To make the workshop relevant to both programmes and the current climate, Covid-19 clinical presentation and diagnosis was included as part of the tutor-led material. Student cohorts were taught new information about diagnostic tests used to screen for Covid-19. Less than half the student cohort were able to correctly identify diagnostic tests for screening coronavirus infection. Despite the principle behind testing being the same as those used to detect other viral infections, students struggled to apply this knowledge from prior learning, which re-enforces the need for further opportunities to apply pre-existing knowledge.

From the survey students had reported that the online delivery of the IPL enabled them to meet the learning outcomes of the session (78.5%). There was high engagement in the chat function in feedback post activities and the online polling. In face-to-face large group teaching, multiple sessions would be delivered due to cohort size and space requirements, as well as interaction with individual student groups would require multiple staff to monitor and facilitate group discussion, meaning a larger number of staff hours required. In order to participate in interactive polls in traditional IPL, students would have required either specialist equipment or software. Blackboard Collaborate facilitates interactive polling where students can engage anonymously. The interactive polls held during the workshop had high levels of student engagement (with up to 85% of students interacting), which is considerably larger than what is typically observed in a traditional classroom setting. High levels of student attendance and engagement using Blackboard Collaborate has been previously reported, as it also provides the option for students to join sessions wherever they are, through their laptop, computer or smartphone (27). The workshop in the current study included ∼200 students across the two cohorts and the online platform successfully accommodated this large number of attendees. Feedback from students showed the online platform enabled interactivity and discussion. Furthermore,

other work has reported that virtual interprofessional education is as effective as face-to-face delivery, with students reporting an increase in interprofessional knowledge, attitudes and team-playing attributes (15).

The success of the IPL in part may be explained by the workshop being delivered to only two disciplines. Other work involving IPL activities across five or more healthcare disciplines reported that the results were hindered by excessive disciplines working on a single activity. It has been suggested that reducing the number of disciplines within each team would increase student engagement and improve the interprofessional experience (4, 28). Furthermore, the success of IPL is also dependent upon the relevance of the topics being included to the programmes involved. Despite the benefits of online delivery, there still remains the challenge of timetabling multiple cohorts of students to attend the same session.

LIMITATIONS

Whilst IPL has an important role to play in higher education, the planning and design of the activities is time consuming and resource intensive. The complexity of the planning is increased by academics from across disciplines being involved in the co-creation of the workshop. A previous study also reported that interprofessional education requires three times the amount of preparation compared to traditional course content delivery (29). In the current study we were unable to distinguish the polling responses of Biomedical Science students and Medical students. An additional limitation of hosting online sessions is poor internet connectivity, with a small number of students in the workshop periodically having to re-join the session (exemplified in the table 2 response rate). This is not only frustrating for the student, but also interferes with group discussions and completion of the tasks. Thirty four percent of participants completed the survey and we believe this is reasonable as no incentives were offered to participants. Survey return is difficult in the HE setting, especially as students are encouraged to fill in numerous surveys per module and course and it is not clear if the student sample is biassed relative to the whole cohort. Perhaps if survey return was marked compulsory or incentives were offered it would have increased the survey return rate.

FUTURE WORK

IPL is recognised to be valuable for multi-disciplinary team work and ultimately patient care. Studies suggest embedding IPL early into the curriculum is optimal (30, 31) using relevant and mutually beneficial topics for all undergraduate programmes involved. Previous studies have shown the benefits of IPL, with it helping students greater understanding their own professional role, as well as understand the role of other health professionals (1, 32, 33). To address the limitation of being unable to differentiate polling responses by student group, future work should seek to use an external polling software. This would enable a comparison of student understanding across different cohorts, although the survey data did enable a summative exploration of what student's had learned. Future work could explore the effects of social, cultural and economic backgrounds on the impact of IPL (34) and then seek to address these factors as part of the design of interprofessional education. To further explore any potential benefit of IPL on practise, a longitudinal study investigating the impact of IPE on Biomedical Science graduates who decide to practise as registered Biomedical Scientists within the NHS would be useful to examine the impact of IPE in HE on clinical practise.

CONCLUSION

IPL online using a PBL approach was successful in enabling students across two programmes to work together and learn from each other. There was a significant positive impact on the understanding of other healthcare professional roles, markedly for the medical students understanding the Biomedical scientist role in patient care. Online delivery has clear benefits for enabling large cohorts to work together without the limitation of room size and without requiring multiple parallel sessions to deliver events; thus, reducing the overall resource of staff number required for delivery. The online platform successfully facilitated the delivery of one scheduled session for a large number of students, reducing the number of staff required to facilitate polling, breakout groups and discussion. Engagement was evident from the use of the various tools within the online platform, particularly polling where anonymous responses were collated to test student's immediate understanding, whilst respecting the individual learner. With professional bodies recognising the importance of interprofessional teams within the clinical setting, more educators need to collaborate and create IPL opportunities within the curriculum to teach students the true benefits of multi-disciplinary team working, whether online or face to face.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Life and Health Sciences Research Ethics Committee (Project #1494). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AB contributed to the conception of the study. WL and AB designed the research approach for this study. AB led the design of the online workshop, AB and RP created the Biomedical Science taught material and the workbook students completed. ED created the taught Medical content. All authors contributed to the design of the interactive activities and RP created the interactive polling questions. WL gained ethical approval on

project Interdisciplinary Education at Aston and created the online survey. AB and RP analysed and interpreted the data and wrote the first draught of the manuscript. WL and ED provided feedback and contributed to some sections. All authors edited the manuscript, read, and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.747751/full#supplementary-material

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Smartphones and Educational Apps Use Among Medical Students of a Smart University Campus

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Background: Smartphones and medical education apps are popular with and are widely used by medical students to facilitate peer interactions, communication and collaboration in addition to their "learn anywhere" advantage. Smartphone use by medical students has not been studied in the English-speaking Caribbean. Study objectives were to assess in preclinical students attending the University of the West Indies in Barbados, smartphone ownership, usage and attitudes toward use in medical education.

Methods: First and second year preclinical medical students completed a self-administered paper-based questionnaire during the 2018–2019 academic year. Survey questions included sections on smartphone ownership, medical apps used, phone usage for education related tasks, and the perception on the usefulness of smartphones in medical education.

Results: Of 112 participants (response rate 67.4%), 43% considered using the smartphone for medical education when acquiring it but 92% were currently using it for this purpose, with 80.3% ($p < 0.01$) specifically using it for learning anatomy. The majority of the students felt that the use of smartphones would improve their educational experiences (89.1%) ($p < 0.01$), be beneficial to medical faculty for teaching (84.8%) ($p < 0.01$), and could be more effectively used in medical education (50.9%) ($p < 0.01$). For information resources students used Medscape (67.9%) and Mayo Clinic (57.1%) and the most frequently used search engine was Google (95.5%). Most students (67.9%) used medical apps and 79.5% would buy more useful apps provided they were affordable. The popular apps were: 'Teach me Anatomy' (11.9%), 'UpToDate' (10.3%) and 'Medscape' (8.8%). Most students (66.1%) felt a Smart Campus should ensure e-learning platforms were compatible with smartphones and university policies regarding smartphone usage for academic purposes were needed.

Conclusion: Findings show that smartphones and related medical education apps are widely used by medical students and improve their educational experiences. Universities should develop a policy regarding smartphone usage for academic purposes.

Keywords: smartphones, medical education apps, medical education, smart campus, Barbados

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Abbreviations: UWI, The University of the West Indies; COVID-19, Corona Virus disease 2019; PDA, Personal Digital Assistants; FMS, Faculty of Medical Sciences; MBBS, Bachelor of Medicine and Bachelor of Surgery; IRB, Institutional Review Board; CARICOM, Caribbean Community and Common Market

INTRODUCTION

Smartphones and medical education apps have become popular and are widely used by medical students because they facilitate peer interactions, communication and collaboration in addition to their "learn anywhere" advantage (Valle et al., 2017). Mobile learning (m-Learning), an extension of e-learning (Ventola, 2014), utilizes mobile devices such as mobile phones, smartphones, personal digital assistants (PDAs), netbooks, tablets, e-readers, and gaming devices (Gavali et al., 2017). Smartphones, a combination of mobile phone and handheld computer, allow web browsing and use of online applications (Apps) (Ventola, 2014). Due to their versatility, educators are integrating smartphone use in curriculum delivery, with an emphasis on the advantages and with amendments to curtail disadvantages (Darko-Adjei, 2019).

It is well-established that learning is most effective and efficient when it is situational (tied to actual activity), continuous, and life-long (Sung et al., 2016; Kim, 2020). Instruction models informed by constructivist theories to integrate mobile technology are widely advocated in higher education settings (Sung et al., 2016). Social media when used for educational activities encourages greater engagement of students in learning and facilitates peer interactions, communication and collaboration (Latif et al., 2019). The concept of situated learning by Lave and Wenger (Lave and Wenger, 1991), emphasizes the need for contextualization of knowledge. Smartphones being portable devices allow ready access to information during clinical encounters (Lave and Wenger, 1991). Knowledge acquired via a smartphone device and its reflection facilitate learning (Davies et al., 2012). Honey and Mumford (2006) classified learning preferences into four broad styles - activists, pragmatists, theorists, and reflectors. The activists learn by doing things (e.g. group discussions and problem-solving), pragmatists learn by practical application of acquired information in the real world (e.g. experiment with theories and ideas), theorists strive to interpret a theory behind any action (e.g. reading stories and quotes), and reflectors learn best by making observations and collecting data (Honey and Mumford, 1992). Taking these learning styles into account can lead to more effective teaching and medical teaching apps can be tailored to the varied learning needs of individuals (Honey and Mumford, 2006). It is suggested that to be successful learning must be based on contemporary practices matching a social-constructivist approach that is active as well as learner, knowledge, assessment and community centered (Shaples, 2016).

The constructivist learning is considered as 'a holistic approach' which is purposely tailored to the curricular goals and students' needs to offer learning experiences related to their personal and professional development (McGrath, 2007). Learners construct their knowledge through a process of active enquiry and engagement and take responsibility for their own learning. Constructivists believe that assessment should be used as a tool to enhance both the student's learning and the teacher's understanding of student's progress i.e. assessment for learning (Rahman and Majumder, 2014). Social constructivists believe in collaborative approach that knowledge is constructed through interaction with others which facilitate life-long learning (Akpan et al., 2020). Information and communication technologies need to integrate with social constructivist approaches in order to assist and facilitate the construction of knowledge. Contemporary learning approaches and e-learning systems need to include cultural and behavioral aspects to integrate pedagogical issues (Louvigne et al., 2018). In traditional teacher-centered classroom teaching, students are passive learners, work primarily alone, and teachers disseminate information to students (Lord, 1999). Teacher's role is directive, rooted in authority an assessment is focused on through testing and correct answers. Traditional method ignores the students' psychological level of interest and motivation of the students (Singh et al., 2019). In constructivist learning, 'interaction is perceived to be one of the most important components of the learning experience', and 'students are given sufficient opportunities to express themselves and to share their own experiences with others' (Alt, 2016).

The increasing use of advanced technologies, especially smartphones (Mohapatra et al., 2015) is reported in the literature (Payne et al., 2012; Wallace et al., 2012). Medical students accept, adapt, and utilize high-quality electronic information resources much more than clinicians (Pedro et al., 2018). Students who use smartphones and medical apps agree that smartphones have a positive effect on their education (Zhao et al., 2018; Maudsley et al., 2019). Moreover, an association between smartphone use and academic performance among medical students is reported in the literature (Craig and Van Lom, 2009; Sheikhtaheri and Kermani, 2018). Many tertiary level medical institutions have implemented m-Learning in order to provide flexibility in learning. For instance Standford University provides students with iPads in place of textbooks (Quant et al., 2016). Smartphone-related medical education apps have also witnessed increased usage among medical students (Zhao et al., 2018), since students find them helpful for their education (Green et al., 2015; Alhazmi et al., 2018). Medical school surveys have shown that approximately 80% of health care professionals and students used their mobile devices for patient care communication (e-mail, telephone and text messages) and 85% reported using them at least once daily for information and time management or communication (Wallace et al., 2012; Ventola 2014). Smartphones offer many advantages including portability, fast access to online information, efficient use of time, flexible communications, applications and access to multimedia resources (Chase et al., 2018). Medical students use smartphones for accessing diverse resources such as learning anatomy, drug information, clinical scoring systems, and eBooks. Increased usage is observed during the transition from preclinical to clinical years (Chase et al., 2018). Clinical students find that with a smarthphone, downtime between clinical activities can be converted into learning opportunities (Chase et al., 2018).

Smartphone use also has limitations which may include superficial learning, use of unreliable information sources, worsened psychological well-being, insomnia, poor sleep quality, anxiety, depression, low self-esteem, higher cognitive

distraction, smartphone addiction, poorer academic outcomes and concerns related to privacy and professionalism (Chen et al., 2017; Chase et al., 2018; Loredo e Silva et al., 2018; Maudsley et al., 2019; Goh and Sandars, 2020; Kim, 2020). Medical students are potentially vulnerable to smartphone addiction due to heavy use (Chen et al., 2017; Alhazmi et al., 2018). Loredo e Silva et al. recommend that faculty members "advise and educate their students about conscientious use of this tool to avoid detrimental impact on the learning process" (Loredo e Silva et al., 2018). It is imperative that educational institutions, medical students, and clinicians realize the potential impacts and limitations of m-Learning.

The smart campus, a recent trend in higher education, uses innovative technologies to create a digitally connected campus, thus enhancing the student experience and connecting to a wider audience (Fortes et al., 2019). The Cave Hill Campus of The University of the West Indies (UWI), Barbados undertook a Smart Campus initiative as a part of the major reorientation of the campus' model of delivering higher education (The University of the West Indies, 2020). There is an ongoing emphasis on smart-learning, through delivery and expansion of online learning using the University's eLearning Moodle Platform and outfitting the campus to create smart classrooms (UWI, 2020). There are very few publications on smartphone use by undergraduate university students in the Caribbean (Ahmad, 2018; 2019), and to date none on the use by medical students from this region. Against this background, the authors conducted this study to assess the utilization of smartphones and commonly used medical education apps as educational aids by the preclinical medical students of the Faculty of Medical, Sciences (FMS), Cave Hill Campus.

MATERIALS AND METHODS

A cross-sectional survey was conducted from September 2018 to april 2019 amongst all Year 1 (n = 68) and Year 2 (n = 98) Bachelor of Medicine and Bachelor of Surgery (MBBS) students of FMS, UWI, Cave Hill Campus, Barbados. Ethical approval was obtained from the joint Institutional Review Board of Cave Hill campus and the Ministry of Health (Approval no: 180210-B). Participation was anonymous and voluntary with informed verbal consent. Students who did not give consent or were absent during the survey period were excluded from the study.

A paper-based self-administrated questionnaire developed by Wallace et al. (2012) was adapted for use. Approval to use the instrument was obtained from the authors. The questionnaire was reviewed by the research team and medical educationists and pretested with 15 students to check the clarity, validity, and suitability of the questionnaire. Modifications were done to include the latest development in the field (e.g., the latest iPhone models, WhatsApp communication for smartphone utility, a list of latest medical references to choose from, etc). Survey questions included sections on smartphone ownership, medical apps used, education related tasks the phone was used for, and the perception on the usefulness of the phones in medical education.

TABLE 1 | Demographic characteristics, Smartphone ownership of the students.

Variables	Frequency
Year of Study	
Year 1	48 (42.9%)
Year 2	64 (57.1%)
Gender	
Male	18 (16.1%)
Female	94 (83.9%)
Nationality	
Barbados	53 (47.3%)
Bahamas	13 (11.6%)
Trinidad &Tobago	42 (37.5%)
Others[a]	4 (3.6%)
Brand of Smartphone	
iPhone	62 (55.4%)
Android	46 (41.1%)
Others (specify)	4 (3.6%)
Duration owned	
2–6 months	2 (1.8%)
6 months - 1 year	4 (3.6%)
1–2 years	5 (4.5%)
>2 years	101 (90.2%)

[a]*Others include Dominica, St. Kitts and St. Vincent and Grenadines.*

The frequency of usage of smartphones for academic and communication purposes was rated on a 6-point Likert scale, ranging from never (a score of 1) to more than once a day (a score of 6). Responses on general use, limitations, and improved future use of smartphones in medical education were rated using a 5-point-Likert scale, ranging from strongly agree (a score of 1) to strongly disagree (a score of 5).

The questionnaire was distributed to students at the end of scheduled lectures, as evidence suggests, it provides a better response rate than with online questionnaires (Wallace et al., 2012), and this allowed for the contents and purpose to be explained by one of the authors (KS). Participants were assured that their responses would be kept strictly confidential. Students were given 20 min to complete the questionnaire.

Statistical Analysis

SPSS version 25.01 was used to analyse data. Data are presented as frequencies and percentages. The Pearson's Chi-square test was performed to determine the significance of differences in the frequencies of responses.

RESULTS

Of 166 eligible students, 112 completed the survey giving a response rate of 67.5% (**Table 1**). Of the respondents 57.1% were year-2 students, 83.9% female and 47.3% Barbadian. All participants possessed a smartphone. Apple's iPhone was the most owned brand (55.4%) followed by Google android phones (43.8%). More than 90% had a smartphone for more than 2 years and the mean age of the current smartphone owned was 1.5 years.

Google (95.5%) was the most popular search engine used by respondents for researching unfamiliar terms or concepts. Medscape (67.9%), and Mayo Clinic (57.1%) were commonly

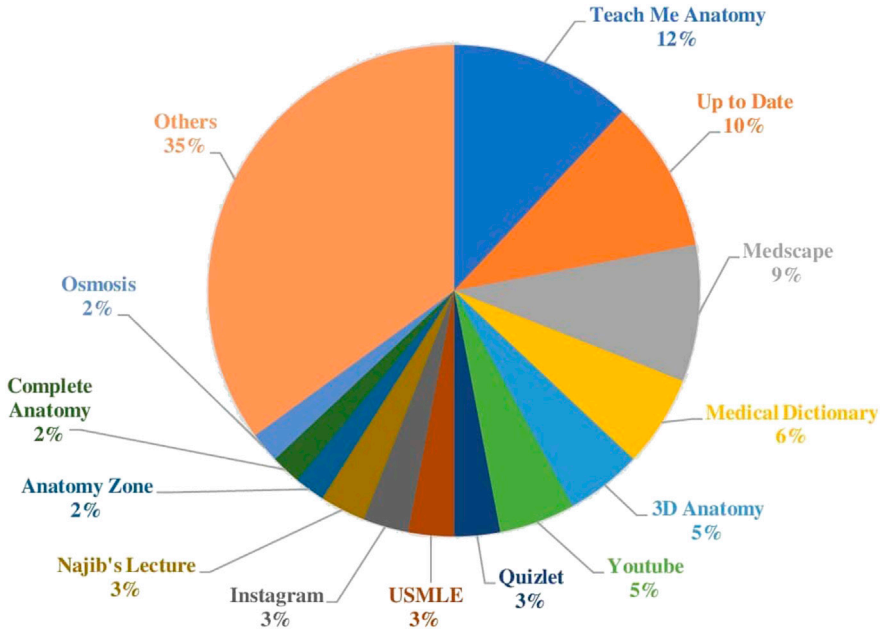


FIGURE 1 | The most preferred and most often used apps as reported by the students.

TABLE 2 | Specific utilization of smartphones in medical education.

Purposes	Usage (frequency)	Respondents (%)[†]	X^2
Academic			
Looking up unfamiliar terms/concepts	>Once/day	78 (70.3%)	<0.001
Camera to take educational pictures	>Once/day	44 (40.4%)	<0.001
Taking Medical related notes	>Once/day	38 (34.9%)	<0.001
Reading Medical textbooks online	>Once/day	24 (24.2%)	<0.001
Listening to lectures online	Several times/week	41 (37.3%)	<0.001
Managing tasks	Several times/week	40 (37%)	<0.001
Watching medical videos	Several times/week	25 (23.4%)	<0.001
Reading Medical news	Only once/week	28 (25.2%)	<0.001
Reading medical research journals	>Once a month	19 (19.3%)	<0.001
Listening to medical Podcasts	Never	56 (50.5%)	<0.001
As a medical Calculator	Never	27 (24.1%)	<0.001
Communication with			
Peers by WhatsApp	>Once/day	81 (78.6%)	<0.001
Peers by email	>Once/day	31 (29%)	<0.001
Peers by Phone	>Once/day	74 (66.7%)	<0.001
Faculty by email	Several times/week	31 (27.7%)	<0.001
Faculty by SMS	Never	84 (75.7%)	<0.001
Faculty by Facebook	Never	83 (74.1%)	<0.001
Peers by SMS	Never	62 (56.4%)	<0.001
Peers by Facebook	Never	55 (50%)	<0.001
Faculty by WhatsApp	Never	49 (46.2%)	<0.001
Faculty by Phone	Never	43 (40.2%)	<0.001

[a]*Highest responses are reported in each category.*

used as information resources. Medical apps were used by 67.9 and 79.5% were willing to buy more useful apps for learning purposes if they were affordable. The most preferred and most often used apps as reported by each student were: 'Teach me Anatomy' (11.9%), 'UpToDate' (10.3%), and 'Medscape' (8.8%) (**Figure 1**).

Scale used: Never, More than once a month, Once a month, Once a week, Several times a week, Once a day, and More than once a day.

Students utilized smartphones mainly for academic and communication purposes. More than 65% of the students used their smartphone to search the meaning of unfamiliar terms/

TABLE 3 | Overall utilization of smartphones by the students.

	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree	Total	*p* Value
General use of smart phones							
Most medical students are currently using smartphones in their medical education	1 (0.9%)	2 (1.8%)	6 (5.4%)	26 (23.2%)	77 (68.8%)	112	<0.001
Most medical students are currently using smartphones for anatomy learning	NR	1 (0.9%)	21 (18.8%)	38 (33.9%)	52 (46.4%)	112	<0.001
Smartphones will improve a medical student's educational experience	NR	1 (0.9%)	11 (9.9%)	49 (44.1%)	50 (45.0%)	111	<0.001
Smartphones will be beneficial to medical faculty to improve medical education	NR	2 (1.8%)	15 (13.4%)	50 (44.6%)	45 (40.2%)	112	<0.001
The smartphone brand I currently use is the best one for medical education	2 (1.8%)	3 (2.7%)	18 (16.1%)	52 (46.4%)	37 (33.0%)	112	<0.001
I would recommend my smartphone brand to a medical peer	2 (1.8%)	3 (2.7%)	18 (16.1%)	52 (46.4%)	37 (33.0%)	112	<0.001
My smartphone should only be treated as an additional resource in medical education	5 (4.5%)	20 (18.0%)	10 (9.0%)	44 (39.6%)	32 (28.8%)	111	<0.001
My smartphone is more valuable to me as a personal device than as a medical tool	7 (6.3%)	20 (17.9%)	28 (25.0%)	33 (29.5%)	24 (21.4%)	112	<0.001
I feel as though I could be using my smartphone more effectively in medical education	3 (2.7%)	6 (5.5%)	7 (6.4%)	56 (50.9%)	38 (34.5%)	110	<0.001
Overall, smartphone has had a negative impact on my medical education	35 (33.0%)	48 (45.3%)	15 (14.2%)	6 (5.7%)	2 (1.9%)	106	<0.001
Limitations of smartphone in medical education							
Smartphones are a distraction in the classroom	4 (3.6%)	14 (12.5%)	26 (23.2%)	53 (47.3%)	15 (13.4%)	112	<0.001
Concerns regarding privacy /security has limited the usage of my smartphone in medicine/medical education	16 (14.3%)	43 (38.4%)	29 (25.9%)	20 (17.9%)	4 (3.6%)	112	<0.001
I am worried that using my smartphone in medical education compromises my professionalism	13 (11.6%)	43 (38.4%)	17 (15.2%)	34 (30.4%)	5 (4.5%)	112	<0.001
Small screen size a major detractor to using smartphone more often	10 (8.9%)	33 (29.5%)	12 (10.7%)	44 (39.3%)	13 (11.6%)	112	<0.001
A smartphone has very little usefulness in medical education compared to a laptop	27 (24.1%)	51 (45.5%)	16 (14.3%)	12 (10.7%)	6 (5.4%)	112	<0.001
Smartphone keyboards make them difficult to use effectively in medical education	22 (20.2%)	51 (46.8%)	20 (18.3%)	13 (11.9%)	3 (2.8%)	109	<0.001
I feel as though smartphone use creates an unfair advantage for students who own them	26 (23.2%)	55 (49.1%)	21 (18.8%)	9 (8.0%)	1 (0.9%)	112	<0.001
Cost of smartphones is a significant limiting factor for medical students/ residents	8 (7.1%)	20 (17.9%)	28 (25.0%)	38 (33.9%)	18 (16.1%)	112	<0.001
I would purchase more useful medical education apps, but they are too expensive	3 (2.7%)	5 (4.5%)	15 (13.4%)	43 (38.4%)	46 (41.1%)	112	<0.001
I feel as though I don't know enough about what is out there to use effectively on smartphones	12 (10.8%)	34 (30.6%)	22 (19.8%)	31 (27.9%)	12 (10.8%)	111	<0.001
Use of smartphone to improve medical education							
University policy regarding smartphone usage in medical education would be beneficial	NR	6 (5.4%)	32 (28.6%)	57 (50.9%)	17 (15.2%)	112	<0.001
Smartphones will only increase in usage in the future of medical education	1 (0.9%)	1 (0.9%)	8 (7.1%)	56 (50.0%)	45 (40.2%)	111	<0.001
I am worried at the prospect of mobile computing devices becoming more prevalent in medical education	17 (15.2%)	53 (47.3%)	33 (29.5%)	7 (6.3%)	2 (1.8%)	112	<0.001

NR = No Response. Cronbach's alpha = 0.70.

concepts and communicate with peers by WhatsApp and/or phone. The majority of the students never used smartphones for listening to medical podcasts (50.5%), communicating with faculty by SMS (75.7%) or by Facebook (74.1%), and peers by SMS (56.4%) or Phone (40.2%). All X^2 values in **Table 2** were found to be statistically significant ($p < 0.001$).

Forty three percent of respondents considered 'using smartphones in medical education' when they first bought/received their current smartphones. Ultimately, 92% were now using their smartphone for learning purposes, with 80.3% ($p < 0.01$) for learning anatomy. The majority of the students felt that the use of smartphones would improve their educational experiences (89.1%), be beneficial to medical faculty for teaching (84.8%), and could be more effectively used in medical education (50.9%) (**Table 3**). Approximately, three-quarters of the respondents disagreed when asked whether a smartphone has very little usefulness in medical education compared to a laptop. Most students (78.3%) however did not agree that their smartphones had a negative impact on their learning. All X^2 values in **Table 3** were found to be statistically significant ($p < 0.001$).

DISCUSSION

The authors report to the best of their knowledge, this is the first study from the English speaking Caribbean, exploring smartphone and medical education apps use as educational aids by preclinical medical students. The study found that all respondents possessed a smartphone and used the device mainly for academic and communication purposes. More than 90% were using a smartphone for learning purposes, 89.1% said that it improved the educational experience and 80.3% used it for anatomy. Apple's iPhone was found to be the most owned smartphone brand; Google, the most widely used search engine; and Medscape and Mayo Clinic were commonly used educational resources. Among the medical education apps, 'Teach me Anatomy' and 'UpToDate' were mostly used. Students recommended that the university should adopt online learning platforms for mobile learning and a policy should be put in place for better learning experiences.

The response rate in this study was 67.5% which is similar to a study conducted among the medical students in India (Rohilla et al., 2016). This may be due to the use of an in-person paper-based questionnaire for the collection of responses. However, it was higher than a study conducted amongst medical students, residents and faculty in Canada (14%) (Wallace et al., 2012) and Australia (32.3%) (Wynter et al., 2019) who used online questionnaires. Online surveys particularly recorded low responses in most published studies due to 'non-response' and 'voluntary response' biases (Payne et al., 2012) or 'survey fatigue' (Ahmad, 2019). To improve the survey response rate in medical education, Brown and Watson suggested using the 'captive audience' technique supported by technology devices (e.g. iPad) online survey tools (e.g. Survey Monkey) (Brown and Watson, 2016).

In our study all students owned a smartphone with over half owning iPhones. The mean age of the phones was one and a half years and approximately three-quarters used medical apps on their phones. In other studies the phones used by medical students were older, being on average 4 years old or more (Gavali et al., 2017; Chase et al., 2018; Clarke et al., 2019) and medical apps usage was similar (Payne et al., 2012; Latif et al., 2019). Previous surveys report that smartphones and medical apps were a great help to medical students (Brown and Watson, 2016; Alhazmi et al., 2018; Loredo e Silva et al., 2018; Sheikhtaheri and Kermani, 2018).

Smartphones are primarily used for information management in medical education, communication and time management (Mohapatra et al., 2015). The top two uses of smartphones in our study were for communicating with peers by WhatsApp (78.6%) and looking up unfamiliar terms and concepts (70.3%) greater than once a day. Half of the students (50.9%) valued their smartphone more as a personal device than as a medical education tool. It has been found elsewhere that even when smartphones are initially acquired for personal use, their usefulness for study purposes is recognized with time (Latif et al., 2019). Ifeanyi and Chukwuere (2018) reported that smartphone usage fostered better communication between students and tutors but many of our students reported that they do not use their phone to communicate with tutors. Smartphones aid the discussion of concepts with colleagues, sharing facts and illustrations, downloading of study materials including lecture slides, doing assignments and recording of lectures (Ifeanyi and Chukwuere, 2018). A study investigating student preparedness for mobile learning found that smartphones allow better interaction between students and instructors in comparison to face-to-face learning (Corbeil and Valdes-Corbeil, 2007; Kim, 2020). Other studies report that smartphones help students learn at their own pace, retrieve up-to-date information for their assignments without the need to physically visit the library and facilitate reading ahead of class (Corbeil and Valdes-Corbeil, 2007; Subhash and Bapurao, 2015). There are encouraging reports of effective delivery of distance education courses via smartphones with students accessing lecture materials on their phones and interacting with their lecturers (Kim 2020). This is particularly relevant to the current COVID-19 pandemic with the shift to teaching online (Cecilio-Fernandes et al., 2020; Gaur et al., 2020; Goh and Sandars, 2020; Majumder, 2020; Singh et al., 2020).

Medscape and Mayo Clinic were frequently used as information resources in this study while Google was the most frequently used search engine. Studies have found that Medscape (Venkatesh et al., 2017; Smalls et al., 2019), Wikipedia and Google (Ventola, 2014) are the most commonly used and easily accessible reference sources for the medical community. Many default to Google search results due to the usefullness and to avoid the time required logging into library licensed resources or downloading an app (Wang et al., 2012). Most information resources listed by our students were free with easily downloadable apps.

The focus of mobile technology has shifted to "Apps" (Masters et al., 2016). Most students in our study used medical apps (67.9%). The most preferred and most often used apps as reported by each student were 'Teach me Anatomy' followed by 'UpToDate' and 'Medscape' (**Figure 1**). However, 35% (others) represented a long tail of less frequently used apps which were only mentioned once or twice (**Figure 1**). Variations in the use of apps has been reported. Medical students prefer drug handbook and medical book apps in the UK, guidelines and dictionary in the United States of America (Golenhofen et al., 2020), Medical Dictionary and Medscape apps in India (Gavali et al., 2017) and UpToDate and PubSearch in Iran (Jebraeily et al., 2017). The usage of anatomy apps was very popular among students (80.3%), as supported by previous studies (Pedro et al., 2018; Pires et al., 2018; Golenhofen et al., 2020). Usage of anatomy apps have been associated with lower failure rates and better exam grades (Golenhofen et al., 2020). However, students expressed the following concerns in using apps for learning and assessment: superficial learning, lack of reliability and accuracy, quality and safety, security and privacy of patient information, medical apps not being developed by professionals appropriately trained in medical education, lack of accreditation of medical apps by recognized health institutions, lack of support and update of apps by their developers, and lack of easy usability of applications (Kim, 2020) (Masters et al., 2016; Jebraeily et al., 2017).

This study showed that WhatsApp or phone calls were the common daily modes of communication with peers and faculty. Studies confirmed that WhatsApp's online group discussions may provide students with a one-point learning and information source (Latif et al., 2019). Current research highlighted WhatsApp can be effective as a medical learning tool (Salam et al., 2021) to facilitate classroom learning and clinical training (Coleman and O'Connor, 2019). Similarly, instant messaging applications can improve "the way medical education is delivered, by creating communication channels between students and tutors, increasing learning opportunities and providing an overall superior educational experience for medical students" (Coleman and O'Connor, 2019). However, there are reports of adverse effects on academic performance with the use of applications such as WhatsApp, Facebook, and games being addictive and stealing students' study time (Salam et al., 2021). Thus, smartphone learning also has challenges (Kim, 2020) along with its many benefits, indicative of its effect on academic performance (Ifeanyi and Chukwuere, 2018; Darko-Adjei, 2019).

Smart devices used in smart campuses significantly impact student learning, the most remarkable being significant cost savings and a direct impact in improving student learning (Ahmad, 2018). Smart campuses should have a clear policy to integrate online learning in the curriculum with adequate technology support which was also recommended by the students. Medical educators and policymakers should also take necessary measures to improve the quality of online learning and assessment as the use of emergent technology is likely to continue as an indispensable component of post-COVID medical education (Majumder et al., 2021).

Limitations

The present study has notable limitations. This cross-sectional study involved only Year one and Year two students and had a small sample size; therefore, caution needs to be taken to generalize the data to other settings. Another limitation is of using 'captive audience', there is a possibility that respondents felt coerced to participate and so it is less likely that they answered questions honestly. Lastly, this survey looked at only preclinical medical students, therefore does not represent the current practices or needs of clinical or other health science disciplines.

CONCLUSION

Our study shows that smartphones and related medical education apps are widely used by medical students and majority of the students felt that the use of smartphones would improve their educational experiences, be beneficial to medical faculty for teaching, and could be more effectively used in medical education. Medical schools should take appropriate measures to guide and educate students on the effective use of smartphones and medical apps for learning purposes. Universities should make e-learning platforms compatible with smartphones and develop a policy regarding smartphone usage for academic purposes.

Future Directions

Smartphone learning fosters discussion, communication and collaboration, and assures better student engagement. The millennial learners prefer student-centered, active, and self-directed learning. Smartphone learning has shifted the location of education settings outside of classrooms, demanding a suitable shift in delivery methods. Mobile learning can be integrated into medical education to assess its effectiveness; learning materials should be in a digital format as far as possible to fuel smartphone learning and online education in smart campuses. A faculty guided approach in the selection of suitable and cost-effective medical education apps can be adopted. Universities should have ongoing teaching and learning programs for educators to develop, collaborative, communication-based, interactive, new online teaching skills and assessment methods, thus, shifting the role of educators to facilitators. Smart campuses must develop internet-based, smartphone-compatible learning platforms. Universities should develop policies for staff and students regarding smartphone usage for academic purposes (The University of the West Indies, 2018).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board (IRB), UWI, Cave Hill/Barbados Ministry of Health Research Ethics Committee (Approval no: 180210-B). The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

KS and MAAM conceived and designed the study and led data collection. All authors (BS, MAAM, KS, OPA, SS, UG, and SG) were involved in analyzing and interpreting the data. The manuscript was drafted by MAAM and KS with notable input from SS, OPA, BS, and SG. All authors reviewed and approved the final version and have agreed to be accountable for all aspects of the work including any issues related to accuracy or integrity. The manuscript has been read and approved by all the authors and authorship has been determined based on ICJME guidelines.

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Design of a Clinical Practice Guideline in Nurse-Led Ventilator-Weaning for Nursing Training

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Cardiothoracic intensive care unit (CICU) nurses have shared the role and responsibility for ventilator-weaning to expedite decision-making in patient care. However, the actions taken are based on individual's unstructured training experience as there is no clinical practice guideline (CPG) for nurses in Malaysia. Hence, this study aims to design a CPG for the process of weaning from mechanical ventilation (MV) for a structured nursing training in a CICU at the National Heart Institute (*Institut Jantung Negara,* IJN) Malaysia. The Fuzzy Delphi Method (FDM) was employed to seek consensus among a panel of 30 experts in cardiac clinical practice on the guidelines. First, five experts were interviewed and their responses were transcribed and analyzed to develop the items for a FDM questionnaire. The questionnaire, comprising of 73 items, was distributed to the panel and their responses were analyzed for consensus on the design of the CPG. The findings suggested that the requirements expected for the nurses include: (a) the ability to interpret arterial blood gases, (b) knowledge and skills on the basics of mechanical ventilation, and (c) having a minimum 1-year working experience in the ICU. On the other hand, the CPG should mainly focus on developing an ability to identify criteria of patient eligible for weaning from MV. The learning content should focus on: (a) developing the understanding and reasoning for weaning and extubating and (b) technique/algorithm for extubating and weaning. Also, the experts agreed that the log book/competency book should be used for evaluation of the program. The CPG for structured nursing training at IJN in the context of the study is important for developing the professionalism of CICU nurses in IJN and could be used for training nurses in other CICUs, so that decision for ventilator-weaning from postcardiac surgery could be expedited.

Keywords: structured advanced nursing training, mechanical ventilation, nurse-led ventilator-weaning protocol, clinical practice guideline, Fuzzy Delphi Method

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INTRODUCTION

Mechanical ventilators (MV), which are introduced as breathing aids to save lives of critically ill patients, enable gaseous exchange for acceptable oxygen concentrations, tidal volumes, and respiratory rates to be maintained. On recovery, patients need to be weaned-off (withdrawal) the MV gradually and carefully (1–3). In fact, the weaning process should be

conducted with caution and consistent to reduce the time and unexpected consequences to the patients (4–6). Also, this is to comply with the indications and prevent any complications from postcardiac surgery. This is a routine procedure among CICU nurses with interprofessional collaboration between the doctor (specialists in general and cardiac anesthesiology/intensivist) and cardiothoracic intensive care unit (CICU) nurses. This collaboration for sharing responsibilities has been documented in Malaysian practice since 1990 (7). It is also one of the several factors influencing nurse-led decision-making for the weaning process from MV.

The complexity of this process is dependent on the condition, complication, and need for MV among the patients (4). However, to maintain standards, prevent mismanagement, malpractice, unsafe treatment, any negligence, carelessness, inattentiveness, and ensure patient safety, a clinical practice guideline (CPG) is required for structured nursing training (8). As outlined by Blackwood et al. (9), the therapists or nurses should be able to: (a) establish clear criteria for patient readiness to begin weaning, (b) develop an organized guideline for therapists or nurses in reducing the patient's ventilatory support, and (c) establishing a clear set of criteria to help them decide the patient's readiness for extubation.

The collaboration for sharing responsibilities for the weaning process and the shortage of specialist doctors have led to nurses' assistance on the patients' situation to expedite medical decision-making (10). However, nurses risk medicolegal issues when performing ventilator-weaning without any structured training experience, guidelines, or evidence of documented practice. Hence, in protecting CICU nurses from medicolegal issues, a CPG for structured training to update nurses' knowledge and ability for critical thinking and clinical decision-making is required. The training requirement is part of the Nurses' Code of Conduct, which indicates that nurses can look forward to extended work rules, provided there is a structured training with a particular number of hours of credit (11).

Although in other countries, the roles and responsibilities of nurses extended to ventilator-weaning, this is not practiced in Malaysia, as there is no structured training for nurses. Currently, the CICU, IJN has allowed new nurses to perform ventilator-weaning for patients after cardiothoracic surgery under the guidance of an anesthetist, surgeon, or senior nurse. However, professional and ethical considerations are required for CPG for the process. Hence, this study aims to design a CPG for nurse-led ventilator-weaning for structured nursing training to improve knowledge and skills. This guideline would enable nurses in Malaysia to have protocols for practice and enhance their professionalism.

REVIEW OF LITERATURE

Mechanical Ventilation

Mechanical ventilators can sustain patients' life in the event of inadequate spontaneous ventilation for breathing. However, the machine cannot cure the disease but only assists breathing as the patient's underlying condition needs to be corrected. Selecting the suitable mode of operation for the MV requires expertise and the focus of MV management is to ensure patients get adequate support to prevent complications.

The Ventilator-Weaning Process

The ventilator-weaning, or the patient's withdrawal from ventilator support and restoring spontaneous independent breathing, has a specific protocol. The protocol depends on factors such as patient's preexisting lung condition, duration of MV, and patient's general condition (physically and psychologically). The patients on MV for short periods may be weaned from ventilator support using a T-piece connected to an oxygen supply, and then, closely monitored for tolerance to the switch with assessments on vital signs and arterial blood gases (ABGs) concentration. An initial rise in respiratory rate, pulse, and blood pressure is expected but oxygen saturation and partial oxygen in the body should remain within satisfactory limits. However, patients who have been on ventilator support for longer periods may require gradual weaning from the MV.

The criteria for weaning are found in the Malaysian Ministry of Health's Program *Anaestesiologi dan Cawangan Kualiti Penjagaan Kesihatan BPP* (2006) ICU Management Protocol No. 10. The protocol is valid for general ICU patients, with intraoperative care and more than 24 h on MV. However, in IJN, cardiac cases are normally straight forward without intraoperative care, and patients were on MV for 4–6 h <24 h. Hence, this protocol is not relevant for IJN's needs.

Nurse-Led Ventilator-Weaning for Cardiothoracic Intensive Care

A CICU nurse's responsibility is to provide critical care to patients with potentially life-threatening heart conditions. The management of critically ill patients takes on many levels (12–14). First, improving patients' outcomes with patient-centered care, proactive management, and vigilance, coping with unpredictable events, and providing emotional support (4, 15). Second, continuous observation, so as to reduce a patient's risk of deterioration, monitor their total dependence on support equipment, and prevent their agitation or confusion that may lead to harm (16). This means assimilation, interpretation, and evaluation of information, including the patient's physical and psychological response to interventions, changes in condition, the significance of monitored physiological parameters, and the safe functioning of equipment. Lastly, communication, as the nurse is the key provider of information to patients, relatives, and other members of the interdisciplinary team. Hence, nurses in CICU are expected to be innovative, adopt new roles, multitask, and have cultural awareness. They need to be able to apply knowledge and skills to new situations to enhance the continuity, efficiency, and effectiveness of patient care (17). Thus, evidently the process of ventilation-weaning, originally the responsibility of the specialists, is done by nurses managing patients to expedite medical decision-making (10). Hence, regardless of the blurred boundary, nurses are expected to lead the ventilation-weaning perform (18).

The responsibility of ventilator-weaning allows nurses to expand their theory and practice, but nurses in Malaysia

may not have sufficient evidence-based practice to absolve them from legal misconduct issues (19). In Australia, working across boundaries is common and protocols exist for the implementation of effective ventilator-weaning (16). On the other hand, some doctors believe cross-boundary work, such as ventilation-weaning in the CICU, does not require protocols as there are existing work instructions (20). Further, nurse-led ventilation-weaning saves patients' lives, as is within the scope of the objective of the CICU is to reduce the period of patients' stay and rate of infections while in the unit.

In Malaysia, the Code of Professional Conduct states that the nurses' responsibility is to protect the best interests of society. However, without structured training, nurses face the possibility of professional misconduct, as stated in the Nurses Act and Regulations, 1985 (Part V Practice and Part VI on Disciplinary Proceedings). Nurses can undertake extended work roles only when they have participated in structured training (NBM, 1998). Although there exists a protocol for anesthesiologists to employ safe procedures during the process of weaning (ICU Management Protocol No. 10, Program Anestesiologi & Cawangan Kualiti Penjagaan Kesihatan BPP, KKM, 2006), this protocol is for general cases and needs to be modified for CICU patients and for nursing training. Hence, a CPG for nurse-led ventilator-weaning is required for structured nursing training in Malaysia, in compliance with the Nurses Act and Regulations 1985 (NBM, 1998) to ensure the professionalism of critical care nurses.

Nursing Training in CICU

Training systematically influences behaviors in changing knowledge, attitudes, and skill. In nursing, practitioners are encouraged to reflect critically on their practice and to view research as integral for quality care (21). Hence, training considers the variables influencing practice and explores different conditions for practitioners adopt to enable generating new knowledge and innovative practice (21). Nursing education and training need to build frameworks for evidence-based practice for critical care education and practice.

Training for skills development in the post basic intensive care unit, critical care unit, or trauma unit is conducted to ensure practitioners are protected from issues of malpractice due to uncertain boundaries. The Institute of Medicine has developed structured protocols in their CPG to systematically assist practitioners in decision-making for appropriate health care in specific clinical circumstances (22). The CPG is a reference against malpractice, unsafe treatment, negligence, and inattentiveness, and it is used to guide health-care providers in patient-related procedures. The CPG is a resource for the continuing professional development (CPD) for nursing education (23). In the United Kingdom, CPG is used to train health-care providers in clinical aspects for nursing education (24). However, this is uncommon for nursing education in Malaysia. Hence, for CPD in addressing workplace issues and for career development, CPG for nurses is required.

Taba Model for Curriculum Design

The Taba model for curriculum design is suitable for designing training based on the CPG for nurse-led ventilator-weaning process for nurses to improve their knowledge and skills. This is because this model takes into account the opinions of experienced practitioners for the design of the structured training. The following seven steps of the Taba model are used in the designing of the CPG: (1) identify the needs of the learner and the expectations of society, (2) formulate the learning objectives, (3) select the learning content based on the objectives, (4) decide how the content is organized based on the learning needs, (5) select the learning experiences required, (6) determine the organization of the learning activities, and (7) identify evaluation criteria for the effectiveness of the curriculum (25). Hence, for the structured training and CPG, the objectives, content, teaching strategies, and evaluation measures would be determined (26). The experts with knowledge and experience in the health-care setting were invited to contribute to the design of the structured training for nurse-led ventilator-weaning process for nurses to improve their knowledge and skills.

Johns' Model of Reflection

The instructional design for the structured training using the CPG for nurse-led ventilator-weaning process for nurses to improve their knowledge and skills would be based on Johns' model of reflection with the Carper's ways of knowing (27). Reflective practice is important in nursing education as nurses learn through on-the-job training. The following four fundamental patterns of knowing is suitable for nursing training: (a) empirical knowing that comes from factual knowledge, (b) aesthetic knowing arising from the awareness of the patient and the wholeness of the situation, (c) personal knowing from self-understanding and empathy toward the situation, and (d) ethical knowing arising from attitude and knowledge from ethical frameworks (27). This enables nurses to critically evaluate existing practices and determine whether there is a need for change. In addition, it promotes meaningful learning as nurses have the opportunity to critique practice based on evidence and prior knowledge.

The Current Study

Hence, for this study, the experts' consensus for determining the requirements of a structured training for nurse-led ventilator-weaning process for nurses to improve their knowledge and skills were sought in order to answer the research questions as follows:

1. What are the requirements for nurses should have before being able to perform ventilator-weaning independently in terms of knowledge, skills, and experience; and minimum work experience?
2. How can the CPG for nurse-led ventilator-weaning process for nurses assist nurses?
3. What is required in a CPG for nurse-led ventilator-weaning process for nurses to improve their knowledge and skills in terms of:
    a) aim
    b) learning objectives
    c) essential content, additional content, technique for weaning,

TABLE 1 | Education background and working experiences of the experts.

	Frequency	Percentage (%)
Education background		
Master in doctorate or nursing	9	30
Bachelor of nursing	8	27
Diploma of nursing	13	43
Total	30	100
Working experiences		
5–10 years	12	40
11–20 years	14	47
21–30 years	4	13
Total	30	100

d) patient readiness for weaning, most appropriate step-on mode, and setting before weaning, and
e) evaluation/ assessment?

METHODOLOGY

Research Design

The experts' consensus can be determined using the Fuzzy Delphi Method (FDM) in order to address issues such as ambiguity and subjectivity of the experts' responses (28). The FDM uses the triangular fuzzy number and defuzzification process to represent the consensus on the information and the importance of each item (28). FDM has been used for accurately predicting future trends (29), for quantifying experts' opinions on regional and urban road safety for the improvement of road safety in the future (30), and identifying key performance indices for mobile services providers (31). Clearly, FDM is a useful method for ensuring that experts' opinions are exempt of the influence of others while also ensuring their completeness and consistency (32). Although the FDM has the potential to be used to improve nursing education, it has not been utilized much. Hence, in this study, FDM may be beneficial in determining consensus on the design of a CPG for nurse-led ventilator-weaning process for nurses to improve their knowledge and skills.

The Criteria of Experts

The panel of experts for the FDM could comprise between 10 and 50 participants (33). In this study, a panel of 30 experts was selected for decision-making and to ensure the validity and reliability of the study; the criteria for their expertise and experience were determined. The experts had to be professionals with more than 5 years' experience in clinical practice such as critical intensive care and cardiac intensive care. Next, they need to be routinely handling and performing the ventilator-weaning process. These experts were anesthesiologists, cardiac anesthesiologists, cardiac intensivists, nurse educators, nurse managers, nurse mentors, and senior staff nurses in CICU and critical care areas. These experts mostly have Diploma in Nursing (n = 13, 43%) and have 11–20 years of working experience (n = 14, 47%). **Table 1** below provides a summary of educational background and working experiences of the experts.

TABLE 2 | The five point linguistic scale.

Linguistic variable	
Strongly disagree	(0.00, 0.10, 0.20)
Disagree	(0.10, 0.20, 0.40)
Moderately agree	(0.20, 0.40, 0.60)
Agree	(0.40, 0.60, 0.80)
Strongly agree	(0.60, 0.80, 1.00)

FDM Procedure

First, consent to conduct this study has been obtained from the National Heart Institute (*Institute Jantung Negara,* IJN) Malaysia and the selected experts should be the respondents for the FDM. Then, these five experts from the different care areas were interviewed to determine the items that would be in a FDM questionnaire. The responses from the interviews were transcribed and analyzed to develop the items for the questionnaire. There were 73 items in the FDM questionnaire, which was distributed to the panel of 30 experts. Their responses were analyzed using the Fuzzy number technique to ensure reliability and validity and a five-point linguistic scale was used (see **Table 2**) (29). The Triangular Fuzzy Number with three mean points (m1, m2, and m3) is used to calculate the defuzzification value (DV) for the ranking of the consensus (34, 35). First, the distance between two fuzzy numbers and threshold value, d, was determined. When $d \leq 0.2$, and the percentage of consensus is above 75%, this indicates consensus among panel members of the panel and the item was accepted (34, 35). Finally, the DV was calculated to rank the items.

FINDINGS

The findings of this study would determine the design of the structured training with the CPG for nurse-led ventilator-weaning for nurses. The analysis was employed to answer the research questions and only items that were accepted, with $d \leq 0.2$, are shown in the tables.

Knowledge, Skills, and Experience Required for Nurses to Be Able to Perform Ventilator-Weaning Independently

The basic knowledge required by all CICU staff before they could independently care for CICU patients was determined. This would ease the concern that junior nurses may lack the skills and knowledge for the procedure as a standard guideline with the requirements for ventilator-weaning would increase confidence (36). The experts achieved consensus with the highest ranking for the ability to interpret arterial blood gases (DV = 0.76), followed by knowledge and skill on the basics of mechanical ventilation (DV = 0.75) (see **Table 3**). Items that emerged during the interview such as knowledge and skill for troubleshooting for simple mechanical ventilators, knowledge on

TABLE 3 | Knowledge, skills, and experience required for nurses to be able to perform ventilator-weaning independently.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Able to interpret arterial blood gases (ABG)	(16.8, 22.8, 28.8)	0.76	Accepted
Knowledge and skill on basic mechanical Ventilation	(16.6, 22.6, 28.6)	0.75	Accepted
Able to look after a critically ill patients in ICU	(15.5, 21.4, 27.4)	0.71	Accepted
Staff must be credentialed and privileged	(15.4, 21.4, 27.4)	0.71	Accepted

TABLE 4 | Minimum work experience required for nurses to be able to perform ventilator-weaning independently.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
One (1) year in ICU	(16.4, 22.4, 28.4)	0.75	Accepted
Six (6) months in CICU	(11.3, 17.1, 23)	0.57	Rejected

TABLE 5 | Function of CPG for nurse-led ventilator-weaning process in assisting nurses.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
As a guide for straight forward surgical cases in process of weaning	(16.4, 22.4, 28.4)	0.75	Accepted
Provide a standard technique of weaning in the ICU	(15.4, 21.4, 27.4)	0.71	Accepted
To ensure standard of care are maintained and followed by all staff	(15.4, 21.4, 27.4)	0.71	Accepted
Provide the nurse with a correct way to wean patients	(15, 21, 27)	0.70	Accepted

TABLE 6 | Aim of the CPG for nurse-led ventilation weaning process.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Provide a guideline as a method of standardization of care for best practices in ICU	(16.8, 22.8, 28.8)	0.76	Accepted
CPG as a guide to the nurse to perform step by step in weaning	(16.4, 22.4, 28.4)	0.75	Accepted
As a reference when weaning off ventilation	(15.2, 21.2, 27.2)	0.71	Accepted

anatomy and physiology of respiratory system or cardiothoracic and cardiovascular care, and having a basic life support (BLS) certification were rejected and deemed unnecessary for CPD.

Minimum Work Experience Required for Nurses to Be Able to Perform Ventilator-Weaning Independently

Nurses with work experience are able to undertake new roles such as ventilation-weaning to be more responsible and self-sufficient (14). The experts determined that at least 1 year's work experience in the ICU (DV = 0.57) and 6-months experience in CICU were sufficient for nurses to be able to undergo the training for ventilator-weaning (DV = 0.57) (see **Table 4**).

Function of CPG for Nurse-Led Ventilator-Weaning Process

The function of the CPG should be determined to indicate when and how it could be used. The consensus among the experts was that the CPG would be used as a guide for weaning with straightforward surgical cases (DV = 0.75), to provide a standard technique of weaning in the ICU, and ensuring the standard of care is maintained followed by staff (both with DV = 0.71) (see **Table 5**). However, during the interview with experts, an item emerged, which was providing a template to safely wean-off patients but this was rejected (DV = 0.67), as it was believed that this process is specific to the individual and could not be generalized with a template.

The Aim of the CPG

The aim of the CPG would determine the rationale for use. The highest consensus was for providing guidelines as a method of standardization of care for best practices in ICU (DV = 0.76), followed by being a guide for the nurse to perform the process of weaning step-by-step (DV = 0.75) (see **Table 6**). Items rejected were "to promote patient safety and reduce complication" (DV = 0.69), "as the correct approach for weaning off from mechanical ventilation" (DV = 0.68), "help the nurses in clinical decision making" (DV = 0.68), and "reduce weaning time" (DV = 0.59). Hence, the emphasis was on the CPG being a guide for practice.

The Learning Objectives of the CPG

The panel of experts achieved consensus on three learning objectives for the CPG with the highest ranking for nurses to be able to identify criteria of patient eligible for weaning from MV (DV = 0.76) (see **Table 7**). However, the item "reduce variation

TABLE 7 | Learning objectives of the CPG for a nurse-led ventilator-weaning.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Must be able to identify criteria of patient eligible for weaning from mechanical ventilation (MV)	(16.8, 22.8, 28.8)	0.76	Accepted
Must be able to perform process of weaning without any risk and complication to the patient	(16.4, 22.4, 28.4)	0.75	Accepted
Must be able to identify criteria of failed weaning & extubation	(15.2, 21.2, 27.2)	0.71	Accepted

TABLE 8 | Essential content in the CPG for a nurse-led ventilator-weaning.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Inclusion and exclusion criteria of weaning & extubation	(16.4, 22.4, 28.4)	0.75	Accepted
Criteria & Technique for weaning	(16.2, 22.2, 28.2)	0.74	Accepted
Weaning algorithm	(16.2, 22.2, 28.2)	0.74	Accepted
Criteria when a nurse should escalate to Mentor/ Doctor	(16.2, 22.2, 28.2)	0.74	Accepted
Acceptable range of haemodynamic parameters during processes of weaning	(16, 22, 28)	0.73	Accepted
Intubation and extubation technique	(15.2, 21.2, 27.2)	0.71	Accepted
Understand the reason for ventilating a patient	(15.4, 21.4, 27.4)	0.71	Accepted

TABLE 9 | Additional content for the CPG for a nurse-led ventilator-weaning.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Criteria of extubation	(16.4, 22.4, 28.4)	0.75	Accepted
Weaning algorithm	(16.2, 22.2, 28.2)	0.74	Accepted
Hemodynamic monitoring- normal parameter for weaning	(15.8, 21.8, 27.8)	0.73	Accepted
Inclusion and exclusion criteria	(15.6, 21.6, 27.6)	0.72	Accepted
Indication and complication	(15.4, 21.4, 27.4)	0.71	Accepted
Basic mechanical ventilation—application, mode and setting	(15, 21, 27)	0.70	Accepted

from common practice" was rejected (DV = 0.68) as the CPG was only a guide.

Essential Content in the CPG

There were seven essential contents for the CPG, which emerged during the first round of interviews. All the seven contents that emerged were accepted to be included with the highest consensus for the inclusion and exclusion criteria of weaning (DV = 0.75) and the process of intubation and extubation (DV = 0.71) (see **Table 8**).

Additional Content for the CPG

Other than the essential contents, the panel of experts identified six additional contents that should be included in the CPG to ensure it was relevant and effective. The highest consensus was for criteria of extubation (DV = 0.75), weaning algorithm (DV = 0.74), and hemodynamic monitoring normal parameter for weaning (DV = 0.73) (see **Table 9**). However, items such as having a "background section" and "basic anatomy and physiology of the respiratory system" were rejected (DV = 0.64 and 0.57, respectively). Only relevant content was prioritized for CPD, so as to achieve excellent outcomes.

Techniques to Be Included in the CPG

The techniques would be the skills that were needed to be included in the CPG for nurses to perform ventilator-weaning. There were six techniques identified with the highest consensus for clinical assessment (physical assessment) (DV = 0.75) followed by criteria for weaning (e.g., hemodynamic stability, low ventilator setting, resolution of the cause of intubation) (DV = 0.73) (see **Table 10**). However, items such as "Change to Pressure support (P/S) or Trachy Vent" and "Observe for signs and symptoms of Increase Work of Breathing such as Tachypneic, Sweating, Reduce Saturation Partial Oxygen (SPO2)" were rejected (DV = 0.69 and 0.60, respectively). Performing the right techniques would depend on the staff's experience.

Strategies to Be Included in the CPG

The strategies that were recommended for the CPG would ensure the knowledge and skills were transferred to the nurses. The experts achieved consensus on conducting training and education (DV = 0.75) and rejected items such as conducting an audit, looking at other weaning protocol, and including recent research/ continuous studies for improvement (see **Table 11**). Some of the items rejected were related to designing

TABLE 10 | Techniques to be included in the CPG for a nurse-led ventilator-weaning.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Clinical Assessment (Physical Assessment) before processes of weaning	(16.4, 22.4, 28.4)	0.75	Accepted
Criteria for weaning (eg. Hemodynamic stability, low ventilator setting, resolution of cause of intubation)	(15.8, 21.8, 27.8)	0.73	Accepted
Check ABG	(15.4, 21.4, 27.4)	0.71	Accepted
Decide whether patient fulfill extubation criteria	(15.4, 21.4, 27.4)	0.71	Accepted

TABLE 11 | Strategies to be included in the CPG.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Conduct training and education	(16.6, 22.6, 28.6)	0.75	Accepted

TABLE 12 | The patient information needed to decide patient readiness to be included in the CPG for a nurse-led ventilator-weaning.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Stable Hemodynamic parameter	(16.4, 22.4, 28.4)	0.75	Accepted
Neurological status—Patient is full conscious/ Glasgow Coma Score (GCS)-more than 13, Rass Score (+1)—(−1)	(16, 22, 28)	0.73	Accepted
Minimal ventilation setting	(15.6, 21.6, 27.6)	0.72	Accepted
Minimal inotropic support	(15.4, 21.4, 27.4)	0.71	Accepted

TABLE 13 | Step-on mode and setting before weaning to be included in the CPG for a nurse-led ventilator-weaning.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Mechanical ventilation mode SIMV with VC + PS → start reduce the FiO2 from 50 to 40% → Check ABG Result- If normal or hemodynamic normal → tail down the MV setting: Respiratory Rate until Minimal (eg., 12 until 8) and PEEP until minimal → Check ABG – If Normal → reduce to MV Mode CPAP/ PS → Initiate PSV **(**PEEP = 6–8 cmH2O, P/S = 10–14 cmH2O, reduce P/S by 1–2 cmH2O/h, Until a minimum P/S = 6 cmH2O, Vt > 6 ml/kg IBW) → Assess for extubation criteria → extubate	(16.4, 22.4, 28.4)	0.75	Accepted

and implementing the new CPG for evaluation and were not relevant.

Patient Information Needed to Decide Patient Readiness to Be Included in the CPG

The CPG would ensure nurses made quality and relevant decisions to prevent harm and complications to the patient. The highest consensus was for stable hemodynamic parameter (DV =0.75), as this would indicate patients' readiness for extubation, followed by determining neurological status (DV = 0.73) (see **Table 12**). Patient readiness was important for decision-making to avoid bringing harm to the patient.

Step-On Mode and Setting Before Weaning to Be Included in the CPG

The process of discontinuing MV is divided into three phases: preweaning, weaning, and extubation (37). The assessment of physiological readiness of patients for weaning is to identify the criteria to begin the processes of weaning. The pulmonary function parameter for predicting weaning lists that parameter that can be determined at the bedside to predict weaning success. Establishing a relationship of trust and support is essential in avoiding the panic and anxiety that commonly prevents weaning attempts. There were four possible step-on modes and settings before weaning off the MV emerging for weaning, which emerged during the interviews. The expert consensus was only on one mode: Mechanical ventilation Mode SIMV with VC + PS → start reduce the FiO2 from 50 to 40% (DV = 0.75) (see **Table 13**). This is significant because this is a process of reducing MV support based on a weaning algorithm and would involve strategies to ensure patients received the best treatment with the fewest complications during the weaning process.

Evaluation of Training for the CPG

It is important to evaluate any training to determine the success of a program (38). However, in this case, the evaluation of the CPG needs to be done for the effectiveness of the program. The evaluation tools were determined before the implementation

TABLE 14 | Evaluation for the training for the CPG for a nurse-led ventilator-weaning.

Details for subitem	Fuzzy evaluation	Defuzzification value (DV)	Consensus
Log book/competency book	(16.4, 22.4, 28.4)	0.75	Accepted

of the CPG but the experts' consensus were only on one evaluation tool, a log book/ competency book (DV = 0.75), which could be used as an evidence for the training in order to evaluate skills (38). Other items that emerged from the interviews were rejected by the experts as evaluation tools (see **Table 14**).

DISCUSSIONS AND CONCLUSIONS

The CPG was important as it provided guidelines on a method for standardization of care and best clinical practices in the CICU for nurse-led ventilation-weaning procedures. The study determined the knowledge, skill, and experience required before nurses could perform ventilation-weaning confidently according to the opinion of experts. This means that the prior skills which needed to be prioritized before training is conducted such ability to interpret the ABGs could be identified before patient readiness for extubation and techniques for ventilator-weaning including determining weaning mode and setting before extubation. Only nurses who had acquired sufficient skills in the CPG and experience (a minimum of 1 year in ICU or 6 months in the CICU) would be allowed to participate in the training.

The essential content and techniques to be applied were consolidated for the CPG for the institute in the context of the study. This process would be applicable to all nurses working in cardiac intensive care settings in Malaysia. After undergoing training, the effectiveness of training could be determined, and the experts agreed that the log book/competency book was the best evaluation tool. Nurses learnt through experience and reflected on the cases based on the ways of knowing (27).

The CPG would be a resource for the algorithm, a technique, and an essential content for nurses to perform ventilation-weaning procedures. This is extremely beneficial to the CICU nurses and especially junior nurses in managing patients' postcardiac surgery toward ventilation-weaning. Having the CPG ensures standardization and prevents malpractice as it is an evidence-based method for nurses to performing the procedure, thus reducing the hospitalization cost on patient and CICU hospital stay.

The CPG would also assist in nursing training by enabling a structured training program for nurses to recall and reflect on their previous work practices in the CICU. Hence, nurses could evaluate the existing and past practices to contemplate whether it was reliable and suitable and so advance the nursing profession. The reflective model can improve nursing education in a systematic manner and nurses can benefit from the different perspectives of reflective learning (27). Hence, this design was helpful for the practice of learning the process of weaning from MV in nursing education and will enable nurses to perform the procedure confidently and safely.

This CPG focuses on postcardiac surgery for adult patients with minimum complication and not for high-risk cases or difficult intubation, and it is only for CPD for training nurses at the CICU for the process of weaning. The CPG can be used as a guide for workshops, training, or programs, to enhance CICU nurses' knowledge and skills in this area. However, it can be a benchmark for staff competency based of CPG. Hence, in this study, a new perspective for nurse education was provided in combining Taba's model for curriculum design (25) and John's model of reflection (27) for designing a CPG. In addition, the CPG for nurse-led ventilator-weaning process for training nurses was designed with experts' consensus using the FDM for nurses' training and CPD at the National Heart Institute CICU. This CPG enables practice in the clinical area, and protects the nursing profession with strong evidence for advancing education in the nursing profession. Hence, the CPG promotes collaboration and teamwork to hasten patients' recovery process and reduce complications. Recommendations for future research can include expanding on this study by developing a teaching model for nurse-led ventilation-weaning process using interpretive structural modeling (ISM). In addition, an instructional module on nurse-led ventilation-weaning process could be developed using a design and development research framework.

The CPG clearly reflects recommendations to improve the implementation of MV process as proposed by Blackwood et al. (9), which include: (a) establishing clear criteria for patient readiness to start weaning, (b) developing an organized guideline for therapists or nurses in reducing patient's ventilatory support, and (c) establishing a clear set of criteria to help them decide the patient's readiness for extubation.

In conclusion, the CPG designed for a nurse-led ventilation-weaning process for nurses' training may change the perception of Malaysian nursing practice and professionalism in the international arena. Thus, in implementing the training for nurses before they perform the ventilator-weaning procedure will prevent any issues of medicolegality in their practice.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institut Jantung Malaysia (The National

Heart Institute of Malaysia). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SA, NA, and DD: conceptualization, methodology, and original draft preparation. SA, NA, DD, KJ, and MA: data curation. SA, KJ, and MA: formal analysis and writing-review and editing. All authors contributed to the article and approved the submitted version.

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Real Workload-Situated Training in COVID-19 Prevention of General Practice Residents in China: A Situated Cognition Study

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Objective: The participation of general practice (GP) residents in COVID-19 prevention and control tasks touched workload participation in public health and disease prevention and control and was also a rare, valuable training experience for the residents and research material for medical education. This experience contributed to the understanding of three key points: First, was the content of the COVID-19 prevention task suited to them, or did it overload them in the present? Second, their competence in the COVID-19 prevention task reflected whether the early medical school training was sufficient or not. Third, what can be drawn from this study to promote public health training in the future? This study aimed to explore these issues by conducting a real epidemic situated training (REST) program.

Methods: A situated cognition study was designed that included situational context design, legitimate peripheral participation, and the construction of a community of practice. The Task Cognitive Load Scale (NASA-TLX Scale) and self-developed questionnaires were adopted to conduct a questionnaire survey of resident doctors in a GP training program from West China Hospital of Sichuan University, and 183 questionnaires were collected. SPSS 23.0 statistical software was used for the statistical analysis of data.

Results: The NASA scale showed that the intensity of field epidemic prevention and control (training) was tolerable. In particular, there was statistical difference in the cognitive load intensity of training before and after the epidemic occurred at different time points ($P < 0.05$). This shows that they were early trained and well-prepared before sudden outbreak of the COVID-19. Before the outbreak of the epidemic, the public health knowledge and training received came from undergraduate education (83.16%), early residents program training (69.47%), online self-study (49.16%), and continuing education (20.53%).

Conclusion: Former medical school education and training at the regulatory training stage have a good effect and enable residents to master the skills required for

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epidemic prevention and control and to physically and mentally prepare for the task. After this stage, epidemic prevention and control training in real situations will make important contributions to the self-assessment and performance improvement of public health training.

Keywords: situated cognition, workload, COVID-19, general practice, resident

INTRODUCTION

The sudden outbreak of the COVID-19 pandemic highlighted the importance of competent community prevention as the front line of epidemic prevention and control and obliged practitioner residents to become part of such teams. The involvement of residents touched workload participation in public health and disease prevention and control and was also a rare and valuable training experience.

The main aim in the study was to assess whether the GP residents had the ability to respond to public health emergencies and well-prepared mentally and physically. In the study, the REST program (real epidemic situated training) was conduct to reveal the fact. On one hand, the REST program was a training program, on the other hand, the program was a mission in which a nature assessment was taken to evaluate whether the residents had the ability to respond to public health emergencies by evaluating their performance and workload item. The scale should be in acceptable range.

In the program, the study fully followed the process of situated cognition theory. Learning evolves within the simulation environment from the interactions of (a) activity, (b) people, and (c) prior knowledge that is brought to the situation. When knowledge and learning are theorized in terms of representations stored and processed in the mind, empirical and theoretical developments in very different scholarly disciplines have led to the emergence of the situated cognition hypothesis, which consists of a set of interlocking theses: cognition is embodied, fundamentally social, distributed, and enacted and often works without representations (1). A number of theoretical perspectives (2–4) have suggested that learning is socially situated, and cognitive development occurs through relations between human interactions and the social or cultural context of everyday activities, thereby laying the groundwork for challenging the assumption that skills learned in the classroom can simply be transferred to a practical environment (5). In other words, students, as newcomers, are guided by more experienced faculty and clinicians to actively take part in the learning process, which allows them to construct their own knowledge based on relationships with other learners, activities, environmental cues, and the social organization of learning events. Situated cognition has been established as a useful framework for understanding and guiding teaching and learning processes in medicine education and training (6).

Simulation-based learning is a dynamic process that can be used to build a community of practice where learners can observe and participate in meaningful realistic encounters to build their skills and understanding (7–9). Moreover, they can gain insights and feedforward, which is described as the opportunity to envision future activities after mastering certain skills and behaviors (5, 10).

The outbreak of the COVID-19 pandemic conducts a real situation for the GP resident to participate in the public health task (11, 12). This real situation may be a once-in-a-century experience that cannot be replicated. The real epidemic situated training (REST) program during COVID 19 has many implications for the field public health training. This study aimed to explore the research on the training content for residents as well as their cognitive load and abilities improvement at different time points (before, during, and after the outbreak) in a real situation, to use in the study of the resident training process.

METHODS

Participants

In the study, the full sample population survey was conducted, 183 questionnaires who enrolled GP training program in West China Hospital of Sichuan University were finally collected.

Design

Situated cognition is classified into studies of situational context design, legitimate peripheral participation, and the construction of a community of practice (1).

Situational Context Design

Following the outbreak of the COVID-19 epidemic, China initiated a first-level response to the public health emergency (13). The main purpose of standardized training is to train qualified grassroots general practices, and an important part of the training content concerns responding to public health emergencies. Community health service centers played an extremely important role as the first line of defense in the prevention and control of the COVID-19 epidemic. They also provided real training scenarios for scientists' basic epidemic prevention practices. Each grassroots practice base must be reinforced according to the epidemic prevention and control situation. The teaching, training, and practice of infectious disease prevention and control knowledge and skills will use the completed training practice as an important basis for assessment of the process.

a. Pre-vocational training (before they tackle the real task) and assessment

Abbreviations: GP, general practice; REST program, real epidemic situated training.

1. National Basic Public Health Service Standards—Service Standards for Reporting and Handling of Infectious Diseases and Public Health Emergencies
2. Knowledge of epidemic prevention and control, hospital infection prevention and control, personal protection skills, etc.
3. Introduction to each point of the institution's epidemic prevention and control work (layout, process, work content, specifications, etc.)
4. Written examination to assess knowledge of epidemic prevention and control
5. Standard patient (SP) assessment, prevention and control deployment process.

b. Materials guarantee

Provide personal protective materials (such as masks, gloves, protective clothing, isolation clothing, etc.) required for training participants at different points in the work.

Legitimate Peripheral Participation

"legal peripheral participation" means learners should enter the scene, start at the edges, and continue to advance gradually and more deeply to master the core essentials and exert their subjective initiative in practice (7, 14). The acquisition of practical skills by students is a gradual process that does not occur overnight and requires the joint effort and participation of teachers and students. Online virtual simulation experiments can provide modular learning, and learners can complete different learning tasks according to their own learning needs (15–17). Through activities ranging from easy to difficult, teachers can inspire or induce students to actively explore in real or virtual experimental environments to give full play to the students' subjective initiative and in-depth studies. When students have cultivated themselves with competence, support and help from teachers can be appropriately reduced. According to the prevention and control work needs, the West China Hospital of Sichuan University arranges training for trainees to rotate in various epidemic prevention and control positions in the community health center and participate in prevention and control work. In addition, it arranges special personnel to be responsible for teaching. Under the guidance of the senior physician, the resident gradually becomes familiar with the work process.

The real epidemic situated training (REST) program during COVID-19 was conducted as following.

1. Pre-inspection and triage: participate in pre-inspection and triage, become familiar with the work process and specifications, master the main points of pre-inspection (temperature measurement, epidemiological history collection, simple inquiry of clinical symptoms, full use of general practice thinking) and become familiar with the triage process (outpatient clinic, general outpatient clinic, fever clinic, and referral).
2. Medical observation of quarantined persons:
   1) Home quarantine personnel: participate in the medical observation work of home quarantine personnel temperature measurement and health and traveling history inquiries
   2) Observation and isolation personnel: participants in medical observation on the personnel under centralized observation
   3) Concentrated residents: trainees of the plan can participate in the duty and medical observation of the hotels where people from Hubei (or other areas with a high rate of infection) are concentrated in Chengdu.
3. Participation in epidemic prevention and control and the daily work of the family medicine team:
   1) Education on epidemic prevention and control knowledge of contracted residents conducted through online methods such as online telephone and online software
   2) Chronic disease follow-up and health management during the epidemic period
   3) Practice of group epidemic prevention and elimination in enterprises, institutions, and schools
   4) Prevention and control of hospital infection and practice of occupational protection
   5) Other public health work in the community.
4. According to the specific situation, arrange for training students to participate in fever clinics, general clinics, children's health care, Chinese medicine, and rehabilitation and record the workload.

Construction of a Community of Practice

Contextual cognitive learning theory emphasizes the construction of a community of practice. Teachers are not only lecturers of knowledge, but also the promoters of knowledge, the learning partners of students, and the promoters of communication among members of the community (18, 19). While teaching knowledge and cultivating abilities, experimental teaching also emphasizes the establishment of good thinking habits for students. Based on the real clinical cases, students can restore the complex context of knowledge generation and development under the guidance of teachers and obtain more flexible knowledge which adapt to the real situation. Through different case situations, students will have more opportunities to solve problems and apply the theoretical knowledge they have learned to their practice. In the community, there is interaction among individuals and between individuals and the environment. This learning process is a process of interaction, communication, and dialogue. Participants share resources, respect, and trust one another. In the practice community, the identity of the learner is continuously reproduced, and the learner moves from being a bystander to a participant and, finally, to a demonstrator of mature practice. In other words, they change from being a legitimate marginal participant as a novice to being a core member of the community as an expert step by step (20, 21).

COGNITIVE LOAD SCALE (NASA-TLX SCALE) AND QUESTIONNAIRES

The NASA Task Load Index (TLX) is a popular technique for measuring subjective mental workload (22–24). It relies on a multidimensional construct to derive an overall workload score based on a weighted average of ratings on six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration level (23, 25). The Object Cognitive Load Scale (NASA-TLX Scale) and self-developed questionnaires were adopted to conduct a questionnaire survey of resident doctors who were in a GP training program in West China Hospital of Sichuan University, and 183 questionnaires were finally collected. The NASA-TLX Scale and self-developed questionnaires were finally merged into one questionnaire. The questionnaire prompts were as follows:

1. Have you participated in community epidemic prevention work?
2. When you participated in the epidemic prevention work, your identity was [single-choice question]
3. You participated in the prevention and control of the epidemic several months after the outbreak. [single-choice question]
4. In which community health service centers did you participate in epidemic prevention and control? [multiple-choice question]
5. The main contents of your participation were [multiple-choice question]
6. The training you received before taking up your post-included [multiple-choice question]
7. The teacher who provided you with pre-vocational training came from [multiple-choice question]
8. Degree of mental and cognitive stress when you participated in prevention and control work [single-choice question]
9. When you participated in the prevention and control work, did you have a heavy mental and physical burden? [multiple-choice question]
10. When you participated in the prevention and control work, did you have a strong sense of time urgency? [multiple-choice question]
11. When you participated in the prevention and control work, how hard did you need to work compared with other work? [single-choice question]
12. Did you feel pressure or worry during your participation in the prevention and control work? [multiple-choice question]
13. What is your satisfaction score with the REST program?
14. Are you willing to participate in epidemic prevention and control and continue to receive relevant training? [multiple-choice question]
15. Before the outbreak, the public health training you received included [multiple-choice question]
16. Before the outbreak, the public health knowledge and training you received came from [multiple-choice question]
17. If you are responsible for the prevention and control of an epidemic situation in a community in the future, the level you can achieve is [single-choice question].

RESULTS

According to the pre-survey and statistical analysis, the Cronbach's alpha coefficient of the questionnaire was 0.91.

For the "Situational Context Design"

The real situational context of REST program is drawn in **Table 1**.

For the "Legitimate Peripheral Participation"

Before the outbreak of the epidemic, the public health training received included basic knowledge of infectious diseases (81.58%), putting on and taking off protective clothing and other aseptic operations (84.74%), and hospital infection training (85.26%). Before the outbreak, the public health knowledge and training received came from undergraduate education (83.16%), early resident training (69.47%), online self-study (49.16%), and continuing education (20.53%).

In the REST program, more than 60% indicators of the GP residents' cognitive load on the NASA scale were at a "moderate" level, indicating that the physical and mental workload of the GP residents in the REST program during COVID 19 was at an acceptable level, and the training content, ability improvement, and cognitive load were also fair. In other words, as a GP residents, they were well-prepared for such a pandemic outbreak.

For the questionnaire, The NASA scale showed is as following **Table 2**. This generally indicated that the intensity of field epidemic prevention and control (training) was tolerable. This also showed that participants were well-trained, prepared, and qualified, with public health knowledge and skills from their former medical schools and through other relevant methods.

The result of workload is ideal, not too high or too low. And for the data analysis, There was statistical difference (Chi-square estimates, $P < 0.05$) in the cognitive load intensity of participants who participated at different time points after the outbreak of COVID-19 (0∼1, 1∼3, 3∼6 month, later than 6 month), which also shows that the previous and pre-vocational training was relatively sufficient and adapted well to the public health emergency and the epidemic.

For the "Construction of a Community of Practice"

"Construction of a Community of Practice" call for sociality situatedness. In the REST program, many relevant personnels provided pre-vocational training for prevention and control included undergraduate teachers, hospital-related department teachers, community-based teachers, grassroots government, community staff and hotel staff, senior resident students and other teachers, indicating that a network was initially formed for epidemic prevention and control.

To determine how well-resident doctors would perform if responsible for managing public health disease prevention and control, they were asked, "How well would you perform if you took on the responsibility of prevention and control of an epidemic situation in a community in the future?" The answers were divided into five levels:

TABLE 1 | The relationship between the situated cognition theory and the REST program.

Analysis dimension		Basic theory	Training	Training procedure				Evaluation of training	Training environment
Analyze content		Situation	Cognitive	Learning goal	Situation	Synthesis	Collaboration	Evaluation	Real workload
Basic principle	A real s		√	√	√	√	√	√	√
	Real activities and responsibilities		√	√	√	√	√	√	√
	Expert performance			√	√		√	√	√
	Multiple roles and diversity		√	√	√	√	√	√	√
	Provide support and guidance			√	√	√	√	√	√
	Collaborative knowledge construction		√	√	√		√	√	√
	Pay attention to reflection		√	√	√	√	√	√	
	Clear expression		√	√	√	√	√		√
	True evaluation		√	√	√	√	√	√	√
Basic features	Context-based action		√	√	√	√	√	√	√
	Legal margin participation			√	√	√	√		
	Community of practice			√	√	√	√		

TABLE 2 | Task cognitive load distribution (from NASA scale) table.

degree/percentage (%)	Mental and cognitive stress	Physical burden	Time urgency	Degree of effort required	Task pressure	Frustration
Heavy	12.06	20.5	21.9	21.9	11.3	11.3
Middle	62.4	60.9	61	65.2	62.4	62.4
Light	25.54	18.6	17.1	12.9	26.3	26.3

- Mid-level: the participants could take on responsibility with guidance and supervision (50%)
- Fair: the participants could accomplish it independently (24.74%)
- Well: the participants could instruct junior or other students (11.58%)
- Very well: the participants would have more constructive suggestions (4.74%)
- Unsure: 8.95%.

Different supervision reflects different relevant learning performance outcomes (26–28).

DISCUSSION

Whether our education and training for GP resident is suitable or sufficient needs to be verified in practice. The sudden outbreak of the COVID-19 pandemic highlighted the importance of competent community, creating a real worked loaded public health training experience for the GP residents and cognitive load of residents to reveal training implications for how well we do just before the COVID-19 pandemic, during the COVID-19 pandemic and what can we promote for the future (6, 29, 30).

The REST program for GP residents in COVID-19 prevention and control tasks touched workload participation in public health and disease prevention and control and was also a rare, valuable training experience for the residents and research material for medical education.

Based on the Situated learning theory, it concerns the characteristics of learning, such as sociality situatedness, complexity, and competence. Situated learning theory has expanded the nature of learning, which is "from getting to participate." Legitimate peripheral participation provides an innovative analytical insight into medical education.

From the study, we learned that most GP residents were well-prepared for taking real pandemic prevention and control task

during the residents stage, and their public health knowledge and training received came from undergraduate education, early resident training, online self-study and continuing education. As the pandemic prevention and control task need "Construction of a Community of Practice," many relevant personnel provided pre-vocational training for prevention and control, helping the GP participants to understand how to run the public health control task in the current society. To determine how well-resident doctors would perform if responsible for managing public health disease prevention and control, many shows positive attitude, which reflecting their potential as the "gate keeper."

The situated learning theory provide the medical education research a framework to design and make assessment for one particular learning content. However, sudden outbreak of the COVID-19 has created a real nature circumstances for public health program design and assessment. Considering the workload result, the REST training mode can be applied in future circumstances. Additionally, the study can be applied to other further study in public health education.

ADVANTAGES OF THE STUDY

The sudden outbreak of the COVID-19 pandemic was a rare occurrence in history that allowed for a unique study case. This situated cognition study was naturally designed in a workload training situation in real disease prevention circumstances and included situational context design, legitimate peripheral participation, and construction of a community of practice, which made it unique among other situated cognition studies. The Object Cognitive Load Scale (NASA-TLX scale) (31) were applied to measure the public health training outcome, especially before the COVID-19 pandemic, during the COVID-19 pandemic and in the future.

LIMITATIONS OF THE STUDY

Further study need to be followed-up, especially regression discontinuity design (RDD) research method, to reveal the effect of public health prevention training at different stages of the COVID-19 pandemic.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by West China Hospital Ethics Committee (2020YFQ0011, Sichuan, China). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RX designed the research and was major contributor in writing the manuscript. LL and SQ guided the discussion parts. WX discussed the result. All authors participated in the design of the study, contributed to the drafting of the paper, and read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.765402/full#supplementary-material

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Artificial Intelligence in Medicine: A Multinational Multi-Center Survey on the Medical and Dental Students' Perception

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Background: The emerging field of artificial intelligence (AI) will probably affect the practice for the next generation of doctors. However, the students' views on AI have not been largely investigated.

Methods: An anonymous electronic survey on AI was designed for medical and dental students to explore: (1) sources of information about AI, (2) AI applications and concerns, (3) AI status as a topic in medicine, and (4) students' feelings and attitudes. The questionnaire was advertised on social media platforms in 2020. Security measures were employed to prevent fraudulent responses. Mann-Whitney *U*-test was employed for all comparisons. A sensitivity analysis was also performed by binarizing responses to express disagreement and agreement using the Chi-squared test.

Results: Three thousand one hundred thirty-three respondents from 63 countries from all continents were included. Most respondents reported having at least a moderate understanding of the technologies underpinning AI and of their current application, with higher agreement associated with being male ($p < 0.0001$), tech-savvy ($p < 0.0001$), pre-clinical student ($p < 0.006$), and from a developed country ($p < 0.04$). Students perceive AI as a partner rather than a competitor (72.2%) with a higher agreement for medical students ($p = 0.002$). The belief that AI will revolutionize medicine and dentistry (83.9%) with greater agreement for students from a developed country ($p = 0.0004$) was noted. Most students agree that the AI developments will make medicine and dentistry

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more exciting (69.9%), that AI shall be part of the medical training (85.6%) and they are eager to incorporate AI in their future practice (99%).

Conclusion: Currently, AI is a hot topic in medicine and dentistry. Students have a basic understanding of AI principles, a positive attitude toward AI and would like to have it incorporated into their training.

Keywords: artificial intelligence, dental students, medical students, medicine, survey

INTRODUCTION

In general, artificial intelligence (AI) refers to the concept of automated machines able to perform human tasks (1). AI is a fast-paced developing field, with many applications already being available for use in our daily life activities (e.g., speech-/text-recognition, email spam-filters) (2) and emerging uses attracting a great deal of attention in Medicine and Dentistry over the past decade (3). It has already started to impact on specialties such as radiology (4), pathology (5), dermatology (6), and dentistry (7) especially in the developed world. However, it has been postulated to revolutionize global health in low- and middle-income countries as well because of its ability to apply novel analytical methods in large datasets related to complex diagnostic tasks (8). Throughout the world, the advent of commercially available AI products are heavily advertised and discussed in the medical field as specialized robots and algorithms have the potential to dramatically assist and possibly replace the human physician (9). As AI is yet to be fully established in Medicine and Dentistry, it will have the biggest impact on the next generations of doctors and dentists, respectively. Recently, a small cohort study in Germany found out that medical students have a positive attitude toward integrating AI in the medical procedures (10). However, it remains uncertain whether medical and dental students in general are concerned that AI could significantly affect the current practice of clinical and academic medicine in the future.

A conceptual framework (11) discussing the prospect of incorporating AI in the medical training has been recently designed (12). Although the framework discusses AI content to be included in the curriculum and administrative issues which may need to be overcome, the desire of the medical and dental students to be taught AI related concepts is yet to be elucidated. Although similar surveys have been performed (10, 13, 14), the topic remains relevant because (1) the hype around AI is unprecedented, (2) the impact of AI in Medicine is evolving as currently there is no AI widely adopted and infallible, and (3) the perception of stakeholders may change over time even in the short term. In addition, to the best of our knowledge, our survey is the first one to explore this topic from a multinational perspective. Thus, we designed an electronic survey to assess attitudes of undergraduate students in Medicine and Dentistry toward AI. We chose to include both medical and dental students as: (1) their training is similar (i.e., divided in pre-clinical and clinical years) based on a foundation of biology and chemistry disciplines (i.e., physiology, biochemistry etc.) and (2) AI is a fast-growing field in both Medicine and Dentistry.

Abbreviations: AI, artificial intelligence.

METHODS

Ethical Considerations

According to the University College London Research Ethics Committee guidelines, ethical approval was not required for our study and a waiver from the Joint Research Office (University College London/University College London Hospitals) was applied (15). All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Participation was completely voluntary and data collection was entirely anonymous by design. All the respondents provided informed consent after being instructed on the nature and purpose of the survey and were offered the possibility to withdraw at any time.

Study Design

An electronic survey was designed using Google Forms (Google LLC, United States). The survey was divided into five subsections. The first subsection aimed to gather general demographics data including: age, gender, student category (medical/dental), year of study, and self-reported tech-savviness. Tech-savviness was scored using a four-point Likert scale (strongly disagree, somewhat disagree, somewhat agree, strongly agree). The second subsection explored the understanding on AI basic principles (e.g., machine learning), daily life use (e.g., speech-/text-recognition, email spam-filters) and personal sources of information (e.g., media, social medical, university, friends/family, web browsing). The third subsection aimed to explore the understanding of AI as a topic in Medicine and Dentistry asking whether the participant is aware that: (1) AI in medical research attracted more investment than any AI projects in any other fields, and (2) AI and deep learning are broadly discussed in the medical community. The fourth subsection assessed students' feelings and attitudes toward AI exploring whether the respondent: (1) perceives AI as a partner or a competitor, (2) believes that physicians will be replaced in the foreseeable future, (3) is frightened or excited by the developments, and (4) thinks that AI will improve medicine and would like it to be incorporated into the medical/dental training. These sections were scored via three types of five-point Likert scales: (1) not at all, to a little extent, to a moderate extent, to a great extent and to a very great extent, (2) not at all aware, not so aware, somewhat aware, very aware, extremely aware, and

(3) strongly disagree, somewhat disagree, undecided, somewhat agree, strongly agree. The fifth subsection consisted of two short-answer questions related to what the respondent finds exciting about AI in the medical field, and what they would like to hear/learn about AI during their medical/dental studies.

Recruitment

Facebook has emerged as a tool for survey data collection given its targeted advertisements (16). Thus, the questionnaire was advertised on Facebook to undergraduate medical and dental students across the world. As such, we used a generic Facebook advertising campaign to reach users who specify that they are currently a student of Medicine or Dentistry. To avoid restricting the target population, we did not specify any other characteristics for 1 month. Then, we have evaluated the demographic characteristics of the participants and noticed that females, those from a developing country, dental students, and clinical students were under-represented. Thus, we created four additional advertising campaigns for another month to target underrepresented groups aiming for: 55–70% females, 20–30% from a developed country, 10–30% dental students, and 50% clinical students. We did not try to enforce stricter ratios because: (1) it is unclear what the ratios are globally, (2) there is geographical variation in the ratios, and (3) to avoid attrition bias as the Facebook targeting algorithm is more likely to show the advertisement to individuals having similar characteristics to the ones that have been previously interacted with the ad.

During the Facebook advertising period, the survey had a distributor recruitment rubric at the end at the end of the questionnaire. From the 173 students who have shown interest, only 45 agreed to comply with the distribution requirements and actively participated in the process. In an attempt to obtain an unbiased sample, we have asked the distributors to: (1) write to their medical/dental school and inquire whether they would be willing to distribute the survey to the whole cohort; (2) attempt to gain access to social media groups (Facebook, What's App etc.) containing all students from each year of study; (3) don't send the survey to their friends or to any groups not containing all the year students and (4) translate the study into their language if necessary, appropriate or feasible.

To prevent fraudulent responses a series of security measures were implemented (17): (1) the responses were limited to one only; (2) Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA) script was created and implemented into the Google Form; (3) students were required to specify their medical school; (4) two short-answer questions were included and awards advertised for the best answers; and (5) collected data was checked for inconsistencies. The data collection period was between 11/04/2020 and 01/10/2020.

Statistical Analyses

After the closing date, the results were downloaded. Tech-savviness was binarized as follows: 0 = strongly or somewhat disagree and 1 = somewhat or strongly agree. For each other question, the categories were preserved as above and recoded numerically from 0 to 4. The variance of its question was also recorded.

Comparison of the distribution of responses for each second, third, and fourth section questions were evaluated for the following categories: (1) male vs. female, (2) tech-savvy vs. non-tech-savvy, (3) pre-clinical vs. clinical, (4) dental vs. medical student, (5) young (aged 21 or younger) vs. mature (aged 22 or older) as defined by the UK's University and Colleges Admissions Services (UCAS) (18), and (6) from a developed vs. from a developing country as defined by the United Nations (19). In addition, we have analyzed the distribution of responses for the second, third, and fourth sections per country for any state having more than 50 respondents.

Distribution of data was assessed visually on histograms. Given the non-normal distribution of categorical data, Mann-Whitney *U*-test was employed for all comparisons.

A sensitivity analysis was also performed by binarizing responses to express disagreement (strongly or somewhat disagree, not at all, to a little extent, not at all or not so aware) and agreement (somewhat or agree, to a moderate or great extent or very great extent, and somewhat or very or extremely aware). Pearson's Chi-squared test with Yates' continuity correction was employed for all comparisons.

As most of our respondents regarded themselves as tech-savvy, we performed an additional sensitivity analysis. We considered the Likert response scale an ordinal scale and used generalized linear models with ordinal logit link (i.e., ordinal logistic regression) to assess whether the above associations persisted after adjusting for tech-savviness. The proportional odds assumption for ordinal logistic regression was tested using a Brant test (20).

A $p < 0.05$ was considered statistically significant. All analyses were performed using R version 3.6.3.

RESULTS

Participant characteristics are summarized in **Table 1**, while full survey results are presented in **Table 2**. A breakdown of respondents per country is presented in **Supplementary Table 1**. The participants were more likely be female (66.5%) and study pre-clinical (55.8%) medicine (79.6%) in a developing country (73.6%). In addition, the slight majority of the participants were aged 22 or older (51.7%) with a mean age of 22.0 ± 2.8 years, and mostly self-rated themselves as being tech-savvy (79.5%).

Regarding the sources of information on AI, most relied on web browsing (1,883 responses, 60.1%) and social media (1,861, 59.4%), while least relied on university (1,053, 33.6%) and friends or family (772, 24.6%). As regards the perceived applications of AI in Medicine and Dentistry, the most popular answers were medical education optimisation (1,880, 60.0%) and enhanced/automated medical diagnostic tasks (1,804, 57.6%). Conversely, the main concerns on the utilization of AI were the expected less human interaction with the patient (1,938, 61.9%) and any sensitive data leakage including cybersecurity attacks (1,323, 42.2%).

TABLE 1 | Participant demographics, sources of information on artificial intelligence (AI), perceived potential applications of AI in medicine/dentistry, and concerns on AI.

Participant characteristics ($n = 3,133$)	**$n = 3,133$**
Age, years	21.95 ± 2.77
Males, (%)	1,050 (33.51)
Tech-savvy[a], (%)	2,489 (79.45)
Medical students, (%)	2,495 (79.63)
Clinical students, (%)	1,385 (44.21)
From a developed country[b], (%)	828 (26.43)
Sources of information on artificial intelligence	
Media, (%)	1,265 (40.38)
Social media, (%)	1,861 (59.40)
Web browsing, (%)	1,883 (60.10)
Friends or family, (%)	772 (24.64)
University, (%)	1,053 (33.61)
Perceived potential applications of artificial intelligence in medicine/dentistry	
Enhanced/automated medical diagnosis, (%)	1,804 (57.58)
Enhanced/automated disease prognosis, (%)	1,423 (45.42)
Optimized medical education, (%)	1,880 (60.01)
Optimized patient workflow, (%)	1,488 (47.49)
Nothing at all, (%)	96 (3.06)
Concerns on artificial intelligence	
Data privacy, (%)	1,144 (36.52)
Hacking and cybersecurity attacks, (%)	1,323 (42.23)
Fear of job replacement, (%)	1,209 (38.59)
Less human interaction with the patient, (%)	1,938 (61.86)

[a] *Individuals who responded either somewhat or strongly agree to the questions asking whether they self-regard as tech-savvy were considered tech-savvy.*
[b] *Countries were classified as developed or developing as defined by the United Nations (19).*
Data is presented as mean ± standard deviation or counts (%) as appropriate.

Understanding on AI Basic Principles

Most students claimed at least a moderate understanding of the: (1) AI as an umbrella term encompassing many technologies (2,095, 67.9%), (2) current AI applications in medicine and dentistry (1,771, 56.5%); and (3) daily life AI applications (2,653, 84.9%). A higher agreement was associated with males ($p < 0.0001$), being tech-savvy ($p < 0.0001$), pre-clinical students ($p < 0.006$), and participants from a developed country ($p < 0.04$).

AI as a Topic in Medicine and Dentistry

Most respondents were at least aware that AI is being broadly discussed in the medical community (2,337, 74.6%) and that healthcare AI projects attract more investment than any AI projects globally (2,461, 78.6%) (21). Higher rate of agreement was associated with tech-savvy respondents ($p < 0.0001$), medical students ($p < 0.02$), studies in a developing country ($p < 0.007$), pre-clinical students ($p < 0.0001$), and being 21 or younger ($p < 0.004$). When asked to indicate the specialty where AI will play the most decisive role in 20 years, most students answered surgery (1,146, 36.6%), followed by radiology (1,092, 34.9%).

Attitudes and Feelings Toward AI

Students perceived AI as partner rather than as competitor (2,261, 72.2%) with a greater agreement rate observed for tech-savvy respondents ($p < 0.0001$) and medical students ($p = 0.002$). AI is believed among students to revolutionize medicine and dentistry (2,628, 83.9%), an opinion advocated strongly by males ($p = 0.005$) and students from a developed country ($p = 0.0004$). Interestingly, only the slight majority of the students agreed that AI will never make the human physician expendable (1,779, 56.8%). Furthermore, it was common belief in dental students ($p = 0.001$) and from respondents in developing countries ($p < 0.0001$) that non-interventional physician will be replaced. Most students agreed that the AI developments will make Medicine and Dentistry more exciting in the future (2,189, 69.9%) and that AI should be part of the core medical training curriculum (2,683, 85.6%). Higher agreement was only observed among tech-savvy respondents ($p < 0.04$). The slight majority of the respondents agreed that they would usually or always incorporate AI in their future practice (1,655, 52.8%) (**Figure 1**). The highest response variance was observed for "In the foreseeable future, all physicians will be replaced," and "These developments frighten me, while the lowest variance was seen for "Artificial intelligence will improve Medicine in general," and "Artificial intelligence should be part of medical/dental training."

Sensitivity Analyses

Binarizing survey responses to express disagreement (strongly or somewhat disagree, not at all, to a little extent, not at all or not so aware) or agreement (somewhat or agree, to a moderate or great extent or very great extent, and somewhat or very or extremely aware) was consistent with our initial analysis, with the exception of some results of borderline significance (**Supplementary Table 2**).

When pursuing adjustment for tech-savviness, the vast majority of associations persisted in the ordinal logistic regression models (**Supplementary Table 3**).

Results by Country

A breakdown of survey responses for each country who had more than 50 respondents is provided in **Supplementary Table 4**.

DISCUSSION

Principal Survey Findings

The data from this international multi-center survey study indicate that medical and dental students agree that AI developments make Medicine and Dentistry more exciting to them. They would like to see these developments implemented in their university curricula and plan to employ AI in their practice when they will graduate and qualify for their subspecialty.

Key Survey Results

Firstly, most students have a basic understanding of the AI principles, are aware of the AI technologies they are already using and are up to date with the AI topics discussed in the medical community. Interestingly, this was particularly evident in pre-clinical students; this fact can be potentially attributed to their

TABLE 2 | Survey results.

n = 3,133	Strongly disagree or equivalent	Somewhat disagree or equivalent	Undecided or equivalent	Somewhat agree or equivalent	Strongly agree or equivalent	Variance	*P*-value (male vs. female)	*P*-value (tech-savvy vs. non-tech-savvy)	*P*-value (dental vs. medical student)	*P*-value (pre-clinical vs. clinical)	*P*-value (young vs. mature)	*P*-value (developed vs. developing country)
Understanding on AI basic principles												
Artificial intelligence is an umbrella term encompassing many technologies (e.g., "Machine Learning"). Do you have a basic understanding of these technologies?	195	743	1,340	536	219	0.969	**<0.0001**	**<0.0001**	0.438	**0.004**	0.879	**0.038**
Currently, AI has many applications in medicine (e.g., AI-assisted robotic surgery). How familiar are you with these applications?	515	847	1,075	510	186	1.228	**<0.0001**	**<0.0001**	0.570	**0.006**	0.790	**<0.0001**
Many applications we use in daily life already use AI (e.g., speech-/text-recognition, email spam-filters). How familiar are you with these applications?	133	347	989	1,073	591	1.103	**<0.0001**	**<0.0001**	0.757	**0.002**	**0.002**	**0.003**
AI as a topic in medicine and dentistry												
AI in medical research is rapidly evolving. Healthcare AI projects attracted more investment than any AI projects in any other field globally. How aware are you?	155	517	1,285	853	323	1.002	0.078	**<0.0001**	**0.021**	**<0.0001**	**0.003**	**<0.0001**
"Artificial Intelligence" and "Deep Learning" are currently being broadly discussed in the medical community. How aware of this are you?	173	623	1,222	807	308	1.050	0.057	**<0.0001**	**0.021**	**<0.0001**	**0.004**	**0.007**
To what extent do you feel you have an understanding of the technologies which underpin "Artificial Intelligence" and "Deep Learning"?	270	851	1,271	562	179	1.002	**<0.0001**	**<0.0001**	0.159	**<0.0001**	**0.012**	**0.0006**
Attitudes and feelings toward AI												
I perceive artificial intelligence in Medicine as a partner rather than as a competitor.	43	194	635	1,219	1,042	0.906	0.052	**<0.0001**	**0.002**	0.077	**0.024**	0.066

(Continued)

TABLE 2 | Continued

n = 3,133	Strongly disagree or equivalent	Somewhat disagree or equivalent	Undecided or equivalent	Somewhat agree or equivalent	Strongly agree or equivalent	Variance	*P*-value (male vs. female)	*P*-value (tech-savvy vs. non-tech-savvy)	*P*-value (dental vs. medical student)	*P*-value (pre-clinical vs. clinical)	*P*-value (young vs. mature)	*P*-value (developed vs. developing country)
Artificial intelligence will revolutionize medicine/dentistry in general.	12	117	376	1,285	1,343	0.683	**0.008**	**0.005**	0.146	**0.017**	**0.0006**	**0.0004**
The non-interventional physician will be replaced in the foreseeable future.	388	780	950	794	221	1.270	0.394	**0.004**	**<0.0001**	**0.001**	**0.0007**	**<0.0001**
In the foreseeable future, all physicians will be replaced.	1,380	793	470	346	144	1.442	0.072	**0.028**	0.085	**0.002**	**0.0003**	**<0.0001**
These developments frighten me.	374	832	783	847	297	1.391	**<0.0001**	**<0.0001**	0.142	**<0.0001**	**0.004**	**<0.0001**
These developments make Medicine in general more exciting to me.	83	254	607	1,380	809	0.984	**0.003**	**<0.0001**	0.801	0.157	0.443	0.754
Artificial intelligence will never make the human physician expendable.	141	460	753	904	875	1.361	0.954	**0.015**	0.221	0.523	0.187	**0.046**
Artificial intelligence will improve Medicine in general.	17	78	272	1,352	1,414	0.598	**0.0004**	**<0.0001**	0.059	**0.014**	**0.011**	**0.005**
Artificial intelligence should be part of medical/dental training.	22	97	331	1,247	1,436	0.679	0.676	**0.037**	0.747	0.084	0.169	0.099

All reported analyses used Mann-Whitney U-test. Significant p-values are highlighted in bold. For the directionality of the comparisons, please look at ***Supplementary Table 3*** *where odds ratios are presented.*
AI, artificial intelligence.

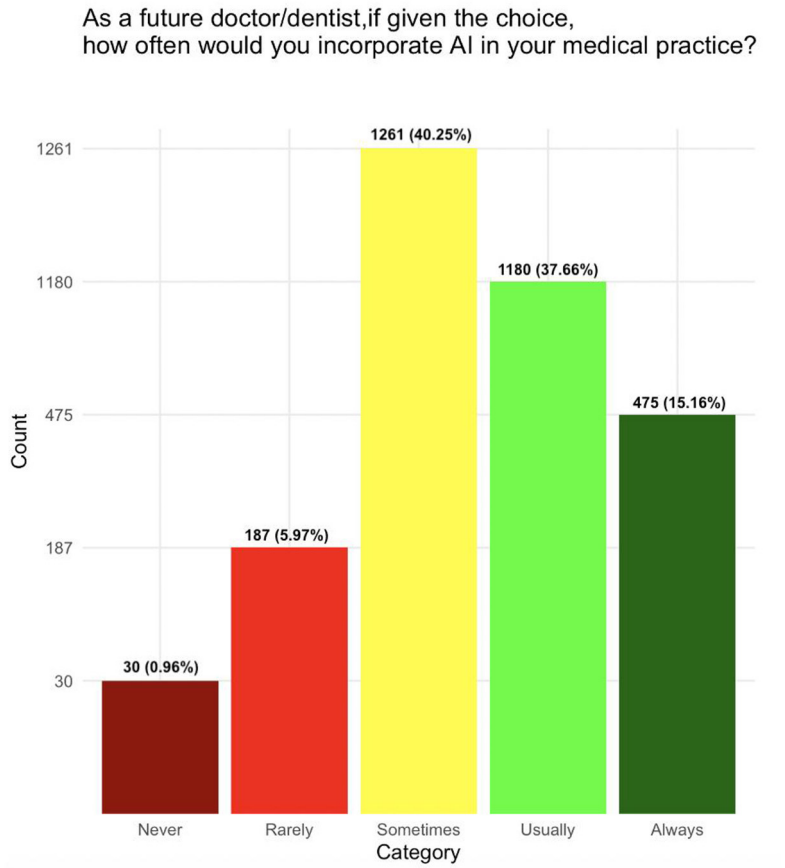


FIGURE 1 | Inclination of medical and dental students to incorporate artificial intelligence in their future medical practice.

tendency to have higher exposure to science. Another possible explanation could be that as students get immersed with the clinical practice, their focus might be increasingly on the current scope and methods of clinical practice losing base with the latest research developments. Students from developed countries displayed higher agreement of having a better understanding of AI and its current developments, whereas our study states questions regarding the opportunity discrepancies among different country income categories indicating that students from developing countries might be at disadvantage. This further widens any existing global health inequalities (22). In support of this statement, is also the fact that there was a stronger majority among students from a developed country than from the lower income countries that AI will revolutionize medicine (**Supplementary Table 4**). Secondly, medical and dental students had mostly homogenous opinions except that medical students thought they were better informed on AI, while dental students were in stronger agreement that AI will replace human physicians. This is in keeping with the fact that their training is similar, and their fields are experiencing a similar exposure to AI. Thirdly, most students claim to use web-browsing as their primary source of information on AI. Self-initiated information gathering may be correlated with a better understanding and higher attraction to the AI. Only a third of respondents selected their university as a source of information on AI. This might reflect a level of satisfying exposure to AI education during their studies. Thus, our survey highlights an unaddressed need of incorporating AI into the medical and dental schools' curricula emerged from our investigation. Students would like namely to get more acquainted with AI and currently resort to internet sources to satisfy this demand. Similarly, most students (60.01%) also believe that AI could lead to an optimized medical education highlighting the room for improvement in the current teaching methods. Thus, it is not surprising that most students agreed that "Artificial intelligence should be part of medical/dental/training" and the variance of the survey item was one of the smallest. At the opposite end of the variance spectrum, the responses were widely distributed when the students were asked whether the AI developments frighten them, although most perceive AI as a partner rather than a competitor.

Study Implications

AI in Medicine is undeniably an exciting prospect that could dramatically influence the next generation of professionals (23). AI interfaces using narrow and usually supervised machine learning can outperform under controlled circumstances certain medical specialties such as radiologists (24) and dermatologists (6). Medical and dental students are aware that AI is a hot topic

in the domain, and most retrieve their information from web browsing or from social media. Currently, most students do not discern AI as a threat or fear job replacement. Nevertheless, they clearly desire to obtain ground-breaking knowledge in AI and be in pace with the latest developments. This could stem from the presumption that the doctors who are knowledgeable about AI will replace the ones who don't use it in this competitive field (25). Apparently, the medical and dental schools are lagging in providing their students with teaching of the basic AI principles and application, let alone providing technical support for basic machine learning experimental work. We feel that these results add to the empirical insights into the constraints of the current medical training and the appetite for reform. Nevertheless, it is little known whether medical schools are mature or, at least, prepared to embed a stronger emphasis on AI into the curricular medical training. Moreover, as the modern healthcare teams are multidisciplinary and include other professionals, e.g., nurses, clinical scientists, and pharmacists, it is ambiguous whether a cross-disciplinary approach is envisaged. Most respondents (61.86%) expressed concerns that as the role of AI will increase in Medicine and Dentistry, there could be less human interaction with the patient. Historically, the foundations of both professions have always been communication, empathy, and a close and caring relationship with the patient. Thus, these foundations should be persevered as AI immerses into clinical practice healthcare to avoid the loss of the human touch in the profession. However, a recent study highlighted that a lecture about AI reduced the students' concerns which suggests that further educational interventions are required to alleviate worries regarding AI (13).

Although students' perceptions are important, they might not be the ultimate determinant on how the medical curriculum is shaped and structured. Although it is a common practice in most universities to request feedback on the course from the students, it is unclear to what extent that feedback is acted upon. In addition, the primary factors affecting medical education have been postulated to be: social, technological, economic and political (26), and they exhibit a high geographical variation. Thus, it is unclear to what extent the universities' curricula are influenced by the desires of the medical and dental students. The inclusion of AI in the medical syllabus would also be a difficult task as it would be subjected to the policies of universities and national accreditation bodies. The medical students already tend to have a higher workload and be more distressed than their age-matched counterparts studying other degrees (27). To prevent further workload, certain aspects of the current curriculum might need to be removed to make room for AI. Further studies should explore what changes would be feasible. In addition, further research focusing on the attitudes of the academic staff, universities management and accreditation bodies on the utility and feasibility of incorporating AI into the medical curricula would provide more valuable insights.

Strengths and Weaknesses

Although the ethics of Facebook is questionable (28), it has almost 3 billion monthly users as of 2021 and it is able to target a desired population given a set of characteristics. Even though its use in medical research is growing, it is still an underused tool. Our study is novel since it engaged a multinational community to explore the views of medical and dental students on AI using Facebook's targeting algorithm. The large number of study participants ($n = 3{,}133$) spanning 63 countries across all continents is the utmost strength of the study. In addition, the survey was designed sufficiently immune to fraudulent responses by obscuring attempts to submit multiple answers. However, the use of more sophisticated machinery such as virtual private networks cannot be confidently ruled out. The questions addressed covered a wide range of AI-related topics enabling us to explore the topic multidimensionally. We also collected enough demographics data to perform 6 relevant subgroup comparison analyses.

An important limitation of this work is that surveys may not be the best suited tools to conduct such exploratory work. In addition, currently there is no theoretical framework we could have used to guide the contents of our survey. Another impediment is the geographic heterogeneity of the responses. Although we have reached many medical and dental schools with a wide distribution on the world map, most of the students' national groups recorded <10 responses. In addition, within the countries with the highest number of responses, a limited number of medical schools was sampled. In addition, there may be concerns about the representativeness of our sample. Initially, we ran generic Facebook ads to medical and dental students without specifying any further characteristics (e.g., sex, age etc.). Then, we did advertising campaigns targeted to the groups who were under-represented in the first data collection sweep in order to match the sampled population with the medical/dental students population. However, Facebook itself is limited through its inherent non-probabilistic sampling as its machine learning algorithms targets individuals who are more likely to interact with an advertisement. This may have created bias toward tech savvy students who account for almost 80% of our sample. However, the associations persisted affect adjusting for tech-savviness. Please note that tech-savviness was self-rated and might not be a proxy of the respondents' actual technical capabilities. Similarly, the uneven distribution of answers between the countries can be also attributed to Facebook's sampling algorithm. This can affect the reproducibility of the study. In addition, we aimed for a female predominant sample, but there might be countries where males are over-represented as medical/dental students. The questions were selected to explore a wide range of attitudes and perceptions on AI, but they do not form a validated scale. However, the nature of the questions still enables us to infer certain conclusions about students' perception and stance on AI. Moreover, we decided to limit the number of questions asked to increase the number of participants. As self-assessments can be an unreliable proxy of actual knowledge (29), some of our survey questions may be prone to self-evaluation bias. In addition, data collection took place mostly at the beginning of the pandemic. Thus, many students might have had a temporarily elated view on AI brought by media reports portraying digital health as the future of Medicine. Although students raised concerns that AI could lead to less human interaction with the patients, our study did

not explore whether the respondents are interested in AI because it would mean better care for their patients or merely because it would make the field more exciting to them.

Study Position Compared to the Current Body of Evidence

A few other studies have explored the views of medical students on AI including a narrow investigation on specific subspecialties (10, 14, 30, 31). However, the novelty of our work is rooted in our focus on AI in both Medicine and Dentistry rather than in subspeciality such as radiology. In addition, to the best of our knowledge, we are the first to engage a multinational community of students across the globe. Lastly, we provided evidence elaborated at different demographic, geographic, school type (medical vs. dental), and studies level (pre-clinical vs. clinical) groups.

The AI in Medicine topic has ignited mixed feelings in the medical community, but the consensus is that the fate of the medical profession will change as AI gets immersed into the clinical practice (32). Although many see the advent of AI in clinical medicine as inevitable and advocate for its timely implementation in the medical schools' curricula (33), others are a bit skeptical and raised concerns on AI (34). Firstly, the privacy and control over data is ethically problematic (35). Secondly, there is a considerable heterogeneity between AI protocols in different centers (36). Thirdly, there are no standards for clinical care, quality, safety, and malpractice liability in the context of AI (34). Fourthly, there are instances where AI works extremely well [e.g., predicting schizophrenia onset (37)], but it is unclear how the algorithm makes its prediction [i.e., black box phenomenon (38)], making it difficult to rely on something we have no understanding on how it operates. Thus, AI might not be fully implemented in clinical practice very soon making the case for postponing incorporating AI into the medical curriculum.

CONCLUSION

AI is undergoing a rapidly expanding role in medicine and dentistry. The next generation of medical and dental doctors perceive AI as a partner rather than a competitor and is planning to integrate it into their future practice. Thus, there might be a high demand to have AI topics integrated into the university curricula which should be further explored.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SB, C-CT, and ZZ contributed significantly to the conceptualization, implementation, data acquisition, formal analysis, interpretation, and manuscript writing and are joint first authors. A-VI, LS, JS, M-MC, JL-R, DP, DA, CZ, AB, AL, LA-I, AS, AK, KM, EW, AO, DI, and EE contributed to the implementation, data acquisition, interpretation, and manuscript review. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.795284/full#supplementary-material

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A Nationwide Virtual Research Education Program for Medical Students in Pakistan: Methodological Framework, Feasibility Testing, and Outcomes

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Introduction: Equipping young medical trainees with fundamental research skills can be a promising strategy to address the need for professionals who can understand and responsibly communicate evolving scientific evidence during a pandemic. Despite an ardent interest to partake in research, most educational institutions in Pakistan and other low-middle income countries have not yet adopted a comprehensive strategy for research skills education. The authors aimed to design and assess the feasibility of implementing the first nation-wide virtual research workshop for medical students in Pakistan.

Methods: The course "Beginners Guide to Research," designed as a nation-wide virtual research workshop series, was conducted for medical students across Pakistan in June 2020. Four interactive live workshops took place online on alternate days from June 22nd, 2020, to June 27th, 2020, each lasting 1–2 h. Outcomes included: (i) reach, (ii) efficacy as indexed by pre-post change in score pertaining to knowledge and application of research and (iii) self-rated perceptions about understanding of research on a Likert scale.

Results: 3,862 participants enrolled from 41 cities and 123 institutions. Enrolled participants belonged to the following provinces: Sindh (n = 1,852, 48.0%), Punjab (n = 1,767, 45.8%), Khyber Pakhtunkhwa (n = 109, 2.8%), Azad Jammu and Kashmir (n = 84, 2.2%) Balochistan (n = 42, 1.1%). We also saw a few registrations from international students (n = 8, 0.2%). Mean (SD) age of enrolled medical students was 21.1 (2.1) years, 2,453 (63.5%) participants were female and 2,394 (62.0%) were from private-sector medical colleges. Two thousand ninety-three participants participants filled out all four pre-test and post-test forms. The total median knowledge score improved

from 39.7 to 60.3% with the highest improvements in concepts of research bioethics and literature search ($p < 0.001$) with greater change for females compared to males (+20.6 vs. +16.2%, $p < 0.001$) and private institutions compared to public ones (+16.2 vs. +22.1%, $p < 0.001$).

Conclusion: The overwhelming enrollment and significant improvement in learning outcomes (>50% of baseline) indicate feasibility of a medical student-led research course during a pandemic, highlighting its role in catering to the research needs in the LMICs.

Keywords: virtual course, research teaching, feasibility, medical students, public health

INTRODUCTION

Responsible and effective scientific communication has been one of the key lessons during the pandemic (1). Such communication requires a sound understanding of science, epidemiology, and research in medicine (2). This communication is led by experts and is informed by incoming scientific evidence, which is crucial to disseminate appropriately to the public in a time of crisis like the pandemic and during interactions with patients otherwise. However, over the last three decades, the percentage of physician-scientists has plummeted with numbers going down from 4.7% in the 1980s to 1.5% in the 2010s in the US alone (3, 4). While evidence is lacking for a low-middle income country such as Pakistan, there are only a handful of physician-scientists in the country, which can be attributed to an lack of skills, knowledge, mentorship, and funding support leading to poor understanding of research causing misinformation (5, 6).

To address this challenge and reverse this trend, it is necessary to develop and encourage a research potential early on in budding physician-scientists. This is of pronounced importance in settings like Pakistan, which are plagued with a lack of adequate public health training institutions, lower rates of literacy in the general population and an overall mistrust in the profession of medicine. It is critical to develop and encourage an understanding of scientific research potentially early on in emerging physician-scientists during their medical training (7). This skills development lies at the forefront of the information age, where wide access to evidence-based practice and bench-to-bedside translational research has already led the paradigm shift in teaching and learning (8). Thereby, developing equitable mechanisms for resource-limited settings to equip trainees with research skills is imperative. If left unattended, this deficit will only widen the divide and disparity in science and medicine.

While the importance of developing these research skills within medical students has been well-outlined, many universities in Pakistan have not yet adopted a comprehensive curricular strategy which could have come in very handy during the pandemic (9). Aligning with recent calls for medical students to be involved in the pandemic response (10, 11), the Student Research Forum, an autonomous research body at a private medical university decided to implement an intervention for medical students. The intervention was conceptualized to aid bridging the gap of evidence-based communication. In this paper, we first describe the process our team underwent to design and implement the intervention. We also evaluate the feasibility of this intervention.

METHODS

Study Setting

The Student Research Forum (SRF) is a student-run and faculty-supervised research organization registered at the Aga Khan University. The study setting included SRF, the university administrative departments and the SRF Student Ambassador Network. Medical colleges in developing countries such as Pakistan have only recently begun to dedicate their resources toward promoting research within the student community (12). South Asia contributes to only 1.2% of research articles despite being one-fifth of the world's population (13). A cross sectional study conducted in Pakistan showed that a majority of the medical students from either public or private sector universities were keenly interested in medical research and 91% expressed an interest toward having medical research a part of basic medical education (9).

Study Design

A nation-wide virtual research workshop series conducted for medical students across Pakistan was designed as a feasibility study (14, 15). The main objectives of feasibility included (i) the assessment of recruitment capability and resulting sample characteristics, data collection procedures and outcome measures, (ii) acceptability of the intervention and study procedures, resources, and ability to manage and implement the study and intervention, and (iii) preliminary evaluation of participant responses to the intervention (16). Objective outcomes included change in scores (pre-test to post-test) pertaining to knowledge about key research topics and application of research methods. Subjective outcomes involved changes in perceptions toward research on a standard Likert scale.

Sampling Strategy and Study Enrollment

A triphasic enrollment strategy was deployed, which involved marketing and communications on three concurrent fronts: social media (Facebook, Twitter, and Instagram) of SRF. Registrations were done using a Google Form link for 2 weeks prior to the workshop series. The online workshop series was freely accessible to all registered participants, who were provided de-identification codes for the assessment study. Submission

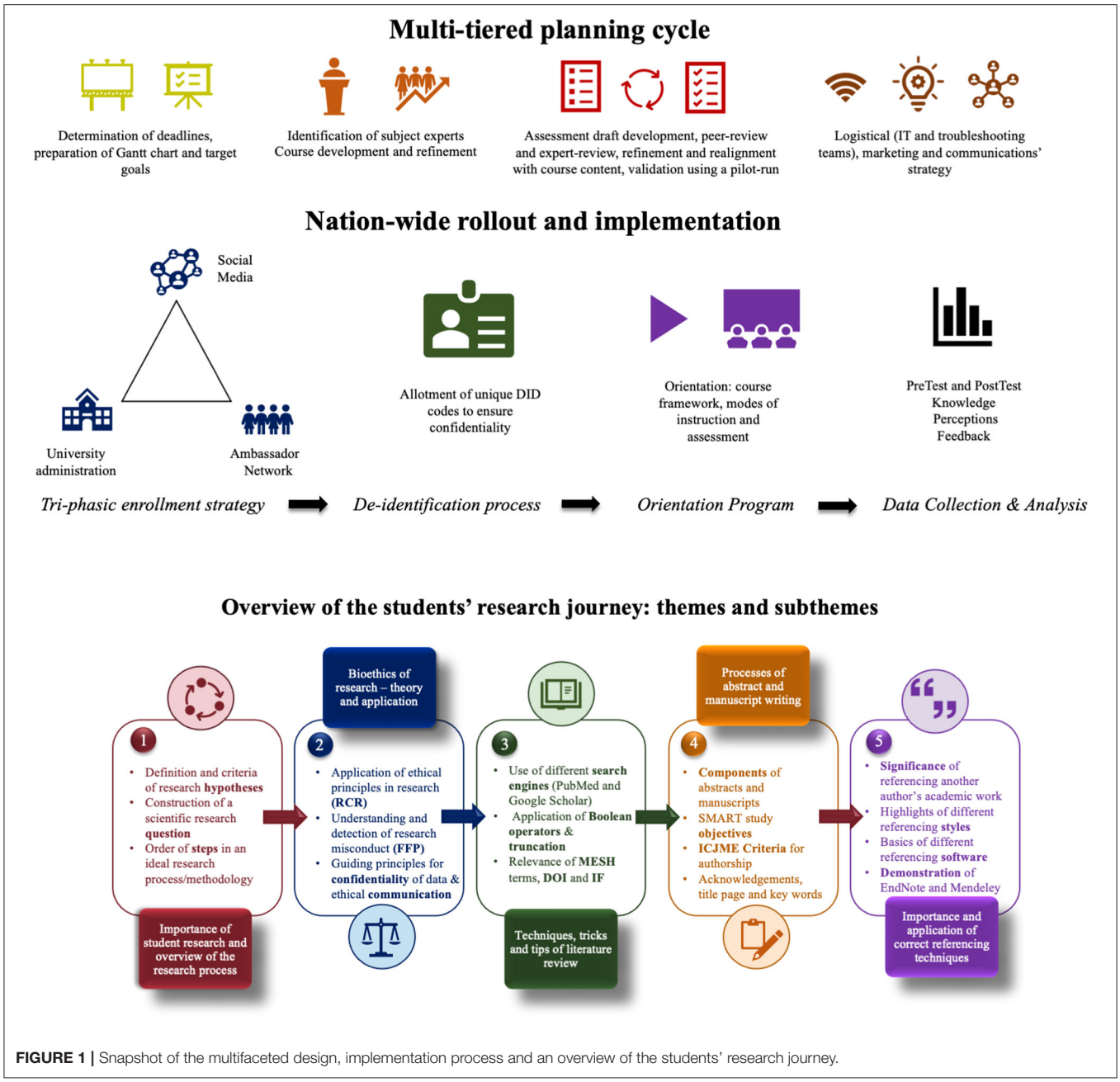


FIGURE 1 | Snapshot of the multifaceted design, implementation process and an overview of the students' research journey.

of both pre and post questionnaires contributed toward the eligibility criteria for inclusion in analysis. This study was approved by the institutional review board (AKU ERC 2020-5131-11751). Digital informed consent was obtained from all students at the time of enrollment.

Intervention Design and Implementation

"Beginners Guide to Research" was a nation-wide virtual research workshop series conducted for medical students across Pakistan. The strategic planning cycle (**Figure 1**) focused on course development and refinement, identification of subject experts in the university and development of the logistical and information technology infrastructure. Four interactive workshops were planned, each with specific learning outcomes that were predesigned and scrutinized by experts in research methodology (**Table 1**).

The workshop series commenced on the 22nd of June 2020 and continued until the 27th of June 2020. The workshop series consisted of four sessions conducted online using Zoom application Version: 5.0.4 (25694.0524) and Live-Streaming Webinar (Video IBM Channel). **Figure 1** comprehensively details the research journey that each individual student underwent throughout the series, with a succinct description of the pertinent learning outcomes and sub-themes. An orientation

TABLE 1 | Summary of the key objectives and format of instruction and assessment employed in the research skills development courses.

	Brief course content theme	Outline and objectives
1.	Importance of research and overview of its components	To discuss the importance of research in the medical community and an overview of its components (research question, literature search and referencing, data collection and analysis, abstract and manuscript writing).
2.	Bioethics of research	To impart an understanding of key terms in bioethics of research (plagiarism, reliability and accuracy of results, consequences of fabrication, importance of IRB approvals).
3.	Importance of literature review and methods of conducting it using different resources	To highlight the purpose of a literature review and the role of authenticity when referencing scholarly work in research papers; To provide an overview on how to conduct a literature search effectively, using various resources such as PubMed and Google Scholar.
4.	Format and components of abstracts and manuscripts	To discuss the format of a manuscript, key ingredients of a robust manuscript, types of abstracts and connecting abstracts and manuscripts
5.	Need for and importance of referencing Application of research management software used in referencing	To underline the need for and importance of duly referencing another author's work; To showcase different styles of referencing most commonly used by journals; To demonstrate and practice referencing software: EndNote and Mendeley

TABLE 2 | Enrollments, demographics and participant characteristics ($n = 3,862$).

Variable	Beginner's guide	
Enrollments	Cities	41
	Universities	123
	Participants	3,862
Age, in years, [mean (SD)]	21.1 (2.1)	
Gender; *n* (%)	Female	2,453 (63.5)
	Male	1,365 (35.3)
	Preferred not to respond	44 (1.1)
Year of education; *n* (%)	1st Year, MBBS	903 (23.4)
	2nd Year, MBBS	872 (22.6)
	3rd Year, MBBS	684 (17.7)
	4th Year, MBBS	802 (20.8)
	5th Year, MBBS	601 (15.6)
Type of education system; *n* (%)	Public	1,468 (38.0)
	Private	2,394 (62.0)
Representation; *n* (%)	Sindh	1,852 (48.0)
	Punjab	1,767 (45.8)
	Khyber Pakhtunkhwa	109 (2.8)
	Balochistan	42 (1.1)
	Azad Jammu and Kashmir	84 (2.2)
	Outside Pakistan	8 (0.2)
Prior publishing experience (optional question); *n* (%)	Yes	140 (3.6)
	No	2,691 (69.7)
	Did not report	1,031 (26.7)

program ensued to give participants an overview of the course framework.

The duration of each workshop was between 1 and 2 h, which was the duration pre-selected to find the balance between providing speakers enough time to explain basic concepts and the audience adequate and digestible content that did not exceed their online attention span. Concepts outlined in the workshop were kept to a beginner's level of understanding.

Interaction and Communication

To make the workshops interactive and to enable brisk communication, the entire cohort of participants was divided into 16 groups and each group was appointed a team-lead from the organizing team, along with a few other members for troubleshooting and communication purposes. Two platforms were maintained and monitored for incoming questions and correspondence: "Backchannel Chat" and a dedicated email address. Both these platforms were operational in real-time and for the duration of the workshop. This "many-to-some-to-one" strategy enabled participants to reach out to the central team and, by extension, the presenter.

Additionally, some workshops also employed techniques for the session presenters to interact with the audience using the "one-to-many" format by conducting live practice-based demonstrations. For example, the session on "Literature Search" included a live demonstration on PubMed, whereby the participants could both observe the presenter conducting the search in real-time, and simultaneously perform the same on their end also.

Data Collection Tools

The study was evaluated for two domains of feasibility: reach and preliminary efficacy (17). Outreach was determined using the total number of registrations, institutions, and cities across Pakistan.

The questionnaires to assess efficacy had two components:

1. Test Section: This included both scenario-based application of basic research concepts and knowledge-based assessment of fundamental terms and principles. The testing approach was Best Choice Questions (BCQs). Pre-test and post-test questionnaires evaluated participants on their knowledge of research and workshop session objectives, as well as application of concepts. The questions were designed as multiple-choice questions including conventional multiple choice and scenario-based questions.

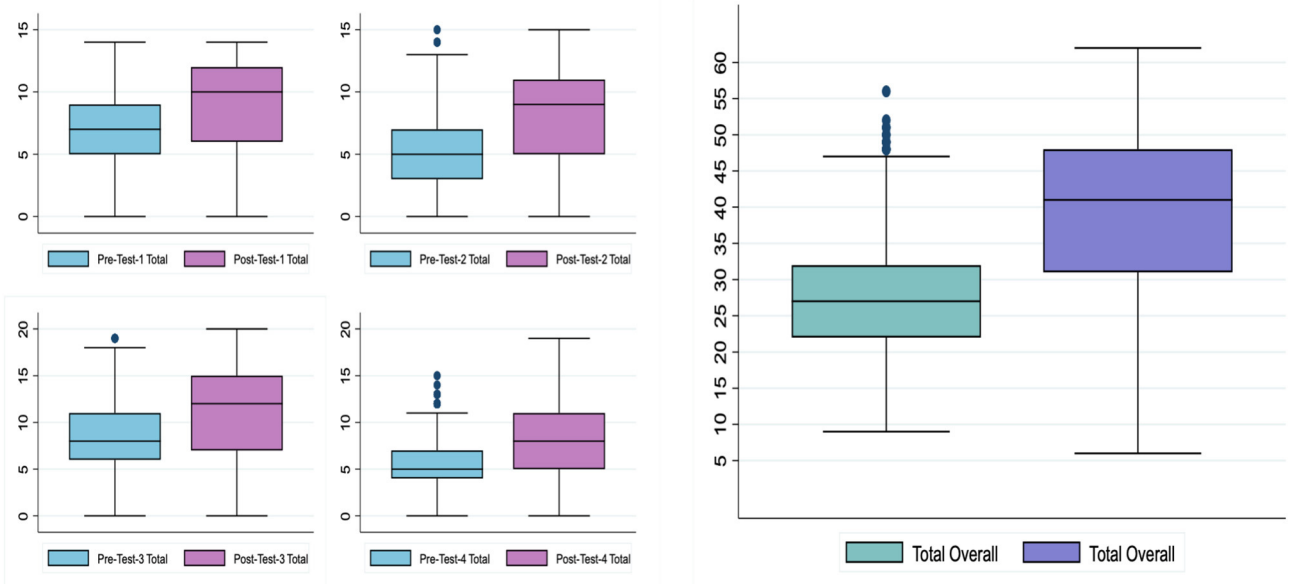


FIGURE 2 | Objective assessment: box-and-whisker plots showcasing changes in total scores from baseline pre-workshop aggregates to post-workshop aggregates.

2. Participants' perceptive rating section: This aimed to evaluate the participants' own perception of their understanding of research sub-topics corresponding to each session assessed on a self-rating scale. A content-relevant Likert's scale was developed to evaluate this, whereby "5" was equivalent to strong agreement with the prompt and "1" was equivalent to strong disagreement. Similar to the test section, participants' perception rating was also collected before and after the workshop.

To ensure reliability of the questionnaire, a pilot run of each test was also conducted. Medical students who were not part of the workshop organizing team and were not registered participants of the workshop were selected for a trial run of the questionnaires from a pre-test perspective. The pilot run was successful and did not require any significant amendments to the questionnaires.

Statistical Analysis Plan

Analysis was done using StataCorp. 2019 (Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC). After the initial registrations were procured, each participant was allocated a unique De-Identification code (D-ID). This step was important to maintain participants' confidentiality and to reduce the risk of researcher bias. To ensure validity and accuracy, only those who filled both pre-test and post-test of a particular workshop were included in the final analysis. Pre-test and post-test scores were calculated overall, for each workshop and for eight distinct categories. Since the data were skewed, median and interquartile range (IQR) were used as a measure of central tendency, and change in medians were calculated for each of the above. The significance in change of scores was calculated using Wilcoxon signed-rank test, and p-values < 0.05 were statistically significant.

RESULTS

Reach

The series saw enrollments from a total of 3,862 participants from 41 cities and 123 institutions (**Table 2**). Enrolled participants belonged to the following provinces: Sindh (n = 1,852, 48.0%), Punjab (n = 1,767, 45.8%), Khyber Pakhtunkhwa (n = 109, 2.8%), Azad Jammu and Kashmir (n = 84, 2.2%), Balochistan (n = 42, 1.1%). We also saw a few registrations from international students (n = 8, 0.2%). In terms of intra-city representation, 1,701 (44.0%) of the participants came from Karachi. Two thousand six hundred ninety-one (69.7%) participants reported having no academic publishing experience prior to registering in the workshop series.

The mean (SD) age of the registered participants was 21.1 (2.1) years. Two thousand four hundred fifty-three (63.5%) participants were females, 903 (23.4%) were in their first year of medical school training and 2,394 (62.0%) hailed from the private-sector medical institutions of Pakistan.

Preliminary Efficacy

Pre-post Knowledge Scores

The assessment part of the workshop was voluntary. In order of the respective workshops (1 through 4), a total of 2,718, 2,690, 2,525, and 2,480 respondents filled out both pre-tests and post-tests for respective workshops indicating slight decline per session. Overall, a total of 2,093 (54% of total registrations) participants filled out pre-test and post-test questionnaires for all 4 sessions.

Full series' analysis (N = 2,093) showed that the overall median (IQR) score increased from 27 (22–32) to 41 (31–48) ($p < 0.001$) and the percentage median score, as a proportion of the maximum possible score, improved from 39.7

TABLE 3 | Comparison and univariate analysis of pre-test and post-test knowledge using Multiple Choice Questions (MCQ) format questionnaires.

Comparison of pre-test and post-test scores									
Test	**Questions**	**Responses; *n***	**PreTest median (IQR)**	**PostTest Median (IQR)**	**Δ Median[a]**	**% Pre-test score[b]**	**% Post-test score[b]**	**Δ % Score[c]**	***p*-value[d]**
Total test 1	14	2,718	8 (6–9)	10 (8–12)	2	57.1	71.4	14.3	<0.001
Category A[e]	5	2,718	3 (3–4)	4 (3–4)	1	60	80	20	<0.001
Category B	9	2,718	4 (3–6)	7 (5–8)	3	44.4	77.8	33.3	<0.001
Total test 2	15	2,690	6 (4–7)	10 (7–12)	4	40	66.7	26.7	<0.001
Category C	9	2,690	3 (2–4)	6 (4–7)	3	33.3	66.7	33.3	<0.001
Category D	6	2,690	2 (1–3)	4 (3–5)	2	33.3	66.7	33.3	<0.001
Total test 3	20	2,525	8 (6–11)	12 (8–15)	4	40	60	20	<0.001
Category E	9	2,525	4 (3–5)	6 (4–7)	2	44.4	66.7	22.2	<0.001
Category F	11	2,525	4 (3–6)	6 (4–8)	2	36.4	54.5	18.2	<0.001
Total test 4	19	2,480	5 (4–7)	8 (5–11)	3	26.3	42.1	15.8	<0.001
Category G	8	2,480	2 (1–3)	3 (2–5)	1	25	37.5	12.5	<0.001
Category H	11	2,480	3 (2–4)	5 (3–7)	2	27.3	45.5	18	<0.001
Overall	68	2,093	27 (22–32)	41 (31–48)	14	39.7	60.3	20.6	<0.001
Univariate stratified analysis (n = 2,093)									
Variable	**Questions**	**Responses *n* (%)**	**Pre-test median (IQR)**	**Post-test median (IQR)**	**Δ Median[a]**	**% Pre-test score[b]**	**% Post-test score[b]**	**Δ % score[c]**	***p*-value[d]**
Gender									<0.001
Female		1,532 (73.2)	27 (23–32)	41 (32–48)	14	39.7	60.3	20.6	
Male		549 (26.2)	27 (22–23)	38 (29–47)	11	39.7	55.9	16.2	
Not Reported		12 (0.6)	26 (22–33)	43 (24–48)	17	38.2	63.2	25	
MBBS year									0.076
1st Year	68	466 (22.2)	26 (21–31)	39 (29–46)	13	38.2	57.4	19.1	
2nd Year		540 (25.8)	27 (22–32)	41 (31–48)	14	39.7	60.3	20.6	
3rd Year		379 (18.1)	27 (21–31)	40 (32–47)	13	39.7	58.8	19.1	
4th Year		417 (19.9)	28 (23–33)	41 (33–49)	13	41.2	60.3	19.1	
5th Year		291 (13.9)	29 (23–35)	42 (32–50)	13	42.6	61.8	19.1	
Institution									<0.001
Private		1,301 (62.2)	27 (22–32)	42 (33–49)	15	39.7	61.8	22.1	
Public		792 (37.8)	27 (22–32)	38 (29–46)	11	39.7	55.9	16.2	

[a] *Δ Median denotes change in median which is calculated by (Post-test median – Pre-test median).*

[b] *% has been calculated using (median/maximum score) × 100.*

[c] *Δ % Score denotes change in score which is calculated by (%Post-test median – % Pre-test median).*

[d] *P-value was calculated using Wilcoxon signed-rank test (comparing pre-test median and post-test median scores) since the post-tests were left-skewed.*

[e] *Category A, Research question, hypothesis, steps and communication; Category B, Bioethics of research; FFP, confidentiality; Category C, Concepts important to literature search, search engines, MESH, DOI and IF; Category D, Application of literature search techniques; Category E, Abstract writing and SMART objectives; Category F, Manuscript components and writing, authorship and acknowledgments; Category G, Concepts important to referencing - significance, styles and softwares; Category H, Application of referencing on EndNote and Mendeley.*

to 60.3% (**Figure 2**; **Table 3**). Similarly, individual workshop scores showed a positive increase in participant scores after attending the workshop ($p < 0.001$; **Table 3**). The workshops on literature search along with those on abstract and manuscript writing showed the highest change in scores (Δ Median = +4 for both, Δ% score = +26.7 and +20.0, respectively). The workshops on referencing and introduction to research also showed positive deflections in the participant scores (Δ Median = +3 and +2, Δ % score = +15.8 and +14.3, respectively).

Analysis by categories showed that the highest improvements in scores were observed in bioethics of research and concepts of literature search (Δ Median = +4, Δ % score = 33.3 for both). Concepts and application of referencing showed the least improvement in scores (Δ Median = +1 and +2, Δ % score = +12.5 and +18.0, respectively).

We found that both females and males started at the same baseline median scores, but females showed a significantly higher improvement in scores (Δ Median = +14 vs. +11, Δ % score = +20.6 vs. +16.2, $p < 0.001$). Similarly, students at both public and private institutions started at the same baseline scores but the latter performed significantly better in terms of score improvement (Δ Median = +11 vs. +15, Δ % score = +16.2 vs.

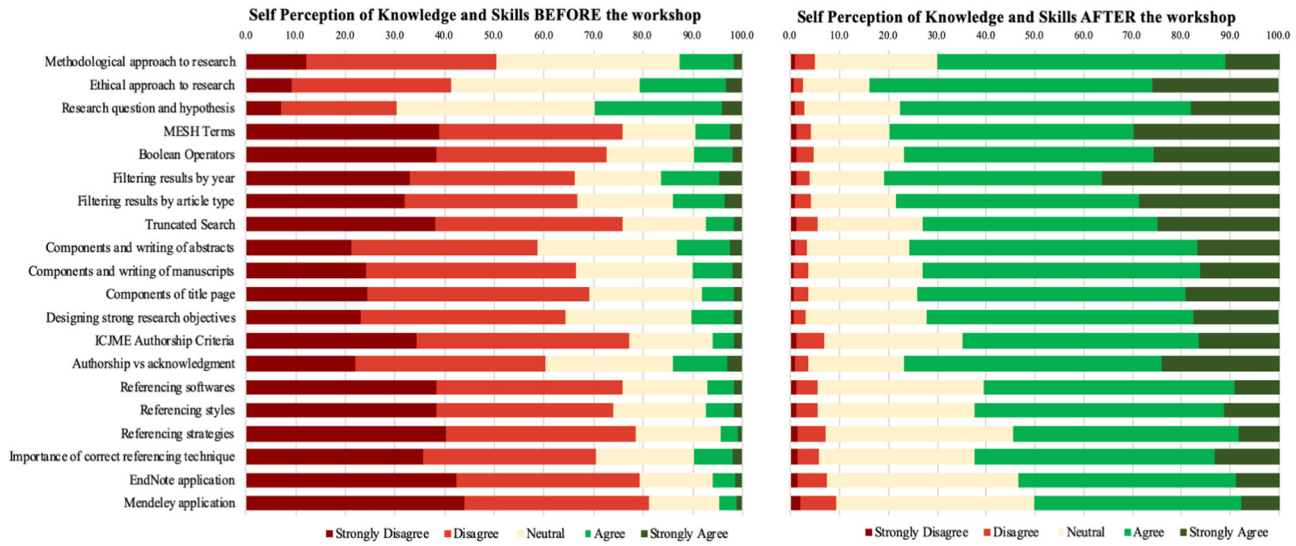


FIGURE 3 | Subjective assessment: categorical assortment of participants' self-perceptions.

+22.1, $p < 0.001$). Although the year of education did not show significant differences in improvement between the categories, an increasing trend in both baseline pre-test and post-test scores was noted as the year of education increased.

Pre-post Self-Rating Scores

On the self-rating scale, the greatest overall red-to-green shift from disagreement (dark red and red) to agreement (dark green and green) was observed for the second (literature search) and third (abstract and manuscript writing) workshops (**Figure 3**). Similarly, within the sub-themes, the largest red-to-green shift was appreciated in perceptions about Medical Subject Headings (MESH terms) and Boolean operators (both part of the second workshop), whereas the smallest corresponding shift was seen in "research question and hypothesis" and "methodological approach to research," (both part of the first workshop). Each item showed a positive trend from strong disagreement (dark red) and disagreement (red) to agreement (green) and strong agreement (dark-green).

DISCUSSION

Our main findings primarily indicate the feasibility of a large-scale national virtual research workshop designed for medical students. The workshop attracted 3,862 registrations across 123 different institutions. Assessment of 2,093 participants indicated an appreciable improvement in overall participant knowledge scores from 39.7 to 60.3% (increase was >50% of baseline) over the course of the series. To our knowledge, this is the first paper to introduce a virtual nation-wide research workshop for medical students in the region in response to the pandemic.

Participants attending our workshop had a baseline assessment score of 39.7%. Many other interventions have implemented and evaluated research skills training at local and regional levels (18–22). A cross-sectional study conducted in India showed the impact of a "Mentored Student Project" in fostering a positive attitude toward student research (23, 24). Within Pakistan, a single-center study in 2006 reported the baseline mean knowledge and attitude scores of medical students regarding research to be 49.0 and 53.7%, respectively (25). Similar to our findings, this study also reported a higher baseline knowledge score on items pertaining to literature search on MEDLINE (60.9%), components of manuscripts (60.4%) and writing of introduction (57.8%), compared to lower scores on themes pertaining to scientific hypothesis (29.4%) and characteristics of research science (23.9%) (25). Another cross-sectional study conducted on 184 medical students in Jeddah, Saudi Arabia reported the cumulative scores for students' knowledge and attitudes regarding participation in scientific research, to be 57 and 76%, respectively (26). The baseline knowledge shown in these studies and our findings collectively demonstrate how critical the need is for a strategically planned research curriculum in the region. However, understanding the baseline status-quo should not be left unattended, but rather be the foundation for a rigorous research program implementation and analysis of post-intervention outcomes.

Due to limitations imposed by the COVID-19 pandemic, our research team leveraged the concurrent ongoing switch to digital technology. Within Pakistan and beyond, there has been a quick uptake of online educational media such as Zoom, Google Hangouts and Skype (27–31). While digital learning and virtual platforms did exist before the pandemic, their use has been small-scale, unstructured, sparse, and unsustainable. Given the rapid uptake of these platforms with the onset of the COVID-19 pandemic, it was possible to reach out to and connect with a large number of participants in real time. It also ensured that costs of transportation, accommodation and logistics to another city were no longer an impediment. This ensured that the workshop

remained accessible and free-of-cost to the participants, which further increased the turnout.

Online delivery of educational content brings forth a multitude of advantages, predominantly cost-effectiveness, scalability, replicability and increased accessibility (32–35). Multiple reports, including those from Pakistan, have demonstrated strong support for online learning (36–38), while others have suggested that traditional modalities of learning may be more effective in enhancing knowledge outcomes (39, 40). While it does not compare the two, our study does resonate with the support expressed for online teaching-learning mechanisms. This is seen particularly by the high response rate, significant improvement in key learning metrics and the feedback received throughout the series. Further downstream, post-pandemic, it may be useful to compare the outcomes of such an intervention between virtual and traditional platforms.

An interesting finding from our study was that a large majority of participants in the workshop were females ($n = 2{,}453$, 63.5%) and scored significantly higher than their male counterparts (Δ % score $= +20.6$ vs. $+16.2$, $p < 0.001$). This is different from baseline snapshots in Pakistan (25) and Saudi Arabia (41), which have reported male medical students to have a higher attitude score toward research. In contrast, a recent assessment of medical research perceptions amongst medical students in Beirut, Lebanon reports female medical students to have a more positive perception (42). The higher enrollment and better percentage improvement in female students further indicates the need to sustain this drive and to work on developing a greater interest toward research in their male counterparts.

Furthermore, a large majority ($n = 1{,}852$, 48.0%) of medical students belonged to the province of Sindh, particularly from Karachi. This can partly be explained by the fact the course was led by a medical school within the city. Also, the city, Karachi has a higher literacy rate (∼75%), which is one of Pakistan's largest metropolitan cities (43). Medical students from Punjab, the most populous province of Pakistan, also participated in high numbers ($n = 1{,}767$, 45.8%). Data also show that the highest number of registered medical colleges (53%) are from Punjab (44). However, we observed that our enrollments did not significantly reach the less advantaged provinces in other parts of Pakistan like Balochistan where literacy rate is below 10% (43). This serves as a call-to-action, accentuating that a lot more needs to be done to increase access and ensure equity in such programs.

Although our workshop was the first intervention of its kind during the pandemic, the curriculum content and teaching-learning pedagogy were carefully developed and curated by experts in academic medicine. In order to attract a wider target audience from varying diasporas across the country and to transcend geographical barriers, the workshop series was deployed on a virtual platform and was kept free-of-cost. This ensured that a student's socio-economic status did not impact their motivation to partake in this learning opportunity. Planning and strategy development were very much emphasized to ensure that the learning and feedback tools were easily comprehensible to a diverse participant population. In the setting of the COVID-19 pandemic, this novel intervention enabled students, experiencing varying levels of detachment from their institutional educational curriculum, to connect and learn together in the pursuit of acquiring new skill sets. It also ensured that students could productively use their free time, while away from formal, in-person, educational programming. Since research education already faces deficits in medical education curricula, this opportunity guaranteed that students were not disadvantaged due to the pandemic, by further reductions in the training of these important skills.

A major strength of the study was led by medical students themselves at a private medical school in the country. We believe this is an example of student leadership during the pandemic apart from their skill set to be utilized in healthcare to designing courses for peers to further research understanding. The study is encouraging in the sense that medical students in LMIC can also be engaged as a workforce similar to high-income countries (45, 46).

There were similar limitations of the study. A major limitation to our study was that despite a large number of workshop participants (3,862), only 2,093 ultimately chose to be part of the assessment study and filled out all eight pre-tests and post-tests. Since the tests were only open at specific intervals before and after the workshop, this can be partly explained by logistical or technical issues that some participants may have encountered. Electricity outages and problems with internet connectivity (47) might have affected participants in certain parts of the country, as Pakistan still has only 85 million 3G/4G subscribers and 40% internet coverage for a population of 0.2 billion people (48). Due to this, while not everyone was able to participate in the time-limited assessments, we wanted to make sure that no student got left behind in the learning component (our primary objective with the workshops). To tackle this head-on, our team posted summary handouts detailing major points discussed in the workshop. This was done only after the post-test submission was closed, to also ensure that the assessment results were reliable. Moreover, our sessions did not have one-to-one direct interaction between the participants and the presenters. Since brisk communication is a central to any teaching-learning activity (49), we anticipated that this may have interrupted rapport building and concomitantly affected the learning outcomes of a few participants. To counter this, we ensured that 20 organizers were available at every time to answer individual queries and troubleshooting concerns.

FUTURE IMPLICATIONS

As a long-term plan, our team has taken the initiative of establishing a nationwide undergraduate research network. Over 1,000 students from all over the country have expressed interest and sent applications to be research ambassadors at their home institutions. We hope that this workshop series was the steppingstone to establishing the first country wide undergraduate student research network.

CONCLUSIONS

This workshop series establishes the first step in the development and feasibility testing of a curated virtual learning platform that has connected the undergraduate community in a low

middle-income country. The overwhelming response seen with registrations ($N = 3{,}862$), particularly from students logging in from remote and rural areas of Pakistan, highlights the need to develop similar virtual workshops for medical students. It is imperative that this new-found momentum does not erode with time, and similar interventions are systematically launched to make undergraduate research understanding more accessible.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, upon reasonable request.

ETHICS STATEMENT

The study was reviewed and approved by Ethics Review Committee, Aga Khan University, Karachi. Digital informed consent was obtained from all students at the time of enrollment.

AUTHOR CONTRIBUTIONS

AN and MI have co-led the entire workshop series planning and execution at every stage since (and including) conception. They have both equally contributed in the writing of the manuscript and final revisions up until the last internal review. HS, HR, FA, FK, SA, AS, MM, and AM have actively participated in the conception, strategic planning, pilot, execution, data analysis and reporting, and manuscript preparation and final revisions. BH, MR, FJ, MT, and AH acted as expert supervisors and participated in the following: providing regular input during the planning and conception stages, assisting with the execution of the workshop series, reviewing and interpreting data, and preparing the manuscript up till the final revisions. AH and MT have led this series as principal investigator and co-investigator, respectively. All authors have read the final draft and approved it before submission.

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Corrigendum: A Nationwide Virtual Research Education Program for Medical Students in Pakistan: Methodological Framework, Feasibility Testing, and Outcomes

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A Corrigendum on

A Nationwide Virtual Research Education Program for Medical Students in Pakistan: Methodological Framework, Feasibility Testing, and Outcomes

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In the original article, there was a mistake in **Figure 3** as published. While converting the figure file to TIFF, the incorrect file was converted and hence resulted in a mismatch between the text describing the figure and the figure itself. This error came to our notice post-publication, and we wanted to fix it as soon as possible, to ensure ethical conduct of research. The corrected **Figure 3** appears below.

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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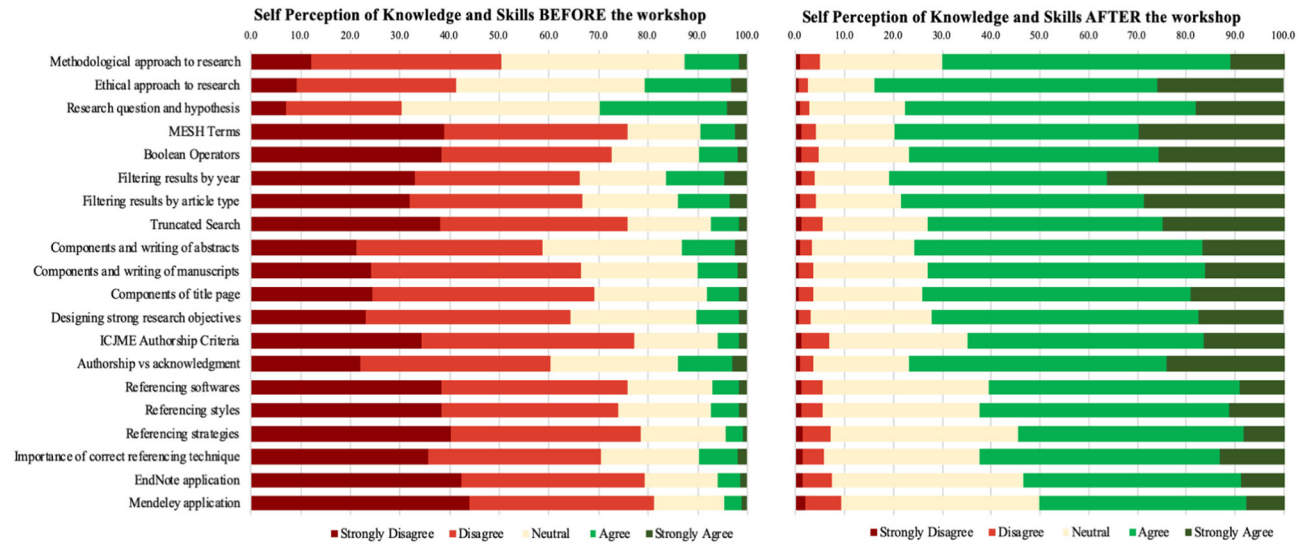


FIGURE 3 | Subjective assessment: categorical assortment of participants' self-perceptions.

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Stratification of Health Professional Education and Its Funding Disparities: Evidence From China During the Period of 1998–2017

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Background: The finance of health professional education (HPE) is of immense importance for effective and sustainable health systems, yet relevant empirical research was scarce due to the lack of financial data. The study aimed to bridge the gap by presenting the scenario of finance for health professional institutions (HPIs) of different tiers in China and exploring how the stratification of institutions affected their funding disparities.

Methods: The study employed data collected from the Ministry of Education in China, and selected the HPIs mainly based on the World Directory of Medical Schools. The funding levels and disparities of China's HPIs during the period (1998–2017) were analyzed with descriptive statistics, and the indicators of funding per institution and funding per student were both considered. The average funding in HPIs was presented by tiers, and the Gini coefficient and Theil index were employed to describe the differences in financing among HPIs over the span.

Results: The study found that the number of HPIs has kept growing over the past two decades, with both the funding per institution and the funding per student increasing steadily. Specifically, the average funding per institution of the three tiers increased by 31.5 times, 13.4 times, and 10.5 times separately, with the first-tier universities having an absolute advantage compared to lower tiers. As for the financing disparities among HPIs, the Gini coefficient of the funding per institution maintained to be over 0.5, with the third-tier institutions scoring the highest, while the Gini coefficient of the funding per student all ranged approximately from 0.2 to 0.3. Through the decomposition of the inequalities measured by the Theil index, the share of the between-tier difference in per-institution funding grew from 29.7 in 1998 to 77.9% in 2017.

Conclusions: The funding disparities between tiers of HPIs in China gradually became more accentuated, with the top-tier institutions taking up the largest share. Although the stratified development in HPE has posed a challenge to the unified quality assurance of medical personnel training, it may also be regarded as an effective pathway for developing countries like China to achieve stable development in health professional education.

Keywords: financing, health professional education, stratification, health professional institutions, funding disparities

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INTRODUCTION

Funding serves as the basis for the development of health professional education (HPE), which ensures normal and effective teaching activities in health professional institutions (HPIs). In particular, public financing should be allocated properly so as to improve efficiency in the national contexts (1). The extant research on higher education finance focuses mainly on fiscal inequality (2), performance-based funding policies (3), the impacts of financial incentives measures on student educational outcomes (4), as well as the determinants of government funding (5), etc. However, related fields have not formed a very clear outline of funding input in HPE and the financial situation of HPIs worldwide. Some studies have examined the financial investment in American medical schools (6, 7), while some others discussed the financing in postgraduate HPE (8), as well as the funding in residents (9), yet there is relatively little empirical research on the finance of HPE compared with the ample exploration on the financing of tertiary education (10). One of the important reasons, as stated in the report published in *The Lancet* in 2010, is that there is a lack of financial data in HPE (1).

A joint report *Health Professionals for a New Century* published by the global commission on education of health professionals for the 21st century noted that the HPE reform in the coming 100 years will require a series of enabling actions, such as enhancement of investment level of HPE, which is a key measure to advance the quality and equity of HPE (1). In the report, a macro estimation approach was adopted by examining the funding of higher education as well as the proportion to HPE, and results showed that the estimated funding per medical student was $122 000 worldwide in the year 2008. The estimated value in Western Europe was similar to those in North America ($497 000 and $400 000, respectively), but was much lower in China ($14 000, 1/35 of North America, and 1/28 of Western Europe) (1).

The funding income of HPIs is directly related to the operational status of the HPIs and will influence the quality of medical students' training. In view of these realities, the commission's initiative is that each country and agency should consider doubling its investments in HPE over the next 5 years as an indispensable contributor for effective and sustainable health systems (1).

STRATIFICATION OF THE HEALTH PROFESSIONAL EDUCATION IN CHINA

Horizontal Differentiation of Chinese Health Professional Institutions

The Ministry of Education (MOE) in China has categorized higher education institutions into comprehensive universities and 11 types of single-subject colleges, including medicine and pharmacy colleges, natural sciences and technology colleges (11). In the early 21st century, some highly competitive colleges of medicine and pharmacy merged into comprehensive universities in China (12); thus, HPE has been offered not only by colleges of medicine and pharmacy, but also by comprehensive universities which include medicine-related departments. In 2017, China had 631 comprehensive universities and 199 colleges of medicine and pharmacy, including both the undergraduate and vocational colleges (13).

China has cultivated the largest quantity of medical students worldwide, though its number of HPIs is not the largest (1). In 2017, Chinese higher education institutions enrolled 7.6 million students in total, with 0.5 million students being admitted into HPIs, accounting for 6.6% of the total (13). In general, Chinese health professional institutions consist of 11 disciplines, namely clinical medicine, nursing, dental medicine, traditional Chinese medicine (TCM), public health and preventive medicine, the combination of modern medicine with TCM, pharmaceutical science, traditional Chinese pharmaceutical science, forensic medicine, allied health and basic medicine (11). Taking clinical medicine as an example, its enrollment took up a large proportion of the total to medicine, but the proportion has been declining year by year, from 63.2 in 1998 to 31.6% in 2012, and then remained at around 30% in recent years. In addition, undergraduate enrollment accounts for about 50% of the total clinical enrollment, while the ratio of master's and doctoral degrees has increased with time, indicating the growing demand for higher educational attainment (14).

Vertical Hierarchy of Higher Education Institutions in China

A series of schemes have been consecutively launched by the Chinese government including *Project 211*, *Project 985*, and the *Double First-Class* program over years in order to improve the education in elite universities and to facilitate the development of tertiary education (15). Specifically, *Project 211* was initiated in 1995 with the purpose of setting a priority to improve the education of leading universities and to enhance their research standards, and the selected 115 prestigious universities have received 70% of the national research funding from 1995 to 2008 (16). In 1998, *Project 985* was launched to build world-class universities and 39 elite universities were chosen to be equivalent to the US Ivy League, which have received substantial public funding and policy support (17). In the year 2015, the *Double First-Class* program, known as the continuation of the two previous projects with a broader geographical spread, was inaugurated aiming to build an outstanding higher education system with first-class universities and first-class disciplines. Altogether 137 universities out of over 2000 universities have been selected, which formed the three selectivity tiers of institutions. The tier 1 comprises 42 universities (including all 39 of the *Project 985* institutions, and three additional universities from the former *Project 211*), which were regarded to have the potential to reach world-class standards. The tier 2 consists of 95 universities (mainly the former *Project 211* institutions) which

Abbreviations: AAMC, the Association of American Medical Colleges; HPE, Health professional education; HPIs, health professional institutions; MOE, Ministry of Education; NHC, National Health Commission; TCM, traditional Chinese medicine; WDMS, World Directory of Medical Schools; WFME, World Federation for Medical Education.

were identified to have strengths in particular disciplines with a solid foundation for development. The tier 3 refers to other non-*Project 211* universities (18, 19).

The distribution of HPIs follows the overall layout of higher education in China (20). In terms of financing allocation, the funding of health professional institutions mainly comes from their competent authorities. HPIs of the top tiers in China are directly affiliated to the MOE or other central ministries, thus their financial resources are mainly from the central government. The second-tier HPI are institutions of higher education with key medical disciplines, which are directly affiliated to the National Health Commission (NHC), and jointly established by the NHC or the National Administration of Traditional Chinese Medicine, the MOE, as well as the local governments. The third-tier HPIs are mainly affiliated to the local ministries, so the local governments provide them the main financial support. There exists a mutual influence between the development situation of HPIs and their financial resources to some extent. Sufficient funding plays a basic and supportive role in ensuring the development of HPIs, while well-developed HPIs, in return, may attract further funding sources.

The extant literature has examined the cost and financial demand of general higher education, but little research has focused specifically on HPE that may function very differently. Relevant studies were either case studies of certain institutions or general analyses based on personal experience, which can hardly provide an overall picture of the national funding situations and disparities among HPIs in China. Therefore, this paper aimed to bridge the gap by analyzing the changing trends of the funding among HPIs of different tiers from 1998 to 2017, and exploring how the stratification of institutions affects the funding disparities across tiers.

METHODS

Data Sources

This study employed data collected from the MOE in China, which encompasses the funding status, student number, and basic information of institutions of higher education nationwide. It should be noted that the statistical calibers of financial revenue and expenditure in China are quite different from the US. The primary sources of funds for public higher educational institutions in China are fiscal appropriation, tuition, fees and scientific research income, operating income, donations and grants, funding for institutional infrastructure, as well as other funding from miscellaneous sources. The financial expenditure includes salaries, wages and employee benefits, purchased goods and services, capital outlay, and other expenditures. Since hospitals are organized and operated as legal entities independent from HPIs, the expense in medical services was not included in the data. HPIs in our study mainly refer to colleges and universities that offer the clinical medicine programs, and usually these universities also have programs of other medical disciplines. HPIs in our study have been selected through three steps: (1) A total of 160 HPIs in the mainland of China have been screened based on the World Directory of Medical Schools (WDMS) provided by the World Federation for Medical Education (WFME) (21). (2) Our research excluded 22 private HPIs that were listed in the WDMS, given that the statistical calibers of financial revenue and expenditure are quite different between the public and private HPIs, and China's higher educational system is dominated by public institutions. (3) We checked the relevant data year by year from 1998 to 2017 considering that the annual lists of HPIs varied since the clinical medicine programs had been established in different years. Thus, all the HPIs in our paper are public institutions offering degree programs, and in accordance with the *Double First-Class* initiative, this paper posits a classification of HPIs into three tiers. The tier 1 HPIs are key universities that have the potential to reach world-class standards; the tier 2 HPIs are institutions with key disciplines; and the tier 3 HPIs are other institutions. We used the 2017 US dollar constant price as the measurement standard by adjusting the funding data based on China's consumer price index (CPI) in 2017, and then converting Chinese Yuan to US Dollar (1 USD $\approx$ 6.752 CNY) according to the exchange rate in 2017 (22).

Data Analysis: Gini Coefficient and Theil Index

The study aimed to present the funding levels and disparities of different tiers of China's HPIs with descriptive statistics. We first compared the means of funding in HPIs when analyzing the finance distributions as well as changes across years, and the indicators of both funding per institution and funding per student were considered in our analysis. Furthermore, the Gini coefficient and Theil index were employed to describe the differences in finance among HPIs over the years. All the statistical analyses were performed using Stata version 15.1. The calculation of both Gini coefficient and Theil index of funding per institution and funding per student comes from the study by Cowell (23). The Gini coefficient, derived from the Lorenz curve framework, ranges between 0 and 1, indicating the income distribution from perfectly equitable to perfectly inequitable (24, 25). According to the United Nation standard, a Gini coefficient of <0.2 denotes absolute equality, while values of 0.2–0.3 represent relative equality; values of 0.3–0.4 stand for relatively reasonable inequality; values of 0.4–0.5 mean relatively big inequality; values over 0.5 represent severe inequality. Gini coefficients can be calculated with the equation 1. n refers to the total number of samples in a certain year; W_i stands for the percentage of funding of group 1 to i in proportion to that of all HPIs.

$$Gini = 1 - \frac{1}{n}(2\sum_{i=1}^{n-1} W_i + 1) \quad (1)$$

Theil index, another measure of inequality, can decompose the differences from within-group and between-group separately, which ranges between 0 and infinity, with greater values indicating increasing levels of inequality (26–28). Theil Index can be measured through the equation 2. n refers to the total number of the sample, which are divided into k groups, and group k was shown as g_k, while the number of the group k was n_k; y_i and y_k stand for the share of individual i and the share of group k, respectively. Our study decomposed the Theil index by the three tiers of HPIs (see equation 3 and 4). P_b refers to the

TABLE 1 | Average funding per institution by tiers of health professional institutions: 1998–2017.

Year	Total		Tier 1		Tier 2		Tier 3	
	N	Mean (US$ in millions)	*N*	Mean (US$ in millions)	*N*	Mean (US$ in millions)	*N*	Mean (US$ in millions)
1998	94	14.2	17	30.2	9	15.5	68	9.8
1999	96	21.7	19	55.0	9	19.8	68	12.1
2000	101	44.9	19	156.4	9	31.8	73	15.6
2001	106	65.0	20	229.7	11	40.4	75	20.2
2002	113	70.6	20	260.5	12	46.3	81	23.5
2003	115	75.1	20	269.2	12	53.4	83	27.7
2004	119	77.8	20	268.0	12	57.3	87	33.7
2005	121	88.3	20	304.2	12	75.4	89	38.6
2006	125	98.7	20	358.4	13	78.2	92	41.9
2007	126	114.6	20	414.6	13	97.4	93	48.7
2008	126	120.9	20	435.9	13	103.7	93	51.7
2009	127	136.2	20	502.7	13	104.8	94	58.1
2010	132	156.8	20	614.6	13	125.9	99	64.3
2011	133	184.2	20	702.4	13	154.3	100	79.9
2012	136	190.7	20	715.7	14	162.6	102	84.8
2013	137	194.3	20	727.6	14	177.1	103	88.8
2014	140	235.8	21	885.3	14	224.8	105	102.2
2015	141	230.7	21	867.4	14	214.9	106	101.6
2016	149	235.8	21	928.8	16	225.4	112	101.2
2017	152	262.3	23	982.2	16	223.4	113	113.1

The funding per institution across years has been adjusted based on China's CPI index in the year 2017, and the Chinese RMB was converted to USD (1 USD ≈ 6.752 CNY) according to the exchange rate in 2017.

share of between-tier difference. P_w refers to the share of within-tier difference. T_b and T_w represent the differences between and within tiers, used for calculating the share of intra-group and inter-group contribution to the total difference.

$$Theil = \frac{1}{n}\sum_{i=1}^{n}\frac{y_i}{y}\ln\left(\frac{y_i}{y}\right) = \sum_{k=1}^{k} y_k \ln\frac{y_k}{\frac{n_k}{n}} + \sum_{k=1}^{k} y_k\left(\sum_{i\in g_k}\frac{y_i}{y_k}\ln\frac{\frac{y_i}{y_k}}{\frac{1}{n_k}}\right) = T_b + T_w \quad (2)$$

$$P_b = \frac{T_b}{Theil}\times 100\% \quad (3)$$

$$P_w = \frac{T_w}{Theil}\times 100\% \quad (4)$$

RESULTS

Distribution of Financial Resources in Health Professional Institutions

Table 1 reports the number of HPIs and the average funding per institution by tiers between 1998 and 2017 in China. In general, the number of health professional institutions kept growing over the span. In the year 1998, there were altogether 94 HPIs, with 17 top-tier institutions, 9 s-tier institutions, and 68 third-tier institutions. By 2017, the number had increased to 152 HPIs in China, and the quantities for the three tiers were 23, 16, and 113, respectively. As for the per institution funding, it has risen by 17.5 times from \$14.2 million in 1998 to \$262.3 million in 2017 on average. Specifically, the average funding per institution of the three tiers increased by 31.5 times, 13.4 times, and 10.5 times separately. Until 2017, the average funding per institution for the three tiers has reached up to \$ 982.2, \$ 223.4, and \$ 113.1 million, respectively; and it is obvious that the first-tier institutions have received the largest share of financial resources.

Table 2 presents the average funding per student of HPIs in China during the period. The funding per student on average nationwide grew from \$2,695 in 1998 to \$6,175 in 2017, though there had been a slight decline in the early 21st century possibly affected by the expansion of institutions. The average funding per student in all three tiers have experienced similar upward trends to \$13,147, \$5,804, and \$4,728 separately until 2017, with the top-tier universities had absolute advantage compared to the other two tiers. This suggested that training a student at top-tier health professional institutions in China usually costs up to ∼\$65,700 during the five years of undergraduate study. In addition, the average annual growth rate in the first-tier institutions reached 7.11%, which was significantly higher than its counterparts in tier 2 (4.5%) and tier 3 (3.4%) institutions.

Funding Disparities Across Health Professional Institutions in China

Figure 1 presents the Gini coefficients of the funding per institution and the funding per student in HPIs over years. Overall, both the Gini coefficient of the funding per institution and the funding per student had increased steadily from 1998 to 2000, after which they experienced a slow decline before they

TABLE 2 | Average funding per student by tiers of health professional institutions: 1998–2017.

Year	Total (US$ in thousands)	Tier 1 (US$ in thousands)	Tier 2 (US$ in thousands)	Tier 3 (US$ in thousands)
1998	2.695	3.560	2.513	2.492
1999	3.083	4.491	2.627	2.727
2000	3.274	5.674	2.601	2.692
2001	3.248	5.900	2.704	2.547
2002	3.125	6.035	2.548	2.434
2003	3.105	5.441	3.036	2.508
2004	3.027	4.989	3.108	2.531
2005	3.283	5.323	3.754	2.736
2006	3.372	6.104	3.451	2.732
2007	3.658	6.689	3.184	3.034
2008	3.743	6.893	3.218	3.099
2009	3.899	7.711	3.260	3.129
2010	4.384	9.209	3.821	3.439
2011	5.057	10.190	4.597	4.045
2012	5.017	9.981	4.812	4.008
2013	4.984	9.803	5.244	3.977
2014	5.734	11.825	6.304	4.395
2015	5.538	11.499	5.666	4.295
2016	5.619	12.275	5.871	4.277
2017	6.175	13.147	5.804	4.728

The funding per institution across years has been adjusted based on China's CPI index in the year 2017, and the Chinese RMB was converted to USD (1 USD ≈ 6.752 CNY) according to the exchange rate in 2017.

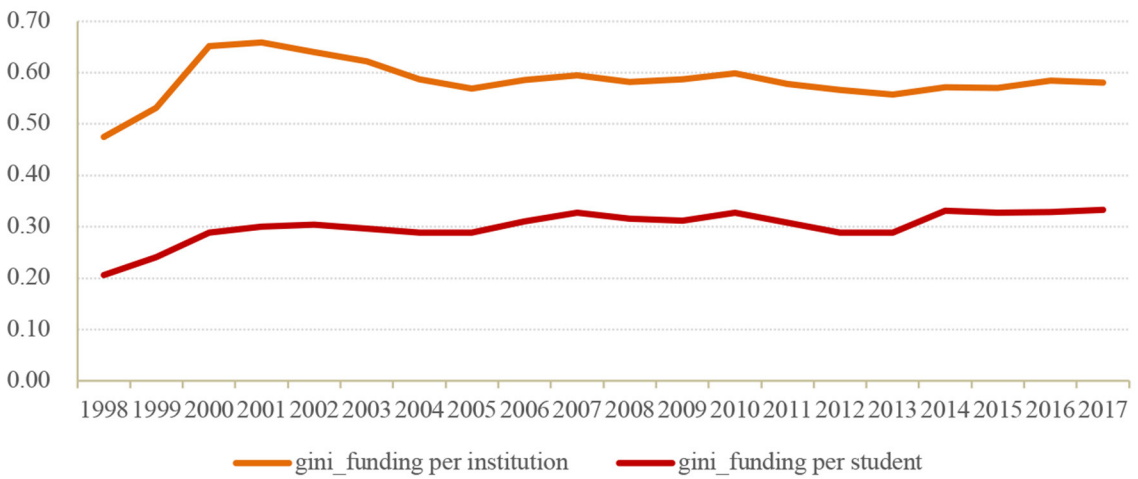


FIGURE 1 | Gini coefficient of funding per institution and funding per student among HPIs in China.

started to remain stable since 2005. The Gini coefficient of the funding per institution maintained to be over 0.5, while the Gini coefficient of the funding per student ranged approximately from 0.2 to 0.3, indicating that the distribution of financial resources among institutions were quite inequal, while the funding was relatively equally allocated among students in general.

Figures 2, **3** show the disparities in per institution funding in HPIs across tiers. According to **Figure 2**, the Gini coefficients in HPIs of the three tiers all experienced an overall decline regarding the funding per institution over years. In general, the financial resources were more equitably distributed within the top tiers of institutions, while the funding allocation among the lower-tier colleges and universities appeared to be more unfair. **Figure 3** further distinguishes the differences between the three tiers of the HPIs in question and the differences within each tier of institutions. The share of within-tier difference declined from 70.3% in 1998 to 22.1% in 2017, indicating that the differences in per institution funding were more distinct within each tier

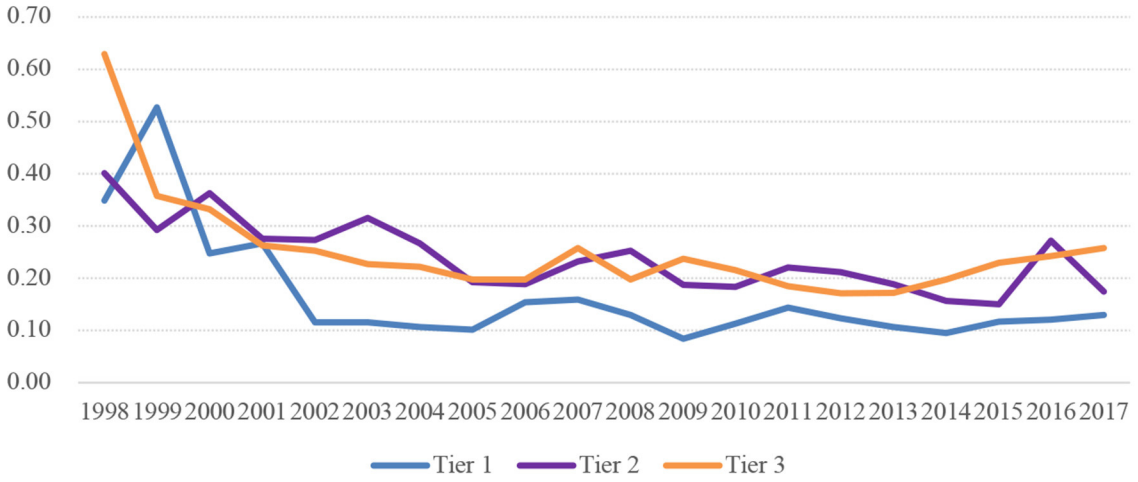


FIGURE 2 | Gini coefficient of funding per institution in HPIs of three tiers in China.

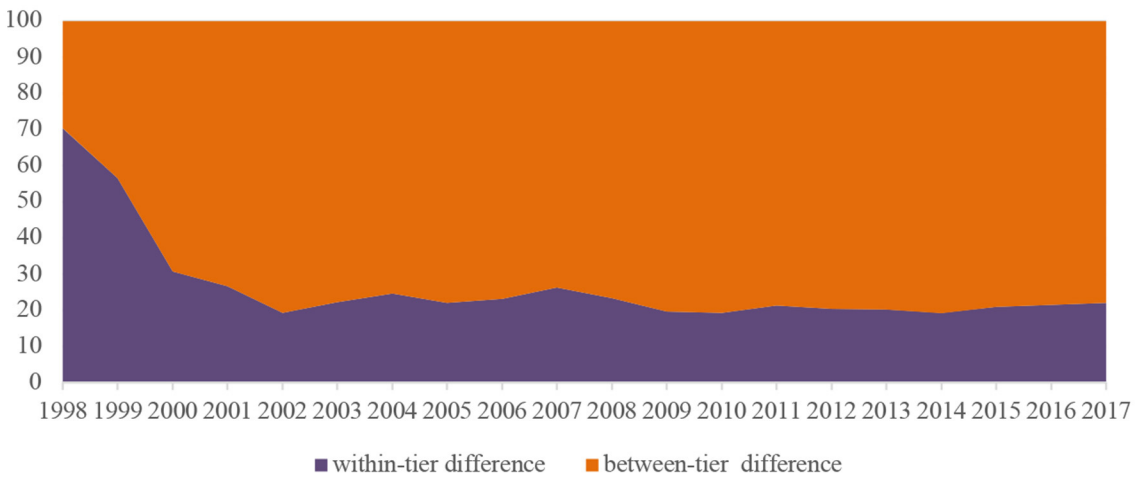


FIGURE 3 | Within-tier and between-tier differences in funding per institution among HPIs in China.

from 1998 to 1999, and since the expansion of higher education, the funding disparities were increasingly noticeable between different tiers after 2000.

Figures 4, **5** display the per student funding differences in HPIs across tiers. As shown in **Figure 4**, the Gini coefficient of funding per student across all levels of institutions has fluctuated over years ranging from 0 to 0.25, presenting a relatively fair layout in each tier of health professional institutions.

As for the shares of differences within groups and between groups, the difference of per student funding within groups witnessed a general decrease from 83.5% in 1998 to 49.7% in 2017, suggesting the stratification of HPIs has played an increasingly important role in explaining the disparities in the funding per student. Nevertheless, the difference within groups still accounts for a relatively large proportion, which can be attributed to the differences in the scale of institutions within the same tier (**Figure 5**).

DISCUSSION

A Move on the Financing Gaps in Health Professions Education in China

The descriptive statistics in our study showed that the number of HPIs and the average funding per institution of all tiers grew steadily between 1998 and 2017. This was directly related to China's college expansion since 1998. In order to promote economic growth, and achieve national quality improvement, the MOE in China implemented the *Educational Promotion Action Plan for the 21st Century* which rapidly expanded the enrollment in tertiary education (29). Meanwhile, the Chinese government has significantly increased the expenditure on higher education (20). As stated in a series of related regulations such as the Education Law (30), the growth of government funding support for education at all levels should overtake the regular budget of the same level, and the funding per student, as well as

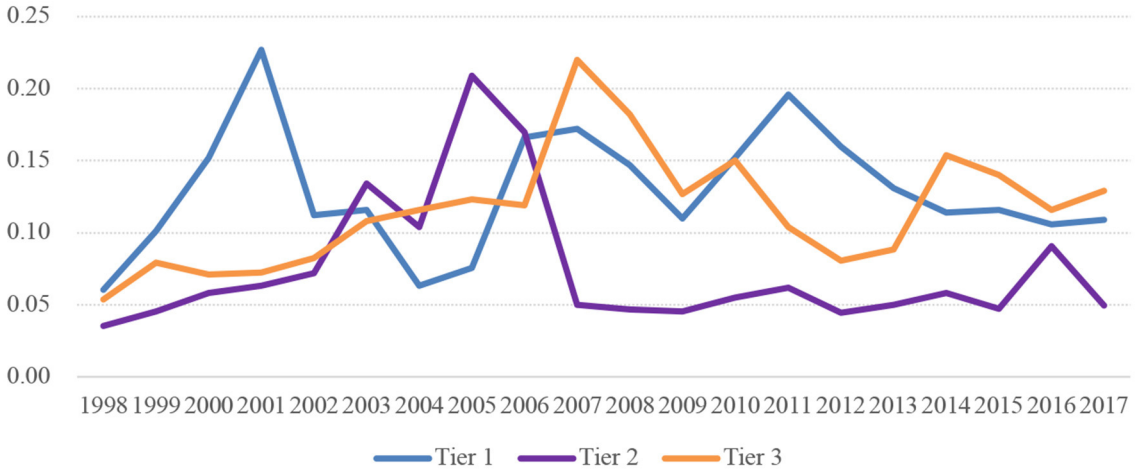


FIGURE 4 | Gini coefficient of funding per student in HPIs of three tiers in China.

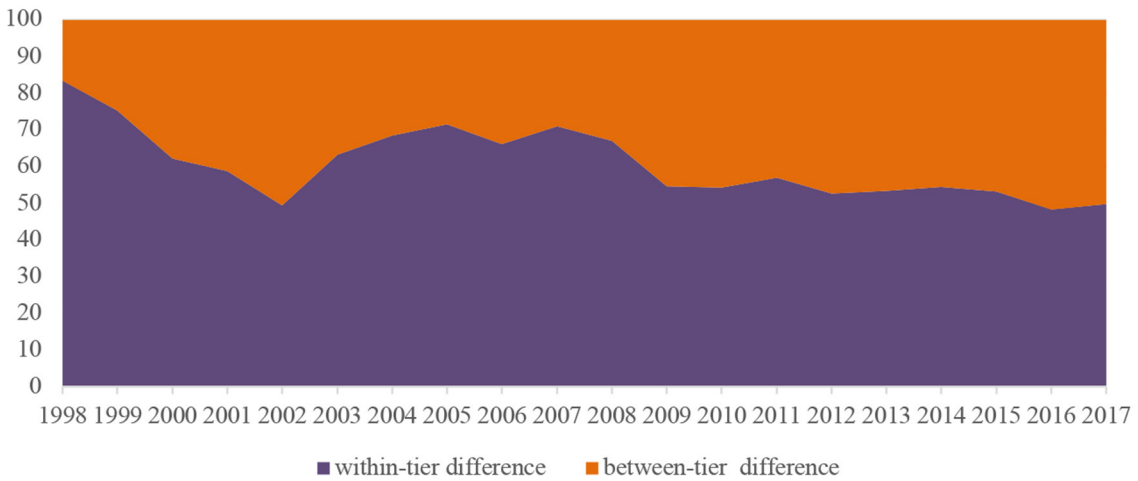


FIGURE 5 | Within-tier and between-tier differences in funding per student among HPIs in China.

the salaries for faculty, should increase gradually. Nevertheless, the rapid expansion in tertiary education in the first few years aggravated the financial burden of governments at all levels, which, regrettably but inevitably, led to the stagnation in the increase of funding per student (31). Although the funding per institution nationwide increased by 17.5 times from 1998 to 2017, the funding per student had only a limited increase of 1.3 times during the period. The basic structure of national higher education was not finalized until around 2008 (30), after which the enrollment numbers have gradually stabilized and the increase in per-student appropriation has gained momentum.

The Chinese government has always attached great importance to the development of the healthcare system and HPE, and have provided with policy guarantee for the year-on-year growth in medical finance. Particularly in the past decade, the Chinese government has established a mechanism of attracting funding through multiple channels in order to support HPE. By 2012, the central government had raised funding per health professional student to $4,000 (¥27,000 Chinese Yuan), reaching the highest standard of students' educational cost in various disciplines (32, 33). In 2014, the MOE pointed out that it was necessary to improve the multi-channel financing mechanism, coordinate the use of resources from all parties including the government, universities, hospitals, and society, and further increase funding in HPE (34). China has gradually formed a diversified pattern of finance on the basis of governmental appropriation and multi-channel funding. Indeed, the growth rate of per-student funding of HPIs in China has overtaken the average level of OECD countries (35).

Despite of the narrowing gaps in the finance of HPE with the developed countries and regions, China still needs to take more measures to further raise funding in HPE and attract more social capital to higher educational institutions. For instance, the average revenue per institution among the 84 fully-accredited

public medical schools of the Association of American Medical Colleges (AAMC) in 2017 amounted to $717 million (36), which was almost 3 times more than the 152 public HPIs offering diploma degree in China ($262 million). Taken the small enrollment scale of American medical schools into consideration, the gaps in funding per student may be even greater. It is gratifying that the Chinese government has made continuous and unremitting efforts in the investment of education by regarding the development of education as infrastructure construction, and the funding in education as a basic investment (29). In 2008–2009, the Chinese government shifted its focus from HPIs affiliated with the central government to local health professional institutions (37), which required further increases in both per-student funding and special funds in teaching (31). It has been advocated that the financial needs of HPE should be satisfied through three main sources, i.e., the investment of governments at all levels, the share in educational costs by individuals and social capital, and the support for school-run industries in self-financing. China will gradually establish a financial system for HPE that suits its national conditions as well as the status of health professional institutions.

Distinct Hierarchy in Health Professional Institutions in China

The results above indicated that the financial differentiation between tiers of HPIs gradually became more accentuated, while the funding gaps contracted within tiers. Concerning the structure of funding sources, the finance system of tertiary education relies mainly on governmental funding, supplemented by multiple channels including tuition, school-run industries, and social donations (20). As for the financing from the competent authorities, the funding of the first-tier universities usually comes from the central government, which is financially more abundant than local governments, especially after the implementation of the tax system reform in 2001. The second-tier universities have two main sources, i.e., the local government finance as well as the special funding from relevant ministries and commissions; and the colleges and universities at the third tier rely heavily on local governments. Considering that the economic development is unbalanced among different provinces and cities, and that local governments may shoulder the financing of multiple institutions, the non-*Project 211* HPIs receive only limited funding support, and their fiscal revenues are quite heterogeneous compared with the upper tiers (38, 39). Apart from governmental finances, tuition fees also play significant roles in the financing of higher educational institutions, and since the public institutions are uniformly priced in China, revenues from tuition fees may be different regarding the scales of institutions. In 2017, governmental funding accounted for 58.2% of the total financing, while tuition fees comprised 22.5%, with the remaining 19.3% from other sources. It should be noted that the financing excluding governmental funding and tuition for the three tiers of institutions accounted for 47.4, 21.6, and 12.9%, respectively, suggesting that it is more difficult for the lower-tier colleges and universities to obtain funds from other channels under the stratified structure. In addition, with regard to the geographic disparity of health education financing, the funds of medical schools in eastern China were significantly higher than the central part, leading to a distinct regional disparity nationwide (35).

The stratification of tertiary education universities in China has increased substantially after the initiation of *Project 211* and *Project 985* at the end of the 20th century. Those selected key universities, with outstanding academic accumulation and profound historical heritage and often located in the political or economic centers of administrative regions, have been obtaining both resource support and policy preferences. In return, the academic strengths and reputation of the upper-tier universities gradually became dominant, which necessarily attracted more non-governmental funding and social donations. Thus, the Matthew effect caused by the stratification of institutions has progressively widened the gap in funding between different tiers of institutions. The *Double First-Class* program with a broader geographical spread in 2015 marked a transition in the competition between institutions from an inherent identity mechanism to a more open competition mechanism. The *Double First-Class* program adopts a rolling elimination system with innovative indicators for evaluation and encourages more institutions to participate in competition and construction. All the colleges and universities should be evaluated every five years, and those which cannot reach the standards of first-class universities and first-class disciplines would be forced out. This, undoubtedly, will reduce the stratification of health professional institutions and strengthen their internal constructions.

Challenges and Opportunities of Stratified Health Professional Education Worldwide

The analysis in this paper provides an overall picture of finance for HPIs in China, which is of great importance for understanding the challenges and opportunities confronted by HPE worldwide. In fact, the decomposition of funding in the US higher education institutions from 2004 to 2017 also revealed increasing inequality in total expenditures and decreasing inequality in per-student funding (2).The stratified development in HPE has posed a severe challenge to the unified quality assurance for medical personnel training. Health professional institutions of lower tiers are disadvantageous in competitions concerning their scarcity of high-level talents, the lagging of comprehensive education reforms, and the limited capability to attract external resources. This will restrict their further development and progress, and the quality of their student training may also hardly be guaranteed.

Nevertheless, the stratification of HPIs in China can be regarded as intentional action to a certain extent. For developing countries as large as China, it is unrealistic to expect health professional institutions to cultivate students with uniform standards. The academic capabilities are inherently heterogeneous for HPIs of different tiers in different regions, which, definitely, would exert differential impacts on the quality of student output. Therefore, it is of practical significance to first give priority to the development of high-level institutions with limited resources, establish their exemplary role and then

facilitate the development of other levels of institutions. The progress of Chinese HPE has been widely acknowledged in the recent decades. According to Academic Ranking of World Universities published by Shanghai Jiao Tong University, 17 institutions in China were shortlisted in the top 500 in 2017, while only 6 were shortlisted in 2005 (40). The guarantee of the quality of personnel training in HPIs can directly promote the improvement of the quality of medical and health services. According to the Lancet ranking of 195 countries and regions in terms of medical quality and accessibility, China achieved a substantial leap with the ranking from the 110th in 1995 to the 48th in 2016. Moreover, China performs significantly better than the average level of middle-income and high-income countries in respect of the main health indicators of residents assured by medical and health services.

The hierarchical development of HPE can be regarded as an effective pathway for developing countries. It may allow certain key universities to take the lead in exploring effective ways of education reform and in establishing pilots for new policies and methodologies. In addition, students from those key universities can be regarded as outstanding talents to meet complicate needs of society. More importantly, the establishment of an open competition mechanism such as the *Double First-Class* program in China can reduce the solidification of the superior status for certain institutions and promote healthy competition by evaluating institutions regularly. In this way, stable development of HPE can be advocated by maintaining the competitive and cooperative relationship between different tiers of colleges and universities.

There were several limitations of this study. First, the paper explored the financing distribution among HPIs, which included not only independent colleges of medicine and pharmacy, but also comprehensive universities with medical-related departments; thus, the funding per institution might be overestimated. Meanwhile, given that students majoring in health professions usually have access to larger shares of financing resources compared to students of other disciplines (32), the per-student funding in our study may be underestimated. In addition, the HPE in our study mainly refers to undergraduate study, failing to take postgraduate study and continuing education into consideration.

CONCLUSION

This paper presents an overview of the education finance of HPIs in China over the span (1998–2017), and explores changes in the disparities among different tiers of institutions. The main conclusions are as follows: First, the number of HPIs in China has kept growing over the past two decades, with both the funding per institution and the funding per student increasing steadily. Second, the funding per institution as well as the funding per student in the top-tier institutions maintained to be much higher than those in the lower-tier institutions, while the gap has continued to be widened in recent years. Third, the school funding was more equitably distributed within each tier of institutions, with the Gini coefficient of each tier remaining under 0.3 over the past two decades; yet the share of between-tier difference rising from 29.7% to 77.9%, indicating that the disparity between different tiers become more dominant over years. In particular, the financial resources were more equitably distributed within the top tiers of institutions, while the funding allocation among the lower-tier colleges and universities appeared to be more unfair. In sum, the paper has proposed the need for increasing the per-student funding in China, and emphasized the probability of the stratified development of HPIs for developing countries and regions.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

HW, WG, and WL conceived the work. WG, WL, and YZ performed data analysis. WG, WL, and YZ were involved in manuscript writing. HW, YZ, and YZh were involved in manuscript revision. WG and WL contributed equally to this work. All authors contributed to the article and approved the submitted version.

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Trends and Innovations of Simulation for Twenty First Century Medical Education

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In the last two decades there has been an enormous growth in the use of clinical simulation. This teaching-learning methodology is currently the main tool used in the training of healthcare professionals. Clinical simulation is in tune with new paradigms in education and is consistent with educational theories that support the use of experiential learning. It promotes the development of psychomotor skills and strengthens executive functions. This pedagogical approach can be applied in many healthcare topics and is particularly relevant in the context of restricted access to clinical settings. This is particularly relevant considering the current crisis caused by the COVID-19 pandemic, or when trying to reduce the frequency of accidents attributed to errors in clinical practice. This mini-review provides an overview of the current literature on healthcare simulation methods, as well as prospects for education and public health benefits. A literature search was conducted in order to find the most current trends and state of the art in medical education simulation. Presently, there are many areas of application for this methodology and new areas are constantly being explored. It is concluded that medical education simulation has a solid theoretical basis and wide application in the training of health professionals at present. In addition, it is consolidated as an unavoidable methodology both in undergraduate curricula and in continuing medical education. A promising scenario for medical education simulation is envisaged in the future, hand in hand with the development of technological advances.

Keywords: simulation, healthcare, competences, COVID-19, medical education, public health

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INTRODUCTION

Medical education has experienced rapid changes worldwide (1, 2) in line with all present challenges. These changes emerged as the product of various problems, including the changing needs of the population and the multiple scientific and technological advances generated by the evidence-based accumulation of medical knowledge. The changing world of medical education, and the consolidation of new educational paradigms, demand the incorporation of innovative strategies (3). Medical education is at the center of these phenomena, since it must use the best educational strategies to transform inexperienced students into competent professionals. This permanent struggle has contributed to the emergence of new and innovative methodologies for teaching, learning and assessment.

Clinical simulation is an innovative methodology for medical education and has been developing rapidly in recent years. Gaba (4) defined clinical simulation as: "A technique, not a technology, to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner". Simulation allows teaching through guided experiences in safe contexts, facilitating adequate learning and standardized assessment of the skills necessary to face a changing world.

Herein, we summarized the history and context of clinical simulation, describing the current state of the art in this area, and suggesting future directions. This review aims to contribute to the formation of a new generation of health educators and professionals that would ultimately benefit patient treatment and public health. We searched PubMed, Web of Science and additional databases for publications, including original articles, systematic reviews and meta-analyses regarding recent evidence on clinical simulation and new developments in this area.

THE PAST AND PRESENT OF SIMULATION

Simulation began before the appearance of man because it is evident in nature, where mimicry is common. According to Jean Baudrillard, when mimicry occurs, it is possible to supplant reality. In 1911, Hartford Hospital used the first full-body simulator for nursing skills training and called it "Ms. Chase" (5, 6). The appearance of simulation is of capital importance in aviation training. Actually, the invention of the "Link Trainer" flight simulator was particularly useful for training thousands of pilots during World War II (7). Currently, the aviation industry uses simulation as a fundamental strategy for training its personnel, helping to build high safety standards (8). A simulator is more effective in training some piloting maneuvers and "no one could imagine using an aircraft to train today" (9). Observing at the practices used to minimize error in aviation can provide new options that can be used in health to reduce medical errors (10). Since the middle of the last century, several simulators have been developed for medical education, such as the Resusci Anne™, SimOne™, Noelle™, and SimMan™, which have increased the fidelity of the simulated scenarios and made them more realistic.

Simulation centers are located all over the world, including simulation hospitals or virtual hospitals that have the same equipment found in actual hospitals. This allows students to be trained and to requalify professionals who are already interacting with patients. Along this line, simulation is one of the key elements used in continuing education (11), aiming to maintain and improve previously acquired skills in conditions similar to the ones present in real environments. This approach has significant advantages over other methodologies because it allows the acquisition of skills in "knowing," "knowing how to do," and "knowing how to be" (12).

Scenarios used in simulation can be predictable, standardized, controlled, safe and reproducible. The, simulation allows training of skills needed for situations that occur infrequently, such as the management of cardio-respiratory arrests. The simulation scenarios are also repeatable, until an optimal degree of training can be achieved. This allows good performance in real clinical practice when an equivalent situation is faced. Repetition of the skill with adequate feedback allows for a high degree of training. Simulations may not be perfect and might not represent reality at its finest. Thus, it is relevant to generate a "fiction contract" and communicate and guide the student, so that this "lack of reality" does not affect future performance. Scenarios should be subject to constant review to ensure they are up to date and valid. One limitation of this methodology is the duration of a scenario, which is not equal to a real-life event. Therefore, the instructor's guide, the brief, and debriefing are key processes: the "transfer" of what the student has learned and its application to a real (and possibly stressful) situation.

The simulation provides immersive environments. Multisensory learning is possible with this modality, because intense emotions are involved in contexts of psychological safety and effective feedback, all of which allow long-term learning. This improves the efficiency of educational systems in relation to costs and training times. Engaging emotions could facilitate long-term learning, although the association between both aspects is not completely clear (13). Learning through emotion is advantageous to the acquisition of skills compared to other methodologies (14).

Currently there are several types of simulation ranging from training with part simulators for specific skills to training multiple and complex skills in immersive environments using strategies such as virtual reality, surgical simulation (15) and the use of standardized patients.

THE TYPOLOGY OF SIMULATION

The typologies allow adapting the simulation to different curricular levels and incorporate related variables, such as the competences to be achieved and resources, available. The simulations were initially classified as low-, medium- or high-fidelity. Fidelity is the degree to which the simulation mimics reality: the higher the fidelity, the greater the sense of realism. Low fidelity simulations are used for training on specific skills and in novice students who do not visualize the context. In that sense, the simulation should be based on small tasks from simple to complex (16). At medium fidelity, additional elements are added and some interaction with environmental "noise" or simulator signals are possible. In high-fidelity simulations, immersion is complete, and the setting of the scenarios are complex. High-fidelity simulations are useful for participants of advanced or competent levels who have already passed the training in parts. These simulations are used for training in more complex skills, such as clinical skills, communication, decision making, crisis resource management, and critical thinking (17).

There are also other typologies. Ziv et al. (18) proposed five simulation categories that are contextualized according to "tools." These categories are: (i) low-tech simulators or part-task trainers, (ii) simulated/standardized patients, (iii) screen-based computer simulators, (iv) complex task coaches, and (v) realistic patient simulators. Gaba (4) proposed a classification according to the available technologies: (i) verbal (role play),

(ii) standardized patients (actors), (iii) part-task instructors (physical; virtual reality), (iv) computer patient (screen-based, virtual world, etc.), and (v) electronic patient (replica of clinical site; mannequin-based; full virtual reality). Alinier (19) proposed a six-level classification system that ranges from the simplest simulations (level 0) to the most complex (level 5), which allows choosing the level according to the skills, the necessary resources, among other variables. The Boston Children's Simulator Program provides a useful guide to planning scenarios with five areas of increasing complexity: Zone 0: basic technical skills training; Zone 1: training of clinical competences; Zone 2: contextualized skills training in more complex/virtual environments, with a focus on clinical decisions; Zone 3: team building and multidisciplinary teams; and Zone 4: real life events.

THEORIES APPLICABLE TO SIMULATION

Adults have a plethora of previous experiences, they value that the learning of values is relevant and applicable to concrete situations (20), prefer problem solving, and possess internal motivation. The educational theories applicable to simulation are the theories described by Vytgosky, Kolb, Dreyfus and Drefyus, Posner, Schon, Bandura and Ericcson, among others. Vytgosky describes the concept of "Zone of Proximate Development," which establishes the progress that a student must have (21). David Kolb describes "Experiential Learning" (20). Dreyfus and Dreyfus describe the existence of skill acquisition levels, from novice to expert (16). Posner establishes consecutive phases for the acquisition of skills (21). For Schon, the reflection on the practice is relevant (21). Bandura presented his theory of self-efficacy, which consists of the perceived capacity of the person to carry out a task. In this way, the greater the perception of self-efficacy, the higher the success rate (22). Ericcson states that the repetitive practice of an activity leads to the acquisition of skills (23). The cognitive load theory establishes that working memory has a limited capacity, and that excess cognitive load is counterproductive for learning (24). The theories described above provide a basis for the concrete and practical application of simulation, how learning occurs, how to insert simulation into the curriculum and how to graduate the complexity of the scenarios.

Simulation is an "active" learning methodology, because it involves the participation and observable actions of the student. In the adult student, active participation increases the effectiveness of learning (20). In simulations, the student interacts with basic or complex simulators, or with standardized patients (which simulate pathologies and allow communication or anamnesis), or they can interact with other students or health professionals, allowing teamwork.

In deliberate practice, the skill is repeated in relation to predefined objectives to achieve a high degree of mastery. The key aspects are setting clear, pre-set goals and then making the student to repeat the tasks to improve specific skills. Students receive feedback on their performance. Rapid Cycle Deliberate Practice (RCDP), is used for training specific skills, and involves repetitive practice of increasing complexity, with an emphasis on real-time error correction (25).

The simulation must be based on adequate teaching practices to reach the desired impact (26, 27). These are: having defined goals, giving effective feedback, offering repetitive practices, integrating simulation into the curriculum, having different levels of training and multiple learning strategies, offering clinical variation, having controlled environments, and having individualized learning. Besides, the use of standardized checklists is key to facilitate training and to propitiate appropriate transfer to actual clinical situations (28).

THE IMPORTANCE OF DEBRIEFING IN MEDICAL SIMULATION

The debriefing corresponds to the systematic reflection on experiences during the simulation (29). Debriefing transforms the experience into learning through reflection (30). According to Kolb (20), when people experience situations (concrete experience), they must reflect on the lived situation, then form abstract concepts and finally test what they have learned in the new situations. The debriefing allows re-examination of the experience (31), and is carried out according to a pre-defined method with certain rules. The debriefing takes place immediately after the experience and is not only applicable to simulation, but also to real clinical experiences. Therefore, reflection is essential, and when carried out in a systematic way, successful results are obtained.

Various types of debriefing are described in the literature. Typically, they are carried out in three phases: Reaction, Analysis and Summary (29). Steinwachs also describes 3 phases: Description, Analogy/Analysis and Application (32). The Center for Medical Simulation (33) describes the three phases as: Reactions Phase, Comprehension Phase and Application Phase. The "D.E.B.R.I.E.F." model establishes a mnemonic to guide debriefing: *D*efine rules, Explain learning objectives, Bench marks for performance, Review what should happen, Identify what happened, Examine why, and Finalize/formalize learning. In the "3D Model," three phases are also proposed: *D*efusing, Discovering and Deepening (29, 34) and the "GAS method" proposes: *G*ather, Analyze and Summarize (29). Recently a type of debriefing that we know as CORE Debriefing has been introduced, which has 4 phases: *C*ompression, Observation, Reflection and Exchange.

The "debriefing with good judgment" approach is a form of debriefing in which the instructor's goal is to understand the students' point of view, to determine how their mental models produce actions that translate into their performance (double loop). The instructor assumes a quota of curiosity and can issue his judgment in a respectful and constructive way- from the observation perspective of the specific events that occurred during the scenario ("good judgment") (33). In this style of debriefing, the thought processes of the students are crucial: it is important to elucidate the reason behind one decision or another, exploring the mental models of their choice, beyond the students' performance (33).

CURRENT TRENDS AND INNOVATION IN SIMULATION EDUCATION

Virtual reality has posited a significant increase in simulation education; however, its effectiveness is not overwhelming (35–40). Simulation has a positive impact on various training areas, such as work in clinical teams (41), improvement in surgical skills (42–47), in ophthalmology (48), in specific health techniques (49–52), critical care (53), pediatrics (54), resuscitation (55), medical emergencies (56), microsurgery (57), anesthesia (58), and nursing (59–61). Training through "Low-Dose and High Frequency" settings can be effective for CPR training (62, 63). The use of standardized patients is common in simulation and has a positive impact on interprofessional education (64). Although its use is frequent in continuing education, there are not many reports describing its effectiveness (65). The interprofessional simulation has a good perception according to some reports (66). Regarding the impact of simulation training on the quality of patient care (translational studies), research must be developed further and grow in number. Currently, there is no evidence to elucidate a strong impact of simulation education on this specific matter (44, 45, 50, 58, 67–70).

There is a wide field of development and validation of new simulation areas. Importantly, this is increasingly being incorporated into the education curriculum. *In situ* simulation is gaining importance for training in real environments and to encourage teamwork (71–74), which must be contrasted with its real effectiveness in certain contexts (73, 75). Surgical simulation emerges as an important development pole (76) while its use in previously unexplored areas such as psychiatry gains relevance (77). The validation of simulation programs is increasingly important, as well as the knowledge of how it impacts patient care (76). Simulation allows for the evaluation of competences. These mechanisms grow in validity and reliability and methods such as OSCE, OSATS, mini-CEX, and DOPS are consolidated. It is important to note that these assessments synchronize with teaching methods and that they should be properly integrated into the curriculum (78). Telesimulation has taken an important place, especially after the COVID-19 pandemic. Specifically, it consists of linking an instructor and a student who are geographically distant through the Internet. It is estimated that this modality has a positive impact on the acquisition of skills in various environments (79, 80); a simulation center or a clinical center with *ad-hoc* technology can provide distance training to centers with less technology (68, 81), and where distance is an impediment. This strategy allows remote evaluation and feedback (68, 80). Although there is a sustained increase in systematic reviews and meta-analyzes in relation to simulation, there is still work pending in terms of improving the methodological designs of the investigations.

IMPORTANCE OF SIMULATION EDUCATION DURING THE COVID-19 PANDEMIC

Universities worldwide announced immediate closures to prevent the spread of the virus, allowing their students to complete the semester remotely (82). This crisis imposed the need for virtual learning. To minimize disruption to teaching and assessment, some universities have replaced face-to-face classes with virtual ones. Unfortunately, this outbreak widens the gap between countries with technologies and support compatible with online learning and those the lack of these technological resources. Even at the same university, and in the same class, many students suffer from unequal access or lack digital connections (83). Maintaining performance standards and quality assurance are unprecedented challenges in pandemic conditions for most universities.

Simulation has become an important tool in meeting the challenges posed by COVID-19 (84). The simulation was necessary for the training and requalification of clinical teams in the face of the pandemic ("first line"), for example in crisis resource management, orotracheal intubation, mechanical ventilation, and the use of personal protective equipment (85).

Undergraduate education was affected by the inability to attend classes in person (80, 86). Keeping students engaged and up to date with the curriculum is especially challenging when they must learn practical subjects remotely. In our experience, a live streaming classroom using HD quality cameras, improved interaction and ensured remote participation of students to the same standard as face-to-face classes.

Virtual simulations increased, with successful implementation (87), and their impact is under evaluation. Using simulation-based platforms, it is possible to perform case-based scenarios online and run virtual OSCEs from anywhere in real-time. The virtual OSCE could offer a suitable platforms to address evaluation options (88, 89). Besides, this type of simulation allows the promotion of skills for decision-making in healthcare.

CONCLUSION

Clinical simulation has made important contributions and is currently a valid and increasingly common option for medical education. Its multiple strategies make this approach useful to meet or overcome multiple challenges (90). In this way, simulation can be transformed into a powerful strategy to appropriately train health professionals to effectively address the challenges of today's changing world.

A positive impact of simulations in the training of graduates working in clinical environments is to reduce the risks by allowing professionals to prepare and anticipate complex clinical situations (17). A recent systematic review shows that *in situ* training improves patient outcomes, such as reduction in cardiac arrest rates or increase in incidence reporting rates (91). Still, few articles focus on patient outcomes as a measure of improved clinical competency, while most studies center on the skill's progression (91). Learning through simulation is frequently used in undergraduate degree curricula. Shortly, the simulation will be mandatory before confronting the patient. Likewise, real clinical experiences will give way to more simulated practical situations.

Simulation can be used in both undergraduate and postgraduate education, from simple situations such as suture training or an IV puncture, to medical interview training, or difficult situations such as emergencies or crisis resource management. The systematic implementation of simulation

has advantages over other methodologies because it allows for greater efficiency in the educational process and also brings the clinical reality closer to the trainee without putting a patient's health at risk.

Simulation is a fundamental strategy for current and future challenges in medical education. The simulation has multiple strategies based on educational theories that allow effective learning. It should be convenient that all health professional training institutions adopt the simulation strategy and that health centers incorporate education through simulation for the continuous training of their professionals in interdisciplinary contexts. Systematic simulation training programs should be conducted to incorporate best practices. Finally, it is very convenient for health centers to train their teams frequently, for example, on a monthly basis incorporating deliberate practice, feedback and debriefing.

AUTHOR CONTRIBUTIONS

EH-A wrote the manuscript. LE wrote and edited the manuscript. All authors contributed to the article and approved the submitted version.

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REVIEW
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Association of Healthy Diet and Physical Activity With Breast Cancer: Lifestyle Interventions and Oncology Education

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Global cancer statistics suggest that breast cancer (BC) is the most diagnosed cancer in women, with an estimated 2. 3 million new cases reported in 2020. Observational evidence shows a clear link between prevention and development of invasive BC and lifestyle-based interventions such as a healthy diet and physical activity. The recent findings reveal that even minimal amounts of daily exercise and a healthy diet reduced the risk of BC, mitigated the side effects of cancer treatment, and stopped the recurrence of cancer in the survivors. Despite the myriad benefits, the implementation of these lifestyle interventions in at-risk and survivor populations has been limited to date. Given the need to disseminate information about the role of physical activity and nutrition in BC reduction, the review aimed to present the recent scientific outreach and update on associations between the lifestyle interventions and BC outcomes to narrow the gap and strengthen the understanding more clearly. This review covers more direct, detailed, and updated scientific literature to respond to frequently asked questions related to the daily lifestyle-based interventions and their impact on BC risk and survivors. This review also highlights the importance of the oncology provider's job and how oncology education can reduce the BC burden.

Keywords: breast cancer, diet, physical activity, oncology education, lifestyle

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INTRODUCTION

Breast cancer (BC) is a growing global public health concern. Although many high-income countries have reported decreases in BC mortality due to the advances in treatment, diagnosis, and implantation mammographic screening (1), BC mortality is steadily increasing in most developing countries due to low health knowledge and limited medical facilities (2–4). According to the recent reports, ∼2.3 million new cases of BC are diagnosed each year, with a mortality rate of roughly 4,50,000 per year (5, 6). The leading risk factors for BC include age, genetic mutations (BRCA1 and BRCA2) (7), lifestyle-based (non-genetic) risk factors (8), early menarche, nulliparity, first pregnancy after the age of 30 years, older age at menopause, dense breast tissue (9), hormone replacement therapy (10), use of oral contraceptives (11), personal and family history of BC, and other clinical complaints (12, 13).

In cancer education, it is challenging but fundamentally important to accurately evaluate the role of modifiable risk factors, such as diet, physical activity, and other non-genetic factors, to estimate BC risk for individual women—the first essential step toward precision prevention.

Evaluating the complex interaction between diet and physical activity and better BC outcomes resulted in a significant reduction in BC incidence and enhanced survival rates (14, 15). Substantial evidence underlines the importance of a balanced diet and increased physical activity to prevent BC and reduce the chances of recurrence and mortality in both pre- and post-menopausal women (16, 17). Currently, exercise and nutrition are considered as two integrative therapy components that play a crucial role in relieving the side effects of active cancer treatment and especially cancer-related fatigue (18). The World Cancer Research Fund recommends specific guidelines of moderate aerobic exercise for muscle strengthening and nutrition, that is, eating more plant-based foods, limiting red and processed meat, limiting energy-dense foods, salt, sugary drinks, and alcohol, and not relying on dietary supplements (19). The published literature has elaborated on the role of physical activity in improving fitness, reducing psychological distress, and enhancing cognitive abilities (20–24), whereas nutritional consultations may help manage challenges associated with anemia, diarrhea, nausea, and vomiting which contribute to cancer-related fatigue (25–27).

Strategies are needed for disseminating literature on the association between BC and physical activity and nutrition. Thus, this review summarizes and reviews the evidence linking lifestyle factors—especially diet and exercise—to BC risks and outcomes. The purpose of this narrative review is to present recent scientific outreach and update on associations between the lifestyle interventions and BC outcomes to narrow the gap and strengthen the understandings more clearly. In comparison with the published studies on the subject, the current review covers more direct, detailed, and updated scientific literature to respond to frequently asked questions related to the daily life style-based interventions and their impact on BC risk and survivors. This review also highlights the importance of the oncology provider job and how oncology education can reduce the BC burden.

SEARCH STRATEGY AND SELECTION CRITERIA

We performed a literature search using the different search databases, PubMed, Google, Google Scholar, and Research Gate with the key words of BC,physical activity, exercise, diet, food menu, and other related terms. In addition to the relevancy of the title and abstracts, for strong conceptual and logical understanding, more recent studies were selected for inclusion based on the year of publication between 2016 and 2021. Though minor older publications and some news agencies, government data reports were also cited to strengthen the subject's background. All selected articles have been cited accordingly.

DIETARY FACTORS IN BC INCIDENCE AND RECURRENCE

Adhering to a healthy lifestyle in terms of high-quality food intake influences the risk of BC onset and post-diagnosis outcomes. Epidemiological and preclinical data suggest that some food and nutrients (e.g., saturated fats, red and processed meat) increase the circulating levels of endogenous estrogens, insulin-like growth factors, and pro-inflammatory cytokines, thus supporting BC development. In contrast, polyunsaturated fatty acids, vitamins C and E, fresh fruits, and vegetables have protective effects against BC onset or progression (28, 29). Several studies report an inverse relationship between BC and the Mediterranean diet. However, there is insufficient information to date to confirm the interplay of diet and BC incidence and mortality (30–33).

Fruits and Vegetables

Fresh fruits and vegetables are known as natural antioxidants. Their routine consumption increases the consumer polyphenols and fiber level in the body, which provides resistance against tumorigenesis (34–36). Polyphenols have the potential to modulate the proliferation and metastatic activity of BC by regulating the cellular signaling pathways and inhibiting the enzymatic activity of tumor-supportive proteins such as the transcriptional factor NF-B (**Figure 1**) (37–39). Polyphenols can also antagonize the estrogen-signaling pathway by inhibiting aromatase and the production of estrogen or blocking the estrogen receptors (ERs) (40–42). A similar mechanism has been observed in fibers to prevent carcinogenesis by binding estrogens and reducing their serum levels or by improving insulin sensitivity and reducing weight gain (43, 44). Furthermore, the European Prospective Investigation into Cancer and Nutrition (Italian) study showed an inverse association between high consumption of fruits and leafy vegetables, which include raw tomatoes, and BC risk (45). However, available evidence suggests that further exploration is needed.

Red Meat

When red meat is cooked at high temperatures, carcinogen compounds such as heterocyclic amines, N-nitroso compounds, and polycyclic aromatic hydrocarbons are released, which potentially mediates the onset of BC (46–48). These compounds, especially heterocyclic amines, are involved in breast tissue-specific estrogen-based carcinogenic activity and support BC progression (49, 50). In other studies, researchers proposed that consuming processed red meat increases free radicals that are further involved in inducing lipid peroxidation (51, 52). Consumption of unprocessed red meat is thought to carry a 6% higher BC risk than not consuming such foods, whereas processed meat consumption is associated with a 9% higher BC risk (53, 54) due to higher levels of heme iron. The complete avoidance of meat is not usually advocated because it is a source of nutrients, such as proteins, iron, zinc, and vitamin B12. The evidence of its role in BC is inconclusive. However, suggestions to limit consumption of processed red meat are almost undoubtedly well-founded.

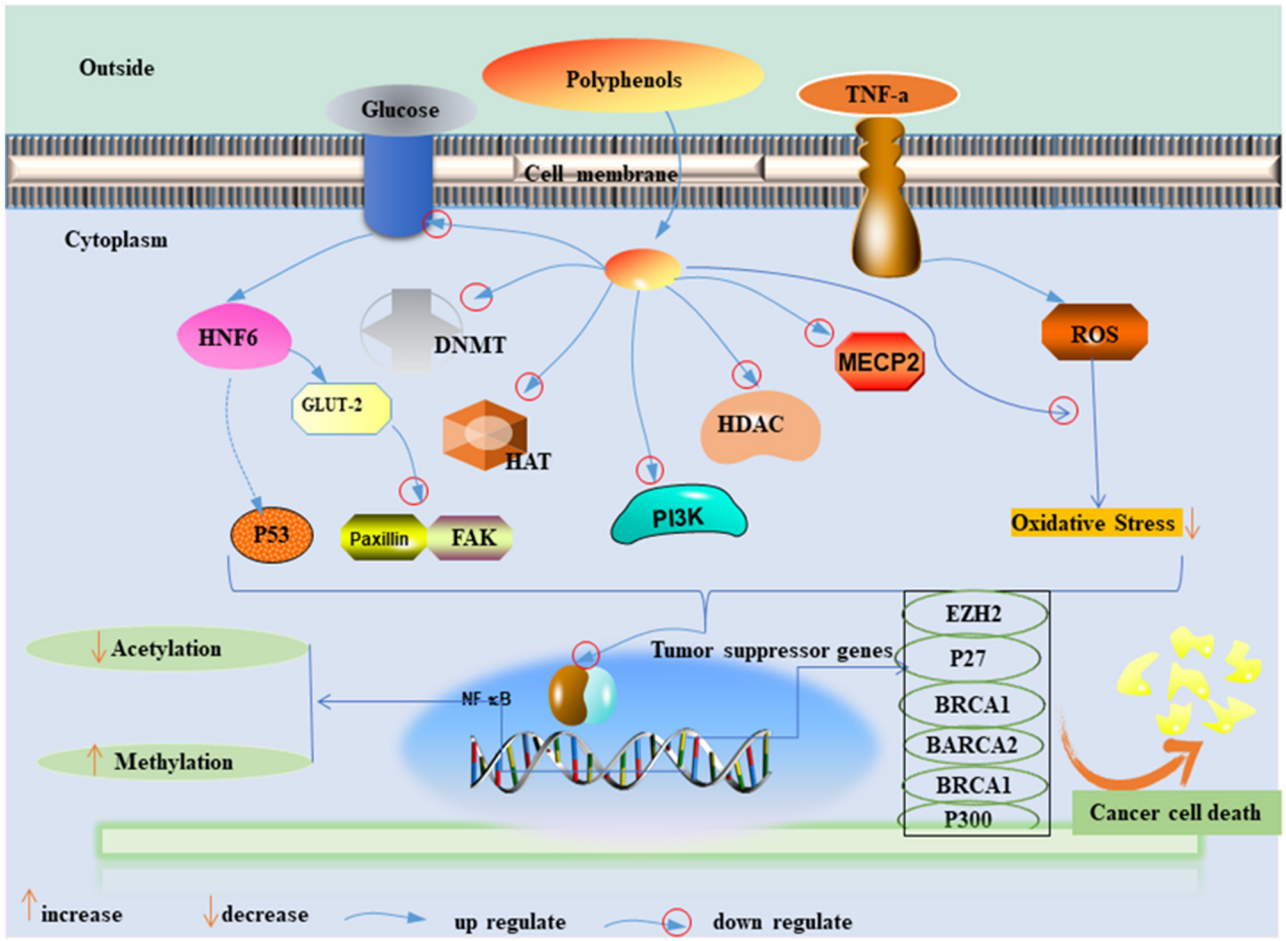


FIGURE 1 | Possible mechanisms of polyphenol effect on the inhibition of BC cell proliferation. PI3K, phosphoinositide-3–kinase; TNF a, tumor necrosis alpha; ROS, radioactive oxide species; NF-κB, nuclear factor kappa light chain enhancer of activated B cells; DNMT, DNA methyltransferase; HAT, histone acetyltransferases; HMT, histone methyltransferases; HDAC, histone deacetylases; GLUT-2, glucose transporter-2; MeCP, methyl CpG binding protein; EZH2, enhancer of zeste homolog 2; BRCA1, 2, breast cancer 1, 2; HNF- 6, hepatocyte nuclear factor 6; FAK and paxillin, two focal adhesion–associated proteins.

Dietary Fat

Menopausal status affects the influence of dietary fat consumption. Dietary fat poses a higher risk of BC in post-menopausal women, whereas for pre-menopausal women, dietary fats appear to have a protective effect (55). A recent study indicated that a high saturated-fat diet increases the risk of BC and, most conspicuously, of receptor-positive cancer, particularly ER+ (56). Cancer science suggests that dietary fats can influence the process of carcinogenesis by modulating intracellular signaling cascades (57). Although a high-fat diet, total cholesterol, and triglyceride levels have mostly been associated with increased risk, the evidence is limited.

Carbohydrate

Associations between BC and carbohydrates have been evaluated using the quality of the glycemic index (GI) and glycemic load (GL). The results are contradictory and inconclusive (58–61). A metadata study indicates that higher GI is associated with increased BC risk in post-menopausal women, but no effect was found in pre-menopausal women (62). Similarly, positive associations between GL and ER base and BC risk in post-menopausal women were explored in another study. The findings suggested that GL might increase the serum insulin that further mediates BC onset (63, 64). Whereas, the association between carbohydrate intake, GI, or GL and overall BC risk requires further research, glycemic control is advisable.

Red Wine Drinking

Red wine drinking is a prominent and modifiable lifestyle risk factor for BC. Some studies provide robust evidence that alcohol intake, regardless of the type of beverage (beer, wine, or spirits), and menopausal status are consistently associated with increased BC risk. A dose–response meta-analysis showed that 10 g of ethanol consumption in a single day contributed to a 5% increase in BC risk for pre-menopausal women and a 9% elevated risk for post-menopausal women (65). The findings

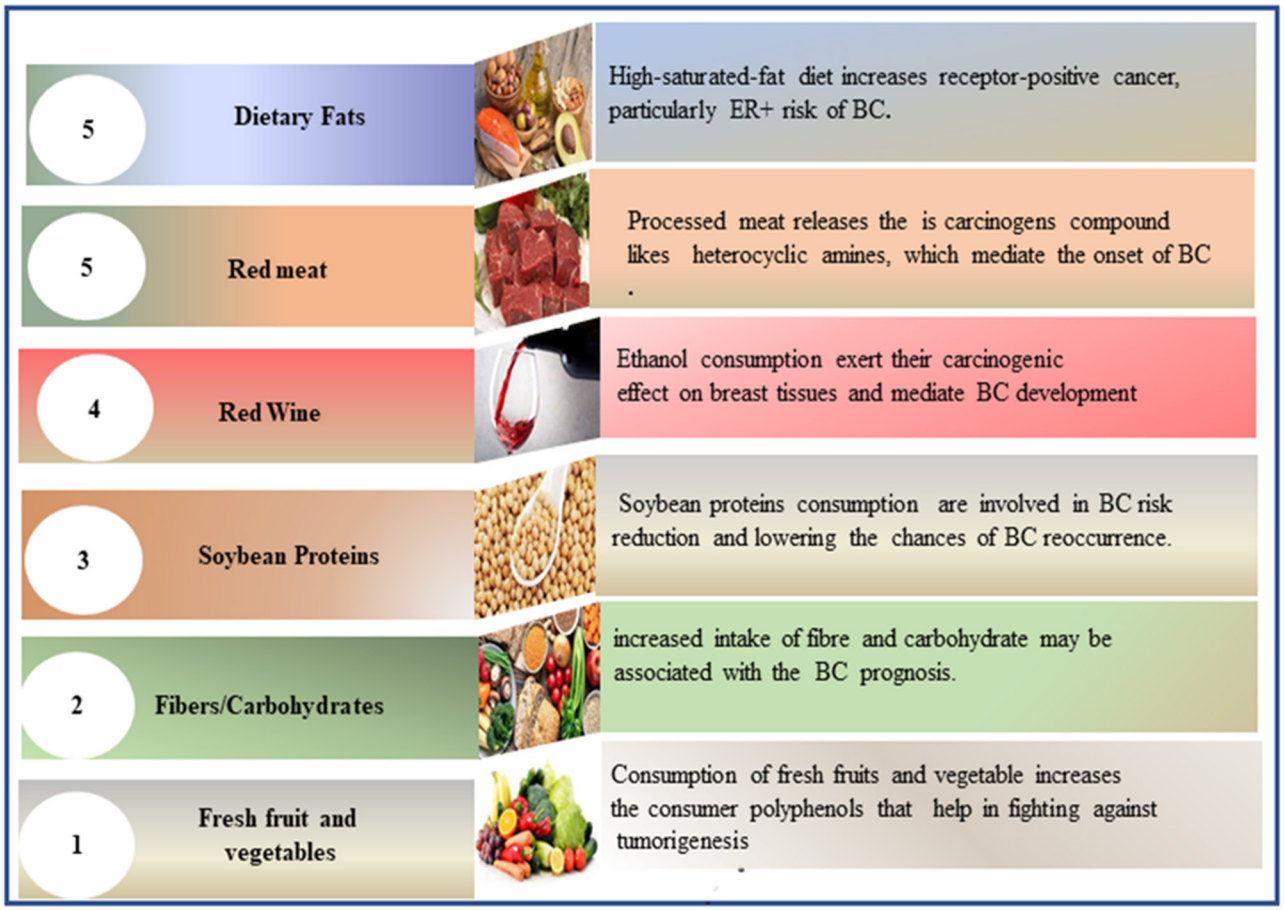


FIGURE 2 | Figurative description of dietary factors involved in BC incidence prevention and recurrence. BC, breast cancer.

reveal that ethanol's association with BC development is due to its ability to promote epithelial–mesenchymal transition, tumor growth, and metastasis formation (66, 67). Ethanol consumption causes an increase in estrogen concentration *via* different physiological mechanisms, for example, increased aromatase activity, prevention of estrogen breakdown, reduction of melatonin secretion, and increased hepatic oxidative stress that allows estrogen to exert its carcinogenic effect on breast tissue (68).

Soy

Soy is considered an optimal alternative to high-calorie protein sources such as meat. It contains soy isoflavones (known as phytoestrogen) and soy proteins (69). Research reveals that high levels of isolated soy proteins increase insulin-like growth factor 1, which may contribute to BC recurrence (70). The clinical findings indicate that soy protein isolate supplementation slightly stimulates epithelial BC in pre-menopausal women (69, 71). Prospective cohort studies that investigate the role of soy in BC risk reduction and its influence on BC recurrence and mortality rates yielded different results, often in support of soybean protein consumption (72–74). Thus, the relationship between soy consumption and BC remains unclear. **Figure 2** provides a figurative description of dietary factors in BC incidence prevention and recurrence.

Physical Activity and BC

Physical activity has been considered a protective tool against BC since 1980, and the past two decades have witnessed many studies addressing the connection between physical activity and BC (75–77). Several studies have depicted the association between daily physical activity and better health outcomes which further reduce the risk of lifestyle-based risk factors for cancer (75, 78–81). The findings have revealed that physical exercise also lowers the chances of recurrence and is associated with a longer life expectancy in survivors (75, 82, 83). Although there is no direct link between physical activity and cancer risk reduction, however, the multiple interconnected physiological processes, which include sex hormones, insulin resistance and insulin levels, inflammation, oxidative stress, and adipokines, are believed to be involved in lowering the risk of tumorigenesis (84–86). Identifying the processes by which physical activity affects BC risk demonstrates biological plausibility for the observed link and provides evidence for the optimal exercise prescription

for cancer risk reduction (15). Furthermore, understanding the exercise and BC link may provide fresh insights into cancer biology, which aids in developing additional preventive and treatment strategies for cancer (86). A more precise understanding of the nature of the association by type, dose, and timing of activity is needed to formulate public health recommendations regarding the association between physical activity and BC risk.

PHYSICAL ACTIVITY AND BC PREVENTION

Researchers have well-explored the essential role of exercise in BC prevention and recurrence (87, 88). According to the World Cancer Research Fund/American Institute Cancer Research project findings, higher levels of physical exercise, with a dose–response connection, reduced the incidence of post-menopausal BC (89). In 2020, Physical Activity Guidelines for Americans from the American Cancer Society also advocated leads a physically active lifestyle to prevent and control BC (90). Physical activity influences cancer risk in several ways, which includes metabolic (calorie balance), hormonal, and immunological responses (91–93). Moore et al. analyzed data from the prospective US and European cohorts with self-reported physical activity measurements to evaluate the link between physical activity and the incidence of 26 different cancers. They concluded that physical activity levels are linked to a decreased risk of 13 malignancies, including BC (94). However, the current understanding of important levels of physical activity and their inverse relationships in patients with ER-negative BC needs further exploration. To address the challenges of women's lifestyle interventions and encourage them to be more physically active to lower their BC risk, many healthcare professionals employ technology-based interventions to raise daily physical activity levels (95–97).

PHYSICAL ACTIVITY AND BC RECURRENCE AND SURVIVAL

Regardless of menopausal status, physical activity plays a significant role in reducing the onset of BC and supports survivors to overcome the disease. However, exercise has a more beneficial impact on pre-menopausal women (98, 99). Similar results were reported in a large-scale dose–response relationship study. Findings confirmed the association between physical activity and lowered risk of BC recurrence and increased survival rates. Furthermore, women with ER-positive tumors benefit the most from exercise (93, 100). However, the clinical oncologists can design the particular exercise program and prescription for women. There are three distinct study phases with different exercise prescriptions, which include treatment phase (three times per week for the length of chemotherapy, plus radiation, if received), post-treatment phase (two times per week for the following 10 week), and maintenance phase (one time per week for an additional 10 week) (101). Similarly, in a recent study, it has been found that a supervised therapeutic exercise program plus patient therapeutic education can significantly reduce the perceived fatigue and increase functional capacity in BC survivors suffering from cancer-related fatigue compared to an unsupervised physical exercise program based on individual preferences with patient therapeutic education (102). Taking all together, these findings suggest that physical exercise is a simple, cost-effective way of mitigating BC risk that could affect the outcome of millions of women with BC.

BREAST CANCER TREATMENTS

Based on the presence and absence of molecular markers on the plasma membrane of breast cells, BC is categorized into three major subtypes (i) estrogen and progesterone receptor-negative BC (HR-), (ii) human epidermal growth factor 2 (ERBB2) receptor BC, and (iii) both hormonal and growth factor negative (TNBC) (103). Totally, 90% of BC is not metastatic at diagnosis (104). All patients with non-metastatic BC are recommended to undergo local therapy that consists of surgical resection and consider postoperative radiation if lumpectomy is performed. However, patients are advised to undergo systemic therapy before surgery (105, 106). All metastatic BCs are treated according to their subtype with the ultimate goal of prolonging life and palliating the symptoms. Treatments of the 3 BC subtypes have distinct risk profile strategies. Optimal therapy for each patient depends on tumor subtype, anatomic cancer stage, and patient preferences (107). **Figure 3** describes the different treatments according to the type of BC.

WHICH LIFESTYLE MODIFICATIONS SHOULD BE ENCOURAGED?

Analysis of critical findings indicates that lifestyle factors, especially diet and physical activity, have the most robust effect on BC outcomes. A trial-based study showed that adapting routines to include 75 min of vigorous exercise per week and 2–3 weekly strength-training sessions can help to reduce the risk of BC recurrence and mortality (110, 111). To modify lifestyle-related health, these studies appeal to all healthcare professionals to promote and encourage exercise in BC survivors, as receiving advice from an oncologist to exercise will increase patients' physical activity levels (112). Considering the impact of primary care in BC risk reduction and prevention, oncologists should recommend and endorse specific exercise programs and non-pharmaceutical treatments.

Clear referral pathways need to be established, so that patients can be directly referred from a cancer care clinic to community-based exercise programs specialized for cancer survivors. Such community-based exercise programs can change individuals' daily routines and result in significant behavioral changes. These interventions can be supported using electronic gadgets or musical instruments for indoor activity, and self-motivation and enjoyment can also be increased through reminders or tracking activities on phones or email (**Figure 4**) (113). Women who participated in an aerobic

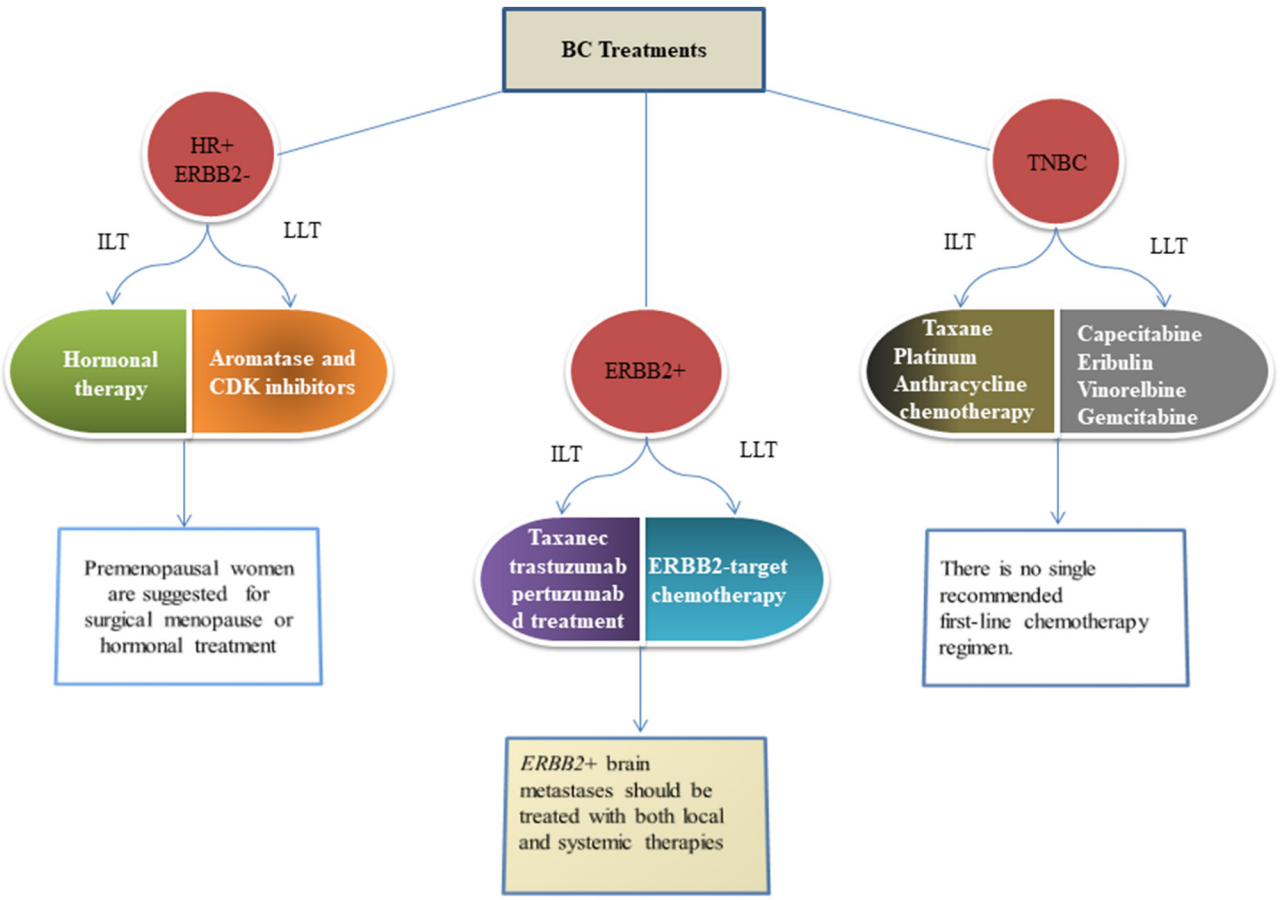


FIGURE 3 | Figures give the recommended standard approaches to therapy of metastatic BC as per the guideline of the American Cancer Society. These recommendations are adopted in (108) and are given as per the guidelines of the National Comprehensives Cancer Network (109). HR, Hormonal receptor; ERBB2, Epidermal growth factor-2; TNBC, Triple negative breast cancer; ILT, Initial line of therapy; LLT, Later line of therapy.

exercise program while receiving adjuvant chemotherapy did not gain weight on average, whereas those who did not exercise gained 3.2 kg (114). In addition, exercise advantages include significant self-perceived improvements in attractiveness, cardiorespiratory fitness, lymphedema, and mental wellbeing (115).

While being overweight or obese at the time of diagnosis has a detrimental impact on BC prognosis, it is uncertain if losing weight improves the prognosis of overweight and obese women. To enhance overall survival—and perhaps BC-specific survival—patients should be strongly encouraged to quit smoking (116). Along with physical activity, there is a need to encourage an anticancer diet to help survivors reduce risks. Excessive consumption of western-style diets (high in processed grains, processed meats, and red meats) should be avoided as they are associated with increased rates of BC recurrence (117, 118). There is an association between BC and saturated fat, especially from high-fat dairy products, which may increase BC mortality (119–121). Soy products have not been found to increase BC recurrence and may even reduce it (122, 123).

IMPLEMENTING PHYSICAL ACTIVITY AND DIET MANAGEMENT INTERVENTIONS IN SURVIVORSHIP CARE

Considering the clinical importance of developing fundamental guidelines for nutrition and physical activity toward health outcomes, especially BC onset, several international health organizations worldwide have developed the basic guidelines for both general and specific cancer prevention (**Box 1**) by adopting certain lifestyle interventions. The guidelines for risk reduction and survivorship by The National Comprehensive Cancer Network and The American Cancer Society are widely used by health institutes (124–127). However, incorporating these guidelines into survivorship care is challenging, and the transformation of scientific knowledge into practice in healthcare units is often problematic (128). There are several barriers to disseminate the oncological risk information and its essential association with nutrition and physical activity. These barriers include a lack of knowledge and interest from the general public, scarcity of public education seminars and conferences,

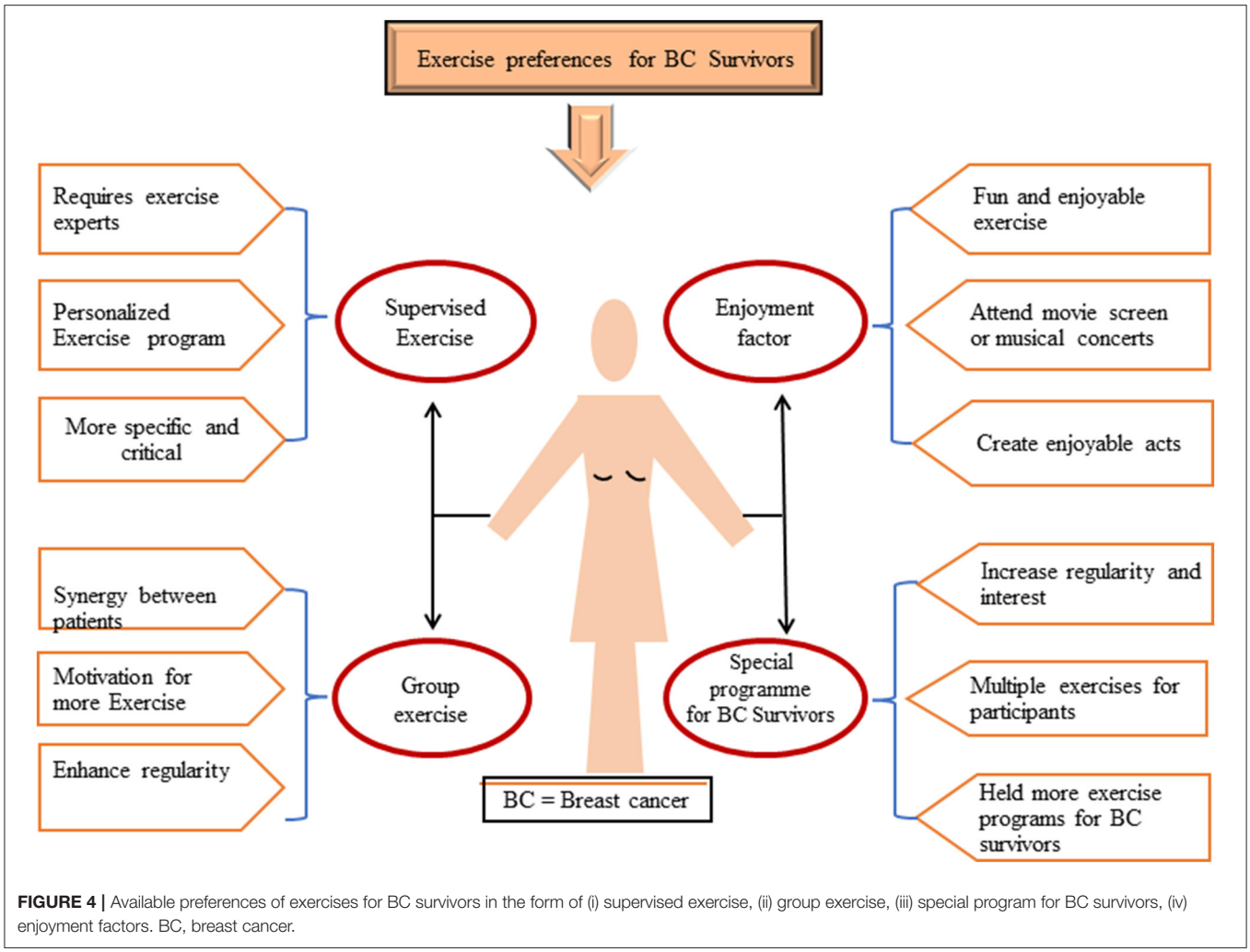


FIGURE 4 | Available preferences of exercises for BC survivors in the form of (i) supervised exercise, (ii) group exercise, (iii) special program for BC survivors, (iv) enjoyment factors. BC, breast cancer.

uncertainty about when in the cancer continuum to introduce such information, a lack of support from hospital administration, and issues of time and patient flow (129, 130).

ONCOLOGY EDUCATION

Cancer education suggests that, at a minimum, oncology practice should provide evidence-based information on the association of BC and diet and physical activity in daily life (108). An oncology counselor's services should include answering questions from survivors about whether it is proper for them to be physically active and continue eating specific foods. An oncology counselor needs to address the lack of health education and manage the flow of misinformation from unqualified sources on the internet or within the community (109). They should provide credibly and trusted educational materials that help survivors make informed choices about physical activity and diet (131, 132). Provision of knowledge should be explicit, easily readable, attractive, and available in suitable languages. Survivors need basic information about health behavior recommendations, and patients with BC who cannot access these resources from care units should receive help from in-house patient education by following the advice of web resources mentioned in **Box 1**.

ROLE OF ONCOLOGY PROVIDER

Risk assessment and counseling of patients on the prevention of BC is highly dependent on the oncology provider. Patients with cancer strongly prefer to receive information about physical activity, diet, and weight management from their oncology providers (133). Studies indicate that oncology providers play a pivotal role and their sessions with patients are very influential (50, 134, 135), which leads to increased physical activity among cancer survivors (136, 137). However, oncology providers may have limited time available for extensive counseling about physical activity, nutrition, and weight management—a further challenge that could be addressed if oncologists themselves advocate around the topic and show the importance of these discussions with their patients. Oncology providers should also become more involved in establishing an advanced infrastructure to reduce BC by emphasizing exercise and diet to cancer survivors and the general public (138). During oncology

- American Cancer Society; www. cancer.org/treatment/survivorship-
- MedlinesPlus; https://medlineplus.gov/
- National Cancer Institute; https://www.cancer.gov/
- Cancer.net; https://www.cancer.net/
- CancerCommon; https://cancercommons.org/home/
- Center for Disease control and Prevention; https://www.cdc.gov/
- Cancer Support Community; https://www.cancersupportcommunity.org/
- the National Comprehensive Cancer Network ; https://www.nccn.org/
- Canadian Cancer Society ; https://www.cancer.ca/en/region-selector-page/?url=%2fen%2f

BOX 1 | For practices that do not have an in-house patient education department, according to the medical library association, there are several cancer patients' educational websites that provide in-house cancer guidelines for both patients and families.

visits, many care providers demonstrate limited knowledge regarding exercise and diet despite established guidelines from health institutes (139). Considering physical activity and diet interventions as critical components of cancer care, many researchers believe non-pharmacological approaches that the oncology provider's role should include discussion of all and special attention to diet and exercise during patients' chemo-sessions to help support healthy lifestyle changes (140, 141).

To reassure patients who are uncertain about the safety or appropriateness of their diet and exercise regime or weight loss after treatment, comprehensive guidelines should be requested from providers. Furthermore, providers should indicate necessary precautions or additional testing that might be warranted (110). The oncology provider is the healthcare professional well-positioned to show the importance of advocating for cancer interventions, which include lifestyle-related secondary measurements, to cope with the burden of cancer, especially BC.

CONCLUSION REMARKS

Increasing size of evidence has supported the interplay of BC development with diet and physical activity. Excessive consumption of saturated fats, red meat and red wine, and low intake of fresh fruits and vegetables leads to the accumulation of triglycerides, heterocyclic amines, and ethanol and a lack of polyphenols and fiber levels in the body which mediate the onset of BC and cause an increase in overall mortality in both pre- and post-menopausal women. Similarly, no or minimal physical activity leads to an alteration in sex and metabolic hormones, which raised oxidative stress and inflammation in the body, affecting the menopausal status of women and potentially facilitating the onset of BC. Considering the importance of these interventions, oncology education and the role of oncology providers can play a potential role in developing healthy interventions and reducing the BC burden effectively. Based on these findings, the current review emphasized the value of physical activity and diet management efforts in daily lifestyle to reduce BC risk and improve outcomes.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, took part in drafting the article or revising it critically, agreed to be accountable for all aspects of the work, read and edited the submitted version of the manuscript, and approved to submit it to the current journal.

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Reconceptualizing the Curriculum for Malaysian Advanced Nursing Education: An Outlook on Mechanical Ventilation Weaning Pedagogy

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Although Advanced Nursing Education (ANE) in Malaysia is still in its early stages, the demand for skilled nurses, particularly those who can perform weaning processes from mechanical ventilation (WPMV), is increasing. These nurses, especially in the Cardiothoracic Intensive Care Unit (CICU) need to be equipped with critical thinking skills in order to make decisions on WPMV. However, the Malaysian ANE is still struggling to achieve this. Therefore, this paper is aimed at reconceptualizing the Malaysian ANE with a specific focus on the development of a Mechanical Ventilation Weaning Pedagogy framework. Building upon previous studies, relevant theories, and WPMV best practices outside Malaysia, this study proposed the development of a pedagogy based on four fundamentals: the Fundamental Pattern of Knowing, Curriculum Planning model, an ideal learning content for WPMV skills development, and local experts' opinions. The findings of this study can serve as a reference for stakeholders, nursing education providers, and relevant parties in improving the current ANE.

Keywords: advanced nursing education, weaning process from mechanical ventilation, Mechanical Ventilation Weaning Pedagogy, nursing curriculum, nursing pedagogy

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INTRODUCTION

Malaysian cardiology and cardiothoracic surgery providers must constantly strive to improve their role in providing high-quality health care. This necessitates more extensive nursing education—an advanced nursing education (ANE) program. However, the Malaysian ANE program is still at its infancy (1, 2). The current Malaysian ANE program is aimed at providing quality education and training to produce skillful Staff Nurse (SN), Clinical Nurse Specialist (CNS) and Nurse Educator (NE) and others. As a result, educational institutions that provide ANE must follow stringent rules and regulations imposed by the Malaysian Qualifications Agency (MQA) and the Ministry of Higher Education (3).

Practical nurses' job scope and responsibilities have expanded throughout time. Their duties and responsibilities, specifically in the Cardiothoracic Intensive Care Unit (CICU) are quickly evolving, necessitating urgent education of health professionals, especially nurses (4). For instance, assisting with pre- and post-operative cardiac care is one of the challenging tasks that they need to quickly learn and master. This includes the ability to utilize mechanical ventilation (MV) machines. MV

is undeniably a life-support treatment, despite the fact that it may inflict discomfort, especially in conscious patients (5, 6).

Nurses in the CICU need to quickly acquire critical-thinking abilities while making decisions on a weaning process from mechanical ventilation (WPMV) (7). While this process is an inter-professional responsibility between physicians with specialized skills (physicians/cardiac anesthetists/intensivists) and nurses (8), in some instances, nurses must take the lead. As previously stated, nurses' roles in performing WPMV, particularly during pre- and post-operative cardiac care, have evolved into one of the shared responsibilities that must be carried out efficiently. Previous studies have concluded that this responsibility is shared to help decrease the patients' length of stay in CICU and facilitate the process of WPMV (9, 10). Thus, nurses should have a strong foundation of knowledge and skills in conducting WPMV.

Technology acceptance model (TAM) provides an insightful explanation of how mechanical ventilation is being approached by nurses in the CICU. Davis et al. (11) explained in this theory that the perceived usefulness and ease of use will determine attitudes and behavioral intentions toward using technology. In this case, the use of mechanical ventilation is viewed as beneficial to increase their job performance, also known as perceived usefulness. Because of that, the ANE curriculum should be able to equip these nurses with adequate knowledge and skills to efficiently conduct WPMV, enhancing their 'perceived ease of use'.

However, the current ANE curriculum is still lacking in producing nurses with high working competencies. Clearly, a number of researchers have identified our local nurses' lack of competence when performing the WPMV process (12–14). Thus, there is a need to redesign the current ANE curriculum by specifically focusing on the development of the Mechanical Ventilation Weaning Pedagogy framework.

REVISITING CARPER'S FUNDAMENTAL PATTERN OF KNOWING

The Fundamental Pattern of Knowing (introduced by Carper (15), shown in **Figure 1** is critical in describing the knowledge pattern in nursing. The first pattern is empirical, or known as the science of nursing. Carper (15) believes that nurses demonstrate empiric knowledge by their skilled execution of tasks that are based on theoretical knowledge. This knowledge is vital in ensuring nurses are able to understand their patients' illnesses and take appropriate actions that are based on theory and facts about the illness. Another fundamental pattern of knowing is esthetics, or the art of nursing. This concerns the process in which nurses gather valuable information about their patients' personalities, prior experiences, and medical history in order to assist them to receive better care in the hospital (16).

On the other hand, personal knowledge, as emphasized by Carper (15) requires an interpersonal communication process that happens between nurses or patient-clients. Critical to nursing, it is vital for every nurse to understand him/herself and be able to be compassionate to their patients. As elaborated by Jones et al. (17), the ability to express compassion toward the patients is able to ease their struggles. Finally, ethics (moral knowledge) is concerned with the nurses' integrity and moral behavior (15). As nursing is a challenging profession, nurses must be able to make sound judgments that are morally correct in order to ensure the safety and care of their patients.

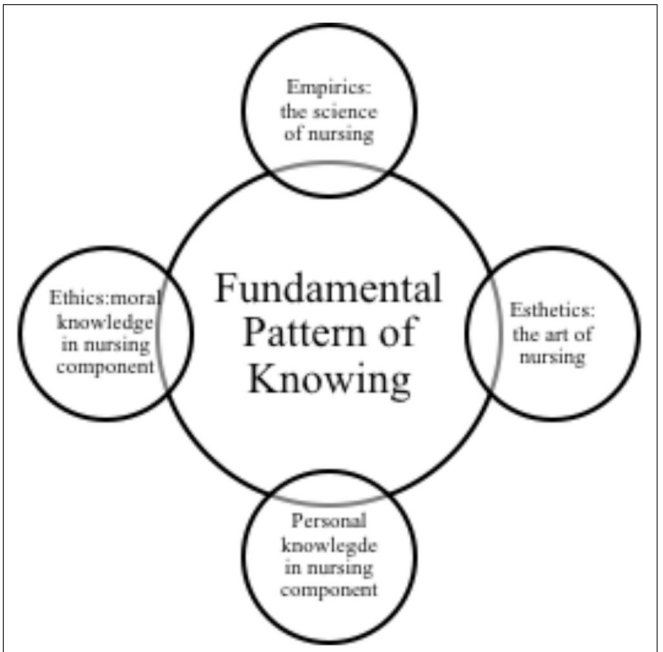


FIGURE 1 | The fundamental pattern of knowing in nursing.

TABA'S CURRICULUM PLANNING MODEL

Taba (18) proposed an inductive approach to curriculum planning which consists of seven steps as illustrated in **Figure 2** below. She believes that a sound curriculum should be responsive to the needs of the society.

She positioned needs diagnosis as the main step to curriculum planning, which means that society's needs should be the foundation of designing the curriculum. In her previous work, Taba asserted that education is to develop individuals to become more intelligent, experienced, and well-organized through stimulating learning experiences and relevant learning content. Thus, the needs diagnosis is the first step in determining what society requires to achieve these goals. From the needs analysis, the curriculum objectives will be developed. This process is critical as it will determine the following steps, which are designing the content of learning, learning experiences, and evaluation of the outcomes.

THE MALAYSIAN ANE AND WPMV SKILLS

Malaysian ANE was first introduced in the Johor Baharu Nurses Training Center in 1959. Among the first programmes offered were Anesthesia basics, Intensive Care (Coronary, Neonatal, Pediatric, Neuro, and others related to neurological treatment),

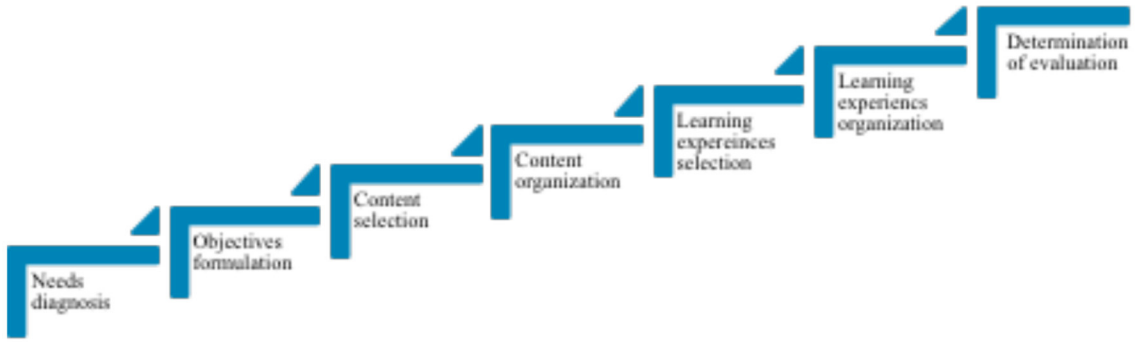


FIGURE 2 | Taba's (18) curriculum planning model.

TABLE 1 | Comparison of course content for WPMV.

Course content	UMMC (25)	ILKKM (26)	Chang (27)
Principle of mechanical ventilation	/	/	/
Operating Modes of mechanical ventilation	/	/	/
Monitoring/ management/ procedures in mechanical ventilation		/	/
Critical care issues in mechanical ventilation			/
Weaning process	/	/	/
Mechanical ventilation in nontraditional setting			/
Haemodynamic monitoring			/
Pharmacotherapy for mechanical ventilation			/
Ventilator waveform analysis			/
Non-invasive positive pressure ventilation			/
Lung capacity, respiratory		/	/

and forensics. It has expanded from one field to another, and the Education Board of Malaysia's Ministry of Health (MOH) has approved 58 courses (19). Beginning in 2005, the course concept was changed to a programme known as post basic education, which includes the following options: graduate diploma, graduate certificate, advanced diploma, and professional certificate.

The ANE curriculum should produce nurses who are (a) responsible and accountable for their profession, (b) capable of applying their knowledge, skills, and aptitude to meet the nursing needs of their patients, and (c) competent and safe in carrying out their responsibilities (20). Thus, the curriculum emphasizes the development of nurses with both theoretical knowledge and practical skills. The ratio of theory to practice in post-secondary education is 40–50: 45–55%. Also, the learning evidences in term of theory demonstration and clinical posting tasks must be carefully documented for certification (20).

However, to be responsive to the current needs and practices in the CICU, the roles of nurses have become more demanding and sometimes overlap with the roles of doctors and specialists in hospitals, especially in conducting WPMV (8, 21, 22). Unfortunately, the current ANE lacks focus on preparing future nurses to be proficient in shouldering this shared responsibility (2, 22, 23). To make matters more complicated, there is no conclusive opinion on this shared responsibility because the working culture of WPMV varies across hospitals. In Australia, for example, there is a well defined protocol for implementing and evaluating the weaning process (24). However, Carter (9) contends that as long as work instructions are followed, there is no need for a constructive procedure for WPMV in the CICU. This resonates with Jansson et al. (10), who believe that this responsibility should be shared as the main goal is to reduce the length of stay in the CICU and the percentage of infection among patients. Undoubtedly, the ANE should be focussing on developing WPMV skills among the future nurses in order to prepare them for the demanding and challenging job scopes as a nurse.

AN OUTLOOK OF THE CURRENT NURSING CURRICULUM IN MALAYSIA

In light of the preceding, it is critical to conduct a critical analysis of Malaysia's current practices for introducing WPMV into the ANE (refer **Table 1**). Undoubtedly, our current curriculum lacks focus on developing a strong foundation for nurses in conducting WPMV.

In comparison to the ideal learning content for WPMV skills development [as proposed by Chang (27)], our local curriculum

(in both the University of Malaya Medical Centre, UMMC and *Institut Latihan Kementerian Kesihatan Malaysia,* ILKKM) lacks focus on expanding these skills. Chang (27) believes that nursing education should focus on the aforementioned content, particularly critical care issues in mechanical ventilation, mechanical ventilation in non-traditional settings, hemodynamic monitoring, pharmacotherapy for mechanical ventilation, ventilator waveform analysis, and non-invasive positive pressure ventilation, which are currently lacking in the local nursing curriculum.

RECONCEPTUALIZING THE ANE TO FOCUS ON DEVELOPING THE WPMV SKILLS

Due to a lack of curriculum focus and inconsistent practices on WPMV duties across institutions, it is critical to reconceptualize the present Malaysian ANE to place a greater emphasis on WPMV skills. The previous discussion indicated a deficiency in the implementation of curricula for the development of WPMV skills in Malaysian ANE. The comparison of the ILKKM (26) and UMMC (25) curricula, as well as Chang's (27) suggestions, demonstrates the Malaysian ANE curriculum's insufficiency in equipping future nurses with WPMV abilities. Thus, immediate action is critical.

However, this process is daunting and requires a thorough examination of current WPMV practices in Malaysian CICUs. As the very step, this paper suggests reframing the current practice by critically based this process on four fundamentals: a. Fundamental Pattern of Knowing (15), b. the Curriculum Planning model (18), c. an ideal learning content for WPMV skills development (27), and d. local experts' opinions.

The Fundamental Pattern of Knowing (15) describes the types of knowledge that are needed by nurses in becoming a competent nurse. This is relevant to Chang's (27) suggestions for WPMV learning content. As for the theoretical foundation, both the Fundamental Pattern of Knowing (15) and the Curriculum Planning model (18) are employed to propose a framework for MPVP pedagogy in the Malaysian ANE. To connect theories and practice, the components of the pedagogical framework are specified using the opinions of local experts and an ideal practice of WPMV outside Malaysia. The general conceptualization of this framework is represented in **Figure 3** below.

This will be accomplished by identifying local expertise. It is recommended that a professional group with at least 5–10 years of experience dealing with life-threatening situations, working in critical care settings, particularly cardiac intensive care, and consistently handling or doing mechanical ventilation weaning be formed (MV). These professionals must have working experience in a CICU or Critical Care Area (CCA) dealing with WMV (Anesthesiology, Educator, Nurse Manager, Nurse Mentor, and senior staff nurse).

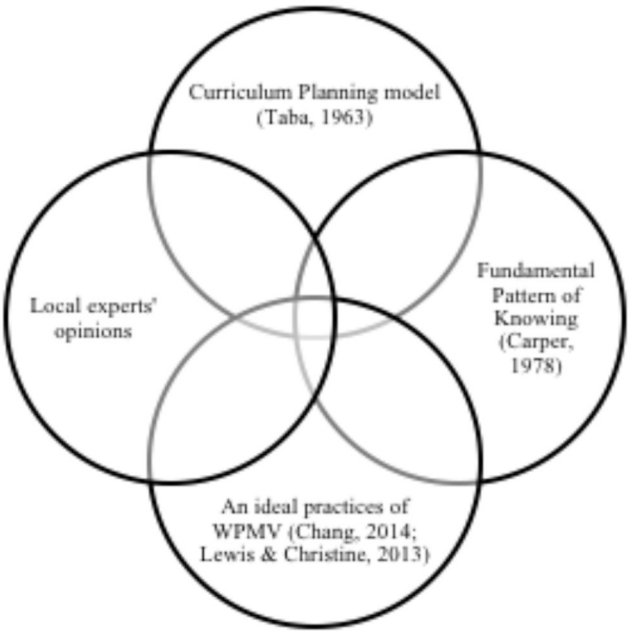


FIGURE 3 | MPVP pedagogy for the Malaysian ANE.

The proposed MPVP pedagogy (shown in **Figure 3**) can serve as the foundation for reconceptualizing the Malaysian ANE curriculum in order to place a stronger emphasis on WPMV skills. In achieving this, future studies should combine the local experts' opinions with the suggested models (Curriculum Planning and Fundamental Pattern of Knowing model) and an ideal practice of WPMV as proposed by Chang (27). Outlining the best practices of MPMV skills introduced in other ANE curricula outside Malaysia and harmonizing them with recommendations from local experts will result in a solid curriculum for Malaysian ANE to develop MPVP skills.

As a suggestion, Fuzzy Delphi Method (FDM) is beneficial in achieving consensus among experts (28). Since FDM uses the triangular fuzzy number and defuzzification process to represent the consensus (28, 29), the findings of this study will provide clear objectives, content of learning, method of delivery and assessment method for the MPVP pedagogy. Additionally, the development, implementation and evaluation of the MPVP pedagogical module should be conducted to identify its effectiveness in addressing the inadequacy in current Malaysian ANE.

CONCLUSION

In conclusion, there is a need to redesign the current ANE curriculum to be more responsive to the current needs and practices in the CICU. As the roles of nurses have become more demanding and sometimes overlap with the roles of doctors

and specialists in hospitals, especially in conducting WPMV, the pedagogy for ANE in developing MVM skills should be revised. In doing so, the MPVP pedagogy development should be based on the theories and local experts' opinions. This is to ensure that the proposed curriculum is aligned with the current needs and practices of Malaysian cardiology and cardiothoracic surgery providers.

While this study has provided a clear direction for reconceptualizing the Malaysian ANE, significant emphasis should be paid to acquiring detailed information on the current MPVP curricular material across various institutions in both the local and international contexts. The information presented in this article is confined to a small number of practices; therefore, a more thorough examination should be undertaken while establishing the MPVP pedagogy for the Malaysian ANE.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

NA, SA, and KJ: conceptualization, writing-review, and editing. KJ and SA: original draft preparation. All authors contributed to the article and approved the submitted version.

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Promoting Techno-Scientific Biomedical Communication in Russia: Pro-government Non-profit Organizations

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The rapidly expanding e-health market tends to reinvent the roles of science, entrepreneurship, and state. However, the results of such reinvention remain unclear. This study investigates the decade-long history (2011–2021) of the promotion of techno-scientific biomedical communication by pro-government non-profit organizations in Russia. In 2021, the World Bank pointed out that digital technologies have played a critical role in the pandemic in Russia and Russia's economic recovery is gathering pace. Thus, Russia tends to correspond to many other emerging health markets. We compare texts from non-profit organizations' websites and Facebook accounts with official state actions and the national mass media health agenda. The instruments that were used for text mining were topic modeling with latent Dirichlet allocation and an algorithm for keyphrase relationship visualization. The results revealed that promotion started no later than 2011 as a general private initiative in health. Throughout the state reforms and geopolitical crisis of 2014, in 2017–2019 digitalization was finally chosen as a model for the healthcare system. Simultaneously, the idea of digital reform for the health system was disseminated by the mass media. The pandemic drew attention to this communication, but it did not create significant change. Pro-government non-profit organizations continue to promote new directions for biomedical communication in Russia.

Keywords: media studies, digitalization and e-health, Russia—economic development and policies, public relations (PR), healthcare system and technologies, biomedical

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INTRODUCTION

The broad context of this study includes changes in forms and modes of communication between states, science, and entrepreneurship during the pandemic. These changes have created new actors, forms of participation, and new roles for infrastructure and governance. The pandemic has questioned the fundamental elements of the current life, and radically altered the social order; since "social interrelations, the economic dynamics… have been minimized and emptied" (Coca and Cárcel, 2021). In the long run, it may affect greatly some businesses and perhaps some social norms and values as well (Khan et al., 2022). In these conditions, features of health communication have a significant impact on perceiving people's relationships.

The rapid increases in communication related to digital healthcare solutions tends to create completely novel social and economic relations. However, one should realize that "not recognizing that novelty needs the familiar and already tried to contextualize what novelty means has created a fixation on the new that undermines the understanding of current events" (Zelizer, 2019). Therefore, according to our hypothesis, communication between states, science, and entrepreneurship has to be discovered during the period of a pandemic, but is rooted in long-term communication, which "assists in public understanding and acceptance of national goals" (Schramm, 1964). Long-term communication creates, maintains, and transforms social and economic practices (Carey, 2009).

This study tests this hypothesis in the context of decade-long health communications (2011–2021) in Russia. The study aims to explore the promotion of techno-scientific biomedical communication by pro-government non-profit organizations (NPOs), such as the HealthNet roadmap of the National Technological Initiative (NTI) and the Agency for Strategic Initiatives (ASI). The aim includes the following research questions. (1) When did the health communications of these NPOs begin and what were their main stages of development? (2) What are the determinants of change (i.e., international, state, or public)? (3) What is the extent of the influence of such communication on the national health agenda generally?

The significance of this study lies in the current successes and failures of the Russian economy. Controversial though it may seem, despite a long chain of problems, such as the stagnation of people's incomes (Euromonitor, 2021) and the state's economic footprint (World Bank, 2021, p. 40), experts have pointed out that some successes occurred during the pandemic. The World Bank suggests that digital technologies played a critical role in this regard during the pandemic in Russia. In 2021, ICT exports were on the rise, expanding by 8.1% in value in 2020 (World Bank, 2021, p. 9). The annual growth rate of the Russian Digital Health market is expected to be 13.97% in 2021–2025, which is higher than the worldwide growth rate (13.45%; Statista, 2021). The lockdown accelerated the adoption of a new law allowing the sale of OTC and some pharmaceutical products on the Internet (Euromonitor, 2021).

The Institute for Statistical Studies and Economics of Knowledge has issued a report which describes "the digital maturity of healthcare" in Russia (ISSEK, 2020). It argues that there is a positive dynamic of financial support for the digitalization of the health system, the actual prices of which increased by 1.3 times between 2020 and 2021 (ISSEK, 2021a). Business spending on innovations increased by 1.7% in 2020, and their share in total sales reached 2.3% (vs. 2.1% in 2019), which corresponds to leading European countries (Finland, 2.4%; France, 2.3%; Austria, 2.1%; ISSEK, 2021b). At the same time, state-driven "national projects remain the main tool for accelerating long-term potential growth" (World Bank, 2021, p. 40). It is not clear when the economy changed: before or during the pandemic? What are the roles of different actors and within them?

Several studies have explored the traditions of science communication in Russia (Balashova, 2018) and soviet-based principles of biotechnology governance (Novossiolova, 2017). These publications propose paying more attention to state-driven actions. These actions can be official, based on laws and programs, or communication-based. Studies that have investigated official actions reveal the shift from the dissolution of the Soviet system of public healthcare (Semashko model of 1930s) to the "shock therapy" of the first half of the 1990s, and to the creation of a stable system in the 2000s and the beginning of the 2010s (see **Table 1** and Popovich et al., 2011; Cook, 2015; Shishkin, 2017; Shishkin and Zasimova, 2018).

Endaltseva (2020) points out that the promotion of high-tech medicine is related to governmental institutions concerns over import substitution resulting from the current geopolitical crisis. She observed the roles of the state, non-government organizations (NGOs), education, and research sectors in the development of communication. She concluded that the patient movement "plays a mediator role" among the government, business, and public (Endaltseva, 2020, p. 212).

Health reforms of the 2010s have been underexplored from a long-term perspective. For example, Gordeev et al. (2011) observed changes in quality, equity, efficiency and sustainability in public healthcare provision from 1991 to the start of the 2010s. Unlike Gordeev's study, which used a systematic literature review approach and focused on the financial results of healthcare reform in Russia, this study offers an original empirical study of techno-scientific biomedical communication with data collected from websites and Facebook (Meta). In regard to continuing and combining Gordeev's data, we explore the communication aspects of the next decade (2011–2021) for an evidence-based evaluation of the changes. Based on the analysis of the decade-long communication between the state, science, and business regarding NPOs communication, we reconstructed and analyzed the roles of NPOs in implementing techno-scientific biomedical communication in Russia.

Pro-government NPOs in Russia

Balashova and Novossiolova point out the importance of state-driven actions in innovative development in Russia (Novossiolova, 2017; Balashova, 2018). Several influential pro-government NPOs contribute to innovative development: the NTI, the ASI, the Skolkovo Innovation Center, the Russian Venture Company, the Foundation for Assistance to Innovations, and the Direct Investment Fund, which was part of the development of the Sputnik V COVID-19 vaccine. In 2019–2020, the NTI received RUB 1578 million (approximately USD 21.5 million) from the state, three-quarters of this in March 2020; the money was provided to resolve issues that arose because of the pandemic (PublSpending, 2021a). For comparison, the ASI received approximately RUB 800 million (approximately USD 11 million) in 2014–2020, which was distributed fairly equally over that time (PublSpending, 2021b).

The NTI and ASI can be represented as promoters of pro-government communication because, by statute, their main activity is the research of the market and public opinion, unlike, for example, Skolkovo or the Foundation for Assistance

TABLE 1 | History of official actions in the Russian health field.

#	Date	Official action
1	1930–1949	Establishment of the Semashko system of healthcare
2	1990–1999	Codification of free universal healthcare (1993 Russian Constitution); Law on Health Insurance (1991); economic shock therapy for the healthcare system (first half of the 1990s); introduction of chargeable healthcare services (1996)
3	2000–2007	Restoration of an increase in health expenditures
4	2005–2006	National Priority Project on Health (2006); beginning of health protection campaigns: (1) pro-natalist, (2) pharmaceutical regulations and price controls, (3) HIV/AIDS and TB prevention
5	2005–2013	Federal and regional programs for the purchase and renovation of equipment in public medical facilities
6	2008–2010	"Single channel" healthcare system financing reform
7	2013–2020	National Priority Project on Health to 2020
8	2013–2025	Strategy for supplying drugs to the population of Russia to 2025[a]
9	2018–2024	National Priority Project on Health and the State Program for the Development of Healthcare to 2024[b]

[a]*Available online at: https://rg.ru/pril/article/70/89/78/Strategiya_lek_obespecheniya_131112.doc.*
[b]*Available online at: https://minzdrav.gov.ru/ministry/programms/health/info.*

to Innovations, which aim to provide financial services (Sparks-Marketing, 2021). This communication focus was even commented upon by Vladimir Putin as the difference between the ASI and Skolkovo: "Skolkovo … aimed to gather interesting people and important projects on a well-equipped platform. Here, in ASI, we are talking about … networking throughout the country" (Lenta, 2020).

The ASI was created in 2011, Freinkman and Yakovlev (2014) defined it as a new type of institution for state-business cooperation; its goals consist not of distributing budgetary funds but of organizing a strategic dialogue with the private sector and reconciling positions within the government (Freinkman and Yakovlev, 2014). The NTI was established by the ASI in 2014 on the example of the European Technology Platforms (Strigin, 2016) and programs for the digital economies of the US, the UK, Singapore, and others (Veduta, 2017). The NTI's framework targets "innovation activity" (Oveshnikova et al., 2017) and has a predominantly "export or import-substituting orientation" (Blagov and Kulaeva, 2020). In 2021, there were 2,400 companies associated with the NTI whose combined revenue was RUB 639 000 million (approximately USD 8697 million; TASS, 2021).

A special aspect of the NTI, the HealthNet roadmap, has directly developed "personalized medical services and medicines that provide increased life expectancy, as well as new effective means of preventing and treating" (Healthnet, 2017). The HealthNet roadmap was signed into law in 2016, but its history begins in 2013 (Healthnet, 2017). This study utilizes the analytical concept of concentric circles to investigate the promotion of HealthNet. The investigation focuses on HealthNet itself when information is available, but it also explores a proto-HealthNet as well as health-related news on the NTI and ASI websites and their Facebook (Meta) pages in the decade from 2011 to 2021.

This complex sample of material is compared with the national mass media's agenda concerning healthcare. To this end, we focus on two prominent Russian newspapers: *Rossiyskaya Gazeta* and *Kommersant*. In a separate study (Marchenko et al., 2021), we showed the Russian health news agenda in 2010–2015 included such the topics as criminality and "modernization" of the state healthcare system. In 2010, the "single channel" healthcare system financing was implemented throughout Russia (**Table 1**), which created many problems concerning how to finance medical organizations in provinces and regions distant from Moscow. In the mid-2010s, the news media paid less attention to health. There was a gap in the number of thematical journalistic texts because of an external political crisis. After 2016, we detected new trends related to digitalization: drug e-labeling, new drugs, networks, and database development.

Implemented in 2017, the Russian state program of drug e-labeling, as well as the import substitution process, exerted a massive influence on the communicative environment. The number of texts related to private initiatives and their regulations increased significantly in the second half of the decade. These trends could signify not only the centralization of the healthcare system, one of the negative consequences of the single channel reform, but also a shift from physical localization of medical services to online healthcare. Public finance issues prevailed over public health issues.

This shift has remained until the present. The pandemic instantiates a health issue that is a concern in the field of international affairs, which is indicated by the inclusion of foreign countries like China and the US, international exchange to combat the current pandemic, and "new/old" geopolitical tensions. The new most popular words that appeared were "domestic," vaccine, and "borderline." However, in main, the national health news agenda continued.

The mass media agenda is associated with social politics (single-channel reform, competitive recovery of Russian pharmaceutical enterprises, and import substitution) and economics (governmental control, drug e-labeling, redistribution of public funds, and other social processes). Below, we consider the role of NPOs in this agenda. We compare NPOs and mass media communications, distinguishing between communications NPOs made as promoters of state influence on the economy and the agenda of national mass media as a reflection of all potentially significant social and economic

facts. The sample description and text mining tools are described below.

MATERIALS AND METHODS

Data Collection

The dataset was collected automatically for the period from 2011 to 2021; it was collected from the websites and Facebook (Meta) pages of the NTI and ASI. Some pages were specifically concerned with the HealthNet roadmap, while others were concerned with innovative activity in general. From the latter, we extracted texts related to the health agenda. The structure of the dataset is presented in **Table 2**. The instruments used for text extraction from the sites were Instant Data Scraper and Octoparse; for the Facebook pages, we used Popsters (https://chrome.google.com/webstore/detail/instant-data-scraper/ofaokhiedipichpaobibbnahnkdoiiah; https://www.octoparse.com/; https://popsters.ru/).

We began with the site of the Infrastructure Center of the HealthNet roadmap of the NTI. Its direct objectives are "assistance in promoting innovative projects, consulting, and analytical support for researchers and entrepreneurs engaged in the development and implementation of future technologies in healthcare" (Infrastructure Center, 2021). Then, we collected the texts from the networks surrounding the NPOs according to the principle of concentric circles, from HealthNet roadmap communications to general health-related news for the NTI and ASI up to 2011. There had to be at least two sources for a year to be included (**Table 3**).

For ease of comparison to the national mass media agenda, we extracted paragraphs from all texts using the same keywords we used in Marchenko et al. (2021): medicine, health, healthcare (health protection), medicine (drug), and hospital.

Text mining was performed using several tools, which increased confidence in the results: topic modeling using LDA, and an algorithm for keyphrase extraction visualization. All texts in the dataset were lemmatized and tagged with parts of speech using PyMystem3 (https://pypi.org/project/pymystem3/).

LDA Modeling

This study employs a conventional topic modeling scheme based on LDA (Blei et al., 2003). As indicated by Hagen (2018), properly trained and evaluated LDA-based topic models are powerful tools for content analysis in the social sciences, as they help find themes overlooked by human coders and are less prone to bias. LDA is a particularly popular unsupervised parametric approach that models documents as mixtures of topics, and topics as mixtures of words (probabilistic distributions over words). For a given time span, each document D from the collection was assumed to have a distribution over k topics, where discrete topic distributions were drawn from a symmetric Dirichlet distribution.

We reviewed recent papers reporting on the application of two widely used LDA-based packages, Java-based Mallet (http://mallet.cs.umass.edu/) and Python-based Gensim (https://radimrehurek.com/gensim/) and extensively experimented with both packages using the same data followed by visualization in LDAvis (Sievert and Shirley, 2014). Ultimately, we selected the Mallet package to compare the tools and indicate that they have their strengths and weaknesses. Mallet's underlying approach relies on Gibbs sampling, which has well-known implications for runtime complexity (Jelodar et al., 2020) because the training process requires keeping the entire dataset in memory. However, as shown by Zhou et al. (2020), Mallet performs better than Gensim from the perspective of coherence value. Coherence roughly reflects the degree of mutual support between subsets (word sets) within each topic in a topic model. The c_v coherence used in this study combines the indirect cosine measure with the normalized pointwise mutual information and Boolean sliding window, and it is reported to be the best measure regarding runtime and correlation to human ratings (Roder et al., 2015). Dataset pre-processing for LDA included lemmatization with PyMystem3, Russian stopword removal using Natural Language Toolkit (https://www.nltk.org/), and bag-of-words representation using Gensim libraries. The best LDA setup was as follows: we used asymmetric alpha (prior to topic proportions within documents), which, combined with symmetric beta (prior to word weights in topic distributions), proved to enhance the quality of topic models. In Mallet, alpha can be optimized for each N iteration by setting the optimized interval parameter to equal N. In the field, although frequent alpha optimization in Mallet increases coherence, it affects topic quality because of the growing prevalence of topics with small coverage (topics that are present in a few documents; https://dragonfly.hypotheses.org/1051). Because we aimed to capture the most prominent topics, less frequent optimization was prioritized.

The optimal number of topics for each time span was searched for in the interval 2–50 with varying optimization intervals (10, 50, 100, 500, and 1,000). A wider search interval was avoided because, as observed in Porter (2018), selecting too many topics leads to overfit. In addition, a few topics ensured explicability and efficient analysis of each topic. We consider the best number of topics to correspond to the best c_v coherence value, which is consistent with several studies, including Zhou et al. (2020) and Fang and Partovi (2020). In addition, if a coherence peak that includes the highest coherence value is shared by the LDA runs with different optimization interval values, it is considered to indicate the best number of topics. The resulting optimal number of topics for this study was 30. LDA topics are represented by a distribution of all tokens (words) in the vocabulary, and LDAvis represents the percentage of tokens covered by each topic (topic proportions in the dataset).

Keyphrase Modeling

Keyphrases were extracted from texts as multi-word continuous sequences of nouns and adjectives separated by punctuation and words with parts of speech other than those mentioned. For each text, the corresponding list of keyphrases was then extended using sequences of two or more words. These word sequences must be presented in their exact form in any keyphrase extracted from a given processed text and must occur more than once as a subsequence within other keyphrases extracted from the text of the dataset. Keyphrases signifies the combination of keyphrases and the extracted word sequences.

TABLE 2 | Sample sources and period and number of extracted texts.

#	Source	Period	Number of texts
1	Infrastructure Center of HealthNet road map of the NTI, news (news media about HealthNet). http://healthnet.academpark.com/news/smi-o-khelsnet/	Dec. 17, 2018–Oct. 1, 2021	220[a]
2	NTI "new" site, HealthNet tag https://news.nti2035.ru/tag/healthnet/	Aug. 27, 2020–Oct. 16, 2021	26[a]
3	NTI Facebook "new" account https://www.facebook.com/2035nti/	Mar. 2, 2015–Nov. 18, 2021	3,731[b]
4	NTI "old" site news (market chronicles) and HealthNet tag. https://ntinews.ru/news/khronika-rynkov-nti/healthnet/ and https://ntinews.ru/search/?tags=Хеπсhet	Dec. 7, 2017–Apr. 21, 2020	157[a]
5	NTI Facebook "old" account https://www.facebook.com/ntinewsru/	Nov. 7, 2018–Apr. 3, 2020	764[b]
6	ASI site news. https://asi.ru/news/	Jul. 11, 2011–Dec. 29, 2017	2,086[b]
7	ASI Facebook. https://www.facebook.com/asi.russia/	Jun. 21, 2011–Dec. 30, 2014	3,262[b]
		Total	10,246

[a] *Only the texts concerning the HealthNet agenda were separated and extracted.*
[b] *Texts concerning the general agenda of the NTI and ASI were extracted; but only the paragraphs mentioning health-related keywords were used for the analysis.*

TABLE 3 | Representation of sources per year, 2011–2021.

#	Year	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011
1	NTI sites	31	170	169	29	4	-	-	–	–	–	–
2	NTI Fb	1,062	821	1,193	395	394	273	357	–	–	–	–
3	ASI sites	–	–	–	–	310	343	368	427	339	258	41
4	ASI Fb	–	–	–	–	–	–	–	846	952	1,214	250
	Total	1,093	991	1,362	424	708	616	725	1,273	1,291	1,472	291

The proposed algorithm was derived from the concepts of the Rapid Automatic Keyword Extraction algorithm (Rose et al., 2010), which was combined with the strategy of extracting the most frequent word sub-sequences rooted in category-based search systems that automatically generated named categories using search results (Bernardini et al., 2009). The Rapid Automatic Keyword Extraction algorithm extracts keyphrases from the text as contiguous word sequences separated by punctuation and terms from the extended stopword list. The extended list includes terms that are found more often next to a keyphrase than inside one and whose frequency is above a given threshold. This list is assumed to be universal for a domain of knowledge. In Rose et al. (2010), it was employed for keyphrase extraction from academic papers. However, it requires a domain-specific collection of documents with keyphrases labeled by domain experts. Since there is no corpus available for our study and its construction is beyond the scope of this paper, an alternative was found that exploits an important observation concerning part-of-speech restrictions on the keyphrase extraction field. According to this observation, keyphrase extraction quality increases significantly when only nouns and adjectives are allowed within the keyphrases (Zesch and Gurevych, 2009). Therefore, all words with parts of speech other than nouns and adjectives were considered additional separators. Another key observation we exploited was that keyphrases should be multi-word because of there are few single-word keyphrases and the percentage of false positives is much higher than it is with multiword keyphrases (Popova and Khodyrev, 2014).

In **Figures 2**, **4**, **5B**, the keyphrases are vertices and edges that connect phrases that co-occur in more than a certain number of text. For example, in **Figures 2A**, **4**, we observe the phrases that co-occur in more than 10 texts; in **Figure 5B**, there are more than eight texts; and in **Figure 2B**, there are more than four texts. This number is higher when there are more texts in the sample, and the homogeneity of these texts is higher.

RESULTS

We identified a proto-HealthNet roadmap agenda in a communication with the ASI in 2011. The word "roadmap" relates to creation of a "project way of thinking" (see **Figures 1A,B**). "Project" had two connotations. On the one hand, it relates to solving medical organizations' problems. Related words were "region," "city," "country," "modernization," and "development." On the other hand, "project" was also related to "production," "business," and "construction," different pro-government councils and roadmaps activities. This is clearer in topics 1–2 of the analysis of the Facebook posts (**Figure 1B**). Regional problems are covered directly only in topic 12 of the

analysis of ASI's website. Its keywords are "non-governmental," "private," "compulsory medical insurance," "organization," "financing," "cost," and "increase" (**Figure 1A**).

We call this the project way of thinking because it was associated with a wide circle of general social issues, including children, retirees, and disabled people. Words like "technology" and "new" began to be used, but they were not related to anything concrete. We also identified the use of the titles of universities and education and science organizations (**Figure 1B**, topics 5–6). However, the Russian Academy of Science was not included, which means that the ASI preferred primarily educational partners over scientific ones.

During and after the crisis of the 2014 transition, we continued investigating ASI site news and began investigating NTI Facebook accounts, which were available from 2015. For this comparison, we preferred keyphrase modeling; it was more applicable because of the compact size and greater expressiveness of the model (**Figures 2A,B**). The results revealed that the ASI agenda had, for the most part, not changed. The project-oriented approach only changed its quality-of-life paradigm, and a national interest was added, which was mentioned by President Putin (**Figure 2A**). Both phenomena can be explained as a reaction to the implementation of sanctions and the internal need for material (industrial) and spiritual compensation, related to the honor of the nation. In addition, ASI's retention of the same theme may have been determined by the delegation of concrete health issues from the ASI to the NTI.

In 2015, NTI's Facebook account posted about the development of relationships with universities as well as concrete vectors of the health market. These posts concerned the following aspects of e-health: digital and information technologies and artificial intelligence; databases of medical knowledge, including e-documentation in hospitals; and the organization of communication with the developer (**Figure 2B**).

For the previous period, we identified the development of the health market from non-concrete projects in a wide ring of social issues to choose the main vector. The following analysis of the LDA vision of NTI Facebook accounts (2015–2019, **Figure 3A**) and news on its website (2017–2019, **Figure 3B**) reflects the vector of the Russian health market transformation in the second half of the decade. In **Figure 3A**, one main topic included the words "technology," "project," "company," "applied," "task," "scope," "result," and "artificial intelligence." Among other topics, we also highlight one (topic#5) that develops the IT theme and includes the words "data," "system," "diagnostics," "analysis," and "digital."

The content on NTI sites comes from the end of 2017, 2 years after the NTI Facebook posts. The content was more diverse, which may be because of the 2 years that had elapsed in the development of HealthNet as well as the website's style of presentation (**Figure 3B**).

The most prominent theme on the site is that of healthcare personalization. This theme displaces geographical items, which were previously more widely used in relation to the state modernization of financing medicine (single channel reform). Personalization is associated with IT (see topics 2–3, **Figure 3B**), and, as we assumed and mentioned in the Introduction, a shift from the physical localization of medical services to online healthcare. Additionally, a response to the need for compensation concerning sanctions continued to produce frequent mention of "world," "international," "Russia," "national," "first," "new," and others.

Figure 4 illustrates the keyphrase model and the core themes from the NTI sites in 2017–2019, including IT and the development of new drugs. However, the space above these core themes contains the next five large plots (full graph in bottom left corner of the figures):

- Creation of a community of healthcare professionals, international communication, a national association developer, and a national medical knowledge database;
- Participating in the NTI basic research medicine and clinical trials; in the state medical policy, improvement legislation, registration of medical products, and support for decisions; and the development and creation of new medicine and products;
- Partnership with state universities, a Russian venture company, the Foundations for Assistance to Innovation, international healthcare clusters, scientific institutes of chemistry and biology, and even a the technopark of the Russian Academy of Science;
- Implementation of AI technology, data bases, electronic medical cards, and biomedical products and materials;
- Finally, the creation a scheme of subsystems as a framework for roadmaps, infrastructure centers, and working groups.

The pandemic has not provided a significant change in the NTI's map of health communication. The number of Facebook posts concerning the development of the market are approximately an order of magnitude greater than the amount of news on the sites; therefore, we selected the Facebook posts as examples. **Figure 5** indicates two trends, the first of which is a deeper concretization of tasks and technologies. This is illustrated by such words as "direction," "framework," and "competition" (**Figure 5A**, topic 2), as well as "monitoring," "artificial intelligence," and "machine learning" (**Figure 5B**). The second trend is the promotion in 2020–2021 of new subcommunities and sub-NPOs to develop additional subtasks (e.g., NTI's elimination of the ASI in 2015), Which is evinced by such terms as: "center of NTI," "infrastructure center," "center of competences," "roadmap," "working group," and "foresight" (**Figure 5B**).

Thus, this overview of the history of the promotion of techno-scientific biomedical communication by pro-government NPOs indicates that the ASI's actions are of paramount importance in the first period. In 2011–2014, the project way of thinking mainly promoted general private health initiatives. The 2014 geopolitical crisis introduced the topics of national interest and import substitution. Subsequently, the NTI searched for a concrete model of high-tech development of the health market. Closely to 2017–2019, this model was clearly focused on e-health. Finally, during the pandemic, the NTI has not changed significantly, but it has proposed and

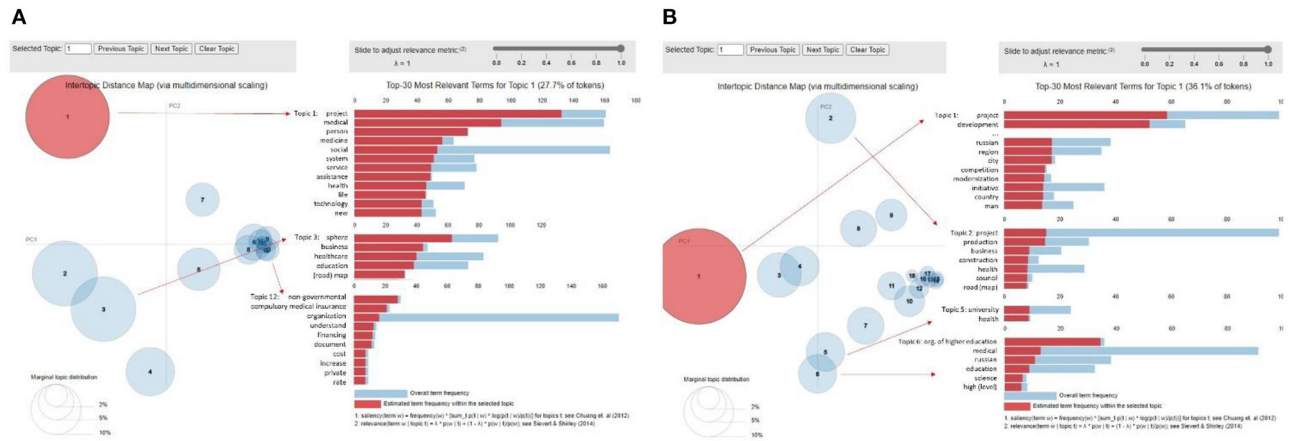


FIGURE 1 | Terms with the highest frequencies of LDA-produced clusters for ASI news online **(A)** and on Facebook **(B)**, 2011–2014.

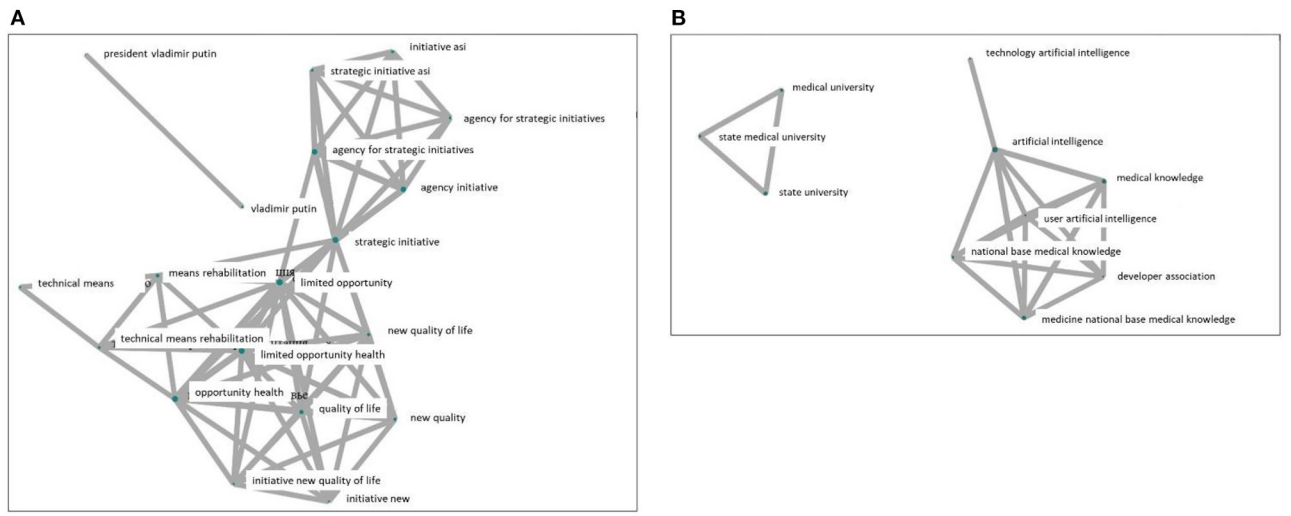


FIGURE 2 | Visualization of keyphrases from ASI's site, link frequency $p > 10$ (2014–2017) **(A)**, and from NTI's Facebook page, link frequency $p > 4$ (2015–2019) **(B)**.

promoted a subcommunities devoted to the development of new subtasks.

DISCUSSION

The study reveals that the claim that the focus on high-tech medicine is novel and that it is driven by the pandemic is unreasonable. Changes in forms of communication between states, science, and entrepreneurship uncovered during the pandemic had been prepared beforehand. The initiation of such communication changes is likely related to a more general timeline to restore and increase health expenditure in the second half of the 2000s (Shishkin and Vlassov, 2009; Cook, 2015). In 2011, we observed this with the first news of the ASI on its website and Facebook account.

The study has identified a proto-HealthNet agenda as a "project way of thinking" in the first half of the 2010s. "Project way of thinking" combines both medical organizations' problem solving and private activities in health. It corresponds to scientific results, obtained by Zemtsov with colleagues. Zemtsov points out that R&D spendings are not the main factor of growth in regional innovation. His econometric analysis shows that "the quality of human capital, a product of the number of economically active urban citizens with a higher education (the so-called creative class) has the greatest influence…," more than the government spending (Zemtsov et al., 2016).

The techno-scientific biomedical communication development in Russia to some level corresponds to other neighboring countries. For example, the ASI was created in

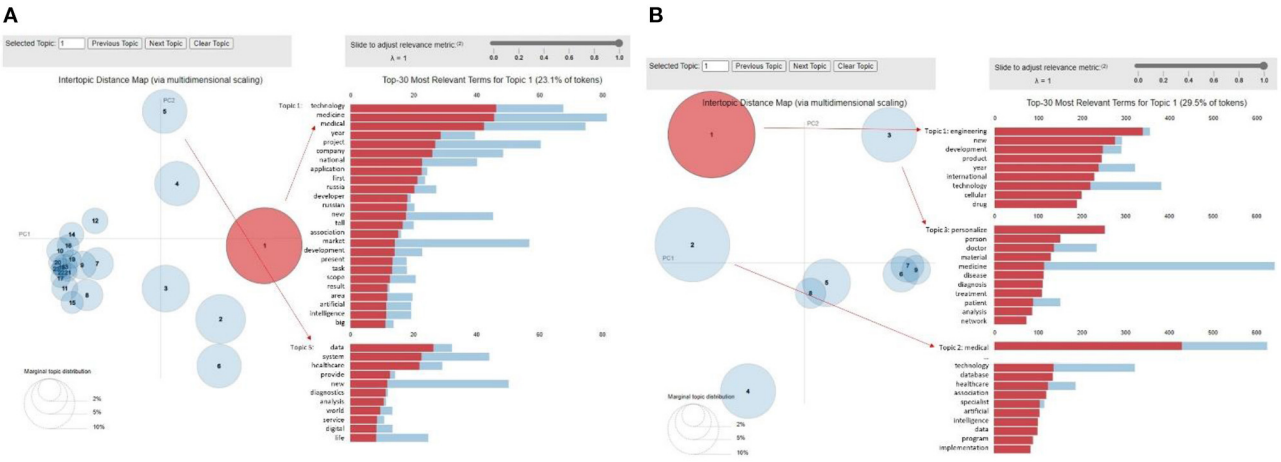


FIGURE 3 | LDA-produced clusters for NTI Facebook accounts (2015–2019) **(A)** and news on its website (2017–2019) **(B)**.

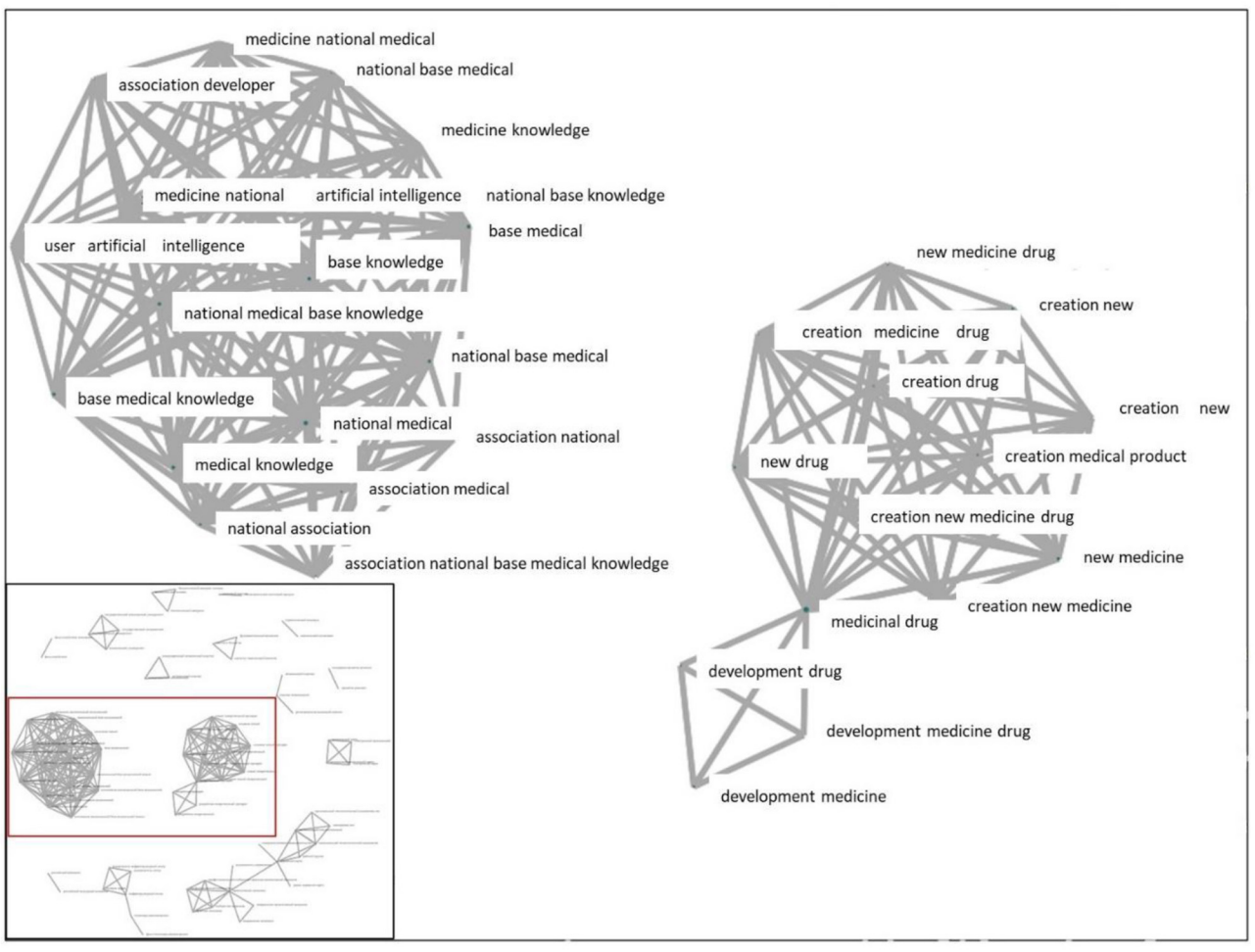


FIGURE 4 | Keyphrase visualization for NTI websites: link frequency $p > 10$, fragment (2017–2019).

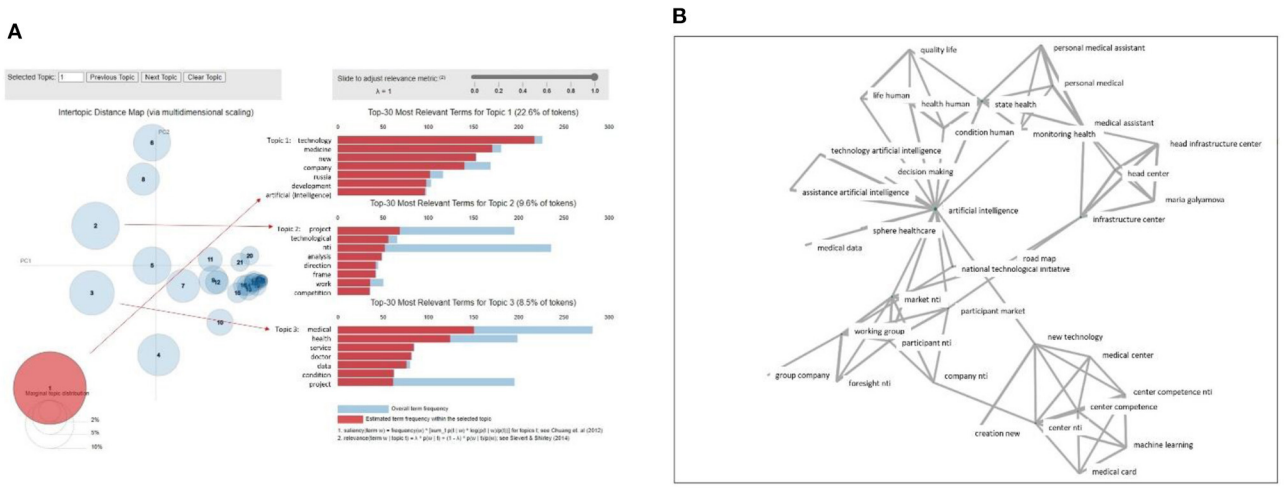


FIGURE 5 | NTI Facebook accounts (2020–2021): LDA-produced clusters **(A)** and keyphrases visualization with vertex frequency $p > 8$ **(B)**.

2011 as a new type of institution for state-business cooperation (Freinkman and Yakovlev, 2014). The NTI was established by the ASI in 2014 on the European and other overseas examples (Strigin, 2016; Veduta, 2017). In this regard, innovation NGOs in Russia have been established about 10 years later than in Europe. For example, in Europe innovation was the cornerstone of the Lisbon strategy, formulated in 2000 (Filos, 2004). However, the development of a model for high-tech development by NTI in Russia corresponds in time to the concept of Digital Innovation Hubs (DIH), launched by the European Commission in 2016. Their functions are similar: "Through a DIH, an organization can thus connect with investors, access knowledge about digital transformation, connect users and potential partners, as well as refine their business and marketing development strategies" (Georgescu et al., 2021). At the same time, closely to 2017, the NTI clearly focused on e-health as a model for Russian health market development.

The communication of pro-government NPOs with universities, education, and scientific organizations corresponds to the experience of other neighboring countries such as Finland and Poland. In Finland, the project "Open innovation platforms" (OIPs) provides interactions between science, education, and innovation, and use the urban environment as a "living lab." And at least three universities implementing this strategy (Raunio et al., 2018). The same pieces of evidence with assent to the foresight in higher education institutions can be found in Poland (Ejdys et al., 2019). Russian communication practices tend to follow the framework of its neighbors of Central and Eastern European (CEE).

So, to answer the first research question, it has showed that the transition has begun long before the pandemic situation. We describe the main stages in the development of health communication of the ASI and NTI.

- 2011–2014: The ASI, a proto-HealthNet, which primarily promoted general private health projects
- 2014–2017: The quality-of-life paradigm, and national interests, and the initial search for an attractive model for the health market
- 2017–2021: Mature HealthNet communication with core themes of IT and the development of new drugs; additionally, community building, taking part in fundamental science and decision making of the government, and finally, the creation of a scheme of subsystems for the health market NPOs.

The crisis of 2014 had a strong negative impact on knowledge-intensive business services, and the share of companies with decreasing revenues has dramatically grown in all industries (Belousova and Chichkanov, 2016). Before and after this crisis, the main stages of the development of health communication are similar to historians' periodization of the three stages of Russian modernization during the 2010s: "The first period was characterized by the fact that modernization was more declarative than practical' (final of 2000s and start of 2010s); the second was a practical implementation of modernization with discussions and searches of attractive models (mid of 2010s); and the third period, which continues to the present moment, does not need discussions, but doing business only" (Kruglikova et al., 2021).

To answer the second research question, we point out that the content of the communications, particularly those of the ASI and NTI, were not directly determined by the state's power. For example, proposing or preferring an e-health market was not temporally related to official policy based on laws and programs (see **Table 1**; Gordeev et al., 2011; Cook, 2015; Endaltseva and Mordvinova, 2015). Single channel health financing reform received little coverage in the news on the ASI site, but so too did the national priority health projects for 2020 and 2024.

We completely agree with the conclusion that the promotion of high-tech healthcare is related to governmental institutions concerns about import substitution owing to the 2014 geopolitical crisis (Belousova and Chichkanov, 2016; Endaltseva,

2020). However, as this study reveals, communication between states, science, and entrepreneurship began before this crisis, and it continues into the present for reasons other than import substitution. Furthermore, it is reasonable to claim that significant issues, such as the 2014 geopolitical crisis and the pandemic, created a primary framework for change in this field. For example, with respect to the former, the national mass media turned to e-health, and the NTI's HealthNet roadmap was created based on the ASI. The pandemic should also significantly influence the current state of e-health communication, but it will be interrelated with other political, social, and economic factors.

So, we tested and confirmed the hypothesis of the rooting of the e-health promotion in long-term communication, which creates, maintains, and transforms social and economic practices (Carey, 2009). This conclusion contributes to the many previous works, in which communication factor in innovations has been considered. For example, Butenko considers how Russia adopts the foreign experiences of the digital economy development (Butenko et al., 2021). Communication factors in innovations as eHealth literacy or consumers' trust, achievement of societal benefits, and subjective wellbeing were indicated as significant for Europe (Birch et al., 2014; Ricard, 2016; Griebel et al., 2017), as well as for emerging economies and developing countries (Marten et al., 2014; Hoque et al., 2017; Bosch and Vonortas, 2019). Some studies check these factors based on methods of a survey (questionnaire) or analysis of macro data of a monitoring report (Marten et al., 2014; Zbierowski, 2017; Elmassah and Hassanein, 2022). For example, Zbierowski (2017) investigated the possible impact of new technology-based firms (NTBF) on the social and economic development of eight countries of CEE and Russia and Kazakhstan as the countries of the Commonwealth of Independent States (CIS). Zbierowski has found that Russia was the lowest country almost in all measurements, although they were based on "the entrepreneur's self-assessment" (Zbierowski, 2017).

Comparing texts from non-profit organizations' websites and Facebook accounts with official state actions and the national mass media health agenda, we have found that they all aim to rise self-assessment. Our study indicates that the common development of these agendas significantly contributes to the trust in innovations. Additionally, the study contributes to the investigation of impact of digital data sources such as social media platforms, electronic health records (EHRs), websites and mass media on people's health. The key impact of these sources is "in the area of infectious diseases and early warning systems, and in the area of personal health, that is, on mental health and smoking and drinking prevention" (Li et al., 2021). The NPOs are able to use communication in social media and by websites to promote the topic of personalization and digitalization of health, as well as for eHealth literacy.

Answering the third research question, we found that the non-profit organizations' impact on the general national health agenda was not as significant as mass media. The non-profit organizations could not provide long-term predictions that the mass media could widely and quickly disseminate. They also did not alter the national agenda for the healthcare system reform, or at least we did not find evidence for this. Finally, the non-profit organizations and the mass media went through different stages in the history of health communication. The non-profit organizations were the first to propose a general private model for the health market, then searched for a specific model, and finally, shifted to digitalization. The media covered modernization reform without either proposing or searching for a model; and then, after a period of silence in the middle of the decade, reoriented themselves to digitalization.

Although NPOs' power of communication is not very significant, when it corresponds to political, social, and economic changes, it plays a more significant role in the transformation of society. This correspondence explains why NPOs and the mass media both finally focused on e-health as their new agendas in 2017–2019, before the pandemic. This dynamic has also continued until the present. Mass media queries NPOs for information and analysis, this information and analysis is reinforced by the media, and together, they create a communicative environment for the transformation of business models. This conclusion corresponds to the previous works on relationships between health news coverage and wider historical transformations in the social organization of health and medicine (Hallin et al., 2013, 2020).

LIMITATIONS OF THE STUDY

For this analysis, the posts from Facebook and websites of Russian NPOs were chosen which are likely to influence techno-scientific biomedical communication in Russia. However, it would be inaccurate to assume that the results from this study refer to the public discourse on the topic. We don't analyze a many different kinds of actors, only NPO and news media. There are too many other players in the health industry which participate in techno-scientific biomedical communication in Russia. The list of potential participants includes: governmental institutions and officials, which exercise the strategy dictated by state policies; patients' groups and associations; pharmaceutical industries; marketing and public relations firms that are outsourced by the industries; NGOs which provide relief and promote self-care; insurance companies and other commercial entities, for example, web platforms and equipment producers; and education and research sector, which uses the current situation to communicate the topicality of medical professions.

Some of these players have been studied before. For example, Endaltseva (2020) points out the role of Russian patients' associations. Activities of pharmaceutical companies were considered by many authors. Rodwin with colleagues argue that "healthcare expenditures in BRIC nations have exhibited the highest revenue growth rates for pharmaceutical multinational corporations. The response of BRIC nations to Big Pharma presents contrasting cases of how governments manage the tensions posed by rising public expectations and limited resources to satisfy them" (Rodwin et al., 2018). Balashova and Volgina express an opinion that Russia, Kazakhstan and Belarus have certain potential to take a leading position in the global pharmaceutical market. It relates to participation in global production and R&D expenditures (Balashova and

Volgina, 2021). In 2020 number of startups has increased in pharmaceuticals by 100% (Zemtsov et al., 2021). Apparently, techno-scientific biomedical communication in Russia is a complicated process which requires future investigation in stakeholders' behavior.

Further limitations refer to the implementation of the content analysis with a conventional topic modeling scheme based on LDA. LDA-produced clusters suggest pictures of semantic relations at the chosen period of time. The algorithm fails to reflect the dynamics of the communication process.

CONCLUSION

This study investigates the decade-long history (2011–2021) of the promotion of techno-scientific biomedical communication by pro-government non-profit organizations in Russia, on the example of the ASI and NTI. We tested and confirmed the hypothesis of the rooting of the e-health promotion in long-term communication, which creates, maintains, and transforms social and economic practices (Carey, 2009). It contributes to the investigation of communication factors in innovations.

The study revealed that the claim that the focus on high-tech medicine is novel and that it is driven by the pandemic is unreasonable. The history of this promotion can be linked to European innovation programs of the 2000s (Filos, 2004), which was reconsidered in Russia and reinforced by the 2014 geopolitical crisis. The NTI searching for a concrete model of high-tech development of the Russian health market may be linked in time to the European digital innovation concepts of the middle of 2010s (Georgescu et al., 2021).

We discussed three research questions. (1) When did the health communications of these NPOs begin and what were their stages of development? (2) What are the determinants of change? (3) What is the extent of the influence of such communication on the national health agenda generally? Answering the first research question, we described three main stages of the development of health communication: (1) proto-HealthNet agenda of 2011–2014; (2) search for an attractive model for the health market of 2014–2017; and (3) mature HealthNet e-health communication of 2017–2021.

Answering the second research question, we pointed out that the content of the communications was influenced by the authorities, NGOs, private companies, and mass media. Answering the third research question, we found that the non-profit organizations' impact on the general national health agenda was not as significant as mass media. Although NPOs' power of communication is not very significant, when it corresponds to mentioned social and political changes, it creates a communicative environment for the transformation of business models.

As a recommendation for the future, we propose to compare the agendas of non-profit organizations and national mass media to develop understanding of the trust in innovation and eHealth literacy.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: Public available page of Yandex.Disk: https://disk.yandex.ru/d/ORywBgAdltWJhQ.

AUTHOR CONTRIBUTIONS

AM: conceptualization and original draft preparation. IB: review and editing. All authors have read and agreed to the published version of the manuscript.

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Does YouTube Provide Qualified Patient Education Videos About Atrial Fibrillation?

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Objective: Patients utilize the internet as a pathway to acquire knowledge of specific diseases. However, there are limited oversight and review mechanisms to ensure the authenticity of online information. This study aimed to evaluate the quality of video-based resources used to obtain information about atrial fibrillation (AF).

Methods: Multiple AF-specific keywords were used to perform a systematic search of YouTube. Two independent reviewers reviewed the top 50 results of each keyword search. To record data, the Journal of the American Medical Association (JAMA) score, modified DISCERN score, AF-specific score (AFSS), and essential score (Escore) were used. The Kruskal-Wallis test was used for intergroup comparisons.

Results: A total of 74 videos that met the inclusion criteria were included in the analysis. In terms of video quality, 68% were poor, 19% were moderate, and 13% were exceptional. Videos submitted by publishers with a medical background were much less popular ($p < 0.05$) than those submitted by publishers without a medical background. The video quality did not differ among those included in this study.

Conclusions: Some videos on YouTube that are of real value are not as popular as those with low-quality content submitted by news agencies/media publishers. Furthermore, videos submitted by those with a medical background do not receive as much attention as others. It is important to acknowledge that video platforms should establish content and quality auditing mechanisms for videos. Furthermore, publishers should ensure that viewers receive accurate and complete knowledge and use more concise and accessible images or animations that are tailored to the audience.

Keywords: patient education, atrial fibrillation, We media, official account, physician, YouTube

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INTRODUCTION

Atrial fibrillation (AF) is the most common clinical arrhythmia disorder. It affects approximately 33 million individuals worldwide (1) and has an estimated population prevalence of 2% to 4% (2). AF is usually followed-up and managed on an outpatient basis; however, the prolonged absence of patients from the care of physicians combined with inadequate recognition of the disease by some patients may result in adverse outcomes. The risk of ischemic stroke for patients with AF is much higher than that for patients without AF, and its consequences are severe, frequently recurrent, permanently disabling, and fatal (3, 4).

Therefore, during the management of chronic diseases, such as AF, it is more important for patients to be fully aware of their pathophysiological status than for physicians to detail the dosage of medications and the timing of follow-up visits; however, both should be given full attention by physicians and patients.

Traditional health education has included the detailed explanation of illnesses by physicians at the clinic, distribution of educational materials such as pamphlets, and displaying of posters detailing relevant diseases; however, the streaming of videos on the internet has gradually become a contemporary and important way for patients and the general public to gain knowledge about diseases. YouTube is becoming an important source of non peer-reviewed medical information because it allows easy access to information and has worldwide popularity (5). The 2018 Health Information National Trends Survey mentioned that one-third of people have searched YouTube for videos about health-related topics (6). Although one study found that interns and attending physicians also acquire relevant knowledge by browsing online videos (7), the general population lacks knowledge of medical terminology, which can lead to the misunderstanding of non peer-reviewed audiovisual information. The anti-vaccine campaign on the internet, for example, prompted some individuals to refuse vaccination, thereby increasing the spread of infectious diseases and endangering the health of the entire population (8). This implies that the integration of online information obtained by such patients and the information communicated by their physicians can influence the process of making medical decisions. No study has investigated the availability and appropriateness of videos explaining AF as a patient-centered resource. In this study, we mimicked patients' self-searching behavior and systematically assessed the quality of videos posted on YouTube about the diagnosis and treatment of atrial fibrillation using four rating scales namely, Journal of the American Medical Association (JAMA), modified DISCERN, AF specific score, and essential score.

MATERIALS AND METHODS

Study Design

This was an observational retrospective study. Using YouTube, we searched for the keywords "Atrial Fibrillation," "AF," and "AF+Management" on 13 September 2021, and recorded the URL, number of views, number of likes/dislikes, and number of comments/responses, which may change over time, of the videos. The video content and quality evaluations were completed within the following month.

Measures

The keyword searches were performed by two authors using a cleared-cache web browser. They selected the top 50 results for each search term because patients who want to learn about AF (9, 10) are unlikely to exceed this range. Videos were excluded if they focused on only academic or narrative guidelines or diagnostic procedures. Videos relating to AF diagnosis, treatment, management were included in the analysis initially. Exclusion criteria were as follows: duplicate videos found during the search; videos with only audio; videos and video titles discordant with the content; and non-English language. Ultimately, 74 videos were included in the analysis.

Abbreviations: AF, atrial fibrillation; JAMA, Journal of the American Medical Association; AFSS, atrial fibrillation specific score; Escore, essential score; CPR, cardiopulmonary resuscitation.

TABLE 1 | JAMA Score benchmark criteria.

Authorship:	Authors and contributors, their affiliations, and relevant credentials should be provided.
Attribution:	References and sources for all content should be listed clearly, and all relevant copyright information noted
Disclosure:	Web site "ownership" should be prominently and fully disclosed, as should any sponsorship, advertising, underwriting, commercial funding arrangements or support, or potential conflicts of interest.
Currency:	Dates that content was posted and updated should be indicated.

JAMA, Journal of American Medical Association.

TABLE 2 | Modified DISCERN criteria.

1. Are the aims clear and achieved?
2. Are reliable sources of information used? (ie, publication cited, speaker is board-certified vascular surgeon)
3. Is the information presented balanced and unbiased?
4. Are additional sources of information listed for patient reference?
5. Are areas of uncertainty mentioned?

Data Collection

After a quick scan of the video during the first round of evaluation, the searcher checked whether the title and content of the video met the inclusion criteria. Finally, the two reviewers examined whether each of the videos met the standards. If there was a difference in opinion between the two reviewers, then it was resolved through consultation and re-examination. If no consensus was reached, then it was resolved by a third reviewer. The following data for each video were required: URL, video name, author qualification, upload date, video duration, number of views, numbers of likes, dislikes, comments, and author responses.

Because there is no scale that can be used to evaluate the quality of information provided by videos about AF, we developed a new scoring system, the AF specific score (AFSS), based on the existing literature and expert guidelines. The AFSS was found to have good reliability and validity (11, 12) (reliability: Cronbach's α =0.877; validity: Kaiser-Meyer-Olkin (KMO) = 0.785; and Bartlett's test of sphericity <0.001). The accuracy and reliability of the medical information in the retrieved videos were determined using the four standards of the JAMA score (13) and the modified DISCERN score created by Ubbink et al. (14) (**Tables 1**–**3**).

After the review, all videos were categorized into the following four groups according to whether the video publisher had a medical background: physicians group, medical facilities group, official accounts group, and news agencies/We media group

TABLE 3 | Video criteria grouped into parent categories.

Diagnose	Treatment	Management
1. Atrial Fibrillation Defination ***(Essential)***	1. Anticoagulant/Avoid stroke ***(Essential)***	1. Discussion of the indications/contradictions/possible complications of various treatments
2. Risk factors for AF ***(Essential)***	2. Surgical options such as AF ablation procedures(catheter/surgical)/left atrail appendage ***(Essential)***	2. Notifications of postoperative or drug follow-up care
3. Common clinical manifestation ***(Essential)***	3. Antiarrhythmic drug therapy ***(Essential)***	3. Mentions of AF is a disease that requires long-term treatment and needs patients' own participation in the management of this disease ***(Essential)***
4. Findings of a physical examination		4. Attention to the prevention and control of risk factors of AF
5. Electrocardiogram?Transthoracic echocardiography as diagnostic technique		
6. The consequences of allowing AF to be left untreated ***(Essential)***		

TABLE 4 | Escore, AFSS, JAMA Score, and DISCERN values categorized by video publisher type on YouTube.

Publisher type	N	Escore	AFSS	DISCERN	JAMA	Exceptional	Moderately	Poor
Medical facilities	13	5.15 ± 2.48	6.08 ± 4.03	2.46 ± 0.66	1.92 ± 0.64	4	2	6
News agency/ We media	24	3.13 ± 2.23	3.46 ± 2.62	1.87 ± 0.74	1.42 ± 0.50	0	4	20
Official accounts	22	4.77 ± 2.67	5.73 ± 3.69	3.09 ± 1.07	2.95 ± 0.72	4	5	13
physician	15	3.87 ± 2.75	4.53 ± 4.61	2.87 ± 0.92	3 ± 0.66	2	3	11
Total	74	4.12 ± 2.60	4.81 ± 3.74	2.54 ± 1.00	2.28 ± 0.94	10	14	50
P-value	N/A	0.078	0.126	**<0.001***	**<0.001***	0.259	0.407	0.325

Values are mean ± standard deviation (median).
*The * symbol indicates the statistical difference and the test method used in this analysis with a p value less than 0.05, Kruskal-Wallis test.*
The bold values indicates the p value which are less than 0.05 is considered to be statistically significant.

(**Table 4**). The scoring criteria were not simple because some points required the existence of more than one item. For example, for AF, three treatment schemes are indispensable; if one happened to be missing, then it may cause patients to misunderstand their condition, which could then delay their seeking of a diagnosis and treatment by a physician. If the video that was watched by patients lacked the introduction of a surgical treatment plan, then it may have caused them to mistakenly think that their disease could be treated only with drugs, thereby causing them to have too high or too low expectations of the diagnosis and treatment. Furthermore, some patients could have received a late diagnosis because of their fear of surgical risks or serious complications induced by the videos. Based on the AFSS, we created the essential score (Escore) as the most basic scale for the diagnosis, treatment, and management of AF. When the AFSS and Escore conflicted, we were able to quickly find and re-evaluate the video quality. The maximum JAMA score, DISCERN score, and Escore were 4, 5, and 8, respectively; 1 point was deducted for each missing item, and the minimum score was 0 points. For the diagnosis section of the AFSS questionnaire, the maximum score was 5 points, and 1 point was deducted for each missing item; the minimum score was 0 points. In the management section of the AFSS questionnaire, the maximum score was 4 points, and 1 point was deducted for each missing item.

These scoring criteria can determine whether the knowledge provided by the videos was sufficient. Furthermore, the essential item veto system excluded some videos that had sufficient elements but simply comprised a patchwork of knowledge points with little actual learning value. Therefore, this study was able to evaluate the usefulness and usability of videos through two screening mechanisms.

Statistical Analysis

All videos were categorized into the physicians, medical facilities, news agencies/We media, and official accounts groups (**Table 4**) and rated as exceptional (10–13 points), moderately useful (5–9 points), or poor (0–4 points). Categorical variables are presented as frequencies and relative frequencies, and continuous variables are reported as means. The research results were statistically analyzed using IBM SPSS Statistics version 26 software. According to the Kolmogorov–Smirnov test, the data in this study were non-normally distributed. The Kruskal-Wallis test was used to perform comparisons between groups. The Mann-Whitney U test was used to distinguish significant differences between groups. $P < 0.05$ was considered significant. Theoretically, video publishers with a medical background should produce high-quality videos that are more popular among viewers because of their authority and production values. During this study, we compared the video durations and numbers

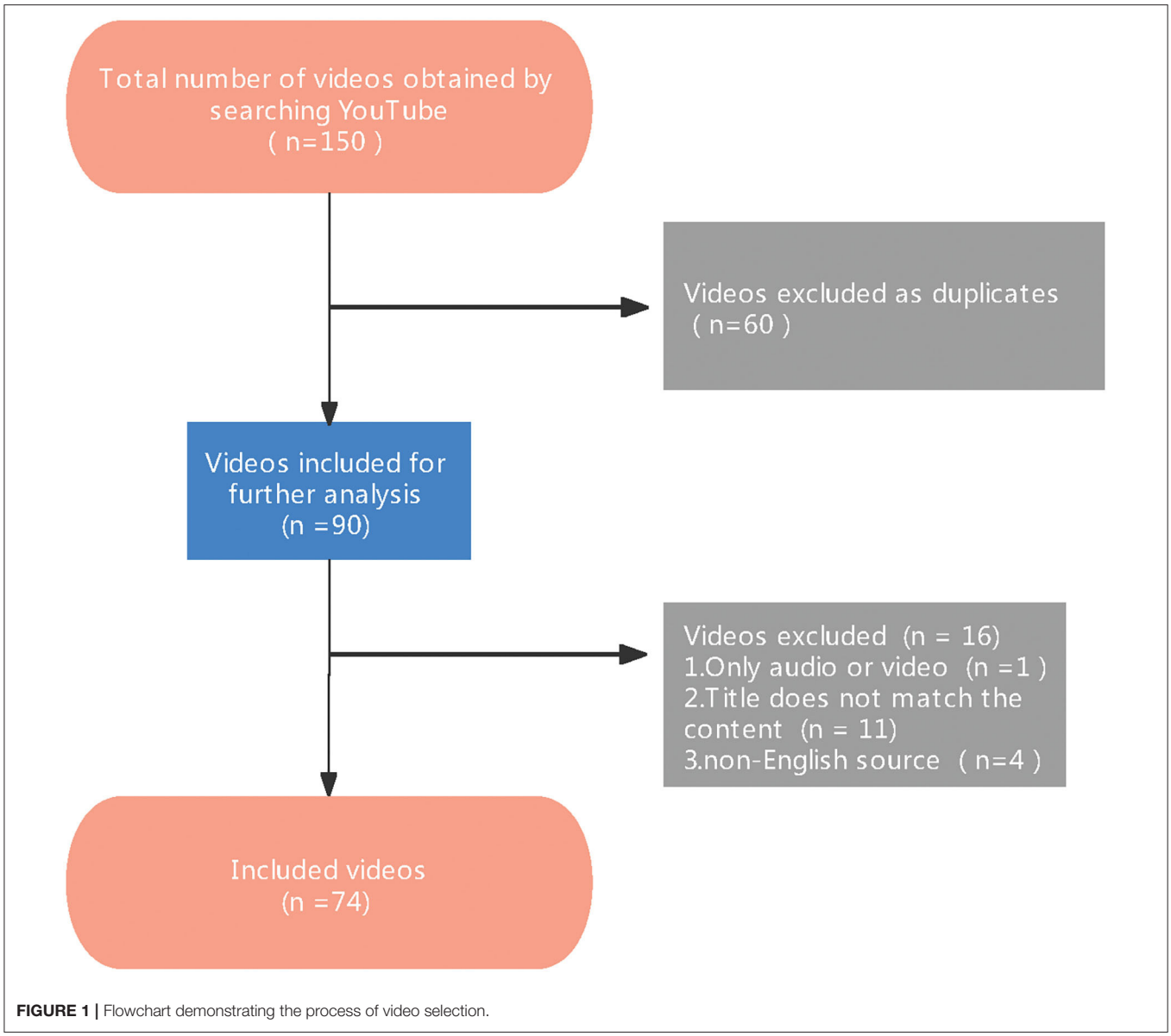


FIGURE 1 | Flowchart demonstrating the process of video selection.

of views, likes, comments, and responses by grouping videos according to their publisher type and quality.

RESULTS

A total of 150 videos were included in the analysis. Of these, 60 videos were excluded because they were duplicates, four videos were excluded because they included non-English language, one video was excluded because there was no audio, and 11 videos were excluded because they were not relevant to the topic. Finally, 74 videos were selected for analysis (**Figure 1**); 16% of these videos were in the medical facilities group, 32% were in the news agencies/We media group, 30% were in the official accounts group, and 22% were in the physicians group.

The percentages of videos with exceptional and moderately poor quality were not statistically different (**Table 4**, **Figure 2A**). The median times of the videos in the medical facilities, news agencies/We media, official accounts, and physician groups were 19.65 min, 5.37 min, 18.10 min, and 10.00 min, respectively ($p = 0.065$). Videos in the news agencies/We media group had the highest number of views (>10,000) (p=0.003) and were mainly within 10 min in length. Only the number of likes was statistically different among groups (**Table 5**, **Figures 2B,C**).

The JAMA score and modified DISCERN score were significantly higher for videos in the medical facilities and physician groups, which were published by those with a medical background, than for videos in the news agencies/We media and official accounts groups ($p < 0.001$). According to the video quality scores obtained using the Escore and the AFSS, there were a large number of low-quality videos with a duration of <10 min; furthermore, the number of views decreased as the running time increased (**Figure 2D**). Objective YouTube data

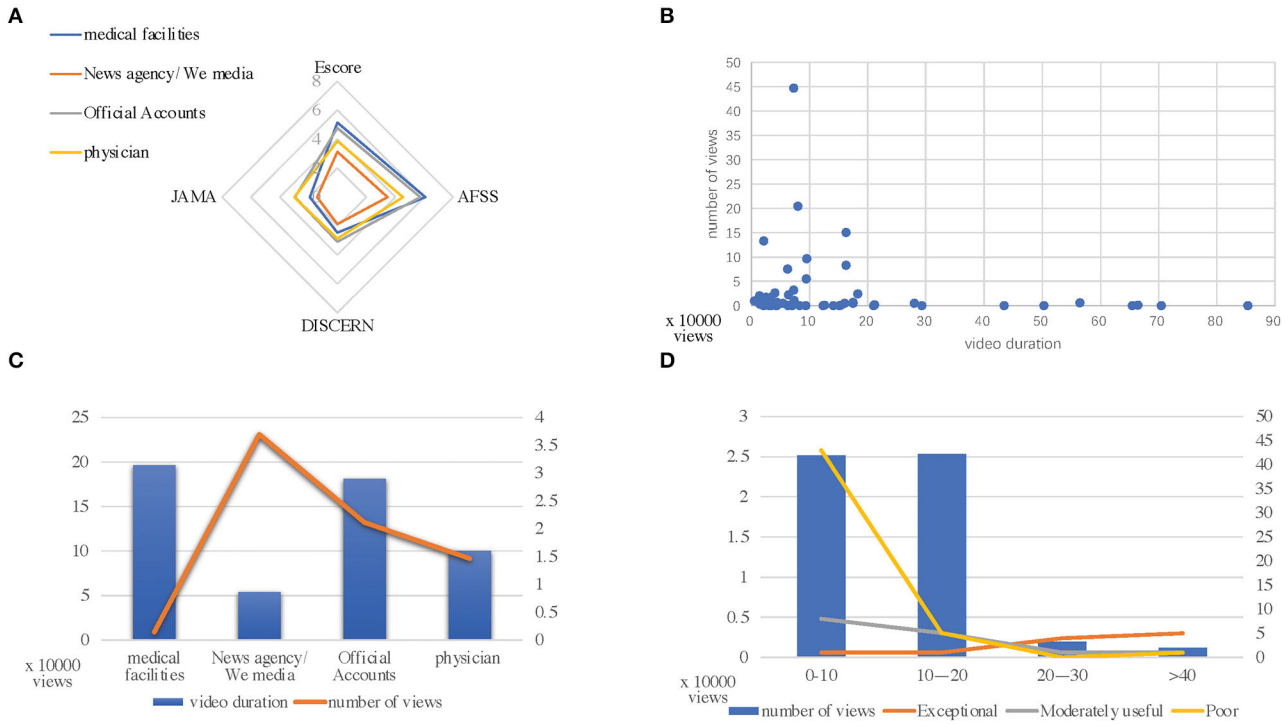


FIGURE 2 | (A) Escore, Atrial Fibrillation Specific Score (AFSS), JAMA, DISCERN values categorized by video publisher type. **(B)** Relationship between views and video duration. **(C)** Relationship between views and publisher type. **(D)** Relationship between views and video quality.

TABLE 5 | Objective data values categorized by video publisher type on YouTube.

Publisher type	Mean. Video duration	Mean. Views	Mean. Likes	Mean. Dislikes	Mean. Comments	Mean. Author responses
Medical facilities	18.69	1,428	15.75	0.5	1	0
News agency/ We media	7.79	36,963	479.75	12.1	20.63	2.29
Official Accounts	17.09	21,097	197.04	4.68	16.91	0.32
Physician	7.77	14,615	252.88	3.69	15.07	0.67
p-value	0.122	**0.003***	**0.032***	0.074	0.234	0.128

*The * symbol indicates the statistical difference and the test method used in this analysis with a p value less than 0.05, Kruskal-Wallis test.*
The bold values indicates the p value which are less than 0.05 is considered to be statistically significant.

(video duration, number of views, and number of likes) were obtained ($P = 0.003$). After integrating these data, we assessed the relationship between video quality and popularity and found that there was still a significant difference between the low-quality videos and medium-quality and high-quality videos during this study ($p = 0.043$) (**Tables 5**, **6**). During this analysis, only the aforementioned indicators were significantly different.

DISCUSSION

This study aimed to provide a better understanding of the quality of evidence provided by videos independently accessed by patients with AF using a large online media-sharing platform (YouTube). We found that lower-quality and less comprehensive videos about AF available on YouTube are more popular. Furthermore, we found no significant differences in the content quality and number of comments when comparing video publishers with and without a medical background.

During our assessment of video quality and review of the previous literature, we found that Ferhatoglu et al. assessed the reliability, utility, and quality of sleeve gastrectomy video information and reported that the use of a single rating scale without a targeted rating system does not accurately assess the true value and accuracy of videos (15). Accordingly, we evaluated the video quality using the JAMA score and modified DISCERN score (13, 14); furthermore, we performed a routine assessment of video items because there is no scale that can evaluate the quality of information regarding AF and created the AFSS and Escore based on the available literature and expert guidelines (11, 12). Of the four rating systems, Escore, AFSS, DISCERN

TABLE 6 | Objective data values categorized by video quality on YouTube.

Video Quality	Mean. Video duration	Mean. Views	Mean. Likes	Mean. Dislikes	Mean. Comments	Mean. Author responses
Exceptional	40.144	1,908	22.5	0.4	2.4	0
Moderately useful	14.6113	71,894	776	19.27	41.27	3.53
Poor	6.1639	10,301	127.32	3.37	9.63	0.39
p-value	**<0.001***	**0.043***	0.362	0.097	0.239	0.065

*The * symbol indicates the statistical difference and the test method used in this analysis with a p value less than 0.05, Kruskal-Wallis test.*
The bold values indicates the p value which are less than 0.05 is considered to be statistically significant.

score, and JAMA score, only the DISCERN and JAMA scores (**Table 4**) were significantly different ($p<0.05$) and able to reflect the rigor and structural integrity of the data used by the video publishers. The quality of the video content did not differ among these four rating systems, which was consistent with the results of Radonjic et al., who evaluated video information about abdominal aortic aneurysms. Theoretically, videos produced by physicians and authoritative medical institutions should have better structural integrity, data rigor, and video quality than those published by others; however, previous studies have not reached this conclusion (16–19). Additionally, our AFSS and Escore developed for AF did not differ significantly across the four subgroups of videos (**Table 4**). This seems to suggest that, on the YouTube platform, publishers with a medical background do not exhibit the expertise that they should. Our results were similar to those of Clerici et al., who analyzed a sample of 145 videos about rhabdomyosarcoma and reported that only 16.7% contained useful information and only one was posted by a physician and included correct information (20). In other words, if patients independently search the internet for knowledge regarding their AF symptoms, then they may find videos without rigorous data, with poor structural integrity, and with inadequate content.

The presentation of video content (graphic, animation, interview lecture, and conference video) varies based on the type of publisher. Gokcen et al. reported that YouTube videos of herniated disks presented by news agencies/We media and official accounts are usually designed to be more suitable for viewing by the general public (9). This has led to a higher number of views and increased popularity. During this study, we evaluated the relationship between the video publisher type and video quality and their associations with video popularity (**Tables 5**, **6**). Interestingly, there was statistically significant variability in the number of video plays and the number of video likes; however, the other evaluated indicators were not significantly different. During our review, YouTube videos with AF content published by those with a medical background did not receive as much attention as videos published by those without a medical background (**Figure 2C**). These indicators suggest that there were differences in video popularity and that the number of post-view comments should increase proportionally to the number of video plays as the popularity increases; however, the gap between the number of views and the number of favorites was too large. We suspect that most viewers do not understand the content of the video and are unable to ask questions or make suggestions about the content, or that the site counts only those who click on the video as viewers, resulting in inflated view numbers. Studies have indicated that attempting to learn specific procedures, such as cardiopulmonary resuscitation, through self-learning videos is a viable approach (21). Therefore, it is important to ensure the accuracy of the content in these videos (22, 23). When we analyzed the relationship between video quality and the number of video views, we also found that lower-quality videos had significantly more views than higher-quality videos ($p = 0.043$) and that the differences among the numbers of views, comments, and replies were too large. Loeb et al. evaluated videos about bladder cancer on YouTube and reported the lack of a corresponding association between the number of video likes and video ratings, suggesting that most viewers do not effectively identify the quality of the videos (24). Similar results were obtained during this study. Using YouTube, we found that the mean video duration was within 10 min and that most of the videos with a high number of views (>10,000) were within this length (**Figures 2B,C**). However, there are several low-quality videos with durations of <10 min, and as the video duration increased, the quality of the videos improved, but the number of views decreased sharply (**Figure 2D**). This indicates that low-quality videos and videos with incomplete content are more easily retrieved and viewed. Regarding the viewers, they do not seem to be able to accurately identify the quality of the video based on views and likes, and they may like lower-quality videos, which seems to suggest that people who view a video and obtain correct but incomplete knowledge may have false perceptions of their illness. As a result, they may avoid seeking the advice of a physician and may not seriously consider their condition. Patients who are provided with misleading information and who have incorrect expectations will find it more challenging to seek medical guidance and the treatment they need.

With the rapid development of information technology, contemporary internet streaming video sites are becoming one of the most important ways for patients and the general public to gain knowledge about diseases. Because of its worldwide popularity (approximately two billion hits per day) and easy access to information by 95% of the world, YouTube is a great source of non peer-reviewed medical information (25). However, medical videos comprise a special category of videos that need to be standardized because they are related to human health; therefore, they should be reviewed before release. ReFaey et al. mentioned that the internet is an important platform for patients

to access relevant resources; however, the control and censorship measures performed by these platforms for medical videos are limited and do not sufficiently ensure that the video content is accurate (26). It is evident that there are no standardized criteria for the intentions of the video publishers, video content, and audience demographics.

Limitations

Although this study simulated the search behaviors of patients independently looking for data, it had some potential limitations. First, we used search terms that may not fully include what the general public might use. We used only the top 50 search results on the YouTube website and excluded non-English videos. Videos from other online platforms were not analyzed; therefore, we may have missed some of the videos that should have been included in the analysis. Objective evaluation indicators, such as the number of views, number of likes, and number of comments on online video sites are dynamic and may subsequently change or affect the statistical results. Second, the scales used for this study, although developed based on authoritative guidelines and the literature, were not professionally vetted. Third, the video search performed during this study only simulated patient behavior and may have been inaccurate. The quality of all videos on YouTube was not fully analyzed; therefore, the overall quality of the videos was not fully reflected.

CONCLUSION

With the advent of information technology, people can access knowledge from multiple sources. This is a double-edged sword that can be both beneficial and harmful. Large amounts of video content regarding AF are available on the internet. During this study, we found that some YouTube videos that are of real value are not as popular as ones with low-quality content submitted by publishers without a medical background and that videos submitted by individuals with a medical background do not receive as much attention as others. The reason for this may be that the video content is not presented in a way that appeals to the masses, and that the quality does not differ from that of other publishers. It is essential to acknowledge that video platforms should establish auditing mechanisms for content and quality. Publishers should ensure that viewers receive accurate and complete knowledge while providing more concise and accessible images or animations tailored to the audience.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

ZW and WL designed and revised the manuscript. CL, LB, and LJ performed data acquisition and statistical analysis. All authors have read and approved the final manuscript.

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Computer Visual Syndrome in Medical Students From a Private University in Paraguay: A Survey Study

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Purpose: To determine the prevalence and factors associated with computer vision syndrome in medical students at a private university in Paraguay.

Methods: A survey study was conducted in 2021 in a sample of 228 medical students from the Universidad del Pacífico, Paraguay. The dependent variable was CVS, measured with the Computer Visual Syndrome Questionnaire (CVS-Q). Its association with covariates (hours of daily use of notebook, smartphone, tablet and PC, taking breaks when using equipment, use of preventive visual measures, use of glasses, etc.) was examined.

Results: The mean age was 22.3 years and 71.5% were women. CVS was present in 82.5% of participants. Higher prevalence of CVS was associated with wearing a framed lens (PR = 1.11, 95% CI: 1.03–1.20). In contrast, taking a break when using electronic equipment at least every 20 min and every 1 h reduced 7% (PR = 0.93, 95% CI: 0.87–0.99) and 6% (PR = 0.94, 95% CI: 0.89–0.99) the prevalence of CVS, respectively.

Conclusion: Eight out of 10 students experienced CVS during the COVID-19 pandemic. The use of framed lenses increased the presence of CVS, while taking breaks when using electronic equipment at least every 20 min and every 1 h reduced CVS.

Keywords: medical students, visual fatigue, computer visual syndrome, eye disorder, Paraguay

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INTRODUCTION

Computer vision syndrome (CVS) is defined as "a group of visual and ocular problems related to the prolonged use of computers and devices with video terminals" (1). This syndrome is determined by three mechanisms: the extra ocular mechanism, due to poor posture in front of computer devices, causing musculoskeletal symptoms; accommodative mechanism produces blurred vision, diplopia, myopia and delay in the change of focus; and finally, the ocular surface mechanism, which is related to corneal dryness, reduced blink rate, increased corneal exposure caused by horizontal gaze at the screen of computing devices (2–5). Currently it is estimated that there are 60 million people who suffer from CVS (6), this is due to the fact that today the hours spent in front of an electronic screen are more constant, in order to meet the demands of the modern world (7). Studies report that spending more than 3 h a day in front of video terminal devices increases the prevalence of CVS (8, 9).

In China, 50.8% and 74.3% of Chinese and foreign medical students; respectively, presented CVS. In Saudi Arabia, a prevalence of 97.3% was found for CVS; in turn, the most frequent symptoms were headache, sensation of affected vision (myopia or hyperopia), itchy eyes and burning sensation (10). In Jamaica, 40.3% of students used the computer for more than 6 h and the most frequent symptoms associated with CVS were neck pain, eyestrain, shoulder pain and burning eyes (11). Another study concluded that pre-existing eye diseases (myopia) had a significant relationship with computer-related visual symptoms (12). In Peru, 61% of postgraduate students presented CVS, in turn those who suffered from myopia and astigmatism had a prevalence of CVS of 36.1% and 24.6%; respectively (13). In Peruvian medical students, in the context of the COVID-19 pandemic, the prevalence of CVS was 80.6%. Male sex, age between 16–23 years, time spent of more than 6 h a day in front of the computer or more than 5 h in front of the cell phone, the use of preventive visual measures and not having eye diseases was associated with CVS (14).

The CVS represents a public health problem (15), mainly in medical students, due to their high frequency of use of computer devices (16–19), even more so in the current context of the COVID-19 pandemic, where they have increased their use for virtual education (14, 20–23). However, few studies have evaluated the impact of virtual education on the development of CVS during the COVID-19 pandemic (20, 21), much less in Latin-America (14). Additionally, the influence of hour of device use per day (notebook, smartphone, PC, tablet) on the presence of CVS has not been explored, which is addressed in this research.

Therefore, the objective of this study is to determine the prevalence and factors associated with CVS in medical students at a university in Paraguay.

MATERIALS AND METHODS

Study Design, Population and Sample

A cross-sectional survey study was conducted in medical students from the Universidad del Pacífico, Paraguay during the period from July to September 2021. For the calculation of the sample size, an expected frequency of 80%, a confidence interval of 95% and a precision of 5% was estimated for a population size of 584 students. A sample size of 174 was calculated, of whom 254 were invited to the study and only 228 accepted, representing 39% of the total. Non-probabilistic convenience sampling was used. Students who completed the variables of interest in the study were included. Students who did not wish to participate in the survey were excluded.

Variables

The dependent variable was CVS, operationally defined as the presence of at least one symptom such as eye fatigue, blurred vision, headache, dry eyes, excessive tearing, blurred vision, double vision, eye irritation, and changes in color vision; that occur due to the use of a computer or other electronic device, either regular or frequent, in at least 1 week of the last 12 months (24).

The independent variables were age, gender, academic block, glasses, hours spent on the notebook, hours spent using the smartphone, use of visual preventive measures, taking breaks when using computers, and previous eye diseases.

Measures

A questionnaire consisting of 2 sections was designed (see **Supplementary File 1**).

Socio-educational data: a questionnaire was constructed based on 9 closed questions, in order to obtain information in a general way from each student surveyed. This questionnaire included: age (expressed in years), sex (male or female), academic cycle (clinical or preclinical), use of glasses (not wearing, glasses with frames or contact lenses), hours of use per day of notebook, Smartphone, PC and tablet (<2 h, 2–4 h, 4–6 h, more than 6 h), use of visual preventive measures (Yes or No), taking a break after using equipment (at least every 20 min, every 1 h, every 2 h, after more than 2 h, no rest), eye diseases (Yes or No).

CVS Questionnaire (CVS-Q): Designed to measure the CVS, it is composed of 16 items, which are the symptoms perceived by the student, in order to evaluate the frequency with its categories of: never (none occasion), occasionally (eventually or once a week), often or always (2 or 3 times a week or almost every day); and intensity with its categories: Moderate or Intense. The values for the categories are as follows: Never = 0 points, Occasionally = 1 point, Often or always = 2 points, Moderate = 1 point, and Severe = 2 points. The result of the multiplication of frequency and intensity will give us the severity that must be recoded with the following values: 0 = 0 points, 1 or 2 = 1 point, 4 = 2 points; and then the severity scores are added, and if they yield a score $\geq$ 6 points, the student will be considered to have a computer vision syndrome. It should also be noted that if the student never marked the frequency, nothing would be marked in the intensity box. This questionnaire presents the following psychometric properties: Cronbach's alpha of 0.87 and a sensitivity and specificity > 70%. With which it becomes an acceptable questionnaire (25).

Procedures

A virtual questionnaire was created using the Google Forms© tool to collect the data. The virtual link of the survey was socialized through social networks (email, WhatsApp groups) of each academic year. After collecting the data, they were processed using the Microsoft Excel program.

Data Analysis

A univariate analysis was performed, which consisted of frequencies (relative and absolute), measures of central tendency and dispersion (mean and standard deviation, median and interquartile range). The factors associated with CVS were evaluated using the chi-square test, after evaluating the assumption of expected frequencies. In the case of the numerical variable (Age), the student's *t*-test was used, after evaluating the assumption of distribution in both comparison groups. $p < 0.05$ was considered as statistically significant.

Simple and multiple regression models were built, and prevalence ratios (PR) and 95% confidence intervals (95% CI)

TABLE 1 | Characteristics of participants and use of technologies ($n = 228$).

Characteristics	*N* (%)
Age (years)*	**22.3 ± 2.6**
Sex	
Female	163 (71.5)
Male	65 (28.5)
Cycle	
Preclinical	119 (52.2)
Clinical	109 (47.8)
Previous ocular disease	
No	87 (38.2)
Yes	141 (61.8)
Use of lenses	
No	86 (37.7)
With frame	135 (59.2)
Contact lenses	7 (3.1)
Use of preventive visual measures	
No	42 (18.4)
Yes	186 (81.6)
Hours in the day spent using a notebook	
<2 h	28 (12.3)
Between 2 to 4 h	38 (16.7)
Between 4 to 6 h	50 (21.9)
More than 6 h	112 (49.1)
Hours in the day spent using a smartphone	
<2 h	10 (4.4)
Between 2 to 4 h	15 (6.6)
Between 4 to 6 h	43 (18.9)
More than 6 h	160 (70.2)
Hours in the day spent using a tablet	
<2 h	157 (68.9)
Between 2 to 4 h	28 (12.3)
Between 4 to 6 h	19 (8.3)
More than 6 h	24 (10.5)
Hours in the day spent using a PC/Laptop	
<2 h	171 (75.0)
Between 2 to 4 h	14 (6.1)
Between 4 to 6 h	15 (6.6)
More than 6 h	28 (12.3)
Breaks taken of technology use	
Don't take breaks	36 (15.8)
At least every 20 min	57 (25.0)
Every 1 h	49 (21.5)
Every 2 h	28 (12.3)
After more than 2 h	58 (25.4)
CVS**	
Absent	40 (17.5)
Present	188 (82.5)

**Mean ± standard deviation **CVS, Computer visual syndrome.*

were estimated to evaluate the potential factors associated with CVS. Poisson distribution family, log link function and robust variance were used.

Statistical analysis was performed in the Stata v.17.0 program.

Ethical Considerations

The research was reviewed and approved by the Ethics Committee of the Universidad del Pacífico, Paraguay. The confidentiality of the participants was preserved at all times, since the questionnaire was anonymous. Informed consent was requested prior to study participation. The principles of the Declaration of Helsinki (beneficence, non-maleficence, autonomy, justice and confidentiality) were considered.

RESULTS

Of 228 medical students surveyed, the mean age was 22.3 years, 71.5% were women, 52.2% were in preclinical academic cycles. Most of the participants (61.8%) reported having a previous ocular disease and 59.2% reported wearing framed lenses. 12.3% of students reported using the computer/laptop for more than 6 h. 70.2% of students reported using the smartphone for more than 6 h. 25.4% reported taking breaks after more than 2 h of technology use. 82.5% presented SVI. **Table 1**

Students who had previous ocular disease had an 18.1% higher prevalence of CVS, compared to those without disease (89.4% vs. 71.3%; $p < 0.001$). Students who took preventive visual measures had a 16.4% higher prevalence of CVS, compared to those who did not take any measures (85.5% vs. 69.1%; $p = 0.011$). Additionally, the use of glasses ($p < 0.001$), hours of daily tablet use ($p = 0.015$) and taking breaks when using electronic equipment ($p = 0.002$) were associated with CVS **Table 2**.

The eye diseases that the students reported most frequently were myopia (41.7%) and astigmatism (23.3%) **Figure 1**.

In the simple model, we found that the factors associated with a higher prevalence of CVS were, having previous ocular disease (PR = 1.11; 95% CI: 1.02–1.20), wearing framed lenses (PR = 1.13; 95% CI: 1.04–1.22), use of a notebook more than 4 h a day (PR = 1.05; CI95%: 1.01–1.11). On the contrary, the factors associated with a lower prevalence of CVS were taking a break at least every 20 min (PR=0.92; CI95%:0.86–0.98) and every 2 h (PR = 0.89; CI95%:0.80–0.99) when electronic equipment is used. In the multiple models, we found that students who wear framed lenses had an 11% higher prevalence of CVS (PR = 1.11; 95% CI: 1.03–1.20). Taking breaks when using electronic equipment at least every 20 min and every 1 h reduces the prevalence of CVS by 7% (PR = 0.93; 95% CI:0.87–0.99) and 6% (PR = 0.94; 95% CI:0.89–0.99); respectively **Table 3**.

DISCUSSION

Prevalence of Computer Visual Syndrome

CVS represents a medical condition which risk has increased exponentially after the implementation of the new public health measures to prevent the transmission of SARS-CoV-2, by suspending face-to-face university activities, exposure to devices has increased. Computer systems, which inevitably represents negative effects at the ocular/visual level (14). In the present study, it was obtained the participation of 228 Medicine students who took hybrid classes, meaning, face-to-face and virtual classes, at a private university in Paraguay.

TABLE 2 | Factors associated with computer visual syndrome.

Variables	*CVS*		*p**
	No (*n* = 40) *n* (%)	Yes (*n* = 188) *n* (%)	
Age (years)***	22.5 ± 2.1	22.3 ± 2.8	0.635**
Sex			0.317
Female	26 (16.0)	137 (84.1)	
Male	14 (21.5)	51 (78.5)	
Previous ocular disease			**<0.001**
No	25 (28.7)	62 (71.3)	
Yes	15 (10.6)	126 (89.4)	
Use of lenses			**<0.001**
No	26 (30.2)	60 (69.8)	
With frame	12 (8.9)	123 (91.1)	
Contact lenses	2 (28.6)	5 (71.4)	
Use of preventive visual measures			**0.011**
No	13 (31.0)	29 (69.1)	
Yes	27 (14.5)	159 (85.5)	
Hour in the day spent using a notebook			0.090
≤ 4 h	16 (24.2)	50 (75.8)	
≥ 4 h	24 (14.8)	138 (85.2)	
Hour in the day spent using a smartphone			0.830
≤ 4 h	4 (16.0)	21 (84.0)	
≥ 4 h	36 (17.7)	167 (82.3)	
Hour in the day spent using a tablet			**0.015**
≤ 4 h	27 (14.6)	158 (85.4)	
≥ 4 h	13 (30.2)	30 (69.8)	
Hour in the day spent using a PC/Laptop			0.517
≤ 4 h	31 (16.8)	154 (83.2)	
≥ 4 h	9 (20.9)	34 (79.1)	
Breaks taken of technology use			**0.002**
Don't take breaks	4 (11.1)	32 (88.9)	
At least every 20 min	15 (26.3)	42 (73.7)	
Every 1 h	10 (20.4)	39 (79.6)	
Every 2 h	9 (32.1)	19 (67.9)	
After more than 2 h	2 (3.5)	56 (96.6)	

*p-value of categorical variables calculated with the Chi Square test.
**p-value of categorical–numerical variables calculated with the Student's t-test.
***Mean ± standard deviation.
Significant p-values ($p < 0.05$) are highlighted in bold.

We found that almost 8 out of 10 students presented CVS (82.5%). This is higher than what was found in Chinese medical students during the SARS-CoV-2 outbreak period, where the prevalence of CVS was 50.8% and 74.3% in Chinese and foreign students; respectively (21). In a study in which the CVS-Q was used in medical university students in Spain, the prevalence was 76.6%, somewhat lower compared to our study (82.5%) (26). A study conducted during virtual education due to the COVID-19 pandemic in Lima, Peru in medical students applying the CVS-Q, estimated a slightly lower prevalence compared to our study (80.6%) (14). However, the prevalence from this study was similar with pre-pandemic estimates. A study in Italian engineering students found that 90% of them presented visual fatigue during long sessions of computer-aided design (27). Also, a study in Malaysian university students showed that 89.9% of them presented CVS (28). Conversely, in office workers, a lower prevalence (approximately 50 to 70%) was reported (4, 5). These differences may be due in part to the different use demands of computers or electronic devices in certain careers, which makes CVS an important feature in students. Also, in the case of work offices, preventive measures may have been timely implemented, such as intermittent breaks during work hours. This contrasts with the medical students' context, in which they are mostly exposed to long and continuous hours of study and therefore potential greater exposure to electronic devices (29). The prevalence reported here allows us to highlight the problem that the pandemic have caused in ocular health of medical students, and how it would shape up in the long term. This inadvertent exposure in medical students would bring health sequelae that we intend to alert the authorities of local and regional medical schools.

Additionally, we found that almost half of the students reported having myopia. This is similar to what was reported in Peru, where almost half (36.1%) of postgraduate students presented myopia (30). However, it differs from what was reported in Arabia, where myopia was one of the most significant findings related to CVS, being found in more than half of the students (77.8%) (12). However, it differs from what was reported in Chinese schoolchildren during the COVID-19 pandemic, where almost half (48%) presented eye dryness and itching (20).

Factors Associated With Computer Visual Syndrome

According to the multiple regression analysis, students who took breaks at least every 20 min and every 1 h reduced the prevalence of having CVS. This is similar to multiple studies conducted in Arabia and Peru reported that taking rest is considered a protective factor for CVS (14, 31). In 2,363 students from China, failure to take a 20-sec break every 20 min of work was found to increase the likelihood of having CVS during the COVID-19 pandemic (20). This association could be explained because it has been seen that taking breaks, whether short or long, contributes to the relaxation of the eye muscles, thus preventing eye fatigue or tiredness (6).

In our study, multivariate analysis showed that those who wear framed lenses have a higher prevalence of suffering from CVS. This contrasts with another study carried out in Peru, in which no significant association was found. On the contrary, other works, such as a study in India, coincide with our reports, where it was found that the use of framed lenses and having blurred vision increase the frequency of CVS. The discrepancy between the studies mentioned could be due to the fact that the use or not of certain protective filters in said lenses was not included in the instrument, generating information bias in the investigations carried out (10, 14, 32).

A noteworthy result from the simple regression analysis showed that students who reported having a history of some ocular pathology had an 11% higher prevalence of CVS, which coincides with other studies reported in Peru and Saudi Arabia (12, 14). This is consistent with what was described by a similar study, where it was found that medical students who had

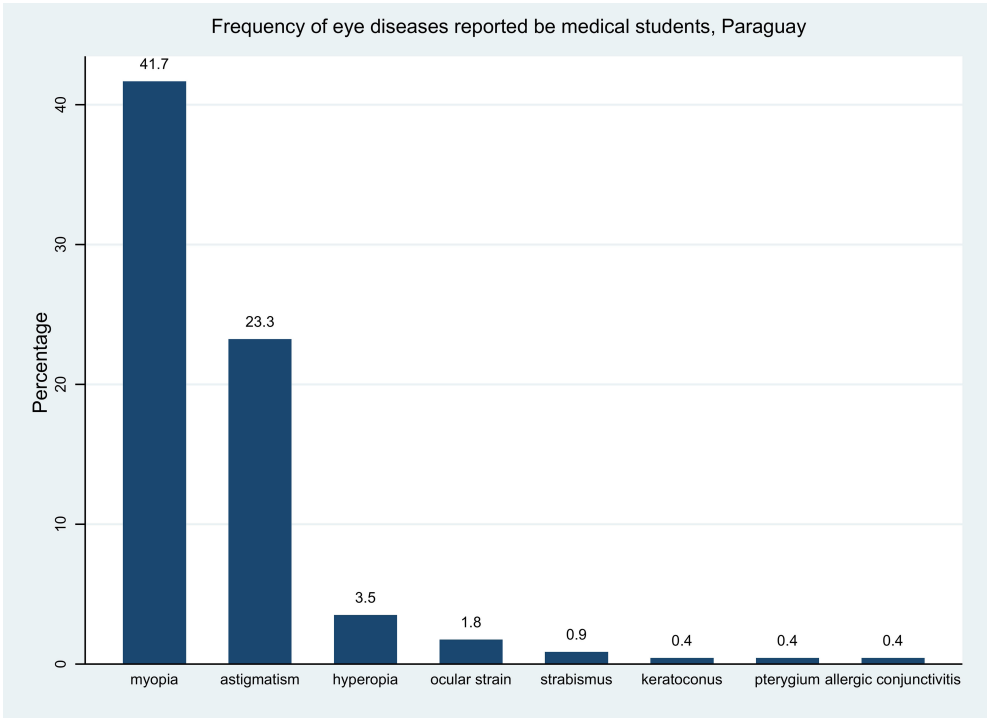


FIGURE 1 | Frequency of self-reported eye diseases.

previous ocular pathologies such as myopia had a significant relationship with presenting CVS (12). In China, research conducted in schoolchildren during virtual learning in the COVID-19 pandemic found that those with other ocular diseases were more likely to have CV (20). However, it contrasts with another study carried out in Saudi Arabia, where it was found that refractive errors such as myopia and hyperopia did not have a significant association with CVS (26). The possible explanation for this association is that due to the long hours that the student spends in front of a computer, a greater sustained effort is needed for visual accommodation and this leads to the generation of ocular discomfort such as a sensation of tearing, blurred vision and other symptoms that make up CVS (16).

In this study, we have found that students used mostly smartphones compared with other electronic devices. This higher use was not supported by the bivariate and multivariate analysis to demonstrate that this behavior increased the prevalence of perceived CVS. This could be explained by the low sample size used to compare the prevalence estimates of CVS according to the time spent on smartphones. However, we did not collect additional information on which device was mainly used for classes or study. This limits our strength to assume that higher smartphone use increased the prevalence of CVS. Another possible reason for this absent difference is that students may have used electronic devices with time breaks for exposure reduction. This particular use may be related to the awareness they had with ocular health. In addition, a cutoff of 4 h to compare the use patterns of electronic devices might not be precise enough to find differences on the prevalence of CVS (33–35).

Limitations and Strengths

This research has some limitations. First, potential selection bias, since they only involve findings from one university site, therefore, the results cannot be inferred to the entire study population. Second, due to the cross-sectional design of the study, it is not possible to attribute causality between the variables that were associated with CVS. Third, it was not possible to measure other confounding variables for CVS such as stress, hours of sleep, presence of dry eye, which could lead to measurement bias. Despite the aforementioned limitations, an instrument with optimal psychometric properties has been used to measure CVS and represents a solid approach on the factors influencing CVS in physicians in training in Latin America during the COVID-19 pandemic.

Public Health Implications of Findings

The findings of this study provide us with preliminary scientific evidence that CVS is very prevalent in human medicine students. Therefore, it provides a consistent analysis to be able to use corrective measures and thus be able to avoid progression to CVS; in turn, avoid generating higher expenses in treatments caused by this syndrome and optimize the student's academic performance. Also encourage other studies to be carried out with greater rigor (in which a follow-up is carried out throughout the different academic cycles, incorporating more university populations from

TABLE 3 | Factors independently associated with computer visual syndrome, simple and multiple regression analysis.

Characteristics	*CVS*					
	Simple regression			Multiple regression		
	PR	95% CI	p*	PR	95% CI	p*
Age (years)		1.00	0.99–1.01	0.694		
Sex						
Female	Ref.					
Male	0.97	0.89–1.05	0.473			
Previous ocular disease**						
No	Ref.					
Yes	1.11	1.02–1.20	**0.015**			
Use of lenses						
No	Ref.			Ref.		
With frames	1.13	1.04–1.22	**0.006**	1.11	1.03–1.20	**0.007**
Contact lenses	1.01	0.84–1.22	0.918	0.98	0.86–1.11	0.706
Use of preventive visual measures						
No	Ref.					
Yes	1.10	0.96–1.25	0.173			
Hour in the day spent using a notebook						
≤ 4 h	Ref.			Ref.		
≥ 4 h	1.05	1.01–1.11	**0.049**	1.02	0.99–1.06	0.235
Hour in the day spent using a smartphone						
≤ 4 h	Ref.					
≥ 4 h	0.99	0.93–1.05	0.767			
Hour in the day spent using a tablet						
≤ 4 h	Ref.					
≥ 4 h	0.92	0.82–1.02	0.117			
Hour in the day spent using a PC/Laptop						
≤ 4 h	Ref.					
≥ 4 h	0.98	0.92–1.04	0.472			
Breaks taken of technology use						
Don't take breaks	Ref.			Ref.		
At least every 20 min	0.92	0.86–0.98	**0.014**	0.93	0.87–0.99	**0.019**
Every 1 h 0.95		0.90–1.00	0.073	0.94	0.89–0.99	**0.019**
Every 2 h 0.89		0.80–0.99	**0.032**	0.91	0.81–1.02	0.100
After more than 2 h	1.04	0.96–1.13	0.327	1.04	0.97–1.11	0.313

**p–values obtained with Generalized Linear Models, Poisson family, log link function, robust variance.*
***Does not enter multiple model due to collinearity.*
PR, prevalence ratio; 95% CI, 95% confidence interval.
Significant p-values ($p < 0.05$) are highlighted in bold.

different academic faculties, incorporating other variables that could be associated with CVS such as dry eye, stress, hours of sleep, among others), it would also be extremely important that the research contains at least one group of specialists in the field, and thus reach conclusions that can contribute satisfactorily in the study of this pathology.

Conclusions

This study determined the prevalence of CVS and its associated factors in medical students from a Paraguayan university. We found that 8 out of 10 students had CVS during the COVID-19 pandemic. Taking breaks when using electronic equipment at least every 20 min and every 1 h reduces the prevalence of CVS. Conversely, the use of framed lenses increases this condition. Our findings highlight the importance of preventing CVS in medical students, encouraging the use of technology in an early and timely manner. Special attention should be paid to those presenting the risk factors described here, to reduce complication related to CVS.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Universidad del Pacífico, Paraguay. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JC-O was involved with conceptualization. JG and PQ-C conducted literature searches. JC-O, JG, and AG wrote original draft of the manuscript and were involved with formal analysis. MV-G gave input on specification of models and methodology. JC-O and MV-G verified the underlying data and curated data. All authors contributed to conceptualization, data interpretation, and manuscript review and editing. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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Knowledge about, attitude toward, and practice of complementary and alternative medicine among nursing students: A systematic review of cross-sectional studies

Fei-Yi Zhao [1,2,3], Gerard A. Kennedy [2,4,5], Sonja Cleary [2], Russell Conduit [2,5], Wen-Jing Zhang [3*], Qiang-Qiang Fu [6*] and Zhen Zheng [2]

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Background: The globally growing demand for complementary and alternative medicine (CAM) has attracted educators' attention to integrate CAM into conventional nursing programs. This systematic review aimed to understand the status quo of nursing students (NSs)' overall rated knowledge of, attitude/belief toward, and practice/previous use or experience (KAP) of CAM in surveys, given these factors may influence NSs' receptivity to CAM curricula, and may be of value in guiding the development of effective teaching strategies.

Methods: Formally published cross-sectional quantitative studies investigating the primary outcome of KAP toward CAM by NSs were searched for from eight databases from their inception through to 28 April 2022. *PRISMA 2020* guidelines were followed.

Results: Twenty-six studies were included for analysis, 25 of which were judged to be of moderate to high quality. Despite limited and poorly informed knowledge of CAM therapies, the majority of NSs generally viewed them in a positive light. Furthermore, NSs usually reported an interest in further learning, and supported and welcomed the integration of CAM curricula, at least as elective modules, into existing nursing programs. Lack of evidence was perceived as a major barrier to the use or integration of CAM. Mass media and the internet were the main sources *via* which NSs access CAM information. Measurement of KAP in all included studies was *via* self-designed questionnaires/scales or adapted from previously developed questionnaires/scales.

Conclusions: The need for integrating and strengthening CAM curricula into current nursing education is identified. Besides theoretical knowledge

and matched clinical placement, skills training in literature searching and evidence-based practice are advised to be included in the curricula design. The experiential learning mode is strongly recommended for delivering specific CAM modalities. In addition, a standard instrumentation for determining NSs' KAP toward CAM should be designed and examined for use in different cultural settings.

Systematic Review Registration: https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=300602, identifier: PROSPERO CRD42022300602.

KEYWORDS

complementary and alternative medicine, nursing students, nursing education, knowledge, attitude, practice, KAP, systematic review

Introduction

Complementary and alternative medicine (CAM) refers to an array of medical- and health- related systems, practices, and products that are not generally considered part of biomedical focused mainstream or conventional healthcare (1, 2). In accordance with the National Center for Complementary and Integrative Health (updated on April 2021), CAM interventions can be classified into five categories depending on their primary therapeutic input: nutritional (e.g., dietary supplements, special diets), psychological (e.g., hypnosis, mindfulness), physical (e.g., massage, spinal manipulation), combinations such as psychological and physical (e.g., dance, yoga) or psychological and nutritional (e.g., mindful eating) interventions, and other complementary health approaches (Appendix 1) (3). Despite the availability and benefits of modern biomedical models of healthcare, the demand for CAM therapies remains widespread and has been grown over the past decades (2, 4). The evidence base for use of certain CAM therapies is also expanding (5). A national population-based survey in 2007 revealed that 68.9% Australians had utilized at least one CAM therapy in the past 12 months; and the annual "out of pocket" expenditure on CAM was estimated over 4 billion Australian dollars (6). A similar survey in the same year in USA demonstrated that approximately four out of 10 adults and one out of nine children used CAM therapies in the previous 12 months (7). In European countries, it is estimated that 20–50% of the population utilized CAM therapies (8), and this percentage is even higher in Africa and Asia, where it is approximately 80% (9).

The evidence associated with the efficacy and safety of CAM is mixed, with some modalities widely accepted by mainstream healthcare whereas others remain controversial (10). For instance, diet and exercise therapies are considered to be a part of mainstream medical and healthcare practice (11); while, the usage of herbal products in combination with conventional medicine is poorly understood and considered to be risky (10). Worryingly, for a diversity of reasons (e.g., their perceptions that the medical physicians lack relevant knowledge, fear of being admonished or evoking negative responses, etc.), more than half of patients did not discuss or inform their physicians about experiences with CAM utilization, which increases lots of associated risks (10). Patient-provider communication about CAM approaches can support patient self-management by minimizing risk and optimizing care (12). In comparison with medical practitioners or other health professionals, nurses may play a more crucial part in communicating with patients about CAM utilization (13) and may be in a unique position to bridge the gap in communication between patients and their physicians, and between the clinical use of CAM and conventional medicine (14, 15). The rationale and justification for this supposition is as follows: Firstly, the basic tenets of most CAM approaches are individualization, and holistic in nature, that is to see humans as the totality of the biological, psychological and spiritual dimensions (8, 15–17). Those approaches are also the basis of many nursing practices (8, 15, 16). Secondly, nurses are the main providers of hands-on healthcare and the largest health professional group (17). Nurses typically spend more time building trust with patients and therefore patients usually feel more comfortable in disclosing details of CAM use to them (10). Thirdly, due to their predominant position in patient care, assessment, education, advocacy, and decision-making, nurses' knowledge of and attitudes about CAM therapies are also likely to affect patients' health beliefs, behaviors and decisions concerning these therapies (2, 17). It is particularly critical for nurses to provide or direct patients toward more evidence-based CAM information for those who rely on advertising or guidance from family and friends (10).

Accumulated evidence indicates that nurses with basic CAM knowledge have a higher likelihood of engaging patients in conversations about their use of CAM products and practice (10, 18–20). Conversely, lack of considerable knowledge is perceived by many nurses as a primary barrier to initiating CAM dialogue with patients (2, 10). More importantly, incorporating CAM into medical training has been found to significantly increase the safe use of integrative approaches in conventional

healthcare (21). Nursing students (NSs), as future healthcare professionals, must be prepared to advise and guide patients to credible resources among a vast array of remedy options available and widely utilized (16), which is an embodiment of the patient-centered care mode. Furthermore, NSs' knowledge and perception of CAM are also key determinants to safe practice (9). This is because NSs' receptiveness to CAM can play a role in how CAM can be safely practiced alongside conventional medicine and if patients' need for CAM is considered in future medicine (22). Given the growing and continuing consumer demand for CAM worldwide (8, 16, 18), NSs thus should also be well-informed about some most commonly-used CAM therapies to the point where they can competently provide patients with holistic care, instruct patients to use some CAM therapies accurately and safely (4, 8), assess patients' usage of these therapies (16), and/or provide targeted referral services (18). After all, in addition to improving safety, equipping nurses with greater CAM knowledge would result in better and more evidence-based referrals to CAM services and thereupon increase the likelihood of patients receiving therapeutic interventions to ameliorate pathological conditions and improve quality of life (18). Unfortunately, whilst the nursing profession is rooted in an integrated practice that encompasses holism, caring and healing, existing nursing education programs do not always emphasize these approaches, particularly pathways for referral (16). Countries such as Australia (23), Turkey (8), and South Africa (13) rarely integrate CAM instruction/knowledge into their current nursing curricula/programs. In addition, CAM appears not to have been incorporated into the curricula of nursing schools in Europe (21).

The addition of CAM elements in biomedicine education is gaining popularity globally, and is becoming a trend in medical education reform in several developed countries such as USA, UK, Canada, Australia, and Germany (24). Is there also a need for CAM education in future nursing programs? What is the overall knowledge level of and attitude toward CAM among NSs? To the best of our knowledge, there is no definitive evidence available that addresses these questions. We conducted this systematic review aiming to understand NSs' overall rated knowledge of, attitude/belief toward, and practice/previous personal experience of usage (KAP) toward CAM in surveys, which is also expected to develop a new, more substantial interpretation of this research theme.

Materials and methods

Registration

The methods adopted for current systematic review are consistent with the guidelines detailed on *Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 Statement* checklist (25). The protocol for this systematic review has been registered in the Prospective Register of Systematic Reviews (PROSPERO): No. CRD42022300602.

Eligibility criteria

Only formally published cross-sectional quantitative studies investigating the primary outcome of KAP toward CAM therapies by NSs were included in this review. Studies were also determined for NSs' major sources of CAM information, barriers to the use of CAM as perceived by NSs, and/or NSs' inclination to recommend CAM therapies to patients, which were viewed as the extension of KAP concept. Regardless of age, gender, race, grade, and academic level (diploma, undergraduate, or postgraduate), students majoring in nursing (excluding majoring in midwifery) could be included. Studies involving multiple professional groups [e.g., NSs versus (vs.) students with other healthcare background, or NSs vs. nursing faculty, etc.] were also included if they presented data separately for NSs. NSs' KAP toward CAM could be macroscopic or focused on a specific health condition (e.g., NSs' KAP toward CAM in stress relief or in the care of cancer survivors, etc.).

The following exclusion criteria were established. Intervention studies, reviews, case reports, study protocols, and letter to editors were excluded. Qualitative studies were also excluded as the current review aims to understand the overall KAP levels of CAM among NSs rather than the underlying causality. In this review, we considered CAM therapies as a broad umbrella term rather than focusing on specific products or practices. Therefore, studies focusing on NSs' KAP of a particular CAM therapy were excluded. Consistently, we also did not use a specific type of CAM therapy as a term for retrieval.

Search terms and search strategy

Following consultation with a professional health sciences librarian with a nursing background who assisted in development of the overall search strategy, we used filters to reliably identify relevant studies published in English or Chinese, and undertook a comprehensive search of four English electronic databases and four Chinese electronic databases—MEDLINE (*via* PubMed), EMBASE (*via* OVID), Nursing & Allied Health Database (ProQuest), AMED: Allied and Complementary Medicine Database, China biomedical literature service system (SinoMed), China National Knowledge Infrastructure (CNKI), Chongqing VIP database (CQVIP), and Wanfang database—from their inception through to 28 April 2022. The search was carried out by combining search terms from three categories: (1) NS, (2) CAM, and (3) KAP (Search terms were listed in Appendix 2). Only studies that were formally published and available as full-text paper were included. To ensure literature saturation, searches were also complemented by an extensive manual retrieval of any

additional articles meeting eligibility criteria that were cited in the reference lists of the included papers and relevant reviews, to avoid potential omission (see Appendix 3 for detailed search strategies used in search of the literature).

Selection of studies and data extraction

Two researchers independently screened the titles and abstracts for eligibility. The full-text was then acquired and cross-checked for eligibility (FY-Z and WJ-Z). Two standardized and predetermined data forms were employed to extract the following information from each study: identification/demographic information (first author, year of publication, and country), study design [application of CAM in general or in targeted disease/health condition/clinical setting, sampling method, study characteristics (sample size investigated/sample size completed/response rate/context), participants characteristics (age range and average age, and gender ratio), control group characteristics (if available), outcome measure/instrumentation and its reliability and validity], and major findings and conclusions (results of KAP, main source of CAM information, the importance of different types of evidence for NSs' acceptance/use/recommendation of CAM, and other additional key results). In each study, information regarding the top three CAM therapies best known to NSs, the top three CAM therapies considered by NSs to be most effective, and the top three CAM therapies that NSs are most likely to recommend to patients were also collected and extracted.

Study quality and risk of bias assessment

Two assessors (FY-Z and QQ-F) performed standalone appraisal of methodological quality and risk of bias of each study using the 11-item *Agency for Healthcare Research and Quality (AHRQ)* checklist which was recommended for cross-sectional studies (26). Each item was answered with "YES," "NO," or "UNCLEAR," answering "yes" to score 1 point, and 0 point for the rest. Quality of each study was then rated as low quality (0–3 points), moderate quality (4–7 points), or high quality (8–11 points) (26). Any discrepancies and/or conflicts were resolved through consulting with a third assessor (WJ-Z).

Data synthesis

All measurement instruments employed in the eligible studies were self-developed questionnaires/scales. Hence, the data derived were too heterogeneous to be statistical pooled for quantitative analysis. Furthermore, the modalities/types of CAM therapy investigated in different studies varied substantially. Given these issues, only a thematic summary, in a narrative fashion, of the results and findings was provided. The relevant information from the included studies was hence extracted and described in categories.

Results analysis

Study selection

A total of 521 articles were identified using our search strategy in the initial search. After removal of the duplicates and articles with unrelated titles/abstract in the preliminary screening process, followed by a careful full-text screening, 26 studies eventually met the predefined criteria (Figure 1). All included studies were published in English. We did not identify any eligible papers available from any Chinese database. The discarded studies with detailed justifications for their exclusion are illustrated in Appendix 4.

Study characteristics

Of the 26 included cross-sectional studies, most studies provided complete data on demographic characteristics (e.g., gender, age, etc.), with participants representing 12 different countries. Eleven studies were from Turkey (8, 27–36), four were from US (15, 16, 37, 38), two were from Australia (14, 39), with one from each of the following countries: UK (40), Canada (41), Norway (42), Hungary (43), Korea (44), Malaysia (45), India (46), South Africa (13), Sierra Leone (9). The convenience sampling method was adopted for all studies. Twenty-three studies investigated NSs' KAP toward CAM in general, while the remaining three studies (30, 33, 40) investigated NSs' KAP toward the application of CAM amongst cancer survivors and/or palliative care settings (Table 1).

Of all the included studies, 12 studies (13, 27, 29–35, 38, 40, 46) investigated KAP toward CAM among NSs only; while the remaining studies further compared the differences in KAP toward CAM between NSs and other groups/cohort, such as nursing faculty, or students/faculty of other health professions (e.g., medicine, pharmacy, rehabilitation/physiotherapy/occupational therapy, midwifery, radiography, nutrition/dietetics, chiropractic, biomedical science, social educator, or health visitor, etc.; (Table 1)).

All except one study (37) described the total number of NSs who participated in the studies, ranging from 9 to 640 individuals. The participants' degrees ranged from pre-nursing to postgraduate majoring in nursing. They therefore span a wide range of ages. Eighteen studies described the gender ratio of participated NSs, with the majority of participants being female NSs. All except four studies (14, 36, 41, 45) reported questionnaire/scale response rates amongst the participants, ranging from 10 to 100% (Table 1).

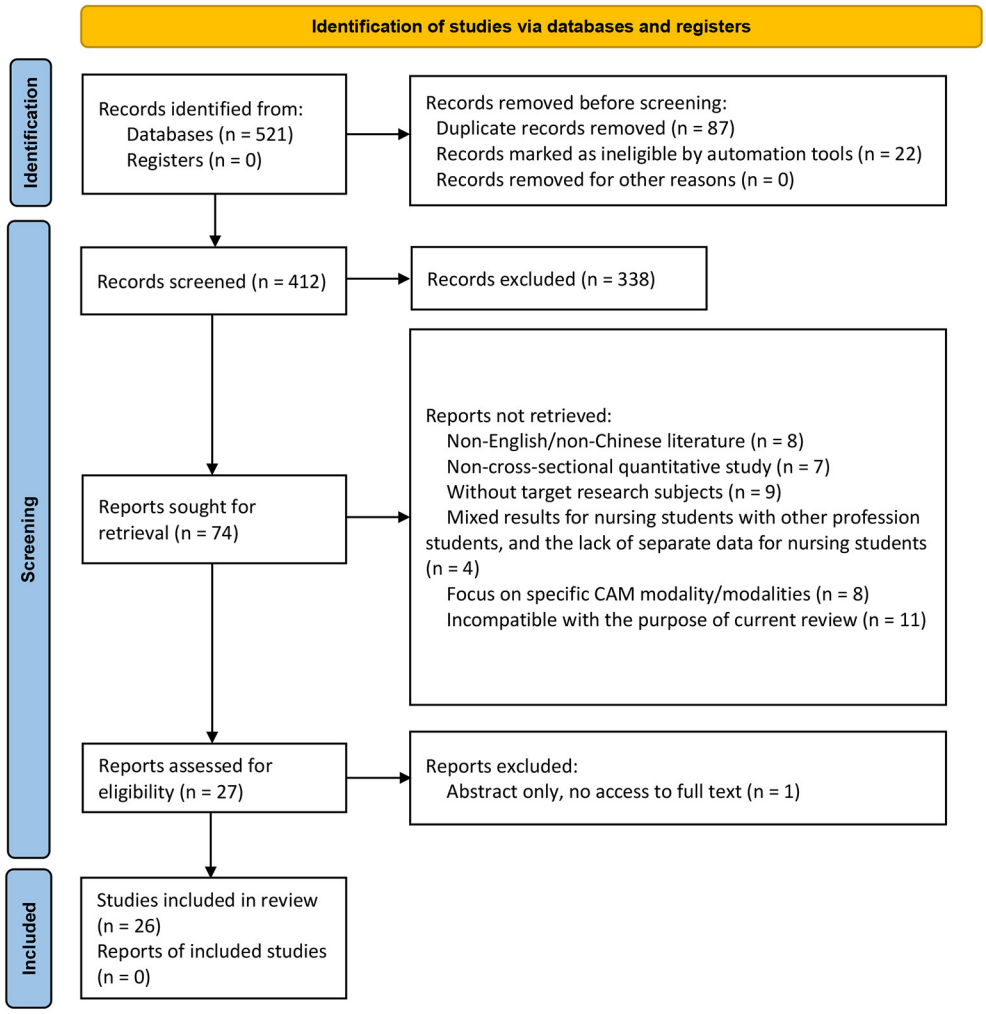


FIGURE 1
Flow diagram of the study selection process.

All except two studies (9, 36) employed or at least included one self-administrated questionnaire/scale as the primary outcome measure. These questionnaires/scales, in general, were developed by the researchers on the basis of expert opinion, review of textbooks, or other authoritative sources. Dimensions assessed by the questionnaires/scales differed from study-to-study, while typically comprised at least two sections: (1) items for collecting socio-demographic data; and (2) items for collecting NSs' level of knowledge of, and/or attitude/belief toward, and/or personal usage experience of each common CAM therapy. Some questionnaires/scales also covered items associated with (1) primary sources of CAM information; (2) perceptions of the effectiveness of each CAM modality; (3) willingness to recommend CAM therapies to patients, or willingness to provide patients with referrals to CAM services; (4) inclination to further CAM learning, or perceptions to incorporate CAM into conventional nursing education; and/or (5) barriers to using or integrating CAM. Measuring tools in five studies were adapted from previously developed questionnaires/scales, including CAM Health Belief Questionnaire (CHBQ) (9, 39), Holistic Complementary and Alternative Medicine Questionnaire (HCAMQ) (27, 29), or Attitude toward Using Complementary Treatments Scale (ACTS) (36). Unfortunately, these three tools were not developed specifically for NSs. It is also slightly unfortunate that psychometric properties such as Cronbach's coefficient alpha of the developed questionnaires/scales were reported in only eight (13, 27, 29, 35, 36, 43–45) of the 26 studies. One of the eight studies also tested the Guttman λ_2 of the questionnaire (43). Those tests are conducted to assess the reliability of the questionnaires/scales included (Table 1).

TABLE 1 Study characteristics and outcome measurement tools of 26 included studies.

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
Avino (15)	USA	Not limited	1,420/578/40.7%	Eight schools of nursing in USA	18–55 (27)	55/523	Convenience	Nursing faculty (155/117/75.5%/▲)	23-item questionnaire consisted of nine sections: 1. General attitudes and barriers to the use of CAM (scoring: very strongly agree to very strongly disagree) 2. Primary worldview guiding personal health view 3. Spiritual or religious beliefs influencing attitudes (scoring: yes; yes, somewhat; no; or no opinion) 4. Sources of CAM information 5. Evidence for use in CAM practice (scoring: essential to unimportant) 6. Effectiveness of CAM modalities (scoring: highly effective to harmful; or no opinion) 7. Previous education/training and further CAM training needs 8. Personal use of CAM (scoring: no, would not consider using it; no, but would consider using it; yes, have used it with positive outcomes; yes, have used it with neutral outcomes; yes, have used it with negative outcomes) 9. CAM approaches in practice (scoring: would not recommend; would endorse, but not personally provide or refer; would personally provide; would refer to a CAM practitioner; unsure)	NR

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TABLE 1 Continued

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
Baugniet et al. (41)	Canada	Not limited	NR/86/NR	Two universities in Canada	25–29 (NR)	NR/NR	Convenience	Students of PT (NR/90/NR/▲), OT (NR/101/NR /▲), pharmacy (NR/102/NR/▲), and medicine (NR/61/NR/▲)	A questionnaire focused on the NSs' perceptions of the general field of CAM	NR
Cinar et al. (27)	Turkey	Not limited	152/152/100%	One health school (university) in Turkey	17–24 (20.09 ± 1.6)	23/129	Convenience	N/A	1. 17-item "Personal Information Form" 2. HCAMQ	Cronbach's alpha 0.72
Halcón et al. (16)	USA	Not limited	174/120/70.0%	One university in USA	21–57 (NR)	10/110	Convenience	Nursing faculty (76/50/65.7%/▲)	Questionnaire consisted of four sections: 1. Demographic information 2. Overall attitudes toward cam 3. Attitudes and information about training, personal use, perceived barriers, intent to integrate CAM into clinical practice 4. Primary worldviews or frameworks guiding personal health views, and influence of own spiritual or religious beliefs on attitudes toward CAM	NR
Hassan et al. (45)	Malaysia	Not limited	NR/33/NR	One university in Malaysia	NR (NR)	NR/NR	Convenience	Medical students (NR/41/NR/▲)	Questionnaire consists of three sections: 1. Knowledge of CAM 2. Attitudes toward CAM 3. Practice of CAM	Cronbach's alpha 0.878
James et al. (9)	Sierra Leone	Not limited	10/9/90.0%	One university in Sierra Leone	≥ 21 (NR)	2/7	Convenience	Medical (46/44/95.7%/▲) and pharmacy students (11/11/100%/▲)	CHBQ	NR

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TABLE 1 Continued

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
Kavurmaci et al. (28)	Turkey	Not limited	655/359/54.8%	One university in Turkey	NR (NR)	NR/NR	Convenience	Midwifery (195/170/87.2/▲) and dietetics students (169/142/84.0%/▲)	29-item questionnaire consists of three sections: 1. Demographic features 2. Knowledge about cam (scoring: yes; no; or do not know); from which source respondents obtained attitudes and opinions; use of cam 3. Whether CAM should be integrated into the education programs	NR
Kim et al. (44)	Korea	Not limited	400/98/24.5%	One school of nursing in Korea	NR (NR)	15/83	Convenience	Nursing faculty (55/100/55.0/▲)	Questionnaire A: demographic characteristics questionnaire B: knowledge of and experience with CAM [9 yes-or-no knowledge/experience items and 1 frequency item (scoring: never to very often)] questionnaire C: 10-item attitude state tool (scoring: 1= strongly disagree; 5 = strongly agree)	Cronbach's alpha 0.886 (attitude state tool)
Kreitzer et al. (37)	USA	Not limited	NR/NR/>50%	One university in USA	NR (NR)	NR/NR	Convenience	1. Nursing faculty (NR/50/>50%/▲) 2. students (NR/NR/>50%/▲) and faculty (70/31/44%/▲) of pharmacy 3. students (NR/NR/>50%/▲) and faculty (NR/64/>50%/▲) of medicine	Questionnaire consists of three sections: 1. socio-demographic characteristics 2. Overall attitudes toward cam 3. Attitudes and information about training, personal use, perceived barriers, the intent to integrate CAM into clinical practice (scoring: 1 = very strong agreement; 6 = very strong disagreement)	NR

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TABLE 1 Continued

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
Laurenson et al. (40)	UK	Cancer and palliative care	51/51/100%	One university in UK	≥18 (NR)	3/48	Convenience	N/A	A "closed question" questionnaire assessing NSs' knowledge of and attitudes toward CAM therapies in cancer and palliative care	NR
Özşaker (29)	Turkey	Not limited	224/224/100%	One university in Turkey	20–32 (22.87 ± 1.37)	31/193	Convenience	N/A	Questionnaire A: Student Identification Form (1. socio-demographic characteristics; 2. questions regarding whether NSs are familiar with CAM modalities; what do NSs think about the effectiveness of these modalities; whether NSs would like to be trained in these modalities) questionnaire B: HCAMQ	Cronbach's alpha 0.74 (HCAMQ)
Oztekin et al. (30)	Turkey	Cancer patients	1,057/640/60.5%	Six schools of nursing at five universities in Turkey	18–34 (21.5 ± 1.7)	0/640	Convenience	N/A	Questionnaire consists of three sections: 1. Demographic information and basic information on CAM 2. Four questions for each CAM modality (scoring: 0 = no, I have not; 1 = yes, I have)	NR
Pettersen et al. (42)	Norway	Not limited	3,170/317/10%	16 Norwegian colleges of nursing	NR (NR)	44/273	Non-probability convenience	Students of PT (300/63/21%/three Norwegian colleges of PT), social educator (590/59/10%/five Norwegian colleges of social educator), and radiography (126/34/27%/two Norwegian colleges of radiography education)	254-item questionnaire consists of three sections: 1. Demographic characteristics 2. "scientific evaluation-test" of health news briefs 3. Several statements involving positive attitude toward CAM, paranormal beliefs, requests, anti-scientistic, religious, spiritual, negative attitude toward science and scientists, and willingness to include CAM in education (scoring: 1 = strongly negative; 5 = strongly positive)	NR

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TABLE 1 Continued

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
Pirincci et al. (31)	Turkey	Not limited	550/489/88.9%	One university in Turkey	NR (21.29 ± 2.02)	214/275	Convenience	N/A	23-item questionnaire consists of two sections: 1. Socio-demographic characteristics 2. Use, knowledge, view of cam, and source of cam information	NR
Poreddi et al. (46)	India	Not limited	143/122/85.3%	One university in India	NR (20.6)	0/122	Non-probability convenience	N/A	Questionnaire consists of four sections: 1. Five-item demographic 2. 11-item perceived effectiveness/knowledge of CAM 3. General attitudes/perceptions of CAM 4. Perceived barriers to use of CAM	NR
Reuter et al. (38)	USA	Not limited	1. Pre-NSs (328/326/99.4%) 2. NSs (104/104/100%)	One university in US	1. Pre-NSs [18–30 (18.9 ± 1.2)] 2. NSs [20–51 (22.7 ± 3.8)]	1. Pre-NSs (32/294) 2. NSs (10/94)	convenience	N/A	Online survey "*Students' Knowledge of and Attitude toward Holistic Medicine Practices*" for pre-nursing students; online survey "*Health Professions Students' Knowledge of and Attitude toward Holistic Medicine Practices*" for NSs	NR
Sahin et al. (32)	Turkey	Not limited	390/264/67.7%	One university in Turkey	18–26 (20.6 ± 1.77)	72/192	Convenience	N/A	Questionnaire consists of two sections: 1. Socio-demographic characteristics 2. CAM knowledge	NR

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TABLE 1 Continued

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
Sárváry et al. (43)	Hungary	Not limited	124/83/66.9%	One university in Hungary	18–31 (NR)	NR/NR	Convenience	Students of midwifery (204/126/61.8%/▲) and health visitor (196/105/53.6%/▲)	Questionnaire consisted of six sections: 1. General attitudes [12 items including 7 positive statements and 5 negative statements (scoring: 1 = strongly disagree; 7= strongly agree)] 2. Knowledge of CAM modalities (scoring: none; very little; some; a lot) 3. Sources of CAM information 4. Personal use and perceived effectiveness of CAM [scoring: yes/no; 1 = completely ineffective; 7 = completely effective] 5. Integration of CAM modalities into undergraduate curricula and health care system (scoring: 1 = strongly disagree; 7 = strongly agree) 6. Evaluation of CAM course [scoring: yes/no for if the respondent has participate in the CAM course; how much of CAM course was useful (1 = completely useless; 7 = completely useful)]	Cronbach's alpha 0.851 and Guttman $\lambda_2 = 0.858$ (12-item questionnaire for attitude)
Topuz et al. (33)	Turkey	Cancer patients	192/148/77.1%	One university in Turkey	NR (21.09 ± 1.54)	2/146	Convenience	N/A	A literature-based questionnaire consists of three sections: 1. Demographical characteristics and experiences of CAM practices 2. Knowledge of and attitudes toward CAM 3. Opinions regarding use of CAM in cancer patients	NR

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TABLE 1 Continued

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
Turker et al. (34)	Turkey	Not limited	354/323/91.2%	One military medical school in Turkey	NR (NR)	0/323	Convenience	N/A	Questionnaire consists of three sections: 1. Demographic characteristics 2. Multiple-choice questions related to frequently used cam therapies 3. Attitudes toward CAM	NR
Uzun et al. (35)	Turkey	Not limited	280/276/98.6%	One university in Turkey	17–25 (20.16 ± 1.45)	0/276	Convenience	N/A	Questionnaire consisted of three sections: 1. General questions (sources of CAM information; attitudes toward inclusion of CAM into nursing curricula/practices) 2. Knowledge (scoring: no idea; a little knowledge; enough knowledge); awareness of therapeutic effect of CAM therapy (scoring: harmful; no idea; beneficial); whether offer CAM therapy to patient (scoring: offer; undecided; do not offer) 3. Perceptions of use and effect of CAM (from strongly disagree to strongly agree)	Cronbach's alpha 0.79

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TABLE 1 Continued

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
van et al. (13)	South Africa	Not limited	202/119/58.9%	One university in South Africa	≥18 (NR)	29/90	Convenience	N/A	12-item questionnaire consists of five sections: 1. Demographic characteristics 2. Personal use (scoring: never; only when needed; monthly; weekly; daily) 3. Recommendations to patients and enquiring about CAM use from patients 4. Knowledge of CAM (scoring: none; some; a lot) 5. Attitude toward CAM [23 statements (scoring: 1 = strongly disagree; 5 = strongly agree)]	1. Cronbach's alpha 0.87 (knowledge) 2. Cronbach's alpha 0.75 (attitude) 3. Cronbach's alpha 0.67 (use)
Walker et al. (39)	Australia	Not limited	321/316/98.4%	One university in Australia	≥18 (27.7 ± 9.0)	21/295	Convenience	Chiropractic students (227/225/99.1%/▲)	Questionnaire A: 15-item questionnaire for knowledge assessment (scoring: good knowledge;, some knowledge; aware; unaware) questionnaire B: modified 10-item CHBQ for attitudes/beliefs assessment (scoring: 1 = absolutely disagree; 7 = absolutely agree) questionnaire C: 10-item questionnaire investigating factors that influenced attitude (scoring:1 = not at all influential; 7 = highly influential)	NR

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TABLE 1 Continued

References	Country	Target disease/ condition	NSs					Control population	Outcome measures for NSs' KAP level	
			Sample size [sample size investigated/ sample size responded/ response rate (%)]	Context	Age (average)	Male/ female	Sampling method	Population [sample size investigated/ sample size responded/ response rate (%)/context (▲represents that the setting context is the same as that of NSs)]	Instrumentation	Reliability
Wilkinson et al. (14)	Australia	Not limited	NR/105/NR	One university in Australia	NR (NR)	NR/NR	Convenience	Students of pharmacy (NR/69/NR/▲) and biomedical science (NR/97/NR/▲)	Questionnaire consists of two sections: 1. Demographic characteristics 2. Use of CAM during the past 12 months (CAM practitioners visited, products used, main sources of information about CAM, attitudes to CAM and conditions suffered)	NR
Yildirim et al. (8)	Turkey	Not limited	589/477/81.0%	One university in Turkey	17–29 (21.76)	NR/NR	Convenience	Medical students (1,353/495/36.6%/▲)	Questionnaire consists of four sections: 1. Socio-demographic characteristics 2. General attitudes toward cam 3. Sources of cam information 4. Knowledge of CAM, opinion of CAM's clinical usefulness, willingness to recommend CAM, and personal use of CAM	NR
Yilmaz et al. (36)	Turkey	Not limited	NR/458/NR	One faculty of health sciences in Turkey	NR (NR)	NR/NR	Convenience	Students of nutrition and dietetics (NR/159/NR/▲), PT (NR/119/NR/▲), and rehabilitation	1. A students' description form 2. ACTS 3. PHNS	1. Cronbach's alpha 0.84 (ACTS) 2. Cronbach's alpha 0.78 (PHNS)

NR, no records; N/A, not applicable; NSs, nursing students; PT, physiotherapy; OT, occupational therapy; CAM, complementary and alternative medicine; CHBQ, CAM Health Belief Questionnaire; PHNS, Perception of Health News Scale; ACTS, Attitude toward Using Complementary Treatments Scale; HCAMQ, Holistic Complementary and Alternative Medicine Questionnaire.
▲ represents that the setting for control population is the same as that of NSs.

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Study quality appraisal

Of the 26 studies included, one (41) (3.8%) was rated as low-quality study, eight (30.8%) (8, 9, 13, 27, 36, 38, 39, 43) were rated as high-quality studies, and the remaining 17 (65.4%) were rated as moderate-quality studies. Due to the lack of description of the assessment and/or control methods of confounding factors and the lack of follow-up data, all studies were appraised as high risk of bias in item 8 and item 11 of the checklist developed by AHRQ, respectively (Table 2).

KAP toward CAM

Knowledge level of CAM

Knowledge level of CAM was generally measured by asking whether NSs were familiar with or had heard about each CAM modality. Respondents usually provided "yes-or-no" and/or frequency (e.g., never to very often, no knowledge to know very well, no idea to sufficient, etc.) as answers. Fourteen studies (8, 9, 13, 29, 31–35, 38–40, 43, 44) evaluated the NSs' overall level of knowledge and the findings were consistent, that is, although NSs' knowledge level differed/varied depending on the specific CAM modality, the overall level was limited, less than satisfactory, and the surveyed students felt poorly informed (Table 3).

Fourteen studies compared nursing students with other healthcare students/faculty. In two studies (8, 45), NSs were found to be more knowledgeable than medical students about most CAM modalities. Three studies (9, 39, 43) reported no significant difference in knowledge levels of CAM between NSs and their counterparts [students with other healthcare backgrounds (e.g., medicine, pharmacy, midwifery, health visitor, and chiropractic, etc.) in same grade level]. No studies showed that NSs had lower knowledge levels of CAM than their counterparts. Whether the overall knowledge levels of CAM among NSs was higher or lower than that of nursing faculty was not disclosed in any of the included studies. Only one study reported that nursing faculty had more knowledge of meditation and acupuncture than NSs, but that study did not provide comparison results for other CAM modalities (44) (Table 3).

Four studies (15, 29, 30, 38) investigated which CAM modality NSs most desired further knowledge. In summary, NSs showed great interests in learning massage, nutritional/diet-based therapy, music therapy, acupuncture, meditation, aromatherapy, phytotherapy, and therapeutic touch/healing touch (Table 3).

Attitudes/beliefs toward CAM

All included studies outlined NSs' attitude or belief toward CAM. In only two studies (13, 34), more than half of the NSs expressed a neutral attitude toward CAM. In the remaining 24 studies, the majority of NSs (>50%) saw CAM positively. Specifically, most NSs respondents in these 24 studies supported the incorporation of CAM knowledge into existing nursing curricula or integration of CAM curricula into the conventional nursing education programs. Nevertheless, with respect to whether CAM courses should be delivered as elective or compulsory module, proponents in different studies expressed inconsistent views. In two studies (9, 32), most NSs showed preference for the CAM course to be taught as an elective module rather than a compulsory module, while few NSs expressed opposite inclination. In addition, as suggested in an aforementioned study (34) which respondents consisted of a majority of NSs who held neutral attitude about CAM, lectures on CAM practices should only be offered to NSs who are enthusiastic about CAM. However, respondents in another study argued for the opposite, by requesting CAM education integrated as a core rather than an optional module in the pre-registration curricula (40). In light of the responses from NSs, the author of one included study even advised education reformers or industry policy makers should consider incorporating CAM content into nursing licensure examination once CAM curricula is widely and fully integrated into nursing programs at all levels (44) (Table 3).

Eleven out of 26 studies examined students' desire for further CAM training, or their perceptions regarding the impact of CAM knowledge/information on their future career. In five of them, many NSs (33.3–81%) conveyed a desire to receive further or sufficient training so that be able to safely advise patients on the use of CAM (9, 15, 16, 37), or to practice a CAM modality (41). In eight studies, most NSs (54.7–93.3%) agreed that knowledge or information of CAM was important for their future careers (15, 16, 28, 32, 33, 38, 45, 46) (Table 3).

In seven studies, most NSs (55.4–73.2%) supported that CAM should be used in the patient care practice (8, 27, 35, 37), or agreed that CAM remedies can be applied in addition to conventional medical treatment (29, 43) and/or conventional nursing practices (31). In contrast, in another study, 21.6% of NSs considered CAM to be antithetical to/conflict with conventional medicine (40) (Table 3).

The question "*Do you agree that CAM is a threat to public health*" was asked in 12 studies, and the agreement with this question was less than half (0 to 40.6%) in each of these studies (8, 9, 15, 16, 29, 31, 34, 35, 37, 39, 41, 45). In two studies (13, 33), some NSs agreed (12.6–26.4%) or slightly agreed (27%) that CAM practices due to side-effects can affect conventional medical treatment. Another study (43) described that only 26.5% of NSs did not support increased utilization of CAM on the grounds that it would raises patients' unfounded hopes and lead to frustration (Table 3).

Nine studies further explored the potential factors influencing NSs' attitude toward CAM. In light of the results, level of knowledge, previous positive personal experience, and/or personal cultural background (including religious/beliefs) appeared to be the major factors (Table 3).

TABLE 2 Methodological quality assessment of 26 included studies based on AHRQ checklist.

Studies\items	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total scores out of 11	Level of quality
Avino (15)	Y	Y	N	Y	U	N	N	N	N	Y	N	4	Moderate
Baugniet et al. (41)	Y	Y	N	U	U	N	N	N	N	Y	N	3	Low
Cinar et al. (27)	Y	Y	Y	Y	U	Y	Y	N	Y	Y	N	8	High
Halcón et al. (16)	Y	N	Y	U	U	N	Y	N	Y	Y	N	5	Moderate
Hassan et al. (45)	Y	Y	Y	U	U	Y	N	N	N	N	N	4	Moderate
James et al. (9)	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	8	High
Kavurmaci et al. (28)	Y	N	Y	U	U	N	Y	N	Y	Y	N	5	Moderate
Kim et al. (44)	Y	N	Y	U	Y	Y	Y	N	Y	Y	N	7	Moderate
Kreitzer et al. (37)	Y	N	N	U	U	N	Y	N	Y	Y	N	4	Moderate
Laurenson et al. (40)	Y	N	N	N	Y	N	Y	N	Y	Y	N	5	Moderate
Özşaker (29)	Y	N	Y	U	U	Y	Y	N	Y	Y	N	6	Moderate
Oztekin et al. (30)	Y	Y	N	U	Y	N	Y	N	Y	Y	N	6	Moderate
Pettersen et al. (42)	Y	N	N	U	U	N	Y	N	Y	Y	N	4	Moderate
Pirincci et al. (31)	Y	Y	Y	N	U	N	Y	N	Y	Y	N	6	Moderate
Poreddi et al. (46)	Y	Y	Y	U	U	N	Y	N	Y	Y	N	6	Moderate
Reuter et al. (38)	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	8	High
Sahin et al. (32)	Y	U	N	U	U	N	Y	N	Y	Y	N	4	Moderate
Sárváry et al. (43)	Y	Y	Y	Y	U	Y	Y	N	Y	Y	N	8	High
Topuz et al. (33)	Y	N	U	U	U	N	Y	N	Y	Y	N	4	Moderate
Turker et al. (34)	Y	N	Y	U	U	N	Y	N	Y	Y	N	5	Moderate
Uzun et al. (35)	Y	Y	N	Y	U	Y	Y	N	Y	Y	N	7	Moderate
van et al. (13)	Y	Y	N	Y	Y	Y	Y	N	Y	Y	N	8	High
Walker et al. (39)	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	8	High
Wilkinson et al. (14)	Y	Y	Y	Y	Y	N	Y	N	Y	U	N	7	Moderate
Yildirim et al. (8)	Y	Y	Y	Y	Y	N	Y	N	Y	Y	N	8	High
Yilmaz et al. (36)	Y	Y	Y	Y	U	Y	Y	N	Y	Y	N	8	High

Y, yes; N, no; U, unclear; AHRQ, Agency for Healthcare Research and Quality.

Item 1: Define the source of information (survey, record review); Item 2: List inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications; Item 3: Indicate time period used for identifying patients; Item 4: Indicate whether or not subjects were consecutive if not population-based; Item 5: Indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants; Item 6: Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements); Item 7: Explain any patient exclusions from analysis; Item 8: Describe how confounding was assessed and/or controlled; Item 9: If applicable, explain how missing data were handled in the analysis; Item 10: Summarize patient response rates and completeness of data collection; Item 11: Clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained. 1 point for "Yes," and 0 point for the rest. 0–3 points for "low quality," 4–7 points for "moderate quality," and 8–11 points for "high quality."

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TABLE 3 NSs' knowledge, attitude, use, barriers to use, recommendation, and source of information toward CAM therapies.

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Avino (15)	NR	1. Massage (12%) 2. Nutritional supplements (11%) 3. Therapeutic touch/healing touch (10%)	– Positive – 81% NSs want further training that is sufficient to advise patients about CAM use or to personally provide CAM therapies – 81% NSs express that CAM practice should be included in the curricula – 88% NSs agree that knowledge about CAM is important to their future career	Spiritual and religious beliefs (reported by 66% NSs)	5%	NR/NR/NR/lack of evidence (96%) and lack of staff training (96%)	1. Nursing faculty and NSs show similar attitudes toward CAM in all areas 2. More NSs (81%) than nursing faculty (62%) want further training	1. Peer professionals (73%) 2. Mass media (55%) 3. Internet (53%)	NR	NR	1. 50% NSs use western biomedicine to guide personal health view and 46% NSs use a combination of western biomedicine and another health tradition to guide health view 2. 82% NSs will consider using all CAM therapies personally, and 68% NSs will use CAM in clinical care by endorsing, providing personally, or referring patients to a CAM practitioner 3. 93% NSs report that evidence is essential or somewhat essential/important when recommending CAM therapies to patients
Baugniet et al. (41)	NR	NR	– Positive – More than 66% NSs have interests in receiving training to practice a form of CAM – 70.9% NSs support that CAM should be taught as a separate course in their curricula	1. Levels of exposure and training 2. Culture and values internalized during the students' training	0	44.7%/NR/ massage/ NR	NSs are more likely to consult a CAM practitioner than other healthcare students	NR	NR	1. Success in practice (96.4%) 2. Patient reports (83.1%) 3. RCTs involving humans (72.3%)	Healthcare students generally have more knowledge about those CAM therapies considered to be the most mainstream (e.g., chiropractic, massage therapy, acupuncture, etc.) and less knowledge about those less-widely accepted CAM therapies (e.g., homeopathy, faith healing, and reflexology, etc.)

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Cinar et al. (27)	NR	NR	– Positive – 61.3–64.5% NSs express that there should be a course on CAM in the curricula – 57.8–62.3% NSs support CAM should be used in patient care practice	NR	NR	NR/NR/NR/NR	N/A	NR	NR	NR	50.7% NSs state that they have no information on CAM
Halcón et al. (16)	NR	NR	– Positive – 93.3% NSs support the integration of CAM into curricula and agree that information on CAM is significant to their professional clinical practice – More than 33.3% NSs desire sufficient training to be able to advise patients about the use of CAM therapies	NR	2.5%	98.3%/NR/ massage/lack of evidence	NSs (95%) are more likely than nursing faculty (94%) to hope to have some CAM therapies available to patients in their practice or networks	1. Peer professionals (82.5%) 2. Professional journals (78.3%) 3. Other health care providers (65.9%)	NR	1. Success in practice (79.2%) 2. Patient reports (74.2%) 3. Published case studies (74.2%)	NSs are more interested in improving their knowledge for providing informed referrals than in gaining education aimed at incorporating CAM therapies into their own practice

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Hassan et al. (45)	NR	NR	– Positive – Support the integration of CAM into curricula and agree that information on CAM is significant to them as future nurse	Level of knowledge	Some NSs	NR/NR/NR/NR	NSs are more knowledgeable and positive about CAM, and more willing to practice CAM than medical students	NR	NR	NR	The more CAM knowledge NSs have, the more positive they will practice in their clinical settings
James et al. (9)	33.3% NSs know CAM	NR	– Positive – 77.8% NSs have interests in studying CAM – 71.4% NSs prefer CAM to be an elective module rather than a compulsory module, while 28.6% NSs make an opposite decision	NR	0	55.6%/NR/ herbal/NR	1. there is no significant difference among the three groups with respect to self-reported use, recommendation of CAM, and perceived knowledge of CAM 2. NSs are less positive about CAM than medical students; no significant difference in attitude toward CAM between NSs and pharmacy students	1. Books/journals (55.6%) 2. CAM practitioner (22.2%) 3. Media (11.1%)	1. Herbal 2. Spiritual/prayer	NR	55.6% NSs indicate that they will recommend CAM to their patients

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Kavurmaci et al. (28)	NR	NR	– Positive – Support the integration of CAM into curricula and agree that information on CAM is significant to them as future nurse	NR	NR	59.9%/NR/NR/NR	1. NSs' use of CAM is more than that of midwifery students (31.8%) and dietetics students (32.4%) 2. NSs are more favorable toward CAM use than midwifery students and dietetics students	NR	NR	NR	NR
Kim et al. (44)	Limited	NR	– Positive – Support the integration of CAM into curricula and support the content on CAM needs to be included in nursing licensure examinations	NR	NR	NR/NR/mineral and herbal therapy/NR	There is significant difference in knowledge level between NSs and nursing faculty (nursing faculty have more knowledge of meditation and acupuncture than that of NSs; NR for overall knowledge level or knowledge level for other CAM therapies)	NR	NR	NR	1. NSs indicate that CAM has its role in the community (83%) rather than in the hospital (75.8%) 2. NSs note that the use of CAM is more appropriate for advance practice nurses

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Kreitzer et al. (37)	NR	NR	– Positive – NSs desire more training in CAM modalities, and have favorable attitudes toward the integration of CAM into education and clinical care	NR	5.3%	NR/NR/NR/lack of evidence	1. NSs are less positive about CAM than nursing faculty; more NSs than nursing faculty agree that CAM is a threat to public health 2. NSs are more positive about CAM than medical or pharmacy students; NSs are more likely than other healthcare students to use or consider using CAM therapies	NR	NR	NR	NSs have limited training of CAM
Laurenson et al. (40)	Limited	NR	– Positive – Need CAM education as a core module rather than an optional module	NR	21.6% NSs agree that CAM conflict with conventional medicine	NR/NR/NR/NR	N/A	NR	NR	NR	1. NSs require more information about CAM if they are going to help patients make informed choices 2. NSs are unsure if CAM may conflict with conventional treatment, but disagree that CAM are ineffective

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Özşaker (29)	Limited	1. Music therapy (83.5%) 2. Phytotherapy (79.9%) 3. Acupuncture (78.6%)	– Positive and moderate – 73.2% NSs support that CAM can be applied in addition to conventional medical treatment – Most NSs want to incorporate CAM lessons into the curricula or learn more about CAM	NR	5.4%	NR/relaxation/music therapy/NR	N/A	1. Internet (68.8%) 2. Scientific/medical books (50%) 3. Family/relatives (48.2%)	NR	NR	Expectations and feedbacks of NSs should be taken into consideration in determining the education standards
Oztekin et al. (30)	NR	1. Nutritional therapy (89.5%) 2. Breathing therapies (87.2%) 3. Massage and manipulation/Tui-Na (87%)	– Positive – Support the integration of CAM into nursing curricula	NR	NR	NR/NR/music therapy/NR	N/A	NR	NR	NR	1. NSs intend to use CAM although they do not have formal education during the undergraduate program 2. NSs' personal use of CAM are limited 3. NSs have limited sources of CAM information
Pettersen et al. (42)	NR	NR	– Positive – Support the integration of CAM into health science education	1. Paranormal beliefs 2. Willingness to include CAM in education 3. Perception of whether reliable knowledge can be obtained by intuition/spiritual 4. Religious	NR	NR/NR/NR/NR	NSs have more positive attitude toward CAM and higher degree of willingness to include CAM in education than PT students have	NR	NR	NR	Discussing the scientific basis of claims of CAM effects is probably an ideal teaching approach

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Pirincci et al. (31)	Limited (only 21.9% NSs feel they have enough knowledge on CAM)	NR	– Positive – 55.4% NSs agree that CAM methods and practice should be combined with conventional nursing practice – 56.2% NSs support that CAM practice should be included in nursing training programs	NR	21.5%	51.3%/treat health problems/herbal products/NR	N/A	1. Internet (68.7%) 2. Family (64.8%) 3. Friend (51.1%)	NR	NR	1. 52.6% NSs would recommend CAM methods to others 2. The use of CAM therapies significantly increase with increases in NSs' ages and their parents' education status
Poreddi et al. (46)	NR	NR	– Positive – 93.0% NSs are in favor of including CAM in the nursing curricula – 76.2% NSs agree that CAM (including Ayurveda) knowledge is needed for future professionalism	NR	NR	NR/NR/NR/lack of evidence	N/A	NR	NR	NR	85.2% NSs agree that patients have the right to choose between modern medicine and CAM

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
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	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Reuter et al. (38)	Limited	Pre-NSs: 1. Cell therapy (37.2%) 2. Acupuncture (31.4%) 3. Diet-based therapy (29.4%) NSs: 1. Aromatherapy (71.9%) 2. Music therapy (70.3%) 3. Meditation (64.1%)	– Positive (NSs are more positive than Pre-NSs) – Overall are interested in CAM (NSs show more interests than Pre-NSs do) – Expect to learn more about CAM in nursing programs, and plan on making CAM practices part of their future careers	Knowledge of or experience with CAM practices [learning about CAM practices may influence how NSs (including Pre-NSs) rate their attitude toward specific practice beyond personal experience]	NR	1. Pre-NSs (73%/NR/diet-based therapy/NR) 2. NSs (81.7%/NR/music therapy/NR)	N/A	NR	NR	NR	It should be noted that the importance of learning about a CAM practice for NSs' decision about which practices to make part of their career
Sahin et al. (32)	Limited (46.6% NSs do not know the definition of CAM)	NR	– Positive – 64% NSs support to have CAM included in nursing curricula [57.6% NSs prefer CAM to be an elective module rather than a compulsory module, while 6.4% NSs make an opposite decision] – 42% NSs support the use of CAM in future nursing practice	NR	NR	49.6/stress/NR/NR	N/A	1. Internet or TV (58.4%) 2. Newspaper, magazines, books (42.6%) 3. Family, relatives, or friends (35.9%)	NR	NR	1. 66.3% NSs have not received any information about CAM 2. There is a positive correlation between CAM knowledge level and CAM recommendations 3. There is a positive correlation between the status of NSs benefitting from CAM and their recommendations of CAM

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TABLE 3 Continued

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Sárváry et al. (43)	Limited	NR	– Positive – 59.8% NSs support the integration of evidence-based CAM therapies into curricula – 54.3% NSs support that CAM should be researched – 53.7% NSs support that the integration of CAM into health care will be effective – Most NSs prefer CAM to be an elective module (courses that are connected to their specialty) rather than a compulsory or an optional module (courses that are not absolutely related to their specialty)	NR	26.5% NSs agree that the increase in CAM use is dangerous because it raises unfounded hopes and leads to disappointment	NR/NR/ massage/NR	1. There is no significant differences in knowledge of and attitudes toward CAM between NSs, health visitor and midwifery students 2. The proportion of NSs participating in CAM courses is lower than that of midwifery students (61.5%) or that of health visitor students (84.7%)	1. Internet (83.1%) 2. Family members, relatives and friends (55.4%) 3. Scientific journals or books (51.8%)	NR	NR	1. There is no significant differences in the attitudes toward CAM between students who participate in and those who do not participate in the CAM course 2. Participants of CAM course prefer formal education as the source for obtaining CAM information

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
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Topuz et al. (33)	Limited	NR	– Positive – 77% NSs support the integration of CAM into nursing curricula – 54.7% NSs support the integration of CAM into future nursing practice	Clinical experiences	26.4% NSs agree and 27% NSs slightly agree that CAM practices can affect medical treatment because of side effects	NR/NR/ NR/NR	N/A	1. Media (67.6%) 2. Internet (61.7%) 3. Books/journals (32.4%)	NR	NR	Lack of nursing faculty members and nurses training, and lack of evidence for practice are two major barriers to develop CAM curricula
Turker et al. (34)	Limited	NR	– Neutral – Most NSs support the integration of lectures of CAM practice into the curricula for the students who are enthusiastic about learning them	NR	40.6%	NR/NR/NR/NR	N/A	1. TV and radio (80.3%) 2. Internet (69.0%) 3. Newspapers/journals (48.6%)	NR	NR	62.9% NSs keep neutral for the statement "CAM therapies are effective and safe"
Uzun et al. (35)	Limited	NR	– Positive – 64.5% NSs support CAM to be integrated into the nursing curricula – 62.3% NSs support CAM therapies to be used in clinical practice	NR	49.6% NSs agree that CAM are not threat to public health	NR/NR/ NR/NR	N/A	1. Newspapers, magazines and TV (37.3%) 2. Nurse education program (26.1%) 3. Social sources, e.g., friends, and family environment in third place (25%)	1. Humor (56.1%) 2. Music therapy (53.2%) 3. Relaxation techniques (51.4%)	NR	1. NSs show willingness to offer CAM therapies if they have sufficient knowledge 2. Proper provision of medical data in CAM therapies will make it easier to apply and to decide which therapy will be used

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TABLE 3 Continued

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	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
van et al. (13)	48% NSs indicate very little CAM knowledge	NR	1. Neutral view (51.2%) 2. Positive/very positive (45.4%)	1. Philosophical congruency 2. Freedom of choice with regard to healthcare 3. Ease of access 4. Cost-effectiveness and perceived efficacy 5. Safety	12.6% NSs agree and 30.3% NSs strongly agree that CAM practice can affect medical treatment because of side-effects	44%/improve condition/ massage/ lack of knowledge	N/A	NR	1. Massage therapy (66%) 2. Homeopathy (53%) 3. Herbal medicine/ phytotherapy (42%)	NR	1. 25.2 NSs agree and 22.7% NSs strongly agree that CAM is a branch of science 2. Almost half of NSs are willing to refer patients to a CAM practitioner 3. 45% NSs report that they always enquire about the CAM use from their patients
Walker et al. (39)	Limited	NR	Relatively positive	1. Scientific evidence 2. Personal experience 3. Cultural background	Some NSs	NR/NR/NR/NR	1. There is no significant difference in knowledge level between NSs and chiropractic students 2. Chiropractic students lean more favorably toward recommending CAM than NSs	NR	NR	NR	NR

(Continued)

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Wilkinson et al. (14)	NR	NR	– Positive – The majority of NSs agree that CAM can improve quality of life	NR	NR	NR/stress/vitamin, minerals and other supplements/NR	1. There is few difference in attitudes toward CAM among different healthcare students 2. More pharmacy students (38.8%) and biomedical sciences students (35.4%) than NSs (19.6%) think CAM have only limited use	1. Friends 2. Family 3. Magazines	NR	NR	NR
Yildirim et al. (8)	Limited	NR	– Positive – 61.3% NSs support the integration of CAM into nursing curricula – 57.8% NSs support the integration of CAM into nursing care	NR	10.3%	NR/NR/prayer therapy/NR	1. NSs are more positive and knowledgeable than medical students about most of CAM modalities 2. NSs believe in CAM's clinical usefulness more than medical students 3. NSs use CAM individually more than medical students 4. NSs have more willingness than medical students about recommending CAM modalities to patients	1. Books (20.2%) 2. TV (18.8%) 3. Newspaper/journals (18.4%)	1. Relaxation techniques (80.5%) 2. Diet (80.4%) 3. Massage (79.0%)	NR	NR

(Continued)

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TABLE 3 Continued

References	Major results regarding NSs' KAP toward CAM [Primary outcomes] and comparison with control population (% represents the proportion of NSs respond)							Other results related to NSs' KAP toward CAM [Secondary outcomes]			
	NSs' KAP toward CAM						vs. control population (if available)				
	NSs' knowledge about CAM		NSs' attitude toward CAM			NSs' practice of CAM					
	Overall	CAM modalities NSs most expect to learn	Overall	Key factors that influence attitude	Agreement that CAM is a threat to public health	NSs' personal use of CAM (overall use/primary reason/top used modality/major barrier to use)		NSs' source of CAM information	CAM modalities most likely to be recommended to patients by NSs	Importance of different types of evidence for accepting/ using/ recommending CAM treatment among NSs	Additional key and valuable findings
Yilmaz et al. (36)	NR	NR	Positive	NSs' perception of health news may affect their attitudes toward using CAM therapies	NR	NR/considering harmless/NR/NR	There is no significant difference in attitudes toward CAM use between different healthcare students	NR	NR	NR	NSs have a low prevalence of CAM education

NR, no records; N/A, not applicable; NSs, nursing students; CAM, complementary and alternative medicine.

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In most of the included studies (8, 28, 37, 42, 45), in comparison with students with other healthcare background, NSs generally showed a more positive attitude toward CAM (Table 3).

Practice/personal use of CAM

NSs' overall personal use of CAM therapies were depicted in eight studies (9, 13, 16, 28, 31, 32, 38, 41). The lowest rate of CAM use reported was 44% (13) and the highest rate of use at 98.3% (16). Reasons for CAM personal use were detailed in only six studies. The major reasons were reduction of stress or relaxation (14, 29, 32), treatment of general health problems (31), improvement of current health condition (13), and consideration of the harmlessness of CAM modalities (36). Twelve studies further detailed the most popular and widely used CAM by NSs, involving massage (13, 16, 41, 43), herbal medicine (9, 31, 44), music therapy (29, 38), diet-based therapy (including vitamin, minerals, and other supplements) (14, 38), and prayer therapy (8) (Table 3).

Five studies (15, 16, 37, 39, 46) examined the major barriers to CAM practice/personal use under the perception of NSs. Congruently, lack of evidence and lack of staff training were judged as the two most significant barriers (Table 3).

Seven studies did not display any information relevant to the practice/ personal use of CAM (Table 3).

As reported, in comparison with other healthcare professions students, NSs were more likely to consult a CAM practitioner (41), or use/consider using CAM therapies (8, 28, 37) (Table 3).

CAM modalities best known to/most recognized by NSs

Of all the included studies, 15 determined NSs' knowledge/awareness rate of various CAM modalities (8, 9, 13, 29, 31–35, 38, 39, 41, 43–45). The top three modalities most familiar to NSs across each study are displayed in Table 4 (two studies counted only the two modalities most familiar to NSs). We noticed that massage, prayer/spirituality/spiritual healing, and herbal medicine were best known to NSs.

Seven studies (8, 16, 32, 34, 35, 41, 46) investigated the CAM modalities that NSs considered to be the most effective. The top three across each study were listed in Table 5. Therapies such as massage, herbal medicine, chiropractic, and diet/nutrition (including vitamins, minerals, and other supplements) were recognized by the nurses for their effectiveness.

By coincidence, massage and herbal medicine are the modalities both best known to NSs and ones the NSs perceive most effective (Tables 4, 5).

CAM modalities that NSs tend to/are willing to recommend

Four studies (8, 9, 13, 35) investigated the CAM modalities that NSs inclined to or were willing to recommend to their patients in the future clinical practice. Massage, herbal medicine/phytotherapy, and relaxation techniques were cited by respondents in at least two of these four studies as one of the top three modalities that were preferred and could be recommended (Table 3).

Importance of different types of evidence to CAM-related clinical decisions

Two studies (16, 41) rated the importance of different types of evidence for NSs in making clinical decisions with respect to CAM, such as acceptance, usage, or recommendation of CAM therapies. For a specific CAM modality, successful use in one's own practice and patient reports are judged by NSs as the most two important pieces of evidence, even more important than proven mechanism of action or proposed biological mechanism of action. Other crucial evidence included randomized controlled clinical trials (RCTs) involving humans and published case studies (16, 41). In both studies, RCTs involving animal studies were considered as the evidence with least importance (Table 3).

Sources for accessing CAM information

Eleven studies (8, 9, 15, 16, 29, 31–35, 43) investigated the sources from which NSs acquire information regarding CAM. These sources of information mainly involve books, written-visual and mass media (newspapers/magazines/TV), internet, family/friends, peer professionals, health care providers, and education programs. For NSs, amongst those sources, the proportion of accessing CAM information from the media and the internet far exceeded the proportion of accessing CAM information from professional healthcare providers or scholastic education (Table 3).

Discussion

Summary of findings

It is clear that insufficient importance is given to CAM theory and modalities in contemporary formal nursing education curricula design. NSs' knowledge level of CAM, although overall limited and poorly informed, was generally comparable or higher than that of other health profession students within the same age/grade group. It is hypothesized

TABLE 4 Top three CAM modalities best known to nursing students in each study.

References	NR	Acupuncture	Chiropractic	Aromatherapy	Diet/ nutrition (including vitamins, minerals, and other supplements)	Herbal medicine	Music therapy	Massage	Meditation/ imagery	Prayer/ spirituality/ spiritual healing	Relaxation techniques	Therapeutic touching	Yoga	Hypnosis	Exercise	Religious practices
Avino (15)	•															
Baugniet et al. (41)			•					•				•				
Cinar et al. (27)	•															
Halcón et al. (16)	•															
Hassan et al. (45)								•		•	•					
James et al. (9)						•				•						
Kavurmaci et al. (28)	•															
Kim et al. (44)								•	•							
Kreitzer et al. (37)	•															
Laurenson et al. (40)	•															
Özşaker (29)		•					•							•		
Oztekin et al. (30)	•															
Pettersen et al. (42)	•															
Pirincci et al. (31)					•	•									•	
Poreddi et al. (46)	•															
Reuter et al. (38)		•							•				•			
Sahin et al. (32)									•	•					•	
Sárváry et al. (43)		•						•			•					
Topuz et al. (33)		•				•										•
Turker et al. (34)						•				•				•		
Uzun et al. (35)					•			•		•						
van et al. (13)				•		•		•								
Walker et al. (39)					•				•				•			
Wilkinson et al. (14)	•															
Yildirim et al. (8)								•	•	•						
Yilmaz et al. (36)	•															

NR, no records; The • symbol indicates the top three CAM modalities best known to nursing students in each study.

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TABLE 5 Top three CAM modalities considered to be the most effective by nursing students in each study.

References	NR	Acupuncture	Chiropractic	Diet/ nutrition (including vitamins, minerals, and other supplements)	Herbal medicine	Homeopathy	Music therapy	Massage	Prayer/ spirituality/ spiritual healing	Relaxation techniques	Support groups	Ayurveda
Avino et al. (15)	•											
Baugniet et al. (41)		•	•					•				
Cinar et al. (27)	•											
Halcón et al. (16)			•	•				•				
Hassan et al. (45)	•											
James et al. (9)	•											
Kavurmaci et al. (28)	•											
Kim et al. (44)	•											
Kreitzer et al. (37)	•											
Laurenson et al. (40)	•											
Özşaker (29)	•											
Oztekin et al. (30)	•											
Pettersen et al. (42)	•											
Pirincci et al. (31)	•											
Poreddi et al. (46)					•	•						•
Reuter et al. (38)	•											
Sahin et al. (32)				•	•			•				
Sárváry et al. (43)	•											
Topuz et al. (33)	•											
Turker et al. (34)					•			•	•			
Uzun et al. (35)							•	•			•	
van et al. (13)	•											
Walker et al. (39)	•											
Wilkinson et al. (14)	•											
Yildirim et al. (8)				•				•		•		
Yilmaz et al. (36)	•											

NR, no records; The • symbol indicates the top three CAM modalities considered to be the most effective by nursing students in each study.

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that this may be related to acceptance by nurses of patient choice in self-care. The current level of CAM knowledge lags behind interest amongst NSs. Unfortunately, when there is insufficient knowledge gained in formal curricula, the media and internet are the primary sources for NSs to obtain CAM-related information or knowledge. The great interest and lack of credible source of information support an important need for change. Approximately 42.0–93.3% of NSs agreed that CAM ought to be combined with conventional medical/nursing practice to better serve patients' health and improve the quality of care available, or believed that information/knowledge on CAM was significant to their future career. Only a minority reported that CAM was a threat to public health or CAM was in conflict with mainstream biomedicine. The proposal to integrate use of CAM into existing nursing programs received extensive support, with approximately 33.3–93.3% NSs expressing interest and intention to pursue further education and training so that they are equipped to advise patients on the utilization of CAM. Approximately 44.0–98.3% NSs had personal experience with CAM therapy and used it primarily for relaxation and stress relief. Of the wide range of CAM modalities, students had higher self-rated knowledge of massage and herbal medicine. Coincidently, NSs considered these two therapies to be the most effective and the most worthy of recommending to patients.

Twenty-five out of 26 of the studies included were rated to be of moderate to high quality. The aforementioned evidence and results derived from the included studies can therefore be considered credible. All studies used investigator-developed questionnaires/scales to measure NSs' KAP toward CAM, and only a small proportion of these studies reported reliability and validity. Therefore, the development of a standardized and credible questionnaire under current research topic is urgently needed. Overall, the integration of CAM modules into the existing nursing education programs is not only desired and welcomed by a majority of NSs, but also essential for patient safety given nurses are often in the position to advise patients about CAM use.

Strengths and limitations

To the best of our current knowledge, this is the first systematic review comprehensively investigating the collective evidence regarding the KAP toward CAM among NSs. Among the 26 included studies, the samples originated from 12 countries, covering North America, Europe, Oceania, Africa, and Asia, reflecting the diversity and representativeness of the sample source (Table 1). The quality of this review is further enhanced by the solid academic background of the researchers and multidisciplinary collaboration, with most of our research team members have backgrounds in CAM and/or nursing science, and all members have a dual role of delivering theory at the university and practicing counseling/treatment in the clinical settings.

Yet, despite this review being carried out strictly in accordance with PRISMA guidelines, there are several limitations. First, the review was restricted to articles published in English and Chinese. Given the popularity of CAM modalities in many non-English/non-Chinese speaking countries, for instance Korea, Japan, India, or Iran, it is likely that there are relevant studies published in other languages that may have affected our current findings or led to different conclusions. Actually, during the screening stage, at least eight of the retrieved articles were excluded due to the language limitation (Appendix 4). Second, to reduce heterogeneity across the included studies, we only considered CAM as a broad umbrella term in the literature retrieval, and discarded studies investigating NSs' KAP toward a specific type of CAM, even including many representative CAM modalities with significant national/regional characteristics [e.g., Ayurveda/Unani for Indian NSs, Traditional Chinese Medicine (TCM) for Chinese NSs, osteopathic/chiropractic for Australian/New Zealand/US NSs, or Arabic medicine for Arab states and regions, etc.]. It is possible that those studies would further enrich the results of the current review. We, however, do not think exclusion of those studies would skew the conclusion of this review given we are only interested in the broad concept of CAM internationally, rather than focusing on one specific region. Third, all studies adopted self-administered questionnaire/scale rather than a standardized and uniform instrument, and only 30.8% of these studies tested psychometric properties of the employed instrument. The reliability of the results is thus undermined. Finally, qualitative study (interview) is more appropriate than quantitative study for accessing and interpreting complex attitudes/belief/perceptions. We did not include qualitative studies and as such, it should be acknowledged that our interpretation/understanding of NSs' attitudes toward CAM are somewhat restricted. Further rigorous and well-designed mixed-methods studies (using quantitative questionnaires/scales with good reliability and validity for investigating NSs' KAP and its influencing factors, and using qualitative depth interviews for exploring reasons underlying their attitudes and behaviors) with larger and more diverse samples are required to build stronger and more conclusive evidence.

A comparison with previous systematic reviews

Two systematic reviews were published in 2017 (2) and 2018 (47), respectively, with the aim of reviewing nurses' KAP toward CAM. The former critically reviewed nurses' attitudes through a meta-synthesis of qualitative research, without covering the knowledge and behavioral dimensions (2). In the latter (47),

however, nurse was viewed as a broad concept, including clinical nurses, midwives, NSs and nursing faculty. As a result, there was considerable heterogeneity among the included studies because of the discrepancy in study subjects, which introduces extra variability and makes it difficult to interpret the results. Here, we only targeted NSs to reduce variability and subsequently to better reflect the real KAP level of this population. In the results section, we also summarized the two to three CAM modalities that NSs were most familiar with, had most interests to learn, found most effective, and had most likelihood to recommend to patients. Such information is considered as KAP-related dimensions, which further flesh out our findings. Finally, based on the NSs' general KAP toward CAM reviewed in this study, we also provide a recommendation to adopt teaching strategies regarding introduction/integration of CAM module in the following paragraphs. None of this information was provided in those two previous systematic reviews. It is acknowledged that our major findings are consistent with those of the two reviews. That is, current nurses/future nurses (NSs) have very limited education in CAM and a lack of professional frameworks to assist them in this area.

Interpretation of findings in NSs' overall KAP levels of CAM

Targeting NSs in the current review is believed to be justified and necessary since the perceptions on CAM amongst the new generation of healthcare workers and professionals are likely to influence the future direction of health care (22), including the development and clinical application of CAM therapies. Moreover, in consideration of the heterogeneity across the studies arising from the research design, particularly the adopted various self-administrated questionnaires/scales in each study, our utilization of a systematic review approach allows for a more comprehensive understanding of the general level of KAP toward CAM amongst NSs.

Nurses are the largest group of healthcare providers across the globe, and the professional recommendation for CAM therapies has been found to be associated with nurses' knowledge background (20). According to the present review, amongst the numerous therapies, massage and herbal medicine are best known to NSs, and also top the list as the two modalities NSs are most likely to be recommend to their future patients. More to the point, the CAM knowledge held by nurses is pivotal in both health promotion and disease prevention (47). In order to manage this role aptly, NSs need to be prepared for their roles from studentship onwards (27, 29). Unfortunately, in light of the evidence collected in this review, it appears that NSs, as future nurses, have limited knowledge of CAM and lack professional frameworks to assist them. NSs' knowledge level of CAM was reported to be higher than that of medical students in two studies (8, 45); and was reported to be not significantly different from that of their counterparts, that is students of other health professions, i.e., medicine, pharmacy, midwifery, health visitor, and chiropractic, etc. in three studies (9, 39, 43). The discrepancy may be attributed to the variations in cultural backgrounds of the respondents and in CAM modalities covered by each different survey. No studies reported that NSs had lower knowledge level of CAM than their counterparts. In line with this, NSs generally had greater likelihood than their counterparts of consulting a CAM practitioner (41), or using/consider using CAM approaches (8, 28, 37). These results suggest that NSs, although with limited knowledge of CAM, are generally comparable or better informed than other health profession students about CAM modalities.

We are not surprised by these findings, as some CAM modalities (e.g., music therapy, simple relaxation therapy, meditation, etc.) in fact are already included in the "Nursing Interventions Classification" developed by the "Iowa Intervention Project" since 1992 and have long been part of nursing practice in some countries (8, 16, 48), as well as being accepted as an independent function used by nurses in patient care (8). Illustratively, the nursing intervention recommended by the North American Nursing Diagnosis Association for diagnosis of "energy field disturbance" includes meditation, acupressure, and simple guided imagery (16, 49). These therapies evidently fall under the umbrella of CAM, whilst they are not labeled as such (16). Some nurses thereby even argue positively that CAM creates an opportunity to reclaim person-centered holistic care and broaden the meaning of contemporary nursing care practice (2). Another possible explanation for NSs show higher CAM knowledge level than medical students is that the latter generally pay less attention than NSs to CAM modalities, as pharmacotherapies occupy the foremost place in the classical understanding of medicine (8). In addition, nurses are more ready to accept patient preferences and autonomy in their own healthcare, which can include CAM therapies that patients report that are effective (2, 10, 50). It is, therefore, clear that the systematic integration of CAM into existing nursing programs is well-grounded in both theory and tradition (16). Furthermore, this kind of pedagogical reform appears to have a positive impact on the knowledge and/or interests of CAM among NSs at any level (43). One strong piece of evidence is that a pedagogical experiment performed in University of Washington has confirmed that following CAM being incorporated into the curricula, 70% of NSs at all levels reported an increase in their CAM knowledge and 50% reported an increase in their level of CAM interests (5). Patients may also benefit from nurses better prepared, as a previous study showed that the greater CAM knowledge NSs possess the more positive they will practice in their clinical area (45).

NSs' attitude toward CAM has been suggested to greatly influence implementation in contemporary nursing practice (46, 51). According to current review, only a low proportion of NSs

surveyed viewed CAM as being in conflict with mainstream medicine, or even a threat to public health. Such findings are in line with the conclusion of a prior systematic review focusing on similar theme but allowing nurses as respondents (2). Clearly, regardless of nurses or NSs, their support for CAM is not an attempt to challenge modern medicine but rather an endeavor to further improve the current care quality to their patients *via* the supplement of CAM and supporting patient autonomy and choice (2). Furthermore, despite debate with respect to the attributes of CAM curricula (elective or compulsory) (9, 32, 40), more knowledge of CAM is in general welcomed among NSs, with most of the NSs surveyed reporting an interest in further learning and support for the integration of CAM courses into existing nursing programs (8, 9, 15, 16, 27–33, 35, 37, 38, 41, 44–46). Just as Lindeman declared, nursing education must be broad-based, community-based, keeping a holistic focus, and affording alternatives to Western medicine (52). These findings are encouraging, because research has suggested that NSs' positive attitudes toward CAM can be used to predict their behavior with regard to CAM's use and recommendation to their future patients (13). Conversely, patients' decision concerning the CAM therapies is also likely to be influenced by nurses' attitude toward these therapies (2).

Besides favorable attitudes, the majority of NSs strongly agreed that patients should inform their medical treating team about their use and preference of CAM modalities (13). Such finding also highlights the need for further education on CAM, so that NSs can safely advise their patients both the effectiveness and side-effects of each therapy. Equipped by greater knowledge and more thorough understanding, healthcare practitioners may also discuss with their patients the indications and contraindications of alternate remedy options so that patients can make an informed choice (2). In contrast, lack of qualifications in practicing such CAM modalities, or lack of sufficient knowledge of their effects or even hazards may lead to varied issues for patients (29).

Development and support from faculty is another identified enabler for the integration of CAM into nursing teaching and clinical practice (16). Promisingly, many studies reported that most nursing faculty expressed agreement and desire for more CAM education (15, 16, 37).

Finally, in the current review, knowledge level, previous positive personal experience, and/or personal cultural background (including religious/beliefs) are identified as the potential factors which can influence NSs' attitudes toward CAM. For instance, increased knowledge contributes to the positive attitudes (53). Schramm et al. reported that following participation in a CAM course, nearly all NSs agreed CAM was important and benefits future advanced practice (54). Interestingly, gender appears to be another possible influential factor. Previous studies demonstrated that female students in general had a more positive attitude toward CAM and they were more likely to use CAM in comparison with their counterparts (14, 43). This may enable it easier to deliver CAM education among NSs, since the potential gender lopsided of the nursing profession and the number of female NSs far exceeds that of male NSs.

In current review, the overall rate of personal use of CAM amongst NSs ranged from 44 to 98.3%. The primary purposes for their CAM usage included reduction of stress, relaxation, and health improvement, which are in agreement with the purposes of personally using CAM by nurse reported in a prior systematic review (47). Previous personal experience is one of the most common and critical factors in shaping NSs' attitudes toward CAM (2, 39) and NSs' likelihood of recommending CAM therapies to future customers (55). Sahin et al. (32) also observed a positive correlation between the status of NSs benefitting from CAM and recommending CAM. The same phenomenon has been identified amongst nurse population as well (2). In study of Sohn et al., over 60% nurse acknowledged that they relied on "personal experience" for knowledge about CAM (56). As reported, even amongst those nurses who are previously skeptical about the value of the CAM therapies, they may also attribute the positive experience with their decision to utilize or recommend such therapies to their customers (2). The current review also found that many NSs' supports for CAM therapies were largely based on their previous positive use experience or based on patients' reports. And, both two bases (personal experience and patients' reports) were also judged by NSs as the most two crucial evidence and reference when making clinical decisions regarding CAM, such as using or recommending a specific CAM modality (16, 41).

Implications for education

Current evidence has critical implications to guide and instruct the CAM courses design, including development of course syllabus, and compilation of teaching materials, for NSs. Several questions associated with curriculum such as "What to teach," "Who can teach," and "How to teach" may also be informed by the results we summarized in this review.

Answers to "what to teach"

Using evidence as a core to select what to deliver and teach

Curricula content about CAM is recommended to be divided into two sections, namely broad foundational skills and specific content areas (57). Introductory foundational principles should be delivered first, aiming to provide NSs a framework for future learning (57). Such principles are advised to cover at least the CAM professional terms, frequent reasons for CAM use, the basic tenets of CAM healing systems, and skills for initiating dialogue (including enquiry and discussion) of CAM with patients in a non-judgmental manner (57). There is a wide

variety of CAM modalities available, and which of these should be prioritized for inclusion in syllabuses and textbooks for specific content section requires discretion. Scientific evidence is central to both healthcare practice and medical education, and CAM must be held to similar standards (57, 58). Hence, the scientific evidence for or against the effectiveness and safety of each CAM modality must be at the center of selecting what to deliver and teach (57). To ensure the updating of knowledge and the sustainability of the curricula, curricula developers should also consider the need for constant review and critical evaluation as curricula-related new CAM evidence emerges (59).

NSs' interest, attitude and level of knowledge can be viewed as other valuable basis and reference. In accordance with current evidence, we recommend that massage, nutritional/diet-based therapy (including vitamins, minerals, and other supplements), music therapy, meditation, aromatherapy, phytotherapy/herbal medicine, and therapeutic/healing touch be programed into the CAM curricula, considering these modalities have been deemed by NSs as the ones they have most interests in. In fact, these modalities cover almost all of the top three modalities that NSs know best, find most effective, and personally use most frequently. Educators are also advised to give consideration to numerous variables regarding use of each CAM modality, including regional beliefs, cultural preferences, traditional practices, economic and income status, and clinical applicability/usefulness when designing course (32). Moreover, these variables should first be investigated and examined in the country and region (32) where the course is delivered/taught, so as to determine if a particular modality is eligible to be compiled into the teaching materials. To exemplify, for Asian countries such as India, Korea, Japan, and China, priority may be given to acupuncture; for Western countries, priority could be given to nutrition and CAM manual therapies such as massage, chiropractic and osteopathy; for religious state, priority may be given to prayer, spirituality, or spiritual healing.

Enhancing knowledge and skill training of evidence-based practice in CAM curricula

Generally in keeping with findings from nurses (47), insufficiency of scientific evidence was also perceived by NSs as one of the biggest barriers to the usage and integration of CAM. These findings are reassuring in that they reflect the great importance NSs attach to evidence-based practice (EBP) concepts and principles. This is extremely valuable because some CAM therapies such as TCM (60, 61) or Ayurveda (62), despite their popularity and prosperity in China and India, respectively, rely heavily on the practical wisdom inherited from ancient practitioner, rather than high-quality scientific research evidence. In fact, the national nursing education policy recently issued in China has made it explicit that EBP should be one of the basic capabilities for nursing undergraduates (including TCM nursing majors), and that TCM nursing discipline can be advanced through the implementation of EBP (60). Takata et al. also suggest that nurses who have been educated about the scientific evidence for CAM may play critical roles in advising on CAM, including its benefits and risks, as well as in supporting the self-care in response to patients' clinical requirements (63). Meanwhile, these roles would also strengthen the relationship between nurses and their patients, which, in turn, enhance the professional motivation of nurses (63). Therefore, we also encourage enhanced training on EBP knowledge and skills in CAM curricula so that NSs are likely to transform CAM nursing care from praxis-based to evidence-based, and consequently, implementing and optimizing evidence-based CAM care in their future professional career (60). Correspondingly, the methodology and the tools used in the evaluating quality of evidence are ought to be introduced or strengthened. Such a course design should make sense. After all, the study by André et al. has confirmed that embedding evidence implementation into programs did improve NSs' EBP capacity (64). Zhou et al. even provided nursing educators with more specific and detailed advice, that is, course syllabuses could be designed on the basis of comprehensive EBP models with five steps, such as the JBI Model of Evidence-Based Healthcare, and the ACE-star model (60).

Incorporating literature/information retrieval skill training into CAM curricula

To avoid harmful practices and reduce associated risks, it is essential that healthcare workers have reliable and accessible information and/or evidence (31). Specifically, healthcare professionals including nurses should be capable of delivering research-based CAM information to their patients (17, 65), and/or guiding their patients to identify the reliable and professional CAM information from the clutter (10). Currently, NSs generally lack adequate information about CAM (31). Also, high-quality sources of information, that is, evidence-based textbooks, clinical guidelines, or expert's consensus, etc. were not the primary source for NSs collecting CAM information. Our review revealed that the most common sources that NSs obtained CAM information were newspaper/magazines/TV and internet, and lower proportion had sourced CAM information from professional healthcare providers or scholastic education. This contrasts to a prior systematic review, in which professional colleagues and journals were the main sources of CAM information for practicing nurses (47). In some regions, apparently, NSs may have no access to credible sources and may have to rely on media and internet to gain relevant information. Yet, the accuracy and reliability of such informal information can be a concern and should be questioned (17, 29). Social media may even contain misleading anecdotal information that promotes unscientific therapies (36, 66). Such scenario also hints at the serious neglect of teaching NSs how to access and screen reliable CAM information in existing nursing education.

These findings lead to the strong recommendation of incorporating literature/information retrieval content of CAM

therapies into nursing curricula, in order to help NSs learn to access scientific, accurate, and reliable CAM information from specialist medical databases. We are confident in the feasibility of this recommendation because a prior study has confirmed that nurses who had previously received CAM-related education were three times more likely to seek CAM information from a medical database than those without (20). Another reason that explains our emphasis on CAM-related retrieval skill is that it can be perceived as a life-long learning strategy or "long-lasting tools" to help NSs better cope with the current and emerging CAM-related therapies that they may encounter in their future clinical work (57). After all, regardless of how much content is delivered in a curriculum, science keeps evolving and questions keep changing. With capability to easily source evidence-based materials, NSs will know where to find reliable and up-to-date evidence/information concerning CAM, and know how to better objectively discriminate, judge, assess, and interpret those retrieved results (57). Accordingly, some practical databases that facilitate students' search for high-quality literature and books related to CAM therapies should be introduced to support the curricula.

Answers to "who can teach"

The lack of teaching staff and their professional training is considered to be one of the most significant barriers to the use of CAM in clinical settings (15). Due to the integrated nature of the CAM curricula, staff usually find it difficult to teach individually and to estimate the amount of time devoted to the teaching work (67). So, who are the most suitably qualified staff? It is suggested that the teaching staff can consist of two types of professionals: First, industry practitioners/community-based practitioners with a full educational background (from undergraduate to PhD) in CAM. Second, registered nurses with enough experience in education/training and clinical practice in CAM. Furthermore, the teaching tasks of these two types of professionals are suggested to be focused. Industry practitioners can lead the delivery of theoretical lectures. And, different CAM therapies should be taught by the corresponding practitioners to ensure the professionalism and teaching quality (e.g., chiropractic/osteopathy is best to be taught by chiropractor/osteopath, TCM/acupuncture is best to be taught by TCM practitioner/acupuncturist, etc.). In contrast, the clinical placements should be led by the registered nurses with extensive CAM experience. Having a nurse as a "peer predecessor" to lead the placement might help NSs quickly adapt to clinical work and better translate theory into practice, so that they can be truly equipped to provide reliable CAM-related advice, treatment or referral services to patients in need. Although both industry practitioners and registered nurses might introduce an element of bias, this could be overcome with an evidence-based teaching method and clear learning outcomes (59). Notably, in view of sustainability, the qualifications of these staff for such curricula must be consistent and their repeated involvement sustainable (59).

Answers to "how to teach"

Specialization determines the nature (compulsory/elective) of the curricula

There is still debate as to whether the CAM curricula should be delivered as an elective or a compulsory module (9, 32, 40). None of the included studies explored this issue. Whereas, inferences made by some authors in the discussion section may provide a few potential clues. For instance, proponents for "compulsory module" might reckon that being taught in a compulsory rather than an elective format would help NSs to overcome the CAM knowledge gap more comprehensively and effectively (40). James et al. suggest one possible reason for those who prefer CAM as an elective to a compulsory module is that the NSs interviewed are already overstretched with their major courses and may view a compulsory CAM module as an added burden (9). It should be stated that the respondents in James' survey were all final year undergraduate students (9). Thus, it is understandable that the extra burden of a compulsory CAM course in last year is unwanted by students nearing graduation.

A compulsory course is a curriculum within the program that must be completed in order to fulfill the requirements to be eligible to graduate; elective course is one which the students can opt into if they so desire and thus are usually more interested and motivated in learning and enriching their professional portfolio (68). It is limiting to discuss the nature/format of a curriculum outside of the disciplinary context, and it may be feasible to defuse this dispute through developing various specializations. In Hong Kong Metropolitan University, Bachelor of Nursing includes three specializations (Bachelor of Nursing, Bachelor of Nursing in General Health Care, and Bachelor of Nursing in Mental Health Care) for potential students to choose[1]. Similarly, in University of South Australia, students who are seeking study in Graduate Certificate in Nursing can choose one specialism from several specializations (e.g., Cardiovascular Nursing, Critical Care Nursing, Health and Aging, Nurse Education, etc.)[2]. With reference to the mode of these majors, we suggest that CAM curricula should be a compulsory module for Bachelor/Diploma/Certificate/Master of Nursing (in CAM specialization), while be an elective module for other Nursing degrees.

1 https://www.hkmu.edu.hk/nhs/programmes-courses/nursing-and-health-studies/undergraduate-programmes/

2 https://study.unisa.edu.au/nursing-midwifery/

Clinical placements and experiential learning mode are strongly encouraged

Given NSs/nurses are used to judging or recommending CAM modalities to patients based on their previous personal experience (which was detailed in the previous paragraph "section Interpretation of Findings in NSs' Overall KAP Levels of CAM"), incorporating clinical placements to match theoretical knowledge (formal lectures or tutorials) is strongly encouraged in CAM curricula (33). Clinical placements provide NSs with learning opportunities that may affect their opinions on CAM practices for patients (33). Experience derived from clinical placements may benefit NSs to better perform their patient assessment and patient engagement capabilities which would include identification of the patients' utilization of CAM therapies, the effects thereof, and keeping the patients and the families informed of these practices (33). Hence, practicing communication and critical thinking skills about CAM therapies and the prevalence of their use should be highlighted in the clinical placements teaching (21).

Additionally, we also strongly recommend the inclusion of experiential learning mode (15, 16), involving activities that include personal participation in self-care activities (15). It is clear that experiential learning will be favored compared to a solely didactic approach, as such immersive approach can significantly enhance student engagement (59). Many mind-body techniques are well-suited and encouraged to being taught in the form of experiential learning mode (57). As an illustration, mindfulness meditation impacts positively on NSs' anxiety, depression, stress, burnout, and sense of wellbeing (69). The same goes for the benefits of yoga (70). Delivering this species of therapeutic remedy *via* experiential learning mode thereby can serve the dual purposes of benefiting the NSs at present and, possibly, their patients in the near future (57). All such designs and ideas mentioned above are not only expected to facilitate the clinical translation and application of NSs' theoretical knowledge of CAM, but are also expected to facilitate them to be more confident in providing unbiased advice to patients in their future career.

Implications for research

Development and test of the professional instrumentation

A crucial research gap of concern is a lack of established instrumentation that can be used to evaluate NSs' KAP toward CAM. Two included studies (9, 39) employed CHBQ, which is a questionnaire for measuring medical students' attitudes/beliefs toward CAM (71). Despite the potential adaptability of CHBQ to other health professions education settings (71), those aforementioned two studies did not re measure its psychometrics (reliability and validity) when adapting the CHBQ (9, 39). Two studies (27, 29) used HCAMQ, which includes 11 questions [six questions are relevant to beliefs about the scientific validity of CAM (CAM subscale), and the remaining five are relevant to beliefs about holistic health (holistic health subscale)] (72). Re-test reliability of the total HCAMQ and CAM subscale was 0.86 and 0.82, respectively (72). Both aforementioned studies adopted total HCAMQ rather than CAM subscale, and calculated the internal consistency and homogeneity between the items, with Cronbach's coefficient alpha were 0.72 (27) and 0.74 (29), respectively. Another study (36) employed ACTS to determine healthy students' attitude toward using CAM therapies (Cronbach's alpha coefficient 0.79). In that study, the Cronbach's alpha coefficient was 0.84 (36). All these three instrumentations are intended to examine attitudes/belief toward CAM only, and do not cover dimensions link to knowledge and behavior/practice nor are they specific to NSs as respondents. Hence, the urgent need remains to carefully develop a practical, valid and reliable instrumentation for assessing NSs' KAP toward CAM.

To better promote and deliver CAM education amongst NSs, evaluation related to effectiveness of this knowledge applied to clinical practice is also necessary. To match this, it is also pivotal to develop and validate methods for measuring other instructional outcomes such as CAM knowledge and skill acquisition amongst NSs at the end of a CAM specific course if that is the chosen model used to embed in the curricula (71).

A need in investigating Chinese NSs' KAP toward CAM

A previous review indicated that nurses from China and US had a more positive attitude toward CAM use than did nurses from other countries (47). We however found no surveys available in the databases that investigated Chinese NSs' KAP toward CAM, in spite of a comprehensive search. Due to the popularity of TCM in China and the labor demand of massive TCM hospitals, many universities and colleges in China (particularly TCM universities) introduce TCM nursing curricula into nursing programs at all levels, covering diploma, undergraduate, and/or postgraduate (73). Whilst many Chinese use other CAM modalities such as yoga, aromatherapy, or massage [non-TCM massage (Tuina)], knowledge of these modalities is hardly taught at any level of nursing education, to our best knowledge. In consequence, clinical practitioners may find it difficult when patients reveal information about preferences and previous utilization of CAM therapies other than TCM (74). These findings imply that there is an urgent need to investigate Chinese NSs' KAP toward different CAM modalities and introduce CAM modules other than TCM into existing nursing education accordingly.

Conclusions

The current review identifies a need to enhance the skills to discriminate evidence-based CAM therapies by NSs through integrating CAM modules into existing nursing programs, in order to prepare future nurses to competently and safely advise patients use and to enhance safe and patient-centered care. In curricula design, the scientific evidence for or against the efficacy and safety of each CAM modality should be considered. Experiential learning is a highly recommended educational mode in the curricula for delivering specific CAM modalities. In addition to theoretical knowledge and matched clinical placement, skills training on CAM-related literature search and EBP are also advised to be incorporated into the curricula. From a clinical perspective, such a teaching model that well bridge theory to clinical practice, will allow for evidence-based practice. To help reduce costs and increase the quality of research associated with NSs' KAP toward CAM, a standard, comprehensive, and applicable instrumentation should be designed and examined for utilization in different cultures.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary materials, further inquiries can be directed to the corresponding author/s.

Author contributions

ZZ, GK, and Q-QF conceptualized and designed this review. W-JZ, Q-QF, and F-YZ performed database search, as well as data extraction, analysis, and interpretation and were also involved in the quality assessment. F-YZ drafted the research protocol and prepared the manuscript. RC, SC, GK, and ZZ provided critical comments for revising the manuscript. All authors have read and approved the final version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.946874/full#supplementary-material

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Evaluation of teaching effect of first-aid comprehensive simulation-based education in clinical medical students

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Background: Although students mastered the composition skills, they lack of the ability to effectively integrate these composition skills in real clinical situations. To address the problem, we set up different levels of situational simulation training for medical students in grades 2–4, and evaluate the teaching effect of first-aid situation comprehensive simulation-based education (SBE) on clinical medical students.

Methods: The medical students in Grade 2, 3, and 4 received different situational SBE, respectively. The 2nd-year medical students received a single skill module which included cardiopulmonary resuscitation, endotracheal intubation, and electric defibrillation training. The 3rd-year medical students received a single subject module which included cardiovascular and respiratory system training. The 4th-year medical students received the integrated multidisciplinary module which combined first-aid skills, clinical thinking, and teamwork training. The primary outcome was the expert evaluation and peer evaluation. The secondary outcome was students' satisfaction questionnaire response. In our training, we arranged an adequate teaching staff for intensive training and timely feedback (the student–teacher ratio of 5:1), adequate time for repetitive practice (Each SBE was carried out within 4 h), curriculum design, and integration from real cases by clinicians, realistic computer-driven mannequins to ensure simulation fidelity, providing a different difficult level of SBE to different grades of students, and pre- and post-tests for outcome measurement.

Results: In all of the single skill module, single subject module or comprehensive disciplines module, the scores in the expert evaluation and peer assessment after the training were significantly higher than before the

training, and the differences were statistically significant ($p < 0.05$). The integrated subject training, although having the lowest pre—and post-test marks, had the largest increase in score.

Conclusion: The first aid comprehensive simulation-based education in grade 2–4 clinical medical students, basing on timely feedback, repetitive practice, curriculum integration, simulation fidelity, and outcome measurement are effective in improving the students' proficiency in managing the real emergencies.

KEYWORDS

first aid, comprehensive, simulation-based education, clinical medical students, teaching

Background

Simulation has had a long and varied history in many different fields, such as aviation and the military. Healthcare, like aviation, is driven by safety, more specifically patient safety. Clinical medicine has begun to focus on the safety of patients and the quality of their practice and not merely on medical education, as well as, patients are paying more attention to the "practice" from medical students and residents on them (1, 2). In 1999, Anderson M et al. reported that many observers of medicine have expressed concerns that new doctors are not as well–prepared as they should be to meet society's expectations of them (3). At present, with the increasing of medical information and research, educators need to constantly adjust the curriculum structure to improve the teaching effective and meet the strict teaching requirements. Therefore, developing medical simulation teaching is more important for improving clinical practice ability. In the history of medical education, the earliest simulated teaching method originated from anatomy. The rise of learning, with the continuous expansion of medical teaching content and the improvement of modern manufacturing technology and electronic information technology, medical simulation technology is becoming more and more perfect in terms of functionality and simulation. As the link between simulation and patient safety becomes increasingly apparent, simulation was adopted as the education and training method of choice for such critical behaviors as communication and teamwork skills worldwide (4).

The classroom model remains disconnected from the actual clinical environment. Many students also lack of training in theoretical study, physical examination, and diagnosis (5). In China, the clinical skills training courses, which appeared in 2000, have experienced from the pure practice of basic skills on simple models to elementary simulation courses, preliminary solving the problems of dispersion of basic skills training and lack of practice chance. Since 2010, the medical college clinical skills centers have kept expanding. The skills training equipment has developed from simple models to computer-driven high simulation models. At the same time, the training and use of standardized patients (SPs) have also kept increasing, which greatly improved the quality of clinical skills training (6). However, the rapid improvement of hardware and SPs also increased the demands for the development of situational comprehensive simulation clinical skills training courses, aiming at improving students' clinical logic reasoning, practice ability, and teamwork.

Medical education attaches great importance to practical operation, and qualified doctors cannot be trained without clinical practice. The traditional teaching model has encountered difficulties in adapting to the requirements of modern teaching, and the quality of clinical practice teaching has been greatly affected, which restricts the development of medical clinical teaching (7). The application of medical simulation teaching, which is more in line with humanistic care, is becoming the dominant mode of clinical medical practice teaching, and is more and more favored by clinical medical education (8). In the course of teaching, we found that although after the early stage of training, medical students have mastered some clinical skills. However, in clinical practice, they still cannot meet the teaching demands of clinical application of basic skills. This is to say, although students mastered the composition skills, they lack of the ability to effectively integrate these composition skills. They are unable to effectively apply the component skills in real clinical situations.

To address these problems, it is very urgent to construct the first aid simulation-based education (SBE) scenarios and to perform comprehensive simulation teaching, and equally importantly, to evaluate the teaching effects (9). Thus, we set up different levels of situational simulation training for Grade 2–4 medical students, and evaluate the teaching effect of first aid situation comprehensive SBE on clinical medical students.

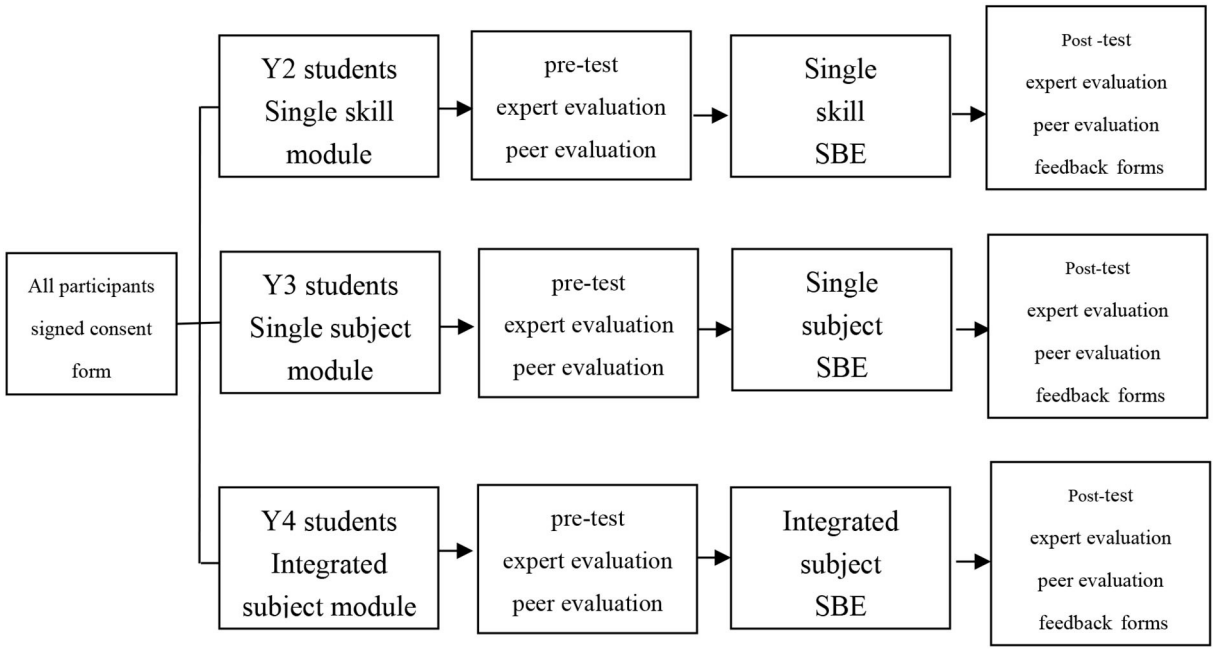


FIGURE 1
The general flowchart of the whole research. SBE, simulation-based education.

Methods

An experiment was conducted to evaluate the effect of SBE on the knowledge, self-efficacy improvement, and composite scores of clinical students.

Participants

The full-time medical students in Grade 2, 3, and 4 of clinical medicine in Shantou University Medical College were eligible for admission to the study. The total number of grade 2 students in Shenzhen class is 35. Excluding those who have received first aid (such as cardiopulmonary resuscitation, endotracheal intubation, and electric defibrillation), 30 students are enrolled. There are a total of 34 students in Grade 3 Shenzhen class, 4 students who have received first aid training were excluded. There are 35 students in Shenzhen class of grade 4. Excluding those who have received first aid training, 30 students are enrolled. The study was undertaken from September 1 to December 31 in 2021. The written consent was obtained prior to the commencement of the scenario. The Ethics Approval was obtained from the Ethics Committee of the third Affiliated Hospital of Shenzhen University.

Study procedure

The medical students in Grade 2, 3, and 4 received different situational SBE, respectively. The design and implementation of the first aid SBE for each grade were carried out by the teachers from the Department of Critical Care Medicine of the Third Affiliated Hospital of Shenzhen University. For the 2nd-year medical students, the SBE is a single skill module which included cardiopulmonary resuscitation, endotracheal intubation, and electric defibrillation training. For the 3rd-year medical students, the SBE is a single subject module that includes cardiovascular and respiratory system training. For the 4th-year medical students, the SBE is the integrated multidisciplinary module that combined first-aid skills, clinical thinking, and teamwork training. The study procedure was listed in Figure 1.

The mannequins used in SBE are realistic, anatomically correct, and computer-driven, which can simulate the physiological reactions of real patients. Each SBE was carried out within 4 h, with 30 students in each grade. The student–teacher ratio is 5:1.

Outcome measures

The primary outcome measured in this research project was expert evaluation and peer evaluation. The expert evaluation was

performed through the expert evaluation table. Peer evaluation was performed through the peer evaluation form. The students' satisfaction with SBE was the secondary outcome of this project and was measured with training feedback forms. The questionnaire was measured on a 5-point Likert scale ranging from 0 (Not at all) to 4 (Totally).

In the first 5 min of each class, all students who participated in these classes were required to take a pre-training test, and the expert evaluation form and peer evaluation form were required to complete. All of these forms were collected before the beginning of each training. At the end of the training courses, the students were required to take a post-training test and the same two forms, together with the students' own learning feedback forms. All questionnaires were issued in paper forms.

Statistical analysis

All analyses were performed by using SPSS version 22 (IBM Inc., New York, United States). All statistical tests were 2-sided, and p-value < 0.05 indicated statistical significance. An independent t test was performed to compare the continuous variables of the normal distribution, and a Mann–Whitney U test was performed to compare the continuous variables of skew distribution. The scores were expressed as means plus or minus standard deviations (SD).

Results

For the cohort of 90 medical students enrolled in the study, none was excluded or declined to participate. Questionnaire response rates for each of the three SBE scenarios and learning reactionnaire are 100%.

In all of the single skill SBE cardiopulmonary resuscitation, endotracheal intubation, electric defibrillation, the single subject SBE (cardiovascular, respiratory), or the comprehensive disciplines SBE, the scores in the expert evaluation and peer assessment after the training were significantly higher than before the training, and the differences were statistically significant ($p < 0.05$, see Table 1). The highest scores pre- and post-test were in the single-skill SBE, and the lowest scores pre- and post-test were in the comprehensive subject SBE.

There was a 100% response rate to the learning reactionnaire. The results indicated that 93.3% of the students scored ≥ 3 (A lot), and 100, 96.7, 96.7, 96.7, 100, and 100%, of the students scored ≥ 2 (Moderately) (see Table 1), indicating that the medical students had a positive feedback on the training effect of SBE.

A total of 90 students from the SBE group provided their complete feedback on the SBE (Table 2). For this course, 95.5% of the students were satisfied with our SBE and more than 80% have a good evaluation (evaluation of the necessity, 95.5%;

TABLE 1 Change in expert evaluation, peer evaluation, and learning reactionnaire response after each simulation-based education (SBE).

'Grade	SBE	Expert evaluation				Peer evaluation				Learning reactionnaire reponse		Total
		Mean pre score	Mean post score	Mean difference	*P*-value	Mean pre score	Mean post score	Mean difference	*P*-value	Rank ≥ 3(%)	Rank ≥ 2(%)	
Grade 2	Single skill 1	53.4 ± 16.5	71.7 ± 14.4	18.3	<0.001	83.1 ± 7.3	90.2 ± 6.9	7.1	<0.001	93.3	100	30
	Single skill 2	46.7 ± 22.1	69.5 ± 24.6	22.8	<0.001	53.4 ± 28.0	82.4 ± 8.7	29	<0.001	93.3	96.7	30
	Single skill 3	49.3 ± 15.8	84.6 ± 10.4	35.3	<0.001	52.5 ± 16.6	84.4 ± 15.0	31.9	<0.001	93.3	96.7	30
Grade 3	Single subject 1	50.6 ± 15.4	73.9 ± 4.3	23.3	<0.001	58.1 ± 11.0	76.2 ± 4.7	18.1	<0.001	90	96.7	30
	Single subject 2	48.2 ± 12.6	62.8 ± 11.5	14.6	<0.001	59.2 ± 10.7	72.0 ± 5.9	12.8	<0.001	96.7	100	30
Grade 4	Integrated subject	28.0 ± 14.3	58.3 ± 7.2	30.3	<0.001	39.9 ± 21.1	62.0 ± 13.9	22.1	<0.001	96.7	100	30

skill 1, cardiopulmonary resuscitation; skill 2, endotracheal intubation; skill 3, electric defibrillation.
subject 1, cardiovascular system training; subject 2, respiratory system training.

evaluation of the form, 94.8%; evaluation of the schedule, 81.4%; level of participation, 95.5%). The majority of these students also thought that SBE may help them improve themselves effectively (98.9%). Moreover, 97.8% of the students were satisfied with their teacher.

Discussion

Medical education is rapidly changing, influenced by many factors including the changing healthcare environment, the changing role of the physician, altered societal expectations, rapidly changing medical science, and the diversity of pedagogical techniques (10). The traditional teaching method is faced with many problems such as fewer clinical patients and uncooperative patients; compared with traditional teaching methods, the advantages of simulation-based education are step-by-step learning, a "hands-on learning experience and the opportunities for repetition until proficiency is reached" (11–13). At present, the first-aid training for clinical 2–4 grade students in medical colleges in China is only in the traditional mode of theoretical teaching by teachers and skills training on models. This teaching method makes medical students lack of clinical thinking, team cooperation, and humanistic concepts. Without the training of various clinical situations, medical students, even after such training, often do not know what to do when they meet real patients in clinical practice, especially in critically ill patients (14).

In real situations, with the development of society, the enhancement of the legal awareness of the whole people and the clear right to know, consent and privacy of patients, as the subject of traditional teaching, patients have the right to refuse to be the object of teaching, especially the examination of some private parts. Most patients refuse to cooperate with the teaching (15). This makes clinical teaching often into an awkward situation. Moreover, the use of real patients in clinical teaching may lead to medical disputes, so that clinical teaching hospitals often sacrifice teaching, medical students should master the various clinical skills which cannot be properly trained (14). According to China's "Medical Practitioners Law", medical students can only be legally engaged in medical practice after obtaining a medical qualification and at the side of patients and their families, especially critically ill patients, they do not cooperate with clinical teaching and refuse to be managed by interns (11). At the side of clinical teachers, they do not arrange interns to deal with critically ill patients due to concerns about medical disputes. In the present course of medical students' skill training, the attention is only paid to the cultivation of composition skills, without systematic logical reasoning, multidisciplinary cooperation, and development of emergency management ability to deal with critically ill patients (16).

In order to solve these problems, it is very urgent to construct first-aid simulation scenarios and conduct comprehensive SBE on this basis, The prevailing view is that SBE is superior to traditional teaching methods (17, 18). In medical education, the traditional education model is generally that students listen to their teacher, and then learn knowledge through their own understanding or observation. The traditional education model fails to provide simulated learning opportunities that affect their transition from theory to practice (19). SBE is also an increasingly important educational strategy that plays an important role in improving patient safety. SBE trainees can improve professionally by learning from their mistakes, which will help them avoid the same mistakes in real life. The main motivation for this study was to evaluate the effectiveness of SBE in training undergraduate students. A study with a sample size of 1,178 students suggested that SBE could have a positive impact on college education. Students in the SBE group had more positive communication with classmates and teachers, which could explain their great improvement in humanistic care and doctor–patient communication (20).

The purpose of the simulation is to imitate real patients, clinical tasks, and the real environment provided by medical services. It can provide feedback after simulation, with repetitive practice habits, course integration, and appropriate difficulty level. The researchers point it out that in order to achieve proficiency, students firstly need to acquire the component skills, then practice to integrating them, and proceed to know when to apply the skills they have learned (Figure 2) (21). The significance of simulation teaching lies not only in the application of simulated mannequins, but also in the integration of clinical situations. It is very important to integrate the clinical context into the teaching scenarios. First of all, the single skill training teaches only component skill, resulting in students' deficiency of clinical thinking. Secondly, without the experience of simulated scenarios, medical students often do not know how to deal with real clinical situations. Thirdly, the integration of clinical situation is helpful to train the medical students' teamwork, humanistic spirit, and to lead students to systematically integrate the knowledge and skills they have learned, thus helping them to reach the level of proficiency (22, 23).

Therefore, we set up three levels of situation simulation for medical students in grades 2, 3, and 4, and evaluate the teaching effect of first-aid comprehensive simulation-based education in these clinical medical students. Our study showed that whether in the single skill SBE [cardiopulmonary resuscitation (CPR), endotracheal intubation, electric defibrillation], the single subject SBE (cardiovascular, respiratory, or the comprehensive disciplines SBE, the scores in the expert evaluation and peer assessment after training were significantly higher than scores before training, and the differences were statistically significant (see Table 1). Our study is consistent with the reports of Issenberg SB et al. (24) and McGaghie WC et al. (25), which showed that SBE with deliberate practice is superior to traditional clinical medical education in achieving specific

TABLE 2 The feedback of students in the SBE group.

Feedback items	0 point	1 point	2 point	3 point	4 point
	Very disagree/dissatisfied				Very agree/satisfied
My overall satisfaction with this SBE course	0.0%	0.0%	4.5%	49.2%	46.3%
Evaluation of the necessity of this SBE course	0.0%	0.0%	4.5%	38.4%	57.1%
Evaluation of the form of this SBE course	0.0%	1.1%	5.1%	46.9%	46.9%
Evaluation of the schedule of this SBE course	0.6%	4.0%	14.1%	46.9%	34.5%
My level of participation in the process of this course	0.0%	0.6%	4.0%	55.4%	40.1%
SBE course helps me better grasp the clinical operation	0.0%	0.0%	1.1%	42.4%	56.5%
My satisfaction with the teachers of SBE course	0.0%	0.6%	1.7%	32.8%	65.0%



FIGURE 2
The ingredients of proficiency.

clinical skill acquisition goals, especially when the courses were arranged with different difficult levels, good curriculum integration, timely feedback, and repetitive practice. We have also developed a feedback questionnaire (a specific evaluation of the course). Feedback is a major component of reporting. This two-way interactive discussion can help participants reflect on their behavior and performance. Feedback is the primary component of debriefing. This bidirectional and interactive discussion could help participants reflect on their actions and performances (26).

Our results also show that while the integrated subject SBE scored lowest in pre- and post-school tests, there was a significant increase in scores. Our integrated clinical situations are modified according to real cases by clinicians, which can simulate the clinical situations to the greatest extent. Not only can we provide medical students with very realistic clinical situations, but also the training is very safe and effective. Medical students often lack confidence in handling common clinical emergencies. Morris MC et al. (25) designed a new sub-module to incorporate high-fidelity simulation into the undergraduate medical curriculum and found that students showed a very positive attitude toward this new teaching method, especially in integrating previously learned knowledge and skills, indicating that simulation-based teaching is feasible and effective in the undergraduate setting.

Among the 2nd-year medical students' single skill training, the skill of electrical defibrillation increased the most after training, and the score of endotracheal intubation increased the least after training. This may be due to the relatively few training steps for electric defibrillation and the complexity steps for endotracheal intubation. Therefore, we need to increase theoretical learning of endotracheal intubation and increase the number of trainings to better master this clinical skill.

Simulation-based medical education is a complex service intervention that needs to be planned and practiced with attention to organizational contexts. In our study, we arranged an adequate teaching staff for intensive training and timely feedback (the student–teacher ratio of 5:1), adequate time for repetitive practice (each SBE was carried out within 4 h), curriculum design and integration from real cases by clinicians, realistic computer-driven mannequins to ensure simulation fidelity, providing different difficult level of SBE to different grades of students, and pre- and post-tests for outcome measurement. These factors are consistent with the features and best practices of SBE that is convinced to be used in medical simulation technology to maximum educational benefits (27). Other studies have also shown that medical simulation teaching can provide opportunities and conditions for medical students to contact the clinical practice in the early stage of school, which can improve medical students' clinical skills, operation ability, bedside comprehensive diagnostic thinking ability, and is beneficial to the cultivation of students' professional ethics and code of conduct (28, 29). Simulation teaching advocates medical teaching in a way that is as close to the real clinical environment

as possible and more in line with medical ethics, and uses all simulated hand segments to create simulated patients, simulated scenes, simulated classrooms for various skills training and assessment, simulated wards, simulated operating rooms, and other software and hardware conditions (13). As an effective supplement to theoretical teaching and clinical practice, simulation teaching has changed the traditional teaching model, provided a safe teaching environment, cultivated agile and correct clinical thinking, and reduced the occurrence of medical accidents and disputes in clinical practices (30).

Our study has limitations. First, only 30 medical students of each grade were included. More participants are needed to further confirm the effectiveness of the first-aid-integrated comprehensive SBE. Second, although improvements were observed in our study post-training when compared with pre-training; there is no comparison to standard educational methods. Thirdly, this research was only based on a single center. Only grade 2–4 medical students were included, so the conclusion cannot be generalized to other populations. Finally, the participants are all from the Shantou University Medical College and may not represent students from other medical colleges.

Conclusion

The first-aid comprehensive simulation-based education in grade 2–4 clinical medical students, basing on timely feedback, repetitive practice, curriculum integration, simulation fidelity, and outcome measurement are effective in improving the students' proficiency in managing the real emergencies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Shenzhen Luohu People's Hospital. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MP and NS prepared the tables and drafted the manuscript. RH, HG, FC, WZho, WZha, JZ, and ZY reviewed the manuscript for its intellectual content. WC were responsible for revising the manuscript. All authors have read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Laboratory and clinical teaching experience of nursing professors in the COVID-19 pandemic era: Now and the future

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Nursing professors must constantly interact with students, maintain a high level of professional performance, and meet targets and deadlines, even during a pandemic. Considering the changing educational environment, it is essential to identify contemporary limitations and problems to provide feedback for improvement. This study aimed to explore the laboratory and clinical teaching experiences of nursing professors during the COVID-19 pandemic. Focus group interviews were conducted with professors from the nursing departments of universities in Korea. In total, 19 professors who had laboratory and clinical experience participated in this study. The collected data were analyzed using thematic analysis. The analysis identified four themes. The themes included feeling helpless in the infection management system, uncertainty about the effectiveness of alternative practice training, acceptance of changes, and preparation for future practice training. As the necessity and possibility of non-face-to-face education have been confirmed by the pandemic, it is expected that classes using technology will be actively developed in nursing practice education. The roles and attitudes of teachers and educational institutions also need to change. Nursing professors should reflect upon and evaluate challenges to prepare for post-pandemic practical education.

KEYWORDS

clinical practice, COVID-19 pandemic, focus group interviews, laboratory practice, nursing faculty

Introduction

The coronavirus disease 2019 (COVID-19) outbreak has adversely affected all social sectors worldwide, including the economy, healthcare, and education (1–5). Its high infectivity has necessitated measures such as social distancing, isolation, and travel restrictions, bringing almost all face-to-face activities to a standstill (1, 4, 6). In particular, the education system has been strongly affected by the COVID-19 pandemic (3, 7, 8). Schools and universities stopped all face-to-face classes, declared temporary closures, and struggled to find solutions (3, 8). To solve this problem, educational institutions worldwide switched to non-face-to-face remote classes, using online technology to maintain the learning process and achieve learning goals (3, 7, 9, 10).

Non-face-to-face classes have existed since before (11). Educational technology has advanced dramatically in the last few decades, and it has proven to be extremely useful during this pandemic (3). Online education is not a new concept for educators (11), and there are several online platforms that support online education (12). Nonetheless, universities have found it difficult to map their educational activities into the online space (7). Regardless of how advanced online learning becomes, it will never be able to replace the real classroom experience, the sacred teacher-student relationships, and the fun of studying in a real class with our peers (13). Furthermore, some students lack computers or mobile devices to study online learning and lack internet quotas (14). An unstable internet connection during lectures may limit classroom participation by making it difficult for teachers to interact with their students (15, 16). Medicine, nursing, veterinary medicine, agriculture, and engineering study programs, in particular, cannot be taught entirely online due to the extensive need for laboratory and internship experience (17).

Nursing education includes various clinical classes, and nursing students must complete a certain number of clinical hours (18). Nursing students in Korea are required to complete more than 1,000 h of clinical time during their enrollment in order to be placed on professional nursing staff after graduation (19). Overall, clinical practice represents an application-based curriculum that establishes the professional intuition of a nurse (20). While clinical practice should be conducted in the clinical field, many departments of nursing have stopped clinical practice due to the pandemic; thus, it is necessary to find countermeasures to prevent infectious diseases during clinical operations (21).

Furthermore, the reputation of educational units is increasingly under scrutiny. How well do they maintain their quality of education amidst this crisis by showing their adapting capabilities? Indeed, academic institutions are not able to transform all their college curricula into online resources promptly (3). University professors must constantly interact with students, maintain a high level of professional performance, and meet targets and deadlines even during a pandemic (22). Both professors and students at universities have experienced non-face-to-face classes for the first time. However, professors are obliged to choose the best teaching methods to provide students with a high-quality education. In addition, professors can use a combination of audio, video, and text to reach out to their students during this time of crisis to maintain a human touch (3).

The professor should choose various teaching methods suitable for nursing education, integrate students' active learning, and establish strategies to promote critical thinking while also playing the role of facilitator, so that students can integrate theory into clinical practice (23). Education includes more than just delivering knowledge through lectures and teaching students in clinical practice. Regardless of the physical and temporal distance from students, professors should help and support students in building their knowledge (24).

Previous studies related to the experience of clinical education during the pandemic have mostly focused on the students (20, 25, 26). Considering the changing educational environment, it is essential to identify contemporary limitations and problems to provide feedback for its improvement. For future innovation in laboratory and clinical education, it is necessary to understand the experience of the professor's education in this chaotic era.

Focus group interviews are in-depth interviews that involve posing open-ended questions and follow-up probes designed to obtain an in-depth understanding of participants' experiences, perceptions, opinions, and feelings. In focus groups, emphasis is placed on group interactions by encouraging participants to talk with each other, ask questions, and comment on experiences and personal perspectives (27). The focus group interviews can clarify the experience of nursing professors in the laboratory and clinical teaching. Thus, this study aimed to identify the experiences of nursing professors' laboratory and clinical teaching in the pandemic era and reflect on the future of nursing education.

Methods

Design

This qualitative study applied the thematic analysis method of Braun and Clarke (28) to explore the laboratory and clinical teaching experiences of nursing professors during the COVID-19 pandemic. This study followed the Consolidated Criteria for Reporting Qualitative Studies, which covers the reporting of studies using interviews and focus groups (29).

Participants

The study participants were nursing professors who had experience in teaching laboratories and clinical experience. The inclusion criteria were tenured, teaching for at least 3 years, and having operated from 2020 to the present. The exclusion criteria were sabbatical or research years and no classes for more than one semester since 2020. Participants were recruited by posting and promoting online announcements to members of the Korean Society for Simulation in Nursing (KSSN).

An ideal focus group interview sample should include 5–8 participants; in groups larger than 10, participants find it difficult to freely share their views and thoughts. The most common and comfortable groups have 5–6 participants (27). However, because the scope of experience was simple and limited, this study decided to include 20 participants, five in each group.

Twenty professors voluntarily applied for participation, but one person withdrew; thus, 19 people participated. All participants were female in their 30 and 50s, and their educational careers ranged from at least 3 years and 6 months to 16 years and 3 months. Their subjects included fundamentals of nursing practice, adult nursing practice, pediatric nursing practice, women's health practice, psychiatric nursing practice, community nursing practice, and simulation practice.

Ethics

This study was approved by the C University Institutional Review Board (IRB NO.2021-1445-0001). The participants were assured of confidentiality and informed that participation was voluntary, and that they could withdraw from the study at any time. They were informed that the transcripts would not be used for any purpose other than research.

Data collection

Data were collected *via* focus group interviews in July 2021. Nursing professors who understood the purpose of this study and voluntarily signed the consent form participated in the study. The focus group interviews consisted of 4–6 participants each, and each group was interviewed once for ∼60–90 min. The data were processed until saturation. Furthermore, when additional information was required, a telephone or message was used. Interviews were conducted in places where participants were comfortable with online, non-face-to-face interviews. The interviews were recorded after obtaining the consent of the participants. During the interview, all participants were allowed to use a pseudonym or freely turn the camera on and off. The burden of the interviews was minimized, and the participants were allowed to talk freely. The interviews were conducted by two female researchers who had previously conducted several focus group interviews and had practical lecture experience as a nursing professor and a doctoral student. The questions were composed of opening, introductory, transition, key, and ending questions. The key questions were as follows: "What was your experience in laboratory and clinical teaching in the pandemic era?" and "How does it compare to before?"

Data analysis

The recorded interview content was transcribed and analyzed using thematic analysis, as described by Braun and Clarke (28). Thematic analysis is a useful method for analyzing the perspectives of subjects; it is not judged by the frequency of occurrence of words, and it is a flexible analysis that requires the analysis of potential meaning rather than the meaning of superficial content (30). The thematic analysis consisted of six phases. The initial phase of thematic analysis aimed to familiarize researchers with the collected data. Repeated reading contributed to better understanding and enhanced the researchers' familiarity with the data. Following the initial stage, initial codes were generated from the dataset that had a reoccurring pattern in the second phase. Coding was carried out through a systematic way of organizing and obtaining meaningful characteristics of the data related to the research question. Two researchers independently conducted the coding. The third phase, searching for themes, focused on a broader level of analysis and involved the researchers identifying suitable themes to which codes could be attributed. More specifically, initial codes pertinent to the research question were integrated into themes, considering how relationships were formed between codes and potential themes. In the fourth phase, the relationship between codes that could be included in the identified topic and other topics or codes was investigated; the similarities and differences were also classified and analyzed. The content of the extracted coding data was fully included in each subtheme by reviewing the formed themes. The identification possibility, interrelationship, and amount of code were considered using the recombination and separation method of the code. Consistency and clear patterns were also confirmed. In five phases, defining and naming themes were completed by refining the existing themes and subthemes presented in the final analysis. The final phase included writing a report that maintained consistency and logic and accurately described the results. In this process, after consulting with two qualitative research experts, each distinctive theme was defined.

Rigor

To guarantee the rigor of the research, we endeavored to have credibility, transferability, dependability, and confirmability, as suggested by Lincoln and Guba (31), at each stage of the thematic analysis.

Results

As a result of the analysis, 48 subcategories were generated, and nine categories were constructed by classifying subcategories related to each other. Further themes were derived from the four principal themes: (1) feeling helpless in the infection management system, (2) uncertainty about the effectiveness of alternative practice training, (3) acceptance of changes, and (4) preparation for future practice training (Table 1).

TABLE 1 Summary of themes, categories, and sub-categories.

Themes	Categories	Subcategories
Feeling helpless in the infection management system	Unpredictable situations	Inconsistent infection control guidelines
		Difficulty in decision making
		Sudden notice
		Persistence of tense situations
		Cessation of practice
		Inevitable situation
	Limitations of class management	Concerns about infection
		Students' anxiety
		Practice operations where maintaining distance is difficult
		Lethargy
		Increasing class hours
		Burnout
		Resignation
Uncertainty about the effectiveness of alternative practice training	Lack of educational resources	Lack of support from schools
		Lack of educational contents
		Shortage of faculty
		Difficulty finding educational methods
		Readjustment of evaluation methods
	Concerns about securing the quality of practice	Concerns about not being equivalent to clinical practice
		Concerns about students graduating without practice
		Insufficient time for clinical practice
		Concerns about students' diminished practical skills
		Guilt about students
	Negative feedback from students	Low lecture evaluation scores
		Non-face-to-face training is not recognized as practice
		Limitations of non-face-to-face practice
		Dissatisfaction with the operation of non-face-to-face practice training
		Dissatisfaction with the amount of assignments
Acceptance of changes	Reconsideration of traditional practice methods	Students accustomed to alternative practice
		Need for clinical practice appropriate for course characteristics
		Need for a flexible practice operation method
		Limitations of traditional clinical practice
	Confirmation of the feasibility of new practice training methods	Increased students' interest
		Improvement of students' self-confidence
		Safe educational environment
		Possible repeated learning
		Accumulation of know-how
		Expanded technical support
		Diversity of contents
Preparation for future practice training	Development of technology-based curriculum for practice	Learners as digital natives
		Joining the new normal era
		Development of practice training tailored to the characteristics of Generation Z
	Responding to the changing practice training environment	Exchange of information on new practice methods
		Clinical advice through industry-university cooperation
		Need to build a network for developing educational contents

Feeling helpless in the infection management system

The participants were placed in an unpredictable situation, where their practice was stopped due to inconsistent infection control guidelines and the continuation of tensions. They expressed the limitations of class operation due to concerns about infection, students' anxiety, and difficult practice operations to maintain distance.

Unpredictable situations

The participants had difficulty in making decisions on the clinical and laboratory practice plans due to inconsistent infection control guidelines. They expressed that the inevitable and tense situations continued, such as receiving sudden notice from school and government.

"Because the guidelines of the country and the Ministry of Education are constantly changing, I think the practice class schedule has been adjusted around 15 times. Everyday things become uncommon, and my plans to do better become meaningless...." (participant 10).

"Even before the start of the class, I wondered whether students would go to clinical practice or not, but I got flustered when I heard that the practice was completely stopped just 1 week before the class started" (participant 15).

Limitations of class management

Participants were concerned about infection, students' anxiety, and practicing operations where it was difficult to maintain distancing. They felt helpless and were exhausted by the increased class hours required to prevent the spread of infectious diseases. They expressed their feelings of resignation regarding the inevitability of the situation.

"It has no problem when students sit and listen to the class. However, when students practice with dummies, they sometimes have to gather, so it is difficult to maintain distance due to the nature of the basic nursing practice. In such a case, we had no choice but to follow quarantine guidelines, such as wearing a mask and sanitizing hands, and continuing the class with the minimum number of students widening the distance from each other" (participant 12).

"First of all, it consumes a lot more energy than before... I had to make a separate program for a few people because I was told that 'Do not force students to participate in the practice' or 'Do not create a situation where students are anxious and unable to speak'. It was very difficult" (participant 10).

Uncertainty about the effectiveness of alternative practice training

Participants tried to operate it as an alternative practice training in an unexpected situation; thus, it was difficult to find alternative education methods due to lack of support from schools and educational content, shortage of faculty, and difficulty in the readjustment of evaluation methods. In addition, participants were concerned about the deterioration of their skills because alternative training was not equivalent to clinical practice and graduation without clinical practice. In particular, there was uncertainty about the effectiveness of alternative practice training with negative feedback from students who did not recognize low lecture evaluation scores and non-face-to-face training as practice.

Lack of educational resources

Participants faced difficulty finding alternative education methods due to lack of support from schools and educational content, shortage of faculty, and difficulty in the readjustment of evaluation methods.

"To shoot VOD, I needed support from the school for everything including the video system, but it's not like the school is spontaneously ready to support it; so, I had to look for various ways" (participant 1).

"It was very difficult because I was not prepared for a scenario that had to be improvised or for a non-face-to-face operation through ZOOM" (participant 9).

Concerns about securing the quality of practice

Participants were concerned about the curriculum not being equivalent to clinical practice and students graduating without clinical practice. When the laboratory practice was changed to online, they expressed concerns and guilt regarding students' diminished practical skills.

"The quality of practice cannot be taken into account. In any case, I had to control the students so that they could complete their practice time… also felt a great sense of disparity about the fact that students had to take the practical exam without experiencing real practice in practice training. I could not evaluate them in the same way as before" (participant 10).

"Is it really okay for students to graduate? Can they go to the clinic? What is the level of students' clinical understanding? Can I ignore it and move on? These remain areas of my greatest concern" (participant 17).

Negative feedback from students

Some participants experienced feelings of depression because of the low lecture evaluations received from students after non-face-to-face practice. Students expressed that they

did not recognize the non-face-to-face practice as practice, and they were dissatisfied with the operation of the non-face-to-face practice training.

"I think I just carried out an absurd practice with a dummy on the screen. Unsurprisingly, I received feedback from the students that it was very disappointing" (participant 10).

"In the case of psychiatric nursing practice, when it was conducted online, students often said that it was difficult to catch non-verbal parts because most of them only heard verbal ones. Students say that they do not know what to say when they meet an actual mentally ill person, even after the practice" (participant 8).

Acceptance of changes

Participants suffered helplessness and uncertainty about the effects of alternative practice education within the infection control system when they started involuntary alternative practice operations; however, they simultaneously reconsidered traditional practice methods. As the alternative practice operation was extended because of the prolonged pandemic situation, it was expressed as a change that must be accepted by recognizing the limitations of traditional practice methods as well as confirming the possibility of a safe educational environment and new practice training methods for infectious diseases.

Reconsideration of traditional practice methods

Participants encountered students accustomed to alternative practices and felt the need for flexible practices tailored to the subject characteristics. The traditional practice method with standardized uniformity and physical limitations in all practice subjects was reconsidered.

"If you look at the situation before COVID-19, especially in children's hospitals, when students go out for clinical practice and just observe, besides measuring the patient's vital sign. After two weeks of observation, the contents of the clinical practice manual were very limited, and there were cases where the same content was repeated and observed, and it was very boring for two weeks" (participant 16).

"Clinical practice is the best, but I think all professors and students complain about the limitations of clinical practice. If so, I think it is right that the direction of practice should change" (participant 1).

Confirmation of the feasibility of new practice training methods

Participants have continued to operate the practice in a new way, different from the existing face-to-face practice, through a long-term pandemic, and have accumulated know-how in the operation of the practice by finding technical support from the school and various contents available. In particular, it was confirmed that students' confidence and interest increased in an educational environment, considering that non-face-to-face online practice is safe from infectious diseases and repetitive learning is possible, confirming the possibility of a new practical education method.

"Communication, which is the core competency of nursing, can be sufficiently taught using VOD, ZOOM, and SP. It was similar to training SP and having a 1:1 conversation with students in ZOOM… I actually tried this method and it worked great" (participant 1).

"I changed the teaching method by using VR simulation and blending in a variety of contents, and I think the students had a lot of fun through various experiences" (participant 7).

"The first semester was chaotic, but after a while, I think it was an opportunity to run a wide range of practice classes with various cases to suit the situation" (participant 15).

Preparation for practice training in the future

Participants felt the need for an educational method to freely operate in practice even during a pandemic. Accordingly, they argued that digital native learners and technology-based practice education, suitable for the new normal era, should be developed. To cope with the changing practice environment, it was suggested that future practice education should be prepared, including the exchange of new information, clinical advice through industry-academic linkage, and the establishment of a network for developing educational content.

Development of technology-based curriculum for practice

Participants reported that most of the students were digital natives called Generation Z, and thus, they were faster in accepting advanced technologies such as AR and VR than their instructors. One participant mentioned that practical education suitable for different learner characteristics should be developed and that even if the pandemic situation ended, it would not be possible to return to the earlier practice operation method completely.

"Even if the coronavirus pandemic is over, it will inevitably become a new normal era in which we cannot go back to the past. Because our students are of the MZ generation and are familiar with YouTube" (participant 12).

"When comparing before and after the pandemic, methods other than face-to-face should be strengthened for students to practice independently. As the pandemic exploded, the cost of VR development, wireless usage fees, and license fees decreased

significantly. As long as there are wireless goggles, core skills are being developed to be used anywhere" (participant 1).

Responding to the changing practice training environment

Participants argued that industry-university cooperation and clinical advice are essential for exchanging information on new practice methods and creating a laboratory environment similar to clinical practice as preparation for future education. In addition, a network for the development of educational content should be established to respond to the changing practical educational environment.

"We need to create an environment that is most similar to clinical practice through the development of various modules, and it is best to seek advice from clinical teachers or clinicians for this part. Because so many things have changed in the past and now, I think industry-university cooperation is very important" (participant 1).

"It is my greatest wish to share information so that various teaching methods can be researched and utilized" (participant 9).

Discussion

This study explored the laboratory and clinical teaching experiences of nursing professors in the COVID-19 pandemic era. As a result of analyzing the contents of the focus group interviews with nursing professors, four themes were derived: feeling helpless in the infection management system, uncertainty about the effectiveness of alternative practice training, acceptance of changes, and preparation for future practice training.

First, participants felt helpless in the infection management system. Under the infection management guidelines that changed with the spread of COVID-19, participants experienced unpredictable situations where laboratory and clinical education were stopped due to confirmed cases on campus. This is similar to other nursing colleges worldwide that have been affected by COVID-19 and have undergone clinical discontinuation (2, 32, 33). Regulations on credit completion at universities in Korea are strictly applied, and the criteria for credit and professors' approval are set for practical courses (19). After clinical practice was suddenly suspended, the professors had to ensure the prevention of infectious diseases and divide the class into a minimum number of people and operate laboratory and online classes. Participants reported burnout as a result of overwork, such as preparing educational materials to be recognized as clinical practice and increasing class hours, and as this situation continued, they gave up.

Burnouts cost both individuals and educational institutions because they undermine the function of teachers and cause poor quality education and health (34–36). Teachers experience a high level of work stress, especially university professors (22). More specifically, university professors are responsible for the essential task of training students in a variety of advanced specialized skills and promoting the development of science, technology, and social progress. In addition, university teachers must constantly interact with students, maintain a high level of professional performance, and meet targets and deadlines, even during a pandemic (37).

Based on the findings of the present study, it is necessary to reduce the psychological impact of the pandemic, as well as to improve and avoid these stressful situations among professors. It is suggested that supervising institutions take steps to encourage these practices and alleviate the problem of stress (22, 37, 38). Furthermore, it would be important for them to receive support in the form of additional educators and resources, as well as emotional support by introducing workshops or programs to strengthen their emotional resources (37, 38). In this way, the emotional environment in universities could be improved and the mental health of professors could be protected.

The second theme was that participants felt uncertain about the effects of the alternative practice training. As non-face-to-face education was conducted in an unexpected situation, it was taught without deep concern for teaching design principles or appropriate non-face-to-face educational tools (39). For professors to manage non-face-to-face practice, it is necessary to have support from educational institutions, including educational facilities, teaching design, technology, image storage ability, and a stable Internet connection (6, 40, 41). However, participants had to run alternative practice training without sufficient educational resources, such as school support, educational content, faculty members, and educational methods.

Planning for meaningful practice training is difficult and, in some cases, presents an ethical dilemma (16). Professors should choose the best teaching method and provide education to students (2, 3, 17). Participants said that alternative training is not equivalent to clinical practice and that they felt guilty about students graduating without clinical practice. As the pandemic is prolonged, students are unable to observe patient care at clinical sites, resulting in a lack of opportunities to acquire problem-solving skills and communication skills (20, 33). This also limits opportunities to learn to cooperate with colleagues and other professionals (42). It has been found that the practice was not simply converted into non-face-to-face practice; specifically, a strategy for maintaining and improving the quality of practical training is needed (9, 25). Therefore, it is necessary to identify the advantages and disadvantages of non-face-to-face practice and prepare effective, non-face-to-face clinical practices.

Third, the participants felt that accepting the non-face-to-face practice warranted a change. Alternative teaching methods such as technology utilization, real-time online interactive classes, online practice content, video streaming, and online practice homework have been used (25). In addition, the

information of various teaching strategies for laboratory and clinical classes has accumulated in a short time. For example, participants utilized the simulation using a standard patient through Zoom and various practical content such as the mobile augmented reality, virtual reality, and video on demand for laboratory and clinical practice. This allowed participants to reconsider traditional practice methods and confirm the feasibility of new practice training methods. This non-face-to-face practice was enabled by the development and spread of educational technology (10, 43). Since the coronavirus pandemic outbreak, educational technology has been actively used in the education sector to facilitate interaction in online classes and systematically manage learning processes (3, 7). Instructors should consider the role and value of education in coping with changes such as the willingness to introduce a new educational technology system as a clinical teaching strategy, the intention to reflect it in the future curriculum, prior knowledge of new technology, and the perception of barriers to technology use (43).

Having started as a temporary measure to improve the situation, online education has led to new discussions in the field of nursing education (9, 16, 33). It is the instructor's role to provide a new learning environment that can integrate these technologies into the curriculum, including clinical practice after the pandemic (44, 45). This effort will provide an opportunity to overcome the problems of traditional nursing education (16, 20).

Traditional universities should not become aliases for today's online universities, but rather capitalize on digital technologies while maintaining a strong link between research and teaching activities and the unique on-campus student experience (17, 45, 46). Furthermore, online universities with extensive experience designing and delivering online learning programs may collaborate with traditional universities (17). This is especially true in technoscientific fields, where face-to-face practical and research activities are crucial.

Finally, the participants needed preparation for future practice training. Currently, nursing college students are a "digital native" generation exposed to the digital environment from childhood (17, 47). Nursing educators should understand the thinking, interests, and communication methods of Z-generation learners and determine the most effective teaching methods (48–51). Therefore, future education should modify the instructor's role in motivating, guiding, and advising the learner to the latter's role in designing and performing learning (52).

To move to the new normal, an approach different from the existing educational paradigm is required. Given these social requirements, what was considered important decades ago might no longer be relevant in the current education framework (16). Unfamiliar with non-face-to-face lectures, professors are currently experiencing difficulties. However, this situation also represents an opportunity to develop and provide higher-quality classes in order to prepare for similar situations in the future (53). Education innovation requires education for learning systems that can systematically implement it and instructors who can freely utilize it (17, 45). A crisis always represents a possibility as well; therefore, it is critical to prepare for another crisis in the future by examining, in detail, education in the current climate (46).

To cope with these changes, it is necessary to develop high-quality educational content based on creative scenarios and actively utilize them in actual curricula, away from the fixed thinking of traditional educational systems (16, 20, 40). This study confirmed the possibility and direction of alternative practical training by examining the laboratory and clinical teaching experience of nursing professors during the pandemic.

Limitation

This study has several limitations. First, it is difficult to generalize the study results because the participants were recruited from South Korea and were only interested in nursing studies. Furthermore, the focus group interview had a small sample size. This study could not consider the perspectives of professors from other nursing colleges around the world. Owing to subjective understanding, there may be errors and biases in the quality and quantity of experience; hence, the results should be interpreted carefully. Additionally, this study lacked a student perspective. The inclusion of students' voices could better convey the situation from a holistic perspective. It is recommended that any future study be conducted at multiple time points and strengthened considerably by including nursing professors from other countries and determining the similarities and differences between professors from nursing as well as other health occupations.

Conclusions

This study explored the laboratory and clinical teaching experiences of nursing professors and reflected on practical operations during the pandemic, as well as discussed the prospects of practical education after the pandemic and the role and direction for nursing professors. During the pandemic, nursing laboratories and clinical teaching experienced chaos and change. However, when experimenting with new teaching methods in various forms, it became an opportunity to consider non-face-to-face lectures, online platforms, and technology use. It is difficult to accurately predict how nursing practice education will change after the pandemic; however, the use of advanced technology in learner-centered education that can be flexibly selected according to the learner's situation is most likely to change the practice environment. In accordance with such changes, the roles and attitudes of teachers and

educational institutions also need to change. During the pandemic, both the necessity and possibility of conducting non-face-to-face education have been confirmed; thus, it is expected that classes using technology will be actively developed in nursing practice education. Nursing professors should reflect upon and evaluate challenges to prepare for post-pandemic practical education.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Institutional Review Board (IRB) of the Catholic university of Korea (No. 2021-1445-0001) reviewed and approved the study protocol. The patients/participants provided their written informed consent to participate in this study.

Author contributions

J-HK and S-YC designed the study and conducted the interview. S-YC and SJ analyzed the data. All authors drafted and reviewed the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Effect of M-Learning on promoting the awareness of faculty members of the universities of medical sciences of Iran about their employment regulations in 2020

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Introduction: New technologies enable universities to incorporate innovative teaching-learning strategies into their curricula. Therefore, this research investigates the effect of mobile learning on promoting the awareness of faculty members of the universities of medical sciences of Iran about their employment regulations.

Materials and methods: The statistical population of this research included all faculty members of Ahvaz Jundishapur University of Medical Sciences in southwestern Iran. One hundred and fourteen people entered the quasi-experimental study through convenience sampling. First, we sent the designed mobile app to them through social networks to install on their phone. We measured their awareness about the app and M-Learning through a researcher-constructed questionnaire.

Results: M-Learning and App was able to increase the awareness of faculty members, which was significant according to their academic rank and work experience. Faculty members who were professor and instructor, as well as those who had e under 5 years or 11–20 years of experience gained more awareness ($P = 0.00$). It was not significant in other variables. Ninety eight percent of the faculty members considered the technical capabilities of the designed app appropriate. Ninety seven percentage of the faculty members suggested M-Learning for teaching similar subjects in their profession.

Discussion and conclusion: The faculty members had a positive attitude toward this designed educational app and M-Learning. Designing similar mobile training apps can improve their professional performance.

KEYWORDS

M-Learning, App, employment regulations, faculty members, Iran

Introduction

Nowadays, many schools and universities use electronic learning and mobile learning to offer their courses and encourage students to use smart devices for their educational purposes (1). Use of mobile devices and apps installed on them that have high capabilities have increased in recent years in schools and universities for learning purposes (2). The use of M-Learning in medical education is expanding. Some of the most important advantages of M-Learning are possibility of learning at any time, saving time and money, continuous communication between learner and teacher, ability to self-assess while learning, high accessibility, ease for the learner, increase in motivation and diversity in learning (use of audio and video that makes attractive and better learning and memory retention) (3). Even in some medical faculties, M-Learning is officially included in the student curriculum. For example, since 2013, the University of Helsinki has given an iPad for their use to the new medical and dental students (1, 3). New technologies enable universities to incorporate innovative teaching-learning strategies into their curricula. M-Learning has significant potential for the classroom (4). M-learning is a popular field in educational organizations, companies as well as for individual study (5). Studies have shown that M-learning is more effective than traditional learning methods (6, 7). M-Learning is also usable as a complement to traditional learning (8). During the Covid-19 pandemic, due to the closure of universities and educational institutions, the role of M-Learning in filling the educational gap and compensating for face-to-face training was quite evident (5).

There are 68 independent universities or colleges of medical sciences in Iran with more than 20,000 faculty members. The Universities and Colleges provide all their employment regulations (such as employment, retirement, promotion, leave, evaluation, etc.) in a bylaw called the employment regulations of the faculty members of the Ministry of Health and Medical Education (Universities of medical sciences) of Iran. The latest amendment to the employment regulations of the faculty members of universities of medical sciences affiliated to the Ministry of Health and Medical Education of Iran was approved in 2012 and notified all medical universities for implementation. This regulation has been amended many times during the last 10 years in the form of various directives and instructions. However, the Ministry of Health and Medical Education of Iran has not yet provided a new version of it. Only a paper version of it is available presently and there is no designed App for it. Therefore, according to his field of study and work experience in recruiting faculty members of Ahvaz Jundishapur University of Medical Sciences and with full knowledge of all these changes, the researcher has prepared a mobile app based on this bylaw and its subsequent amendments and directives. In the "Appendices" section, he has added several widely used directives and instructions for faculty members. Thus, we conducted this research to examine the M-Learning effect in promoting the awareness of the faculty members of the universities of medical sciences of Iran an about their employment regulations.

Materials and methods

The statistical population of this research included all faculty members of Ahvaz Jundishapur University of Medical Sciences in southwestern Iran ($N = 651$). One hundred and fourteen people entered the quasi-experimental study through convenience sampling. In this study, first we sent a mobile app designed by the researcher to faculty members through WhatsApp and Telegram social networks to install on their phones. We measured then their awareness about the designed mobile app through M-Learning after installing the software. This App is also available to the public gratuitously through Iranian internet markets, has been downloaded many times and has had a 5-star rating. Due to some of its unique capabilities, the App provides the possibility of learning administrative and employment regulations better and easier, and meets all the information needs of faculty members. It will also always be available to users. Because it is complete and comprehensive, it has the ability to search for content and updates. The data collection tool was a researcher-made questionnaire. It consists of 3 parts. The first part includes demographic information (5 questions). Its second part has 12 questions according to the content of the administrative and employment regulations of the faculty members of the Ministry of Health and Medical Education of Iran (such as employment, retirement, promotion, leave, evaluation, etc.,). The third part has 2 general questions about the form and technical capabilities of this App and the opinion of faculty members regarding the use of M-Learning for teaching similar subjects in their profession. We designed this questionnaire based on a 4-grade Likert scale (very high, high, moderate and low). Leveling of the questionnaire to evaluate the level of awareness: 12–24 is low, 25–36 is medium, 37–48 is high, and 49–60 is very high. This one-year study was conducted in 2020. The validity and reliability of this questionnaire has been confirmable. The experts confirmed the content validity of the questionnaire, so that the questionnaire became available for 10 educational experts. We used re-test to determine the reliability of the tool; so we distributed 20 questionnaires among the faculty members with an interval of 2 weeks and examined the reliability of the questions. Cronbach's alpha by 95% confirmed its reliability. We analyzed the data through SPSS software version 24 at a significant level of 0.05. We have carried out this research in line with the research plan No. 961036 approved by the National Center for Medical Education Researches of the Ministry of Health and Medical Education (NASR). Its ethical code is IR.AJUMS.REC.2018.583.

TABLE 1 Effect of M-Learning and the designed App in promoting the awareness of faculty members.

Variable		Number	Percentage	Mean	Standard deviation	*P*-value
Gender	Man	66	57.9	46.9	10.59	0.514
	Woman	84	41.1	47.68	10.87	
	Total	114				
Academic rank	Instructor	9	7.9	50	4.82	0.00
	Assistant professor	56	49.1	47.48	11.18	
	Associate professor	36	31.6	42.02	9.51	
	Professor	13	11.4	57	6	
	Total	114	100			
Work experience	Under 5 years	18	15.8	52.17	9.22	0.00
	5–10	34	29.8	45.15	7.54	
	11–20	35	30.7	51.63	10.74	
	21–30	19	16.7	38.21	9.79	
	Above 30	8	7.0	44.50	12.64	
	Total	114	100			
Type of service	Clinical science	62	52.48	46.03	11.68	0.273
	Basic science	52	59.13	48.50	9.43	
	Total	114	100			
Type of employment	Permanent	57	58.4	44.86	11.88	0.94
	Contractual employment	35	31.0	49.88	697	
	Service commitment	13	10.6	50.41	11.20	
	Total	114	100			

Results

Table 1 shows the impact of M-Learning and the designed App in promoting the awareness of faculty members about employment regulations according to their demographic variables. The results of this research showed that the designed App was able to increase their awareness, which was significant according to their academic rank and work experience. Faculty members who had the scientific ranks of professor and instructor gained more awareness ($P = 0.00$). Faculty members who had work experience under 5 years or 11–20 years of experience gained more awareness ($P = 0.00$) but it was not significant in other variables.

Table 2 shows the impact of M-Learning and the designed App in promoting the level of faculty members' awareness of employment regulations according to the content of the App. The results showed that M-Learning and the designed App were able to increase the awareness of faculty members about all chapters and their contents. The chapters of "Payment and Benefit System", "Leaves" and "Basic promotion and the promotion of faculty members" had a higher score respectively.

At the end of the questionnaire, we asked 2 general questions about the form and technical capabilities of this App and the opinion of faculty members regarding the use of M-Learning for teaching similar professional subjects. Ninety eight percent of faculty members considered the technical capabilities of the designed App appropriate (such as form and content, categorization of subjects, and its ability of searching contents). Ninety seven percent of the faculty members suggested M-Learning to teach similar subjects in their profession.

The following Figures 1–4 show part of the internal environment of this app:

Discussion

The results of this research showed that M-Learning and the designed App, while also obtaining the consent of faculty members, has been able to increase their awareness about the employment regulations. Wyatt et al. conducted a study titled M-learning with participation of students at two Mid-Atlantic universities in the USA. Nursing students and their faculty members participated in the 16-month training course and Personal Digital Assistants (PDAs) were in use in the training activities. The results showed that M-learning is useful in the clinical environment and all students, regardless of learning style, benefit from its use. Students also created a collaborative learning community with each other and with students from other more distant universities (4). In a review, Chen et al. examined nursing students' attitudes toward M-Learning. In this study, they evaluated articles published on the subject until 2021. The results showed that most nursing students were

TABLE 2 Effect of M-Learning in promoting the awareness of faculty members according to the content of the App.

Row	Questions	Very high	High	Moderate	Low
1	How much did it raise your awareness after installing and using this App regarding the chapter "Generalities and definitions of the faculty employment regulations"?	33.3%	34.3%	17.5%	14.9%
2	How much did it raise your awareness after installing and using this App regarding the chapter "Entering the service and employing faculty members"?	30.7%	32.4%	28.1%	8.8%
3	How much did it raise your awareness after installing and using this App regarding the chapter "Scale promotion and promotion of faculty members"?	37.7%	31.6%	23.7%	7.0%
4	How much did raise your awareness after installing and using this App regarding the chapter "Missions of faculty members"?	40.4%	25.4%	26.3%	7.9%
5	What was your level of awareness after installing and using this App regarding the chapter "Study opportunities for faculty members"?	35.1%	34.2%	16.7%	14.0%
6	How much did it raise your awareness after installing and using this app about the chapter "System of payment of salaries and benefits of faculty members"?	36.8%	41.3%	12.3%	9.6%
7	How much did it raise your awareness after installing and using this App regarding the chapter "Assessing the performance of faculty members"?	34.2%	34.2%	19.3%	12.3%
8	How much did it raise your awareness after installing and using this App regarding the chapter "Retirement of faculty members"?	37.7%	28.1%	20.2%	14.0%
9	How much did it raise your awareness after installing and using this App about the chapter "faculty leave"?	39.5%	33.3%	16.7%	10.6%
10	How much did it raise your awareness after installing and using this App about the chapter "General Assignments of Faculty Members"?	36.8%	30.8%	21.9%	10.5%
11	How much did it raise your awareness after installing and using this App regarding the chapter "Other regulations of faculty members"?	32.5%	32.5%	23.7%	11.3%
12	How much did it raise your awareness after installing and using this App about the chapter "Attachments (some widely used circulars and instructions)"?	34.2%	24.5%	28.1%	13.2%

inclined to M-Learning, but the rate of actual use was low (6). In a systematic review, Zhou et al. examined the effectiveness of M-Learning in medical education. In this research, they studied 11 articles published from 2000 to 2014. Seven articles showed that the use of Mobile phones for learning improved effectively their clinical awareness and performance (7). Azizi and Khatony conducted a study on the factors affecting the tendency of medical students to accept M-Learning among students of Iranian medical universities. Eighty three percent of the 332 students who participated in this research welcomed this method (9). The results of a study done by Sharma et al. in India showed that the effectiveness of M-Learning training on nurses' knowledge and attitudes about the prevention and control of MDR tuberculosis was favorable (10). Patil et al. used a mobile app to complement learning and teaching in India, and their research showed that medical students have a positive attitude toward M-learning (11). Keane et al. created a mobile app for medical students called "Urology Med". During a month from its launch, its users downloaded it 435 times in five countries on three continents and the App gained 5-star rating in the Apple Store (12). Baghcheghi and Koohestani conducted research among medical students in Iran. Their result was that there is a positive and significant relationship between the desire for M-Learning and academic achievement (13). In their study in Spain, Ortega et al. showed that M-learning has played an effective role in improving the learning of nursing students and have stated that teaching activities and methodology in this area need a fundamental revision (14). In their study in Turkey, Suner et al. showed that most dental students saw M-learning useful in dental courses and their attitude toward education through M-learning is positive. They have recommended that the design of educational materials and Apps for mobile devices may increase students' performance (15). In their study in Canada, Darras et al. showed that most medical students prefer to use M-learning to teach radiology over traditional methods (16). The results of the Sitar-Tăut's research in Romania conducted on 311 higher education learners showed that M-learning has been successful during the outbreak of COVID-19. He believes that incorporating gameplay elements into the learning system can be a pleasurable experience to learners (5). In a systematic review article entitled Features, Barriers and Factors Affecting M-learning in Higher Education, Sophonhiranrak et al. reviewed the published articles from 2006 to 2018. They concluded that mobile devices are

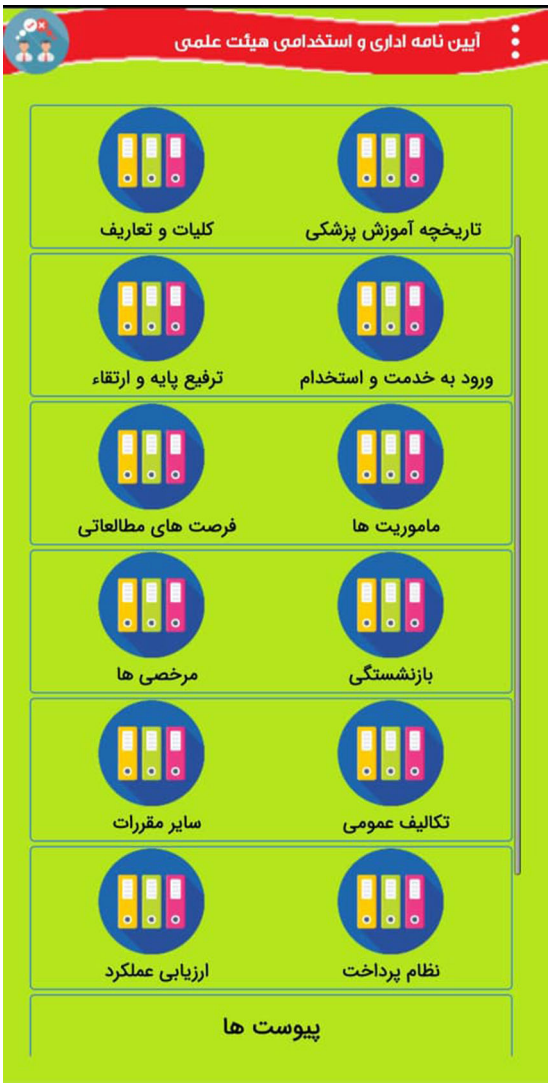


FIGURE 1
The part of the internal environment of App.



FIGURE 2
The part of the internal environment of App.

usable as Learning tools for tasks such as sending homework, reflecting on instant learning experiences, and sharing ideas. At the end of their study, they stated that faculty members should consider three main components (learners and faculty members' readiness, learning management and support systems) in M-learning (17). The results of all this research are consistent with our research.

Conclusion

The faculty members had a positive attitude toward this designed educational App and M-Learning. Designing similar mobile training Apps can improve their professional performance. We can argue that M-learning has a lot of potential and capabilities. Considering the positive attitudes and perceptions of users on acceptance and use of this technology for educational purposes, it is likely that in the near future it is applied as the first strategy of universities and educational institutions for learning and all e-learning work seamlessly on a mobile device.

Limitations

We conducted this research based on a self-report survey to evaluate the views of faculty members of a large university of medical sciences in Iran on the effect of using an App designed to promote their awareness of faculty rules and regulations.

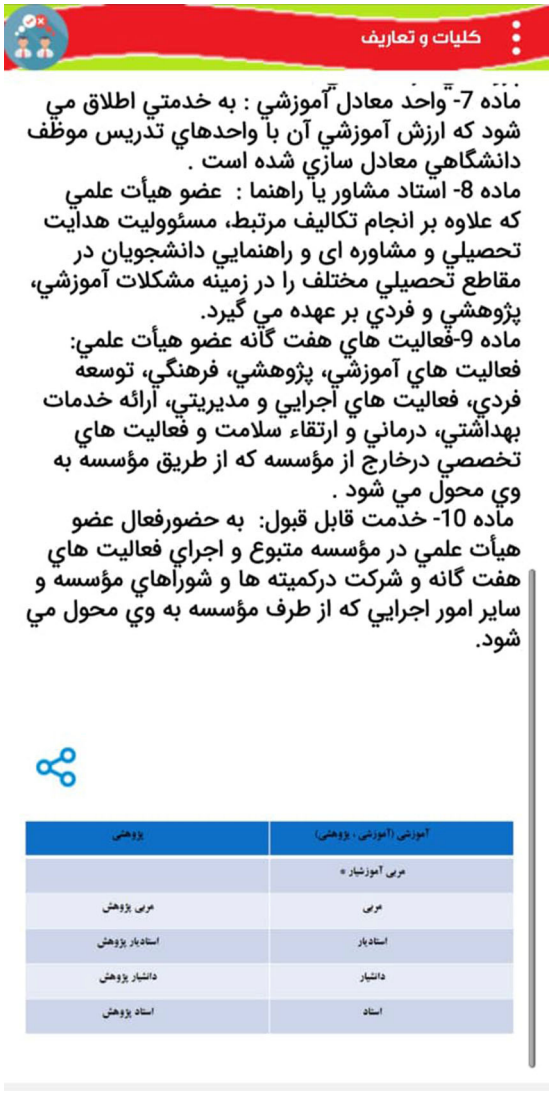


FIGURE 3
The part of the internal environment of App.



FIGURE 4
The part of the internal environment of App.

In regard to other variables, the researcher has ignored them inadvertently and they may be of effect on this assessment.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

This research was derived from a research project (Ethics Code of IR.AJUMS.REC.2018.583). This paper is a systematic scoping study that relied strictly on the review of existing literature, no human participants were involved. Therefore, ethical approval and consent to participate by human participants was not applicable. Ethical issues (Including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Author contributions

AG designed research, conducted research, analyzed data, wrote manuscript, and he had primary responsibility for final content. Author read and approved the final manuscript.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The impact of the COVID-19 pandemic on the mental health and academic performance of medical postgraduates

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Background: The Coronavirus disease 2019 (COVID-19) has presented a major challenge to the health, economic, and social sectors of the entire world. This study aimed to investigate the mental health and academic performance of medical postgraduates during the COVID-19 pandemic in China.

Methods: A cross-sectional online survey was conducted from March 20 to April 20, 2022 at the Zhejiang University School of Medicine in China. The questionnaire consisted of three parts: general information, mental health and academic performance. Mental health outcomes were assessed according to the Generalized Anxiety Scale (GAD-7) and the Patient Health Questionnaire-9 Scale (PHQ-9).

Results: A total of 153 valid questionnaires were obtained. Of the medical postgraduates in this study, (1) 41.8% had no anxiety symptoms. In addition, 51.0% had mild anxiety symptoms during the COVID-19 pandemic. None of the participants had a severe anxiety or depression disorder; (2) Females experienced significantly more symptoms in mental health measure scores than the males ($P < 0.01$); (3) 78.4% believed that the COVID-19 pandemic had varying degrees of impact on their academics. Doctoral postgraduates showed greater academic stress, and they were more worried about not meeting graduation standards than the master's postgraduates ($P < 0.05$). There were no significant differences between the surgical postgraduates and internal postgraduates in either mental health or academic performance.

Conclusions: Our study found that the COVID-19 pandemic has had a mild impact on the mental health and academic performance of medical postgraduates in China. Females experienced significantly more symptoms on mental health measure scores than the males. Doctoral postgraduates showed greater academic stress than the master's postgraduates. There is uncertainty regarding how long this COVID-19 situation will persist and increasing recognition that there may be periods of recurrence in the future.

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We need more active curricular innovation and transformation to maintain and improve medical postgraduates' mental health and academic performance.

KEYWORDS

COVID-19 pandemic, medical postgraduates, mental health, academic performance, education

Introduction

Since the World Health Organization (WHO) declared a global emergency on January 30, 2020 concerning the novel coronavirus disease-19 (COVID-19) outbreak (1, 2), COVID-19 has presented a huge challenge to the health, economic and social sectors of the entire world. The WHO reported 514 million confirmed cases of COVID-19 and 6.2 million confirmed deaths worldwide as of May 4, 2022 (3). Due to COVID-19, mental health illnesses including anxiety, depression, stress, and sleep disorder have become prevalent problems across the world. Various studies demonstrated that during the COVID-19 pandemic, mental health problems such as fear, anxiety and depression were common among the general public, patients, medical staff, children, and older adults (4–8). Previous research concluded that throughout 2020, the COVID-19 pandemic led to a 27.6% increase in cases of major depressive disorders and 25.6% increase in cases of anxiety disorders globally (9). Among general population in China, the prevalence of depressive symptoms, anxiety, and stress ranging from moderate to severe were, respectively, 16.5, 28.8, and 8.1% (10).

Considered as a top-down management system, the Chinese government has effectively adopted a dynamic clearance policy to control the COVID-19 pandemic over the past 2 years (11). Specifically, the local government is carrying out community, block, district, or regional lockdowns as needed whenever COVID-19 cases are reported. Therefore, schools and public places are closed in lockdown areas, and students must study online at home. For postgraduate medical students, many courses have been transferred from classroom learning to online learning due to the changes in learning and living environments. Consequently, medical students are unable to communicate effectively with teachers, and there is a lack of internship opportunities for clinical learning in the hospital (12). These unprecedented changes and unique challenges have affected medical students' mental health and academic performance. There are a growing number of studies on how college and medical students have adapted to the COVID-19 pandemic (13–16). Mental health disorders among Greek medical students have been reported in connection with the COVID-19 pandemic (17). Similar findings have also been reported in China. Specifically, compared with non-medical students, medical students had fewer mental health symptoms in the early stages of the COVID-19 pandemic since they are more knowledgeable about COVID-19 (18).

Medical students in China have experienced various restrictions and challenges due to the prevention and control of the pandemic during the past 2 years. Compared with the beginning of the pandemic, medical students have become more and more adaptable to these various restrictions and challenges, resulting in our study of the impacts on their mental health and academic performance. Undergraduate medical students in China mainly study in the classroom. Meanwhile, postgraduate medical students need to spend a large amount of time in the hospital for clinical learning and research under their supervisors' hands-on guidance. Therefore, the COVID-19 pandemic has had a greater impact on postgraduate medical students' academic studies and clinical learning in the hospital. Therefore, the aim of the present study is to evaluate the impact of the 2 year COVID-19 pandemic on the postgraduate medical students' mental health (e.g., anxiety, depression) and academic performance in China. The present study was a web-based, cross-sectional study. The questionnaire consisted of three parts: general information, mental health and academic performance.

Methods

Setting and sample

A cross-sectional survey using structured questionnaires was conducted among medical postgraduate students at the Zhejiang University School of Medicine in Hangzhou, China. The data were collected from March 20 to April 20, 2022. During this period, students in China were still affected by the COVID-19 pandemic. The inclusion criteria were as follows: students (1) had normal mental state in the school; (2) who agreed to participate in the study after being fully informed of details of the study. Exclusion criteria were any physical or neurological disease, substance use, psychotic disorders, and personality disorders. We adopted the method of stratified random sampling, and divided the postgraduates in the school of Zhejiang University School of Medicine into a doctoral class of surgery, a master's class of surgery, a doctoral class of internal medicine and a master's class of internal medicine. Forty to

fifty postgraduate students were randomly selected from each class, and 177 medical postgraduate students were selected as research objects. They were invited to voluntarily participate in the survey through the network platform (http://www.wjx.cn, which is one of the most popular electronic survey platforms in China). We tested its internal consistency in a pilot study of 50 students. The questionnaire had a high level of internal consistency among our study population, with a Cronbach's alpha 0.88. An online survey questionnaire was distributed randomly to students *via* WeChat. Participants were asked to read the instructions about the purpose and methods to fill out the questionnaire carefully. Participants were also informed that the survey was anonymous. A total of 177 questionnaires were sent out. Twenty-four of the retrieved questionnaires were invalid and were thus excluded from the study, and 153 were valid. The effective survey questionnaire retrieval rate was thus 86.44%. Ethical approval was obtained from the ethics committee of the Second Affiliated Hospital, School of Medicine, Zhejiang University in China. All participants provided written informed consent prior to participating in the study without identifiable data.

General information

The first part of the questionnaire asked about the basic demographic information of the participants (such as gender, home location, grade, academic major, marital status and health status).

Mental health

The second part of the questionnaire addressed the participants' general anxiety and depression disorders during the COVID-19 pandemic. The questionnaire was adapted from the Generalized Anxiety Scale (GAD-7) and the Patient Health Questionnaire-9 Scale (PHQ-9) (19–21). The revised GAD-7 questionnaire had a total of 6 items. Example item is "I feel nervous or anxious during COVID-19 pandemic." Items are scored on a four-point Likert scale ranging from 0 (never) to 3 (always), with scores of 0, 1, 2 and 3 according to "none at all," "a few days," "more than half of the days" and "almost every day." According to the final score of the questionnaire, the research subjects were divided into the normal group (0–3 points) and the anxiety symptom group (3–18 points). The revised PHQ-9 questionnaire had a total of 4 items. The total score of the questionnaire is 0–12 points, 0–3 points were divided into normal group, and those with ≥3 points were judged to have depressive symptoms. The higher the score, the more severe the social anxiety or depression. In previous studies on Chinese general and adolescent populations, the GAD-7 and PHQ-9 scores showed good psychometric properties (22–24).

Academic performance

The third part of the questionnaire was the investigation of the personal academic performance of the clinical medical postgraduates. They were asked about the overall impact on academics, worrying that they would not meet graduation standards, the percentage of offline courses converted to online courses, the percentage of practice opportunities reduced and the frequency of counseling and academic communication with graduate tutors.

Statistical analysis

The data from the retrieved electronic survey questionnaires were gathered using Questionnaire Star. Categorical variables were described as counts (*n*) and percentages (%). The questionnaire scores were expressed as mean ± SD, and between-group statistical comparisons were made using an independent sample *t*-test or the Mann-Whitney *U* test, depending on normal distribution (25, 26). Two-sided *P*-values were considered significant at $p < 0.05$. All data were analyzed using SPSS version 22.0 software.

Results

Demographic Characteristics

A total of 153 medical postgraduates completed the survey. Table 1 shows the distribution of the study participants. Most (67.32%) were female. Those who completed the survey were 45.76% master's students and 54.24% doctoral students. 55.56% of the postgraduates who participated in this questionnaire were surgical students, and 44.44% were internal medical students. Most were unmarried (88.24%). The current health status of the postgraduates was basically good, and the proportion of students with a poor health status was 0%, based on self-assessment.

The impact of the COVID-19 pandemic on the mental health of medical postgraduates

Most of the medical postgraduates who participated in this study had no or mild mental health symptoms during the COVID-19 pandemic (Table 2). Most had low scores for

TABLE 1 Demographic characteristics of the study subjects.

Essential information	Classification	No. of people	Percentage (%)
Gender	Male	50	32.68%
	Female	103	67.32%
Home location	Town	93	60.78%
	Countryside	60	39.22%
Grade level	First year, master's program	31	20.26%
	Second year, master's program	20	13.07%
	Third year, master's program	19	12.42%
	First year, doctoral program	21	13.73%
	Second year, doctoral program	20	13.07%
	Third year, doctoral program	19	12.42%
	Fourth year, doctoral program	12	7.84%
	Fifth year, doctoral program	11	7.19%
Major	Surgical	85	55.56%
	Internal medicine	68	44.44%
Marital status	Unmarried	135	88.24%
	Married	18	11.76%
	Divorced or otherwise	0	0%
Current health status	Very good	70	45.75%
	Good	79	51.63%
	General	4	2.61%
	Poor	0	0%

anxiety or depression. Only two people (1.3%) felt that it was hard to relax in the COVID-19 environment almost every day. One person (0.7%) had a severe symptom of anxiety. In addition, none of the participants had a severe depression disorder.

The impact of the COVID-19 pandemic on the academic performance of medical postgraduates

Of the medical postgraduates who participated in this study, 54.9% felt that the COVID-19 pandemic had a mild impact on their academic studies. 22.2% felt that the COVID-19 pandemic had a moderate impact on their academics. Two people (1.3%) believed that the COVID-19 pandemic had a severe impact on their academics. And 83 (54.3%) had varying degrees of concern that they would not meet graduation standards due to the COVID-19 pandemic (Table 3). Furthermore, after investigating the changes in postgraduate courses during the COVID-19 pandemic, we found that the proportion of offline courses that changed to online courses increased, resulting in a reduction in practical operations and less interaction between teachers and students (Table 4). This may explain postgraduates' concerns about their academic performance. Most of the postgraduates (85.0%) were not seeking psychological counseling during this time (Table 5). However, most had an increased frequency of academic communication with graduate tutors. In addition, most of them paid usual attention to information and news related to COVID-19 (Table 5).

Mental health and academic performance among medical postgraduates with different genders, grades and academic majors

The comparison between genders revealed that females were experiencing significantly more symptoms in mental health measure scores ($P < 0.05$) (Table 6). The females felt more nervous or anxious during the COVID-19 pandemic than the males (mean 0.77 ± 0.61 vs. 0.42 ± 0.54, $P < 0.01$). The research showed that the female postgraduates were more likely to worry too much about various things because of the COVID-19 pandemic than the males ($P < 0.01$). In addition, female postgraduates more commonly felt that worrying could not be stopped or controlled during the COVID-19 pandemic (mean 0.64 ± 0.67 vs. 0.38 ± 0.53, $P < 0.05$). There were no significant differences in

TABLE 2 The impact of the COVID-19 pandemic on mental health of medical graduate studies.

Questionnaire content	Absolutely not (0) [95% CI]	A few days (1) [95% CI]	More than half of the days (2) [95% CI]	Almost everyday (3) [95% CI]
Feeling nervous or anxious during COVID-19 pandemic	64 (41.8%) [33.9–49.7%]	78 (51.0%) [43.0–59.0%]	11 (7.2%) [3.1–11.3%]	0 (0.0%) [0.0–0.0%]
Worrying cannot be stopped or controlled during COVID-19 pandemic	79 (51.6%) [43.6–59.6%]	64 (41.8%) [33.9–49.7%]	9 (5.9%) [2.1–9.7%]	1 (0.7%) [0.0–1.9%]
Are you worrying too much about various things because of the COVID-19 pandemic	65 (42.5%) [34.6–50.4%]	76 (49.7%) [33.9–49.7%]	12 (7.8%) [3.5–12.2%]	0 (0.0%) [0.0–0.0%]
It's hard to relax in a COVID-19 environment	91 (59.5%) [51.6–67.3%]	52 (34.0%) [26.4–41.6%]	8 (5.2%) [1.7–8.8%]	2 (1.3%) [0.0–3.1%]
Become easily irritable during COVID-19 pandemic	85 (55.6%) [47.6–63.5%]	59 (38.6%) [30.8–46.4%]	8 (5.2%) [1.7–8.8%]	1 (0.7%) [0.0–1.9%]
Fearing that something terrible is about to happen during COVID-19 pandemic	97 (63.4%) [55.7–71.1%]	49 (32.0%) [24.5–39.5%]	6 (3.9%) [0.8–7.0%]	1 (0.7%) [0.0–1.9%]
Not feeling motivated or having fun doing things during COVID-19 pandemic	99 (64.7%) [57.0–72.4%]	42 (27.5%) [20.3–34.6%]	12 (7.8%) [3.5–12.2%]	0 (0.0%) [0.0–0.0%]
Feeling down, depressed or hopeless due to COVID-19 pandemic	91 (59.5%) [51.6–67.3%]	55 (35.9%) [28.3–43.6%]	7 (4.6%) [1.2–7.9%]	0 (0.0%) [0.0–0.0%]
Difficulty falling asleep, restless sleep or more sleep during COVID-19 pandemic	109 (71.2%) [64.0–78.5%]	39 (25.5%) [18.5–32.5%]	5 (3.3%) [0.4–6.1%]	0 (0.0%) [0.0–0.0%]
Loss of appetite or eating too much during COVID-19 pandemic	114 (74.5%) [67.5–81.5%]	35 (22.9%) [16.1–29.6%]	4 (2.6%) [0.1–5.2%]	0 (0%) [0.0–0.0%]

Date are presented as n (%) [95% CI].

TABLE 3 The impact of the COVID-19 pandemic on medical graduate studies.

Questionnaire content	Absolutely not (0) [95% CI]	Mild (1) [95% CI]	Moderate (2) [95% CI]	Severe (3) [95% CI]
The overall impact on academics	33 (21.6%) [15.0–28.2%]	84 (54.9%) [46.9–62.9%]	34 (22.2%) [15.6–28.9%]	2 (1.3%) [0.0–3.1%]
Are you worried that you will not meet graduation standards?	70 (45.8%) [37.8–53.7%]	68 (44.4%) [36.5–52.4%]	12 (7.8%) [3.5–12.2%]	3 (2.0%) [0.0–4.2%]

Date are presented as n (%) [95% CI].

depression symptoms between the males and females (Table 6). In addition, the data showed that there were no significant differences in academic performance between males and females (Supplementary Table 1). Similar results regarding anxiety and depression symptoms were found between the master's class and doctoral class (Table 7). The doctoral students found it harder to relax in a COVID-19 environment (mean 0.63 ± 0.74 vs. 0.31 ± 0.50, $P < 0.01$). What's more, the doctoral postgraduates were more worried that they would not meet graduation standards (mean 0.78 ± 0.78 vs. 0.51 ± 0.58, $P < 0.05$) (Table 8). Among the medical postgraduates, there were no significant differences between the surgical students and internal students in either mental health (Supplementary Table 2) or academic performances (Supplementary Table 3).

Multivariable logistic regression of factors influencing mental health and academic studies of medical postgraduates

In the Multivariable logistic regression analysis (Table 9), compared with male postgraduates, the females were experiencing significantly more symptoms in mental health

TABLE 4 The impact of the COVID-19 Pandemic on medical graduate courses.

Questionnaire content	0 [95% CI]	≤ 30% [95% CI]	30–60% [95% CI]	≥ 60% [95% CI]
Percentage of off-line courses converted to on-line courses	43 (28.1%) [20.9–35.3%]	44 (28.8%) [21.5–36.0%]	40 (26.1%) [19.1–33.2%]	26 (17.0%) [11.0–23.0%]
Percentage of practice opportunities reduced	52 (34.0%) [26.4–41.6%]	67 (43.8%) [35.8–51.7%]	30 (19.6%) [13.2–26.0%]	4 (2.6%) [0.1–5.2%]

Date are presented as n (%) [95% CI].

TABLE 5 The impact of the COVID-19 pandemic on mental state of medical graduates.

Questionnaire content	Absolutely not (0) [95% CI]	Occasionally (1) [95% CI]	Often (2) [95% CI]	Many times (3) [95% CI]
Frequency of psychological counseling	130 (85.0%) [79.2–90.7%]	21 (14.6%) [8.7–20.4%]	2 (1.3%) [0.0–3.1%]	0 (0.0%) [0.0–0.0%]
Frequency of academic communication with graduate tutors	34 (22.2%) [15.6–28.9%]	59 (38.6%) [30.8–46.4%]	52 (34.0%) [26.4–41.6%]	8 (5.2%) [1.7–8.8%]
Usual attention to information and news related to the new coronary virus	7 (4.6%) [1.2–7.9%]	28 (18.3%) [12.1–24.5%]	91 (59.5%) [51.6–67.3%]	27 (17.6%) [11.5–23.8%]

Date are presented as n (%) [95% CI].

measure scores during the COVID-19 pandemic ($OR = 3.256$, 95% CI: 1.596–6.642; $OR = 2.510$, 95% CI: 1.223–5.150; $OR = 3.011$, 95% CI: 1.481–6.123). The doctoral students ($OR = 2.628$, 95% CI: 1.303–5.301) found it harder to relax in a COVID-19 environment. What's more, the doctoral postgraduates were more worried that they would not meet graduation standards ($OR = 2.019$, 95% CI: 1.048–3.889) than the master's class.

Discussion

This study used a web-based survey to investigate the mental health and academic performance of medical postgraduates during the COVID-19 pandemic in China. Our major findings are summarized below. First, most of the medical postgraduates had mild anxiety or depression symptoms during the COVID-19 pandemic. Females experienced significantly more symptoms in mental health measure scores than males did. None had a severe depression disorder. Second, 78.43% of participants felt that the COVID-19 pandemic had varying degrees of impact on academics. Moreover, the doctoral postgraduates showed greater academic stress, and they were more worried about not meeting graduation standards than the master's postgraduates.

The outbreak of COVID-19 in the world has had direct and indirect impacts on all areas of society, and the COVID-19 pandemic has lasted for 2 years. Various studies have demonstrated that during the COVID-19 pandemic, mental health problems such as fear, anxiety and depression were common among the general public. A cross-sectional multi-country comparison study demonstrated that substantial variations exist in anxiety and depression symptoms across countries during the COVID-19 lockdown, with personal COVID-19 exposure being a significant risk factor (27). College students who received a large amount of negative information about COVID-19 may be at a greater risk of psychological maladjustment (28–30). Medical students in China face severe depression and anxiety because of their difficult circumstances, such as the long length of schooling, academic pressure, and the stress of clinical practice (31, 32). Therefore, it is of great importance to pay special attention to the psychological status of medical students and to take appropriate interventions to improve their mental health. In the early stages of this pandemic, medical postgraduate education was disrupted and transformed into prolonged home isolation and online learning. People knew little about the novel coronavirus, leading to increased anxiety and depression symptoms in medical students (33, 34). In the later stages, pandemic prevention and control work has become a norm (35). The present study showed that most of the medical postgraduates had mild anxiety or depression symptoms during the COVID-19 pandemic. None had a severe depression disorder. This indicated that most medical students had strong psychological adjustment abilities and adaptability during the pandemic period, which is consistent with previous studies (18, 36). Another reason for this might be the enhanced prevention and control behaviors of postgraduates. The interdisciplinary faculty similarly launched COVID-19 courses focusing on the pathophysiology, diagnosis and treatment of the infection, the health disparities and ethical considerations associated with the

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TABLE 6 Comparison of the mental health taken by gender.

Parameter	Gender		*P*-value
	Male	Female	
Feeling nervous or anxious during COVID-19 pandemic	0.42 ± 0.54	0.77 ± 0.61	0.001**
Worrying cannot be stopped or controlled during COVID-19 pandemic	0.38 ± 0.53	0.64 ± 0.67	0.021*
Are you worrying too much about various things because of the COVID-19 pandemic	0.42 ± 0.54	0.77 ± 0.63	0.001**
It's hard to relax in a COVID-19 environment	0.42 ± 0.64	0.51 ± 0.67	0.374
Become easily irritable during COVID-19 pandemic	0.46 ± 0.58	0.53 ± 0.65	0.592
Fearing that something terrible is about to happen during COVID-19 pandemic	0.36 ± 0.56	0.45 ± 0.62	0.415
Not feeling motivated or having fun doing things during COVID-19 pandemic	0.36 ± 0.60	0.47 ± 0.65	0.328
Feeling down, depressed or hopeless due to COVID-19 pandemic	0.38 ± 0.58	0.49 ± 0.59	0.265
Difficulty falling asleep, restless sleep or more sleep during COVID-19 pandemic	0.30 ± 0.51	0.33 ± 0.55	0.836
Loss of appetite or eating too much during COVID-19 pandemic	0.28 ± 0.50	0.28 ± 0.51	0.947

Date are presented as mean ± SD. Mann-Whitney U test. *P < 0.05; **P < 0.01.

TABLE 7 Comparison of the mental health taken by grade.

Parameter	Grade		*P*-value
	Master	Doctor	
Feeling nervous or anxious during COVID-19 pandemic	0.60 ± 0.57	0.70 ± 0.64	0.382
Worrying cannot be stopped or controlled during COVID-19 pandemic	0.51 ± 0.65	0.59 ± 0.63	0.359
Are you worrying too much about various things because of the COVID-19 pandemic	0.60 ± 0.60	0.70 ± 0.64	0.357
It's hard to relax in a COVID-19 environment	0.31 ± 0.50	0.63 ± 0.74	0.007**
Become easily irritable during COVID-19 pandemic	0.44 ± 0.63	0.57 ± 0.63	0.167
Fearing that something terrible is about to happen during COVID-19 pandemic	0.41 ± 0.63	0.42 ± 0.59	0.832
Not feeling motivated or having fun doing things during COVID-19 pandemic	0.41 ± 0.63	0.45 ± 0.65	0.784
Feeling down, depressed or hopeless due to COVID-19 pandemic	0.43 ± 0.55	0.47 ± 0.61	0.786
Difficulty falling asleep, restless sleep or more sleep during COVID-19 pandemic	0.27 ± 0.48	0.36 ± 0.58	0.388
Loss of appetite or eating too much during COVID-19 pandemic	0.24 ± 0.46	0.31 ± 0.54	0.458

Date are presented as mean ± SD. Mann-Whitney U test. **P < 0.01.

pandemic worldwide (37). During the COVID-19 pandemic, especially in the stage of the normalization of pandemic prevention and control work in China, postgraduates have had a relatively positive attitude, doing a good job of protecting themselves in their clinical practice (38).

According to our findings, females experienced significantly more symptoms on mental health measure scores than males did. Previous studies associating gender and mental health have been inconclusive. In a study by Xie et al. (39) males showed more depressive symptoms. However, some previous studies have reported no significant differences in gender with regard to anxiety and depression. This indicates that male and female students experienced similar stresses and negative emotions as a result of the COVID-19 pandemic (29, 40). Another study showed that depression was more prevalent in female students than male students (41). Moreover, a systemic review found that female students experienced higher levels of anxiety and stress (42). These studies are consistent with ours. A possible explanation is that women are more likely to be affected by the COVID-19 pandemic, displaying higher levels of insomnia, sleep disturbances, anxiety and depression (12) and are more likely to report experiencing higher levels of anxiety (43).

The present study also demonstrated that most postgraduates felt that the COVID-19 pandemic had varying degrees of impact on their academics. After investigating the changes in postgraduate courses during the COVID-19 pandemic, we found that the proportion of offline courses changed to online courses has increased, resulting in a reduction in practical operations and less interaction between teachers and students (Table 4). Several barriers to online learning have contributed to students' overall negative experiences. Clinical skills sessions may occur online. Examinations have also been transitioned to online or, in some cases, may be deferred. Many students have reported concerns about not being able to learn

and practice clinical skills in person (44). Moreover, there is a decrease in the number of clinical teachers because some of them have devoted their time to pandemic prevention and control teams (45). These factors may explain postgraduates' concerns about their academic performance. Furthermore, the doctoral postgraduates showed greater academic stress, and they were more worried about not meeting graduation standards than the master's postgraduates. This is consistent with a previous study, which indicated that for more senior students, the academic pressure is greater, and some of them face graduation, employment, and practice, etc., but the epidemic of COVID-19 inevitably affects the development of various things (29). In our study, 68.63% of the postgraduates expressed their willingness to participate in volunteer work. Postgraduates have participated in many ways to care for patients and communities in this crisis.

In the midst of this COVID-19 crisis, it is necessary and important to pay special attention to the psychological status of medical students and take appropriate interventions to improve their mental health. In addition, the COVID-19 pandemic may represent an enduring transformation in medical education. There is uncertainty regarding how long

TABLE 8 Comparison of the academic studies taken by grade.

Parameter	Grade		*P*-value
	Master	Doctor	
The overall impact on academics	0.96 ± 0.65	1.10 ± 0.74	0.200
Are you worried that you will not meet graduation standards?	0.51 ± 0.58	0.78 ± 0.78	0.039*

Date are presented as mean ± *SD*. Mann-Whitney *U* test. *P < 0.05.

TABLE 9 Multivariable logistic regression of factors influencing mental health and academic studies.

	Gender				Grade			
	B	SE	P	OR (95%CI)	B	SE	P	OR (95%CI)
Mental health								
Feeling nervous or anxious during COVID-19 pandemic	1.180	0.364	0.001**	3.256 (1.596–6.642)	0.337	0.343	0.326	1.401 (0.715–2.744)
Worrying cannot be stopped or controlled during COVID-19 pandemic	0.920	0.367	0.012*	2.510 (1.223–5.150)	0.351	0.342	0.304	1.421 (0.727–2.775)
Are you worrying too much about various things because of the COVID-19 pandemic	1.102	0.362	0.002**	3.011 (1.481–6.123)	0.413	0.342	0.227	1.512 (0.773–2.957)
It's hard to relax in a COVID-19 environment	0.360	0.369	0.330	1.433 (0.695–2.955)	0.966	0.358	0.007**	2.628 (1.303–5.301)
Become easily irritable during COVID-19 pandemic	0.194	0.356	0.586	1.214 (0.604–2.440)	0.603	0.343	0.079	1.828 (0.933–3.581)
Fearing that something terrible is about to happen during COVID-19 pandemic	0.335	0.373	0.368	1.399 (0.673–2.905)	0.169	0.352	0.632	1.184 (0.593–2.363)
Not feeling motivated or having fun doing things during COVID-19 pandemic	0.460	0.380	0.227	1.584 (0.752–3.338)	0.209	0.359	0.560	1.232 (0.610–2.488)
Feeling down, depressed or hopeless due to COVID-19 pandemic	0.381	0.369	0.301	1.464 (0.711–3.015)	0.252	0.349	0.471	1.287 (0.649–2.552)
Difficulty falling asleep, restless sleep or more sleep during COVID-19 pandemic	0.126	0.395	0.751	1.134 (0.522–2.461)	0.376	0.382	0.325	1.457 (0.689–3.080)
Loss of appetite or eating too much during COVID-19 pandemic	0.053	0.408	0.898	1.054 (0.474–2.344)	0.402	0.397	0.311	1.494 (0.687–3.251)
Academic studies								
The overall impact on academics	0.070	0.342	0.839	1.072 (0.549–2.095)	0.510	0.332	0.125	1.665 (0.868–3.192)
Are you worried that you will not meet graduation standards?	0.328	0.346	0.344	1.388 (0.704–2.735)	0.702	0.334	0.036*	2.019 (1.048–3.889)

Date are presented as Beta ± SE, OR (95% CI). Multivariable logistic regression analysis. *P < 0.05; **P < 0.01.

this situation will persist and increasing recognition that there may be periods of recurrence in the future. We need more active curricular innovation and transformation to maintain and improve medical students' academic performance. This may be a seminal moment for many disciplines in medicine.

Our study certainly has limitations. First, the sample size was relatively small, but these participants comprised the vast majority of medical postgraduates at the institution in question during the 2 year COVID-19 pandemic. We will combine multiple medical schools distributed over the province to carry out a large sample survey. Additionally, there were a few related factors affecting the postgraduates' mental health and academic performance in this questionnaire. Our follow-up research should strengthen the investigation of related influencing factors.

Conclusions

Our study found that the COVID-19 pandemic has had a mild impact on the mental health and academic performance of medical postgraduates in China. Females experienced significantly more symptoms on mental health measure scores than males. Moreover, doctoral postgraduates showed greater academic stress, and they were more worried about not meeting graduation standards than master's postgraduates. It is necessary and important to take appropriate interventions to lighten their psychological burdens and improve their academic performance.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of The Second Affiliated Hospital, School of Medicine, Zhejiang University. The participants provided their written informed consent to participate in this study.

Author contributions

YY and QT: conceptualization, formal analysis, funding acquisition, writing and preparation of manuscript, and writing original draft. HS, TC, and KY: data curation. YY, YW, and HH: methodology. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.948710/full#supplementary-material

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Training needs and curriculum of continuing medical education among general practitioners in Tibet, China: A cross-sectional survey

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Background: Uneven distribution of health resources is higher in Tibet than in other regions. The development of core professional capability for general practitioners (GPs) is the main goal of continuing medical education (CME) training programs.

Aim: This study aimed to explore the needs of CME for GPs and provide advice for the development of policy, practice, and CME curriculums.

Methods: We conducted a cross-sectional online survey among GPs in Tibet Autonomous Region, China. We designed an online questionnaire including the demographic section, training contents, and training formats about CME.

Results: A total of 108 questionnaires were included in this study. Notably, 79 (73.15%) were women and 56 participants (51.85%) were working in primary care settings. We developed a curriculum priority: first-choice, major alternatives, and secondary considerations. The topics identified as first-choice for CME were related to "cardiovascular disease" (85.19%), "respiratory disease" (81.48%), and "digestive disease" (80.56%). Major alternatives included two essential knowledge and eight clinical skill items. We rated 10 items as secondary considerations. Only 39.81% ranked mental health as an essential priority; bedside teaching (51.85%) was the first choice.

Conclusion: We presented priority areas identified in this study to focus on CME for GPs in Tibet. The 23 topics may reflect the features of general practice, which increasingly require common disease management skills, while a demand-oriented curriculum and staged training plans should be adopted. CME programs should be adapted dynamically to respond to evolving needs.

KEYWORDS

continuing medical education, primary care, curriculum development, training needs, general practice

Introduction

Healthy China 2030 is a breakthrough in the effort to strengthen national health policy and focus on the delivery of comprehensive life-cycle healthcare for the Chinese people (1). This national strategy aimed to provide access to five competent general practitioners (GPs) for every 10,000 residents by 2030 (2). Pairing assistance between the eastern and western regions is a major decision in China to promote resource complementarity and exchange of talents (3). Notably, China has experienced considerable difficulties with the training and cultivation of GPs in resource-poor areas. Over the past 10–15 years, reform of medicine and the healthcare system is providing enough resources to rapidly increase the number of future GPs in underdeveloped rural areas. In 2018, the Tibet Autonomous Region (Tibet) announced incentive policies to recruit additional GPs to work in primary care (4).

In 2020, the Health Commission of Tibet autonomous region put forward a plan: pairing-up assistance from tertiary hospitals across the country, covering all 74 counties and districts in Tibet. Under the policy of pairing-up assistance for Tibet, some excellent hospitals in other provinces were designated to assist in specific areas of Tibet. Such assistance programs from other provincial-level regions enabled the exchange of traditional Chinese medicine, Tibetan medicine, and western medicine and improved accessibility and usability of primary care. Pairing-up assistance belonged to the category of continuing medical education (CME) and was generally assessed by a self-assessment questionnaire. Compared with the "5 + 3" mode and other rigorous programs for training GPs in the US and European countries (5, 6), the CME training in remote Tibetan villages may be a sped-up solution. At present, Tibet has implemented a series of CME training programs, such as transition, short courses, and on-the-job training at hospitals that offer pairing-up assistance (4, 7, 8). In general, training contents include two modules, namely, essential knowledge and clinical skills (9). Consequently, a large number of Tibet GPs are taking advantage of educational opportunities.

Continuing medical education accounted for a large portion of the process of lifelong learning that GPs could use to update knowledge and develop skills. A comprehensive CME program is essential for GPs to maintain high standards of practice (10). CME is an integral part of a lifelong learning process in which GPs constantly acquire new knowledge, skills, and attitudes. A highly effective channel in developing training programs is the assessment of trainee needs. The purpose of educational needs assessments is to identify the gap between what is known and what should be known (11, 12). Individual, work unit, and organization factors should receive high priority in framing government policy (11).

Existing evidence suggests that programs based on well-designed needs assessments are more likely to cause changes in trainee behavior (13, 14). Training formats of CME comprise medical conferences, professional meetings, intensive courses, oral presentations, bedside teaching, and more recently, online courses (15). Diverse learning methods tend to suit different doctors and identified learning needs (14). Different approaches may be necessary at various stages of the learning process. However, few studies have formally explored evidence-based recommendations to improve training satisfaction and participation enthusiasm (16, 17).

To resolve a shortage of GPs and the complex medical needs of an aging population, the design of higher-quality general practice courses and standards has received increasing attention recently (18, 19). The curriculum and practice standards for one provincial-level administrative region do not necessarily wholly relate to the needs of another. The arrangement of medical ability training for GPs in China lacks evidence-based support and is influenced by the subjective opinions of managers. We conducted a questionnaire survey, which covered nine different community health centers within a medical consortium, to collect data about training needs for GPs in the Chinese community health center and formulate a demand-oriented training to provide a reference for policymakers in education (9).

General practitioners in Tibet are few in number and mostly work in rural areas. They rarely travel to hospitals in major cities to accept training due to transportation costs, work pressure, and low-income concerns (20). A demand-oriented training plan and preferred training formats can help bridge the access gap by mitigating the cost and time concerns of Tibet GPs. In this survey, we extended our search through optimized questionnaires. Moreover, this study aimed to determine the demand-oriented curriculum and learning method preferences of GPs in Tibet, given that previous studies suggest that varying GP types have different CME training needs (20).

Methods

Study design

The Department of General Practice of West China Hospital of Sichuan University was launched in January 2020 and funded for 3 years. It provided pairing-up support for Tibet to improve medical services. The project covered most hospitals and community health services across Lhasa, as well as parts of six prefecture-level cities in the region.

We conducted a cross-sectional online study, using convenience and snowball sampling approaches to recruit GPs from partner organizations and the network of general practice in Western China through a questionnaire web link. Furthermore, we sent two reminder text messages. Tibet GPs were characterized by large dispersion, low density, and small scale, which led to difficulty in recruiting. Snowballing sampling is considered an effective and efficient approach to build a

sample through the Internet (21). We invited participants to share the web link with their colleagues on social media (e.g., WeChat, QQ, and other internet platforms). As participants re-shared the link, it led to snowball sampling. Eligible participants included GPs who were registered in a general practice specialty at all levels of the health system in Tibet, recognize Chinese characters, and were willing to participate in this study.

We collected data from 1 January 2021 to 28 February 2022 and invited participants to complete the questionnaire within 1 week, personally, or *via* e-mail.

Quality control

We took quality control measures to ensure data quality. Participants could only submit their responses once and could not edit their responses after submission. All survey items had to be completed on submission. We eliminated survey data with logical errors.

Description of questionnaire

We based the training needs assessment questionnaire about CME on an established questionnaire developed by our previous findings (9). The tool allowed us to assess training needs and format to guide the development of curriculums, determine gaps in needs and training programs, and help establish training and education priorities. The questionnaire was justified by an advisory panel, including educationalists, policymakers, GPs sent to support Tibet, and methodologists. Throughout the modification process, the multidisciplinary team performed a pilot survey to check the length of the questionnaire, which was not more than 15 min, along with its fluency, feasibility, and understandability.

We divided the questionnaire into three sections, namely, demographic (6 questions), training contents (23 questions), and training formats (1 question) (refer to the Supplementary material "Training needs assessment questionnaire in continuing medical education"). First, we collected basic demographic information, including age, gender, years of practice, status of a university degree, workplace (hospital, primary care), and whether they were engaged in chronic disease management (yes/no). Section Methods of the survey inquired about 23 skills in two core professional capability subscale domains, namely, essential knowledge (11 items) and clinical skills (12 items). For the 23 skills, respondents indicated the level of training needs using a five-point Likert scale 1–not a priority; 2–low priority; 3–medium priority; 4–high priority; and 5–essential priority). They were ascribed as not in of need training for topics where they selected "Not a priority" or "Low priority." Scores 1 or 2 in the training need index indicates no need for training in the specific area. Scores of 3 and greater indicate the need for training in the specific area. High total scores indicated higher degrees of training need. We added the score for each item to form the subscale score, which ranges between 11 and 55 and 12 and 60. In section Results, we asked GPs to choose a training format they preferred from a list, including intensive courses, oral presentations, bedside teaching, and online instruction, to determine the best training format through education and learning.

Ethics

The ethical committee of West China Hospital, Sichuan University, Chengdu, China (No. 2021-1735) approved this study. We informed all participants about the purpose of this study. We also informed them that the data would remain anonymous and confidential. We considered data submission *via* a questionnaire as implied consent.

Data analysis

We used descriptive statistics to explore qualitative data. We presented total scores as median (interquartile range, IQR) as they were not distributed normally. We calculated differences in total scores with the Kruskal–Wallis H and Mann–Whitney U tests between each group; $P < 0.05$ (two-tailed) indicated statistical significance. Moreover, we applied a Bonferroni correction for multiple comparisons type I errors. Microsoft Excel was used to create the graphical representations. We analyzed all data using SPSS version 24.0 (IBM Corporation).

Results

Demographic characteristics

Of the 110 questionnaires that were returned, a total of 108 questionnaires were included in the analyses since 2 were logical errors. Table 1 summarized a complete description of the participants. More than half of the samples were women (73.15%), with a university degree (75.00%). Notably, 51.85% ($n = 56$) of responders worked at primary care institutes, 40.74% ($n = 44$) were <30 years, and 71.30% ($n = 77$) practiced for more than 5 years. The minority ($n = 33$, 30.56%) engaged in chronic disease management.

Training needs assessment

The Cronbach's alpha coefficients for individual scales were 0.87 and 0.92. The total training need was the sum of all subscale scores between 23 and 115. The overall Cronbach's alpha coefficient was 0.94, which demonstrated appropriate

TABLE 1 Participants' characteristics and training need variables.

Variable	Total		Essential knowledge		Clinical skills	
	n	%	Median (25–75%)	*p*-Value	Median (25–75%)	*p*-Value
Age group (years)				0.17*		0.87*
−29	44	40.74	50.00 (42.25, 52.75)		56.00 (52.00, 59.00)	
30–39	56	51.85	50.00 (46.00, 54.00)		55.00 (50.25, 59.00)	
40+	8	7.41	53.00 (50.25, 53.75)		57.50 (43.75, 60.00)	
Gender				0.72**		0.32**
Male	29	26.85	50.00 (45.00, 54.00)		56.00 (46.50, 59.00)	
Female	79	73.15	50.00 (46.00, 53.00)		56.00 (52.00, 59.00)	
Year of practice (years)				0.04*		0.13*
<5	31	28.70	50.00 (40.00, 52.00)		55.00 (50.00, 58.00)	
5–9	39	36.11	52.00 (47.00, 55.00)		58.00 (51.00, 60.00)	
>9	38	35.19	50.00 (46.00, 53.00)		54.50 (48.75, 59.00)	
Education level				0.06**		0.35**
No university degree	27	25.00	52.00 (46.00, 55.00)		56.00 (52.00, 60.00)	
University degree	81	75.00	50.00 (46.00, 53.00)		55.00 (50.50, 59.00)	
Workplace				0.43**		0.92**
Hospital	52	48.15	50.00 (45.25, 53.00)		56.00 (50.25, 59.00)	
Primary care	56	51.85	51.00 (46.25, 54.00)		55.50 (51.25, 59.00)	
Chronic disease management				0.30**		0.78**
Yes	33	30.56	51.00 (44.50, 55.00)		56.00 (51.00, 59.50)	
No	75	69.44	50.00 (46.00, 53.00)		56.00 (51.00, 59.00)	

*Kruskal-Wallis test; **Mann-Whitney test.

reliability. The median scores for the total, essential knowledge, and clinical skills were 105 (96.25–112.00), 50 (46.00–53.75), and 56 (51–59), respectively. All items received a median scale rating of 4 or above on the five-point scale. The Kruskal-Wallis test showed a statistically significant difference between the year of practice on essential knowledge scores ($H = 6.31$, $P = 0.04$). After the Bonferroni correction, participants with 5–9 years of practice scored more than those with <5 years of practice [50.00 (40.00, 52.00) vs. 52.00 (47.00, 55.00), adjusted $P = 0.04$]. None of the two subscale scores differed between other subgroups (refer to Table 1).

Evaluation of training priorities

Based on the proportion of participants reporting scores of 5, we ranked the priority from the most to the least needed training area. An appropriate cutoff would ensure that the proper number of skills (17) were chosen. However, we selected 20% points to develop a curriculum priority–first-choice and major alternatives, secondary considerations–to ensure that the number would not be unexplainable. We also used this cutoff in a previous study (14). In this section, we first described the self-assessment of the priorities of the 23 items included in the questionnaire. Figure 1 provides information about the relative priorities of each item. According to the priority of the items, we set up three level modules to construct a systematic multi-stage training course. Across the study population, management related to "cardiovascular disease" (85.19%), "respiratory disease" (81.48%), and "digestive disease" (80.56%) was identified as the first choice. Ten items were rated as major alternatives. Regarding essential knowledge, participants considered the following: management related to "common symptoms" and "endocrine disease." As for the clinical skills in descending order, the topics were "physical examination," "basic first aid," "interpreting radiology reports," "interpreting laboratory results," "asepsis," "minor surgery," "uses and interpretations of ABPM, ECG, and Holter monitor," and "consultation skills and health records writing." Secondary considerations included six essential knowledge and four clinical skill items. Mental health was the least demand item with only 39.81% (43/108) of participants considering it essential. Figure 2 depicts a flowchart of priority levels with percentages of the essential priority.



FIGURE 1
Participants' priorities of training needs.

Training format

The choices of participants regarding training formats were diverse. The vast majority of participants choose face-to-face instruction as the first choice, including bedside teaching (51.85%), intensive courses such as classroom-based (35.19%), and oral presentations such as conferences and lectures (3.70%). Moreover, online instructions were the first choice of 9.26% of participants.

Discussion

This is the first study to address the training needs of Tibet GPs in the field of clinical practice. A wide geographical representation is a strength of our survey. Participants came from one area and five cities. In this study, we developed a curriculum priority: first-choice, major alternatives, and secondary considerations. Our findings underscore the topics and training formats that GPs believe are the top priority for future CME projects. The training priorities can serve as a practical reference for making CME curriculums. Moreover, this research can assist policymakers in providing demand-oriented curriculum and staged training plans for GPs.

In this research, GPs expected almost all the training contents. The demand for essential knowledge training of participants with <5 years of practice was significantly higher than those practicing for 5–9 years, which may be related to clinical experience. There is no significant difference in the training needs between other groups, which may be attributed to the fact that GPs may have a vital requirement for continuing education and a desire for better career development. Furthermore, almost (>80%) identified training in cardiovascular, respiratory, and digestive disease management as their top priorities (22). Studies are consistent with previous studies which show that many physicians consider further education essential to improve chronic disease management and highly value these programs (23). Some common reasons result in the similarity of need: due to fewer types of disease, GPs were unable to enrich their clinical experience by contacting patients frequently; the majority of GPs lack postgraduate medical education, and their clinical skills are inadequate; the syllabus of CME training required GPs to learn much knowledge in a short time, resulting in diminished the training effect (9, 24–26). The following top priorities in clinical skills are mainly involved: physical examination, basic first aid, and interpreting reports (X, CT, and ultrasound). Although community health services do not have some advanced medical

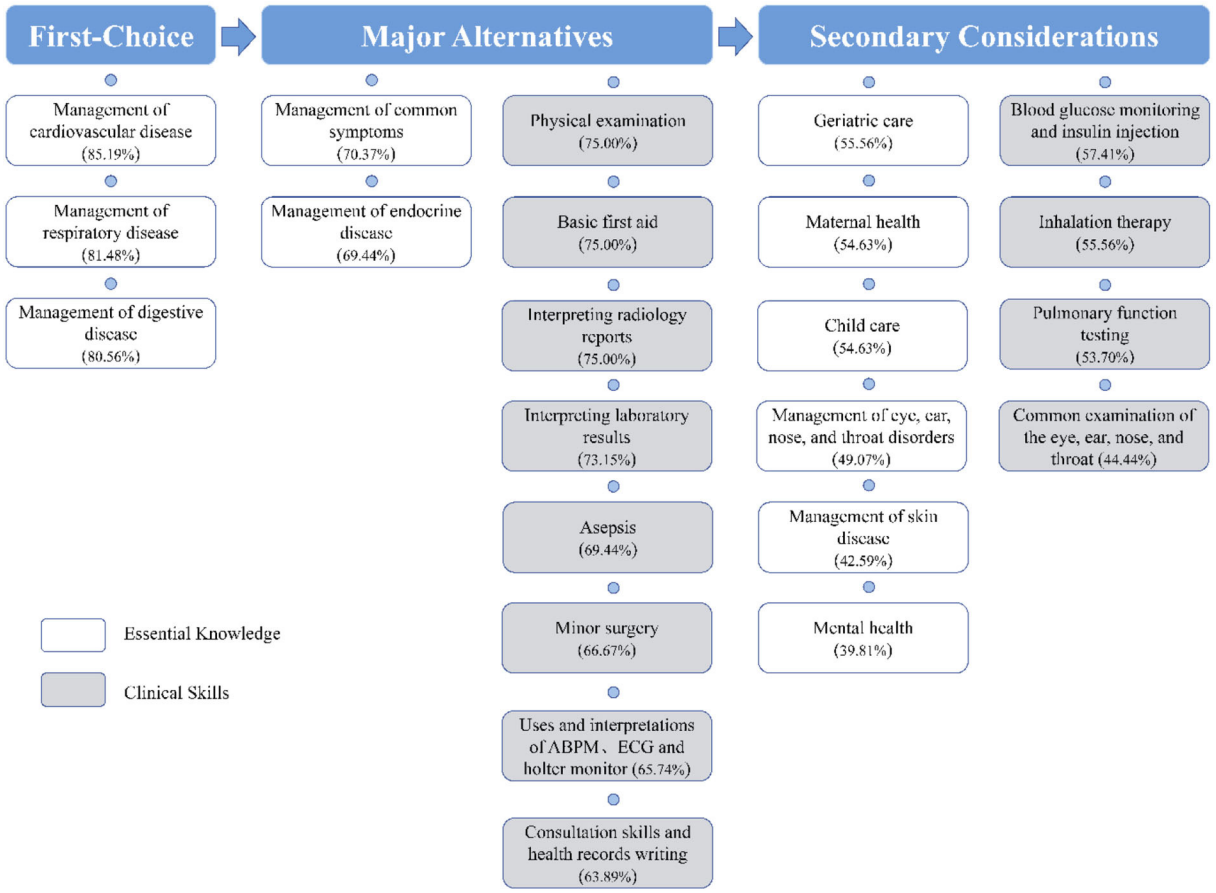


FIGURE 2
Flowchart depicting the priority level.

examination instruments, patients commonly consult GPs on radiology reports and laboratory results. Similarly, GPs should be equipped in delivering prehospital care emergency medical services in the community (27).

Only 39.81% ranked mental health as an essential priority. The comparably low priority rate might be associated with the tendency of GPs to ignore the importance of mental health management. The epidemic data from Tibetans of the Qinghai-Tibet Plateau indicate that the prevalence of depression is higher than the overall Chinese population (28). The international agencies and national mental health guidelines consider integrating mental health and primary care as a priority (29–31). In recent years, there have been increasing calls to provide additional support to guide and promote the nationwide implementation of mental health rehabilitation (32). There is strong evidence to demonstrate that primary care is considerably advantaged in providing evidence-based treatment for patients with mental health (33). Some studies indicate that GPs lacked the expertise to effectively engage with patients with mental health problems (34).

Face-to-face instruction seems to be the most popular option among survey participants. Three possible reasons are as follows: participants may have no previous exposure to distance teaching, the "pairing assistance" measures are based on on-site training, and there is a desire for hands-on skills training. We should not underestimate the value of online instruction during the COVID-19 pandemic as many face-to-face courses were canceled. Worrying about deduction from wages, heavy workload, and transportation costs makes it difficult for GPs to make suitable arrangements between work and training (20). Online instruction is considered the potential for being a convenient, feasible, low-cost alternative to face-to-face instruction (35, 36). A qualitative study of the Chinese community revealed that online training is a solution to the contradiction between work and training for GPs (22). Previous research compared four modes of training format, namely, face-to-face, video conference, online, and blended (37). Findings indicate that all four training formats significantly increased the confidence and knowledge (37) of the trainees. However, web-based conferences are hard to consult in time. The curriculum

is not connected with reality, lack of interaction, and other shortcomings with a single form and mode.

Policy implications

The staged training plans according to an order of priority will be necessary. The policy documents stated that the CME training process would be divided into different stages based on the actual time schedule and the local practical conditions (38). The challenges included the time conflict between work and training, deficiencies of qualified GP teaching teams, and a shortage of educational funds (11, 22, 39). In extrapolating our study results to staged training plans, several points should be considered, including the feedback of trainees, faculty resources, training time, and funding for training (40). As training progresses, three "first-choice" items should be given top priority, followed by the 10 "major alternatives" items and 10 "secondary considerations" items. It is recommended that dynamically adjusting the training plans achieves efficient use of education resources, arouse the enthusiasm of both trainers and trainees, and ultimately integrate education for sustainable development. After the completion of the CME training, it is necessary to pay attention to the effective evaluation and feedback of the training plan.

We call for additional efforts from the National Health Commission and Continuing Medical Education Committee to improve the knowledge and practices of GPs. Chinese health policymakers should formulate evidence-based CME training programs (41, 42). Blended learning is a combination of online with face-to-face training, which allowed GPs in Tibet to choose their training formats and time. The training format provides the staged training plans with feasibility and convenience. Future strategies should also consider building a standardized CME online course library and repeated education by the network to maintain and increase knowledge (43).

These results present the real-world situation of the need for CME training in China, according to the Tibetan GPs' perspective. Nevertheless, some limitations need to be noted. First, snowballing is a well-established technique for recruiting hard-to-reach groups in the public health field. The sampling approach was appropriate for principal purposes as we sought to prioritize participants that presented higher demands in this study. This procedure offers the following advantages over other sampling methods: it is a low-cost and simple process and makes it possible to GPs in remote areas that are difficult to access. Second, the relatively small sample size of GPs may limit the generalizability of our findings. The possible reason lies in the shortage of Tibetan GPs. Finally, this was a cross-sectional, retrospective study, in which participants' needs for CME training might exist reporting bias. Formal methods, such as in-depth interviews, peer assessment, or objective testing, will help us plan education accordingly.

Conclusion

This study shows the real status of CME training needs for GPs in Tibet drawing. We provided important insights into a demand-oriented curriculum and staged training plans that are a vital composition of the framework for high-quality CME. This study also highlights that CME training formats should consist of hybrid face-to-face and online instruction. The findings of this study help to understand how to adjust CME training programs better, which may contribute to further educational policy-making and Tibetan GPs practicing in order to optimize the teaching of the main theoretical content and practical skill.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee on Biomedical Research, West China Hospital of Sichuan University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

This study was conceptualized by KA and QS. The database was organized by RQ, CL, XR, and TM. Data analysis was performed by KA, QZ, and LZ. The manuscript with inputs was drafted by KA, QZ, YM, and LZ and reviewed by KA, LZ, SL, FL, YS, and QS. All authors contributed to drafting or revising the manuscript, have agreed on the journal to which the article will be submitted, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.914847/full#supplementary-material

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Promoting a culture of sharing the error: A qualitative study in resident physicians' process of coping and learning through self-disclosure after medical error

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Purpose: Most physicians, including residents, experience significant emotional distress after making medical 11 errors. As high reliability organizations (HROs), hospitals must not only support physicians' emotional recovery but also promote their learning from errors. Self-disclosure is a process of communication in which individuals reveal information about themselves to others. While many previous studies have focused on investigating the effectiveness of self-disclosure, little is known about the process itself. Therefore, this study aims to explore residents' processes of coping with their emotional distress and learning through self-disclosure after making errors.

Methods: Semi-structured interviews were conducted with 22 residents in their second year from two Japanese hospitals where informal error conferences guided by senior residents are implemented regularly. In the interview, four core questions were posed regarding the nature of the error/incident, their emotions and behavior after the error, ways of self-disclosure, and the results of error-sharing in the conference. Interview data were thematically analyzed, drawing upon disclosure decision model as the theoretical framework.

Results: Five phases emerged from the analysis: (1) emotional distress and reactions before self-disclosure; (2) self-disclosure to individuals to achieve social rewards; (3) emotional sublimation after self-disclosure to individuals; (4) sharing errors in groups for learning opportunities; and (5) transforming the perspectives on overcoming and learning from errors.

Conclusion: This is the study to demonstrate that various types of self-disclosure were embedded in the processes of residents' recovery and learning from medical errors.

The study suggests that a better understanding of the processes of residents' coping with their distress and learning from their errors through self-disclosure is fundamental to the creation of a "culture of sharing errors" in hospitals as HROs.

KEYWORDS

medical error, emotional distress, self-disclosure, resident physician, high reliability organizations (HROs)

Introduction

Most physicians, including residents, experience significant emotional distress after making medical errors or experiencing adverse events (1–4). When an adverse event occurs, it can be a traumatic experience not only for the patient and the patient's family but also for the physicians involved (5, 6). Physicians often experience significant emotional distress in such situations such as shame, guilt, self-doubt, depression, and even suicidal ideation (7–10).

Of these negative emotions, shame and guilt are known to be powerful and ubiquitous in response to negative events. Shame is regarded as negative feeling focusing on the "self" and is associated with negative evaluations of the entire self as "small" and "worthless." Guilt, by contrast, is regarded as a positive feeling focusing on "behavior," which is associated with repairing action (11, 12).

Residents are a particularly important and vulnerable population needing support in cases leading to such emotions as their early experiences of medical errors may shape their future behavior and coping skills (13). The influence of these emotions on healthcare providers has been discussed in medical literature, and further discussion of the impact on residents is needed. Clinical teachers should cultivate engaged, empathetic, and shame-resilient learners using non-humiliating, action-based, and empathetic approaches (12). From that point, it is essential for clinical teachers and concerned individuals to discuss and develop strategies to support residents after making medical errors. Therefore, this study focused on residents' responses to medical errors.

From an organizational perspective, hospitals have a dual role of transforming medical care as high-reliability organizations (HROs), defined as organizations that must be "nearly error-free" to avoid catastrophes despite a high level of risk and complexity (14, 15). First, hospitals as HROs must build a system to learn from medical errors such as reflective error conferences. Second, it is crucial that organizations provide emotional support for physicians who experience significant emotional distress to avoid losing valuable human resources.

Previous studies have focused on investigating physicians' cognitive and emotional processes after medical errors. Scott (8) identified six stages of the natural history for the healthcare provider after adverse patient event: (1) chaos and accident response; (2) intrusive reflections; (3) restoring personal integrity; (4) enduring inquisition; (5) obtaining emotional first aid; and (6) moving on to dropping out, surviving, and thriving. In line with this process, several studies have reported that an organizational support program is needed, such as supervisor support, a private counseling system, team meetings, formal conferences (such as Morbidity and Mortality conferences), and an organizational constructive support system (e.g., Scott's three-tiered system and medically induced trauma support services) (8, 16). Studies have shown that an organizational support program that provide trained peer support for health care providers, mainly nurses, has reduced turnover among them (17).

From an individual perspective it has also been noted in recent decades that self-disclosure to colleagues or peers provides both emotional support and learning opportunities for further growth (13, 18). Plews-Ogan noted that physicians wanted "a peer and an ear" to openly discuss their errors with a supportive colleague. Self-disclosure is a process of communication in which individuals reveal information about themselves to others. The information can be descriptive or evaluative and can include thoughts, feelings, aspirations, goals, failures, successes, fears, dreams, likes, dislikes, and preferences (19). Although previous studies have shown that self-disclosure to colleagues is important, less is known about the process of self-disclosure: when, to whom, and for what purpose physicians disclose, including factors that prevent them from disclosing.

Furthermore, although an informal error conference might be useful, as is a formal one (13, 20), it remains to be determined when and with what purpose physicians intend to present informal conferences and what factors facilitate or discourage them. Engel encouraged more widespread error conferences, including "informal" along with "formal" discussions. Since individuals have varying preferences for these different forms of error disclosure and discussion, combining "formal" and "informal" discussions may generate powerful synergy (13). Research has shown that engaging residents in blame-free discussions encourages communication about learning from errors (21), and, from an organizational

perspective, no-blame practices have been found to be beneficial in HRO environments where learning and reliability issues are particularly relevant (22).

Considering these studies, it is conceivable that residents who have made medical errors are expected to cope with their emotional distress by disclosing errors to their colleagues personally as well as learning through sharing their experiences in informal conferences. However, no study has fully explored the complex process of self-disclosure from the residents' perspective.

Disclosure Decision Model (DDM) is a framework that can be useful in exploring this issue. DDM specifies a cognitive process resulting in decisions that affect the content, depth, breadth, and duration of self-disclosure (23). In the first stage of DDM, self-disclosure is selected as the primary strategy to achieve one of five social rewards: social approval, intimacy, relief of distress, social control, and identity clarification. The second stage involves decisions on whether disclosure is an appropriate strategy and who is an appropriate target. In the third stage, decisions are made regarding what to disclose: how broadly, how much, and how intimately. Based on individuals' perceptions of the situation and target, subjective utility and subjective risk are assessed. Ultimately, this subjective assessment determines the three main dimensions of self-disclosure (breadth, duration, and depth of self-disclosure). Breadth refers to the number of topics covered by disclosure. The duration of disclosure is the sheer amount or persistence of the disclosure. Depth is defined as the intimacy level of disclosure, described as a combination of intense emotional and potentially negative disclosures (23).

Using DDM, we developed the following research questions:

- What is the process of coping with emotional distress through self-disclosure from the residents' perspective?
- How do residents develop an attitude of learning from errors through the process of self-disclosure?
- What factors accelerate or discourage self-disclosure in informal conferences?

This study aims to provide deep insight into how surrounding supporters and clinical teachers should support residents who make errors and how informal error conferences should be conducted.

Materials and methods

Qualitative research design

This study adopted a qualitative research methodology informed by the interpretivist paradigm to conduct an in-depth analysis of the complex phenomenon of residents' perspectives on emotional distress and learning from errors through self-disclosure after making errors. Qualitative data were collected through 22 audio-recorded face-to-face, semi-structured, in-depth, and open-ended interviews. All data were analyzed inductively. To identify cognitive and emotional processes after making errors from the perspective of self-disclosure, we chose reflexive thematic analysis to elicit subjective meanings, which involved generative coding and theoretical interpretations by the research team.

Setting and participants

We conducted the study among residents in their second year at two Japanese postgraduate training hospitals where informal error conferences were conducted. Potential participants were all residents in their 2nd year at these hospitals, with sufficient clinical experience and experience of episodes of errors. Hospital A had 13 and Hospital B had 5 residents in their 2nd year. The programs at the two hospitals were based on a rotation system in each department, and there was no bias in the residents' majors. The conference was implemented regularly (once per week) and was guided by senior residents. Both hospitals had formal reporting systems for medical errors (including incidents) for patient safety. Medical errors were discussed in the medical safety committee and explained to patients and their families based on the conclusions of the committee. Both hospitals also had Morbidity and Mortality conferences. In addition, both had their own mentorship programs to support each resident throughout their residency.

We recruited participants by asking for volunteers from the two hospitals. We intentionally included residents who had experienced an incident or medical error and had attended an informal error conference. Following approval from the research ethics board, over a 2-year period, 17 residents from Hospital A and 5 residents from Hospital B were recruited (13 male, 9 female). All of these residents agreed to participate in the study, and no one refused. The sample size was estimated to be sufficient based on the principle of theoretical saturation (22). The participant details are presented in Table 1. The mean age of the participants was 27.2 years old.

Patient and public involvement

No patients were involved.

Data collection

Semi-structured interviews were individually conducted in Japanese by the first author (MA) in a private room with a safe environment. Interviews lasted approximately 40 min each.

TABLE 1 Participants.

Code	Gender	Hospital	Code	Gender	Hospital
1	F	A	12	F	A
2	F	A	13	M	A
3	M	A	14	F	A
4	M	A	15	M	B
5	F	A	16	M	B
6	M	B	17	M	A
7	M	B	18	M	A
8	M	B	19	M	A
9	M	A	20	F	A
10	M	A	21	F	A
11	F	A	22	F	A

Before the interviews, definitions of the terms used in this study were explained to the participants. For example, following the Institute of Medicine, "medical error" was defined as "the failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim" (1). A "near-miss" was defined as "an event or situation that could have resulted in an accident, injury, or illness, but did not, either by chance or through timely intervention" (24). "Error" is understood as a word that encompasses a wide range of mistakes from the near-miss to a serious adverse event to cast the widest possible net (13).

Based on the interview guide (Table 2), we explored six core questions regarding the content of the error that had a deep impact on the participants, their emotions and behaviors after the event, the type of self-disclosure (when, to whom, and for what), their emotional changes after self-disclosure to individuals, why they shared (or did not share) the error in the informal conference, and their emotional changes after the conference. The interview data were digitally recorded and transcribed verbatim.

This study was approved by the Institutional Review Board of the Gifu University Graduate School of Medicine as the overarching ethical committee, after the approval of the Ethics Committees of the two hospitals.

Data processing

The interviews were audio-recorded, and verbatim transcripts were produced from the recordings. The first author translated Japanese transcripts into English. During this process, private identifiers were replaced with anonymized data. Coding software (NVivo V.12, QSR International, Massachusetts, USA) was used to manage and organize the data. To report this research in an audit trail, this study also carefully documented all components of the data analysis process, including raw data, coded transcripts, researchers' notes, and analysis products.

TABLE 2 Interview guide for all participants.

1. Have you ever had any clinical error or incident that impacted you in the past? Please describe it as far as it's all right with you.
    1) How long ago did the event occur?
    2) What type of event was it? (error or incident)
    3) Describe your specific role in the event.
    4) Describe the patient outcome.
2. How did you feel immediately after the event?
3. How did you handle those feelings?
4. Did you talk to anyone about the event?
    1) Who did you talk to?
    2) Describe the situation in which you talked to him/her.
    3) Did you talk about your feeling to him/her?
    4) Is there any change of emotion or recognition regarding the event after talking to others?
5. Did you share this event in the informal conference?
    1) When did you share it?
    2) Why did you decide to share the event in the conference (or not)?
    3) Are there any changes of emotion and recognition regarding the event after sharing it in the conference?
6. What helped you to recover from your emotional distress regarding the event?
7. What do you think are the better ways for dealing with your emotional distress?
8. Based on your experience, what would you do to support your colleagues who make a medical error?
9. What kind of supports do you think are needed for residents who make a medical error?
10. Have you ever learnt how to deal with medical errors in your professional training?

Data analysis

This study employed Braun and Clark's reflexive thematic analysis in an inductive manner (25). Following the six-phase process of thematic analysis developed by Braun and Clarke, all researchers systematically reviewed the transcribed data to better understand its content. This is called the familiarization phase. The second phase is coding, in which the text data are broken down into small units according to their beliefs, actions, events, or ideas. In this phase, MA and TS individually performed the initial coding of data from the participants. The third phase generates the initial themes. In this phase, all members compared the results of individual initial coding and identified broader significant patterns of meaning (i.e., theme). On this basis, MA coded the remaining transcribed data. Specifically, each small unit was coded with an interpretive description and grouped into more abstract themes from the perspective of self-disclosure.

At this stage, a disclosure decision model by Omarzu (23) was employed as an analytical framework to further explore the

cognitive process resulting in decisions that affect the content, depth, breadth, and duration of self-disclosure. The fourth phase was reviewing themes, where all researchers reviewed the initial themes developed in the previous phases iteratively to ensure that the researchers' interpretations were congruent with the presented data. The researchers then defined the final themes in the fifth phase, which involved developing a detailed analysis, identifying the focus, and determining the story of each theme. Finally, in the sixth phase of writing, the researchers contextualized the analysis in relation to the existing literature. Standards for Reporting Qualitative Research (SRQR) were used to write the report (26).

Trustworthiness of data analysis

To enhance the trustworthiness of the qualitative analysis, two researchers (MA and TS) were independently involved in coding and categorizing the data. The authors then crosschecked their data interpretation and analysis. The preliminary findings were carefully reviewed multiple times by all members of the research team to establish the validity of the data analysis. We also conducted a member check in which some available participants were asked to evaluate the researchers' interpretation of the data.

Results

Five phases and 11 themes emerged from the analysis, presented in Table 3. In the following sections, residents' experiences and perceptions in each phase are described in detail.

TABLE 3 Summary of the result emerged from the analysis.

Phase 1—Emotional distress and reactions before self-disclosure
Theme 1-1: Chaotic emotional distress after medical errors
Theme 1-2: Contrastive emotional reactions to shame and guilt
Phase 2—Self-disclosure to individuals to achieve social rewards
Theme 2-1: Self-disclosure to peers for relief of distress
Theme 2-2: Self-disclosure to senior residents for relief empathy and non-clinical advice
Theme 2-3: Limited self-disclosure to attending doctors and formal mentors
Theme 2-4: Non-self-disclosure to anyone else
Phase 3—Transition from healing phase into learning phase
Theme 3-1: Emotional sublimation by self-disclosure
Phase 4—Sharing errors in groups for learning opportunities
Theme 4-1: Conflicting attitude toward sharing errors in groups caused by situational factors
Theme 4-2: Double-edged sword—self-efficacy after sharing in groups
Phase 5—Transforming the perspectives on overcoming and learning from errors
Theme 5-1: Recognizing the importance of sharing errors in groups
Theme 5-2: Motivation to develop "a culture of sharing errors"

Phase 1—Emotional distress and reactions before self-disclosure

In this phase, immediately after committing medical errors, residents' thoughts were dominated by panic and depression followed by shame and guilt. At that time, there was no room for disclosure to others.

Theme 1-1: Chaotic emotional distress after medical errors

Immediately after the errors, the residents were terribly upset and tried to survive a critical situation while experiencing panic. It was not until the situation stabilized that they gradually began to experience depression and loss of confidence. A more serious error (e.g., an adverse event that affected a patient) was associated with stronger emotional distress. Even when the error was not critical and did not influence the patient's life, they were often shocked.

- I lost my confidence and faced the reality. It was like, "I didn't even know that" (1).

Indeed, although the emotional distress seriously influenced their work, they were not allowed to use it as an excuse to leave their work. For example, they felt it was difficult to focus on their work because their mind was full of distress. It was also stressful to continue to work without showing emotional distress to other patients while pretending to be okay.

- It was hard, and there was such a feeling in the corner of my heart, so it felt strange like that half of the desk of my mind was occupied (3).
- The hardest thing was that [I was] feeling depressed, but I was not allowed to show it to the other patients (13).

Theme 1-2: Contrastive emotional reactions to shame and guilt

When the residents tried to look back on their error experiences, they were gripped by shame and guilt. They felt more ashamed if their self-assessment was based on others' evaluations, comparing themselves with colleagues. Therefore, they were anxious about others looking down on them. These residents felt shame despite the relatively small number of errors. Additionally, some residents felt more shame

because they thought they should be humble regardless of others' evaluations.

- My colleagues would see me like, "That guy screwed up." I'm a person who worries about what others think, so I felt quite embarrassed (4).

In contrast, the residents had a sense of guilt when thinking about their influence on the patients and families rather than themselves. Poorer patient outcomes were associated with stronger guilt. Sometimes, even their own death could cross their mind as atonement due to the strong sense of guilt. Similarly, residents developed a sense of guilt toward their attending doctors who had taken over patient care after they made the error. Some residents felt shame focused on self-esteem followed by a sense of guilt focused on patients.

- I thought that I was an irresponsible person as I had put the patient's life in danger by inappropriate care. I felt that, if he/she had died, it would have been better if I had died instead (20).
- The fact that I messed up in front of my attending doctor made me feel twice as sorry about it (5).

Phase 2—Self-disclosure to individuals to achieve social rewards

After reflecting on their own experiences, the residents started to seek individual targets for self-disclosure. This is because they recognized that they could not manage their emotions, although they tried to rebuild themselves by organizing their narratives. Accordingly, the desire to organize their emotions by talking with someone welled up subconsciously. Regarding self-disclosure to individuals, residents estimated the utility and risk of self-disclosure when choosing targets in advance.

Theme 2-1: Self-disclosure to peers for relief of distress

The residents disclosed narratives of errors to their peers not to seek any advice but rather to seek acceptance and sympathy without judgement. Therefore, they chose peers who shared similar circumstances, difficulties, and hardships in the same training program. Female residents, in particular, preferred female peers because they expected that female peers would give them sympathy without judgement or criticism. Even having someone just listen to and accept their stories could allow them to feel secure since verbalization helped them organize their thoughts and emotions.

- I may be very naive, but my peers don't blame me. I'm sure they understand how I feel (20).
- I [would] talk to one of my peers about it, and if I was depressed, he/she would listen to me as well. That's how it is with both of us (11).
- When I disclose to my female peers, they definitely say things that make me feel better. They empathize with me just by listening to me. I talk to them because it's comfortable (12).
- Just the fact that he/she listens to me is quite refreshing. If he/she can understand that I'm going through something like that, then I'm OK (9).

On the other hand, residents never confessed their errors to peers they considered rivals because the subjective risk of shame and frustration by comparing themselves with peers prevailed. Additionally, in the case of serious adverse events, they may not have talked to their peers while utility was low because they believed it was beyond their peers' capacity to accept.

- It was hard to talk to my peers about it because I saw my peers as rivals, or I was frustrated that I was not capable like them (5).
- I thought this was a bit too much (incident) for my peers to comfort me (1).

Theme 2-2: Self-disclosure to senior residents for empathy and non-clinical advice

After making errors, some residents self-disclosed to senior residents with whom they had a trusting relationship to obtain both empathy and non-clinical advice. They expected senior residents to encourage them without criticism and give them advice on how to overcome the hardship by sharing their own failure stories. Seniors' failure stories could reduce residents' anxiety and allow them to positively think that they can overcome their errors. They believed that experienced senior residents could accept even serious adverse events that were beyond their peers' capacity to accept.

- When I talked to my seniors who have overcome failures, I felt that I could grow in a positive way on my mindset for the future (5).
- What I expect to hear are failure stories of my seniors, such as, "I was like this when I was young." I think that, deep down, I want to hear that such a great senior was like this when he or she was a junior (14).
- I think it's valuable to listen to failure stories of senior residents. I think it has a completely different weight.

I believe that those hardships have made them who they are today (19).

However, when they did not have any senior residents they could trust close to them, they never disclosed to the senior residents because of the high risk of being blamed and disrespected.

- I can't tell my seniors my mistake. I have an obsession that I will be disrespected. They are all excellent doctors, and I don't think anyone would make such a mistake (12).

Theme 2-3: Limited self-disclosure to attending doctors and formal mentors

The residents considered that attending doctors and formal mentors were not the right people to disclose their errors to because of the high risk and low usefulness in terms of relief of emotional distress. They believed that attending doctors would not accept their emotions unconditionally, worried about their evaluation, and cared about the limited time available.

- My attending doctor is not my mother. I don't have any reason in which I feel free to talk with them (12).
- I don't want to be downgraded because some of the attending doctors are in a position to evaluate me (15).

Few residents intended to disclose to their attending doctors to ask for specific clinical advice, rather than sympathy or encouragement. In such cases, they confessed to the attending doctors only after organizing their emotions and carefully planning a reasonable story through disclosure to their peers or senior residents.

- It's not easy to talk to my attending doctor about my failure story like this. [If I would really like to talk,] first of all, I would talk with my peer who is at the same level as me and organize my thoughts. [...] After preparation with peers, I [would] talk to my attending doctor carefully (12).
- It's not something that I need to ask my attending doctor to take the time to do. They are always busy and not available. I have a lot of clinical matters I need to ask for advice right now, so I'd rather spend my time on those (18).

Formal mentors largely depend on each mentor's character and the mentor–mentee relationship. When the residents both had no good relationships and feared the negative consequences of self-image, they never chose their mentors as a target to disclose but rather peers and senior residents.

- My mentor was so strict that I could never tell him about my errors. I've never said it once (14).

Theme 2-4: Non-self-disclosure to anyone else

Residents did not disclose to anyone when they recognized that the utility of disclosure was low or the risk was too high. This strongly depended on their perception of self-disclosure. Some residents recognized the utility of self-disclosure as low; they kept their experiences only in their minds because they recognized that seeking emotional healing through self-disclosure would spoil them or that sharing emotions with others would not give them catharsis, and there would be no benefits.

- I don't need to talk to others about my errors because the answer "I was wrong" is already inside of me. I think I'm being too easy on myself to ask for encouragement (21).

However, some of them may have expressed that self-disclosure was not useful in hiding feelings of shame, pretending to be strong. One of the male residents had a gender stereotype that men should not disclose themselves easily.

- [I don't disclose to anyone because] I'm a man. I think women can talk and let out their emotions and refresh themselves, but I'm not that type of person (16).

Some residents recognized that the risk was too high; they did not disclose their error to anyone because they worried about how they would appear to others, considering self-disclosure as strongly shameful and distressing. Consequently, when they decided not to confess to anyone, they prepared to take it to their heart, carrying guilt for the rest of their lives without forgiving themselves.

- I still remember all my errors. I forget what I forget in my sleep. And what I don't forget, I should carry with me for the rest of my life (14).

Phase 3—Transition from healing phase into learning phase

The residents were able to focus on learning from their errors and applying them to the future only after they had healed their emotions by reflecting on the past through personal self-disclosure.

Theme 3-1: Emotional sublimation by self-disclosure

Residents could relieve their emotional distress after they verbalized their narratives through self-disclosure. They also organized their emotions and perspectives, including shame and guilt. As a result, their thoughts shifted from the past to the future, making the next phase "To learn from the experience of the error and make use of it in the future." They found that studying medicine much harder was not sufficient to rebuild their confidence or bring them to the next phase.

- [By talking about it,] I can organize it rationally and emotionally. I do self-reflection too, but when I talk to others, it means that I can summarize it within myself to some extent (8).
- Talking about it helped me move forward. I thought, "I can't help what I've done; I have to make the most of it next time." When she said, "Making use of it for the next patient is the meaning of this mistake," I felt my mind move forward, not to the past, but to the future (5).
- Of course I had studied much harder, but studying alone did not regain my confidence (1).

Although they still had feelings of shame, some of them tried to take the hardship to heart, using their feelings of shame to avoid repeating the same errors in the future. Even when they had a strong sense of guilt, they were able to forgive themselves through self-disclosure, reaching this mindset, and making use of the error experiences the next time.

- I thought it would be better if I died instead, but, in the end, I wouldn't die, and I would probably continue to be a doctor. I really felt sorry for this patient, but it was about 2 weeks later that I came to the conclusion that I had to make the most of this experience (20).

Phase 4—Sharing errors in groups for learning opportunities

In Phase 2 (self-disclosure to individual targets), individual beliefs and relationships with others significantly influenced self-disclosure behavior. In Phase 4, in contrast to Phase 2, situational factors strongly influenced residents' self-disclosure behavior. Even though they had organized their emotions in Phase 3, they were always conflicted between the expectation of learning and fear of psychological distress with regard to sharing errors in groups.

Theme 4-1: Conflicting attitude toward sharing errors in groups caused by situational factors

In general, the majority of the residents positively regarded sharing errors in groups. Some residents who did not personally self-disclose shared their errors in groups at the last minute. While they were conflicted between the positive and the negative feelings, they believed that sharing errors was beneficial for learning for themselves and others. On the other hand, they had negative feelings that they could be blamed or criticized. Therefore, they sometimes did not share their errors with the groups.

- [I had talked about my error with my peers before...,] and I have been able to organize and accept my feelings that the patient in my case couldn't be saved, so I shared it on the conference (2).
- It might be a good case to learn from, but I wouldn't present a case [at the conference] where my practice was terrible. I'm sure I won't (14).

Whether residents self-disclosed was very situational. The residents had to overcome various conflicts such as cases, emotions, and atmosphere before they shared their errors in groups at the conference. First, they carefully selected cases to share. In particular, they believed that difficult cases had less risk of being criticized. They avoided sharing easy and simple errors because they believed that those cases would not be a lesson for others to learn.

- Difficult cases are easy to share [in the conferences]. I think it is because my lack of knowledge is not exposed. It's easy to present a case like, "He/She had a dissection of the celiac artery." That's difficult for anyone. If I were to say, "He/She had an aortic dissection," most of the participants would think, "So what?" (12).

Second, they were also influenced by their emotions. For instance, they avoided sharing simple errors that had the risk of causing shame by exposing their lack of ability. Even when their sense of guilt was strong, they encouraged themselves to share the errors to confront and overcome their terrible experiences.

- I felt a lot of guilt. I thought that "I don't want others to know my error" was just running away. I really thought, "I shouldn't run away from this case (20).

Third, they were strongly influenced by the atmosphere at the conference. When they witnessed others being blamed (or criticized) or noticed some participants who often criticized colleagues, they thought the risk of being blamed was too high;

therefore, they did not share the cases that they had prepared to share.

- When I saw the other resident being criticized [in the conference], I think, "Oh no, is it OK to share my case? I don't want to do." The atmosphere made me not want to share it (11).

Theme 4-2: A double-edged sword—self-efficacy after sharing in groups

Although the residents managed their conflicted feelings and shared at the conference, there was a fine line between success and failure. Some residents gained self-efficacy when they recognized that it resulted in not only their own learning but also that of colleagues. Even when guilt was overwhelming, they eventually felt a sense of accomplishment like "overcoming the error" through sharing the error.

- I felt triumphant like "I'm glad I shared it." I told them about my error, but I thought, "This is no shame" more than that (1).
- I thought it was helpful to everyone, and I also had a sense of accomplishment when I talked about my error (15).

In contrast, when the residents felt blamed (or criticized) despite motivating themselves to share, they were discouraged, demotivated, and not positive about learning from errors. When they experienced blame in the conference in the early days, they would not like to share their errors because of psychological trauma.

- [When I was blamed at the conference,] I just felt so bad. But it was due to my lack of study, so I was still depressed (12).
- [Being blamed] is too memorable. That hurt me so much in the early days that I don't want to share my cases after that (14).

Phase 5—Transforming perspectives on overcoming and learning from errors

The residents overcame this difficulty and formed a positive perspective toward learning from their errors as they repeatedly had difficulty sharing in groups through various trials and errors. Additionally, some of them realized that the acknowledgment and nonjudgmental manner allowed them to develop a culture of sharing errors.

Theme 5-1: Recognizing the importance of sharing errors in groups

As they gained experience by sharing their own errors and listening to those of others, the residents began to realize the usefulness of sharing errors as well as the importance of mentally supporting each other.

They found the usefulness of error conferences in obtaining learning experiences by simulating in their minds without making errors. They developed gratitude toward their peers who shared errors. One of them noticed that sharing errors allowed the peers to realize that they were not the only ones who made errors, which reduced their sense of shame and created a virtuous cycle that encouraged sharing errors. As they accumulated experience as doctors, they felt more comfortable, which helped them notice the usefulness of sharing errors in groups.

- I'd like to thank my colleagues for exposing their own errors because we all can learn from them without making errors (1).
- I have a limited number of cases I can experience on my own. I think that knowing about others' cases is the same as having my own experience, which increases my experience (18).
- I came to realize that everyone has made errors too. I found that I'm not the only one. By me sharing my errors, my peers don't need to feel embarrassed, and it can also save patients. So the benefits are greater than the risks (19).
- I felt more comfortable, and I also got used to working as a doctor. The room in my mind reduced the disadvantages of sharing errors (19).

Theme 5-2: Motivation to develop "a culture of sharing errors"

As they gained more experience in clinical practice and error conferences, the residents gradually developed their own perspectives on sharing errors in the workplace. They became aware of the importance of error sharing in a safe environment. Some realized that they needed to be good listeners to create a culture of sharing errors.

- I don't think it's reasonable to blame him for it when someone shares an error. Since he knows that he failed, there is no need to say that anymore (18).
- Many doctors take things seriously, so I think that many of them tend to deny themselves when they make errors. We all need someone who acknowledges, like, "You're not a bad person, you're working hard enough." And gives us a positive attitude to make use of errors next time (5).

For instance, some thought it was important to accept others' failure stories without blaming or criticizing and discussing them in a positive attitude to make it useful in the future. One of them also believed that exposing his own errors in groups would reduce the emotional distress of his peers and juniors, promoting a culture of error sharing.

- I want to tell my juniors, "We made these kinds of errors when we were in our first year." There are probably many residents who feel depressed after errors and want to quit being a doctor. So, if I could tell them, "That happened to me too," they would feel completely different (19).

Discussion

Summary

Five phases and 11 themes emerged related to the processes faced by the residents in this analysis. To the best of our knowledge, this is the first study to demonstrate the various types of self-disclosure embedded in the processes of residents' recovery and learning from errors.

This study adds to the existing knowledge of the general trajectory of healthcare providers after adverse events and organizational support. Scott (8) sheds light on residents' in-depth emotional and behavioral patterns from the viewpoint of self-disclosure. Specifically, this study demonstrated the shifting processes of residents' coping through self-disclosure from healing-seeking behaviors through personal self-disclosure to learning behaviors in a conference that reinforces their self-efficacy (Figure 1).

Immediately after the errors, the residents were not motivated to learn from them (Phase 1). Only after self-disclosure to close colleagues to relieve emotional distress (Phase 2) did they develop motivation to share their errors in groups for their own and others' learning (Phases 3 and 4). Through experiences of self-disclosure in the group, they recognized the importance of "a culture of shared error" (Phase 5).

Catharsis and reciprocal effects

This study found two major roles for self-disclosure in the recovery process: catharsis and reciprocal effects. Previous studies have shown that self-disclosure to colleagues is effective in reducing emotional distress after making medical errors (13, 17).

The catharsis effect is the therapeutic release of tension and negative emotions as a result of self-disclosure (27). The results suggest that residents simply sought catharsis rather than clinical advice by verbalizing their emotions. We also found that the residents could move to the learning phase only after feeling "catharsis" through self-disclosure to their close peers. For example, if a Mortality and Morbidity conference is held at a time when one has not yet passed through the cathartic phase, there is a risk that one will not only be reluctant to learn but will also become more depressed.

In addition, the reciprocal effect is defined as the effect by which one person's self-disclosure elicits another person's self-disclosure (28). The results of this study demonstrated that the residents were encouraged to strengthen their relationships with colleagues through reciprocal effects from their peers and senior residents. Especially in self-disclosure to senior residents and attending doctors, most residents were more interested in others' failure stories than in clinical advice. The ability to talk about past failure stories depends on one's pride as a physician and whether there is an atmosphere in the workplace where one can talk openly about errors (29). If senior residents and attending doctors keep a stock of all kinds of failure stories in their minds, they can talk to the residents about their failure stories at the right time. Moreover, the results indicate that residents' self-disclosure has a high impact on encouraging sharing errors by colleagues. This could lead not only to great learning opportunities for residents but also to encouragement of sharing errors in workplaces.

Even incidents and a sense of guilt

Although it is well known that residents suffer various emotional distresses immediately after errors (6, 8, 9, 30), our study found that some of the residents had a sense of guilt even from incidents or near-miss events. Since these events rarely come to light despite large numbers, it is essential to recognize incident-level events to support residents affected by emotional distress as well as to promote medical safety (9, 13, 31). It was also found that an excessive sense of guilt after making an error should be considered. Previous psychological studies have explained that the sense of guilt is basically regarded as a positive feeling associated with recovery and empathy toward others (11). However, as noted in previous studies (12), our findings suggest that residents' excessive sense of guilt after an error can be associated with significant psychological distress.

Factors of self-disclosure in personal and "failure friend"

Based on the results of our study, it is equally important to have a "failure friend" (32), who is willing to self-disclose errors on a regular basis, rather than a counselor who is an expert but has no relationship with the individual. A "failure friend" can be explained as an empathetic work friend who understands the context—someone who is your safety net and for whom you can be a safety net in return. In this study, we revealed that residents' self-disclosing behavior was heavily based on the utility and risk concepts in the disclosure decision model (23). Therefore, it is not surprising that residents would

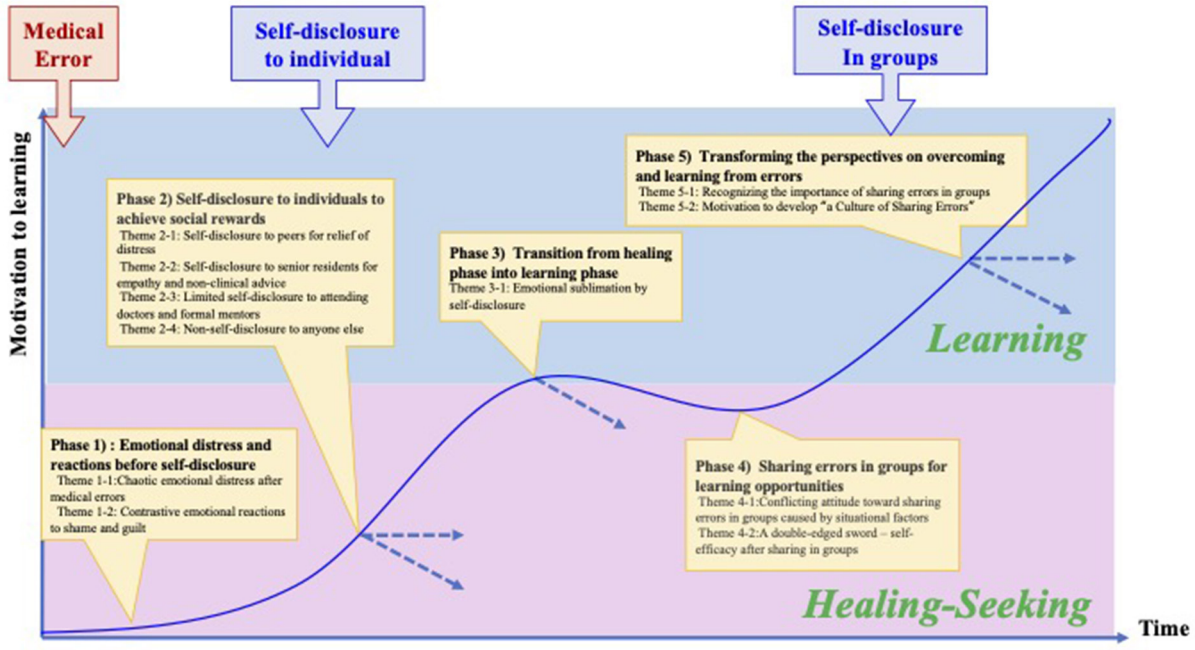


FIGURE 1
The shifting processes of residents' coping process, revealed through self-disclosure.

choose intimate peers or senior residents as their first target rather than attending doctors or mentors. Although previous studies have suggested the establishment of a system of assigning psychiatrists and counselors to reduce emotional distress and prevent burnout and depression (8, 16), it is suggested that having a failure friend is useful for residents to learn from errors through catharsis.

High utility and high risk

Based on the disclosure decision model (23), the combination of high utility and high risk is associated with anxiety and distress, leading to sharing errors in groups. Therefore, the residents were conflicted between positive and negative attitudes toward it. If they decide not to share information, they will miss the opportunity to learn and grow as doctors. Even if they are present, they are traumatized when they encounter the experience of being blamed for errors in front of the audience. This is a double-edged sword that can lead to the formation of a long-lasting negative attitude toward sharing errors in groups.

Organizational culture of talking about errors

It should be noted that, through repeated self-disclosure of errors both individually and in groups and exposure to many situations in which peers disclosed their errors, the residents understood the importance of sharing errors, which in turn would lead to the development of a "hospital culture of learning from errors." This understanding is essential for HROs to promote such a hospital culture. This is because such a culture, apart from a formal reporting system, forms informal norms that promote continuous organizational improvement and open dialogue beyond formal error-reporting systems (6, 33).

Implications for the development of a culture of error-sharing errors

The following is a summary of the skills expected of colleagues and educators. It is expected that all staff will understand the importance of this culture and acquire these skills through faculty development and leadership training within the hospital.

- Just listen to residents' failure stories when confessed by them.
- Have a conscious attitude toward talking about residents' errors.
- Consider the phase of residents' healing and learning after errors, especially when deciding to hold a Morbidity and Mortality conference.

- Pay attention to residents' sense of guilt and encourage their self-forgiveness.
- Be "chosen" or "a person who elicit one's self-disclosure (openers)" (34).
- Create organizational opportunities to learn from sharing errors.

Limitations

This study had several limitations. First, it was confined to interviews with residents of acute-care hospitals that held informal error conferences. Hospitals that hold informal error conferences may face fewer barriers for residents to share their errors than hospitals that do not. However, it is important to recognize that, even in such an environment, residents still experience difficulties in sharing errors. Second, this study focused on Japanese residents. The emotional distress experienced by residents after making errors and the conflict they felt when sharing errors in groups may differ from those in other cultures. However, as the global healthcare environment progresses, there seems to be a certain significance in understanding the characteristics of diverse cultures and in sharing the expertise of each country. Third, one of two hospitals had a smaller number of residents working there, resulting in a smaller sample size. Finally, it remains to be determined how much these implications for residents who have made errors has impacted both hospital culture of learning from errors and their future careers.

Conclusion

This is the study to demonstrate that a variety of types of self-disclosure are embedded in the processes of residents' recovery and learning from errors/incidents. This study also revealed residents' in-depth emotional and behavioral patterns from the viewpoint of self-disclosure. The findings of this study may provide valuable insights to encourage residents to learn from errors as well as to develop an organizational attitude to learn from errors.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Institutional Review Board of the Gifu University Graduate School of Medicine. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MA and TS contributed to the conception, design, acquisition of data, analysis, interpretation of data, and drafting of the manuscript. RI, KH, CK, and YS made substantial contributions to the design of the study, data analysis, interpretation, and drafting the manuscript critically for important intellectual content. All authors reviewed, edited, and accepted the final version of the manuscript. All authors approved the final manuscript and agreed to be accountable for all aspects of the work.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Psychiatry and mental health teaching programs of eight portuguese-speaking schools of medicine: A comparative analysis

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Background: Improvement of teaching methods in psychiatry has been the subject of permanent adaptation and innovation. Strengthening graduate education skills in psychiatry and mental health will allow physicians to have the knowledge, skills, and attitudes to carry out early diagnosis and treatment at primary healthcare settings, taking into consideration that the population should benefit from the best interventions by general practitioners.

Objective: The objective of this study was to examine how the undergraduate program of psychiatry and mental health subject in the schools of medicine of the Community of Portuguese-Speaking Countries in the three continents is structured.

Methods: The methods include a narrative description of the program of psychiatry, the workload, the delivery and assessment methods, and the ethical and socio-cultural aspects in psychiatry and research made by the director of the course of psychiatry in Portugal, Brazil, and Mozambique.

Results: Eight schools of medicine from Portugal, Brazil, and Mozambique participated in the study. All these schools use standards which are defined by the regulatory bodies of their countries. The teaching year varied between the third and the sixth. The workload varied between 140 and 224 h. Topics were addressed in presence or virtual methods. Combined qualitative and quantitative assessment is done to encompass competencies, skills and knowledge based on clinical histories, ongoing assessment, seminars, and final written tests. Ethical and socio-cultural aspects in various strands are taught to be linked to the local reality. Research is encouraged by using grants.

Conclusion: Teaching psychiatry follows global and national standards and is organized according to the reality of each country. Psychiatry departments from these three continents invest in teaching methodologies that encourage self-knowledge and the development of critical thinking, which is evaluated in a holistic context. The authors consider that the programs should have a workload according to the current burden of mental illness.

KEYWORDS

psychiatry, mental health, medical education, teaching and assessment methods, program comparison

Introduction

The teaching of psychiatry around the world has been taking place in medical schools for over a century and has been improving along time. In addition to improving the content taught, the workload has also been increasing that the students must learn the importance of psychological factors in the social and clinical context, diagnose psychiatric diseases, and be able to provide, at least, primary care for serious conditions such as anxiety, depression, psychosis, epilepsy, and mental retardation. In Africa, the challenge of specialized human resources and dependence on foreign experts persists (1).

Psychiatry Training for Medical Students varies widely across the world. High-income countries mainly implement competency-based medical education (CBME) and incorporate training in psychiatry during the basic/pre-internship period itself. There is more confidence in skills development and flexible learning-based training than time-based training (2).

Regarding the Portuguese-speaking countries, advances in the medical field are also associated with the independence and the development of the countries in which Africans now have more recent universities with <65 years of general teaching in psychiatry. Portugal has taught medicine for more than five centuries leading to the evolution of psychiatry, whose teaching only began at the University of Coimbra in 1910, although the University itself was created in 1,308. From 1911 onward, there was a more solid teaching of psychiatry in the new faculties of medicine as reflected in the advances achieved in the teaching methods and provision of psychiatric care and primary healthcare (3). The medical courses in Portugal adopted the model of knowledge and skills as defined in the profile of the Graduate Doctor in Portugal (2005), considered essential for the further development of students and for doctors for their patients and the society (4).

Psychiatric education in Brazil began during the asylum era in the second-half of the 19th century and evolved to occupy the university hospital in the 20th century. Medical residency in psychiatry has shown considerable growth since its implementation 70 years ago and now occupies a prominent place in Brazilian medicine (5).

The university model in Brazil, a mirror of the European model, was officially reformulated in 1968 with the approval of the University Reform Law which extinguished the chairs and replaced them with the departmental structure. In the case of the medical course, the obligatoriness of a basic core, common to all courses in the area of health and the professional cycle (6), was determined.

The pre-defined profile objectives of graduates in medicine in Mozambique recommend that the graduates should be capable in terms of knowledge and have skills and abilities in hybrid teaching models of modules and subjects, the first part being theoretical and the second clinical, which includes internships in hospital units and family follow-up (7).

When we look at the mental health component, it is clear that it continues to be a neglected part of the efforts to improve the global health system, where in low- and middle-income countries mental health budgets are <3% of an already scarce health sector provision (8). The objective of improving these teaching methods is, ultimately, to ensure physicians are capable of recognizing and treating the most frequent pathologies that are often not recognized and, consequently, not treated including mental health disorders.

Mental illness has moved from being the thirteenth cause of care in 1990 to becoming the seventh cause in 2019. Neuropsychiatric disorders attribute for over 10% of the global burden of disease, while mental, neurological, and substance use (MNS) disorders are the leading contributors to years lived with handicap (9). While the physical, social, and economic burden of mental illness is immense, the World Health Organization's Mental Health Atlas (2019) reports that the average number of mental health workers globally is nine per 100,000 people with an extreme variation between the low-income and the high-income countries (10).

In Africa, mental illness continues to be evolved in a mystical world in which the supernatural and witchcraft overlap with scientific concepts, despite educational campaigns promoted by government at the community level (11).

For the treatment of these diseases, while all medical schools are obliged to cover the same required outcomes during the course, they differ in the ways they choose how to deliver the contents of psychiatry and mental health (12, 13). The teaching of psychiatry can start in the 1st years of the medical course, be part of transversal modules, or be taught in the last years of the course.

Clinical experience in general adult psychiatry and sub-specialties is provided by each medical school during that period (14). For example, the University of Alberta MD Undergraduate Program provides for a progressive environment

Abbreviations: A3ES, Agency for the Assessment and Accreditation of Higher Education; CBME, Competency-based Medical Education; CNAQ, National Council for the Assessment of Higher Education Quality; CPLP, Community of Portuguese Language-Speaking countries; DALYs, Handicap-Adjusted Life Year; DSM V, The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition; ENQA, The European Association for Quality Assurance in Higher Education; GBD, Global Burden of Disease; ICD 10, International Classification of Diseases – 10; ICD 11, International Classification of Diseases; MNS, Mental, Neurological and Substance Abuse; OSCE, Objective Structured Clinical Examination; SINAES, National Higher Education Assessment System; WHO, World Health Organization; WFME, World Federation for Medical Education; WPA, World Psychiatric Association.

where education, research, and patient care are integrated into a unified curriculum to make sure that they can provide students with not only the technical skills and scientific knowledge which will allow them to become competent doctors but also to be kind and empathetic physicians (15).

To improve knowledge of psychiatry, the RCPsych has recently encouraged medical schools "to put mental health at the heart of the curriculum" (RCPsych 2017). This suggests amendments to student curricula to offer psychiatry experience as early as possible and in an integrated manner with other specialties (16) since psychiatric disorders are among the world's leading health problems due to their high prevalence and chronic course (17).

Purpose of the study

The purpose of the study was to examine the undergraduate programs of the subject of psychiatry and mental health in the schools of medicine of the Community of Portuguese-Speaking Countries (CPLP) in three continents regarding the standards, delivery and assessment of contents, workload, and teaching methods. Additional information regarding the resources, ethics, and socio-cultural influences in mental health teaching was also analyzed. Major objective is to obtain relevant information for the elaboration of a teaching and evaluation program in psychiatry and mental health that can be used to create and adapt the programs to global needs.

Materials and methods

Survey design

A questionnaire was designed on google forms for online completion to expedite data collection.

The survey, consisting of 48 questions, was divided into nine groups (Table 1) taking into account the purpose of the study raised by the researchers and using Kern's Six Step Approach to Curriculum Development for Medical Education, namely (1) Problem Identification and General Needs Assessment, (2) Targeted Needs Assessment, (3) Goals and Objectives, (4) Educational Strategies, (5) Implementation, and (6) Concepts for Evaluating the Effectiveness of the Curriculum.

Participants

Sampling method

The aforementioned study has been carried out upon the invitation of the director of the discipline of psychiatry and mental health of the undergraduate course in medicine, to answer anonymously to an online survey.

More than 20 emails were sent to the departments of psychiatry and mental health in five Portuguese-speaking countries.

The invitation to participate was sent on January 2021. The survey remained open until June 2021, and the date of completion was recorded with each respondent's data.

Eight departments of psychiatry and mental health from Portugal, Brazil, and Mozambique were enrolled.

This online method was selected given the ease of contacting the psychiatry departments of the medical schools. Each survey was accompanied by an online informed consent, which stated the purpose of the study, a confidentiality clause, and the main researcher's contact details.

The selection criteria for the participants included (a) Portuguese-Speaking Country Schools of Medicine, (b) having a Department of Psychiatry and Mental Health, and (c) agreeing with the referred consent statement.

Type of the study

A qualitative cross-sectional study, using a narrative description of the delivery and assessment of the Psychiatry and Mental Health Program used by the CPLP schools of medicine.

The answers to the online questionnaires were organized in a spreadsheet with the data.

Results

Although there is no ideal model that can be applied in all countries, the implementation of specific standards and core curriculums in medical education as well as academic development programs for the teaching staff are important elements for a proper definition of the discipline.

All departments of psychiatry and mental health participating in the current study have an entity that carries out certification and accreditation. It can, therefore, be said that accreditation is a process that is of great interest to all educational institutions as it allows (1) to determine whether an institution meets minimum quality standards; (2) allows students to determine which institutions are credible for enrollment; (3) assists institutions in determining the essential credits for transfer; (4) helps employers determine the validity of study programs and whether a graduate is qualified; and (5) gives employers evidence that applicants have received a degree from an accredited school or program (18).

The institutions which have been surveyed regularly carried out self-assessment audits and external audit processes, discussing at the level of the pedagogical management, publishing on the university websites or in newspapers the results of these assessments.

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TABLE 1 Process control and commitment to results.

	Portugal 1	Portugal 2	Portugal 3	Portugal 4	Portugal 5	Brazil	Mozambique 1	Mozambique 2
Entity that does Accreditation and certification of schools of Medicine	A3ES	A3ES	A3ES	The Ministry of Health and Education evaluate each course and faculty regularly to keep up with medical education standards.	The Ministry of Science and Higher Education. Also the Medical Council	Inserted in the higher education assessment system	Ministry of Higher Education, Science and Technology	Ministry of Higher Education, Science and Technology
Standards used	A3ES standards	A3ES standards	Criteria common to all Universities	WFME standards	Portuguese Society of Medical Education	WFME standards	CNAQ Standards	CNAQ Standards
Frequency of subject evaluation/audit by students	Annually	Each semester	Each semester	Each semester	The school of medicine has a Pedagogical Council in which students participate. It is only when there are educational reforms that students are heard	Each semester	Annually	Annually
Use of audit report made by students	Published on the Faculty website for public domain	Disclosed internally	Global data is published by the Rectory	Published on the Faculty website for public domain	The Pedagogical Council presents the results to the other bodies of the faculty.	Published on the Faculty website for public domain	Used by the Department to improve quality of teaching	Used by the Department
Frequency of subject evaluation by professors	Annually	Each semester	Each semester	Annually	Annually	Each semester	Annually	Annually
Use of the evaluation report done by professors	Improvement of quality contents	Improvement of quality contents	Improvement of quality contents	Improvement of quality contents	Improvement of quality contents	Improvement of quality contents	Improvement of quality contents	Improvement of quality contents
Entity that performed the last external audit and year.	The University. Every five years. 2017. National entity	A3ES. 2019. National entity	A3ES 2018. National entity	A3ES 2019. National entity	A3ES 2019. National entity	The University. 2019. National entity	Office for Academic Reform and Regional Integration (GRAIR) 2015. National entity	The Faculty. 2019. National entity
Means to deliver the audit report	Faculty guardianship	A3ES report	A3ES report	On the Ministries website and in circulation newspapers	A3ES report	Published on the Faculty website for public domain	University council	University council

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TABLE 2 Organization of the psychiatry subjects.

	Portugal 1	Portugal 2	Portugal 3	Portugal 4	Portugal 5	Brazil	Mozambique 1	Mozambique 2
Year in which Psychiatry is Taught	Fifth and Sixth Years	Fifth and Sixth Years	Fifth Year	Fourth Year	Fourth and Sixth Years	From Third to Sixth Years	Fifth Year	Fifth Year
Mandatory Subjects that precede Psychiatry	Psychology	Pre-Clinical Years are Mandatory	Psychology & Introduction to Clinical Practice	None	Propaedeutics has a Medical Psychology Module before Psychiatry	Internal Medicine	Internal Medicine	Internal Medicine
Monitoring of Classes and Internships	Psychiatric Assistants from the Department	Visiting Professors	Psychiatric Assistants from the Department	Psychiatric Assistants from the Department	Psychiatric Assistants from the Department	Psychiatric Assistants from the Department	Psychiatric Assistants from the Department	Psychiatric Assistants from the Department
Teaching Delivery Methods	Classroom classes; Group and Individual Classes, Online Group and General Classes Internship	Classroom Classes; Group and Individual Classes; Online Group and General Classes; Internship	Classroom Classes; Group and Individual Classes; Online Group and General Classes; Internship	Classroom Classes; Group and Individual Classes Online Group and General Classes; Internship	Classroom Classes; Group and Individual Classes; Online Group and General Classes; Internship	Classroom Classes; Group and Individual Classes; Online Group and General Classes; Internship	Classroom Classes; Group and Individual Classes; Online Group and General Classes; Internship	Classroom Classes; Group and Individual Classes; Online Group and General Classes; Internship
Planning of Classes	A Group defined for that Purpose	Department of Psychiatry and Mental Health and other Specialties, in an Integrated Manner	A Group defined for that Purpose	Department of Psychiatry and Mental Health and other Specialties, in an Integrated Manner	Department of Psychiatry and Mental Health and other Specialties, in an Integrated Manner	Department of Psychiatry and Mental Health and other Specialties, in an Integrated Manner	Department of Psychiatry and Mental Health and other Specialties, in an Integrated Manner	Department of Psychiatry and Mental Health and other specialties, in an Integrated Manner
Workload of the Psychiatry Subject	200 h	140 h	224 h	120 h	180 h	188 h	160 h	140 h
Workload for Practices	120 h (60%)	60 h (42%)	112 h (50%)	80 h (66.6%)	120 (66.6%)	90 h (47%)	80 h (50%)	100 h (71%)
Workload carried out by Digital Platforms (e-learning)	60 h	26 h	66 h	10 h	12 h	47 h	40–60 h	20–40 h

Department of psychiatry organization

About 87.5% of the schools of medicine teach the discipline of psychiatry in the 5th year, after the pre-clinical years, and after the subject of Internal Medicine and Psychology, guaranteeing a basic knowledge on human behavior, of the determining factors in the emergence of mental illnesses and the relevant psychological information leading to psych diagnosis and psychological interventions.

The responsibility for preparing the classes is shared by the professors of the Department of Psychiatry, the workload varying from 120 h (Portugal 1) to 224 h (Portugal 3), divided between theoretical, theoretical–practical, and practical classes.

In terms of delivery services, despite the restrictions imposed by the COVID-19 pandemic that led to confinement and isolation and forced a change and reinvention in teaching methods, only one of the departments uses half of its psychiatry time for classes by remote means of teaching (Portugal 1). Differences also lie in the time dedicated to practical classes, which vary between 60 and 120 h (Table 2, Figure 1).

Psychiatry delivery

Most of psychiatry departments have a focus on psychotic disorders (including schizophrenia), affective disorders,

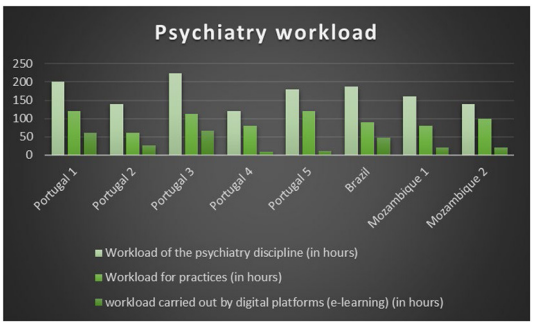


FIGURE 1
Workload of the psychiatry subject.

and substance abuse disorders with the time allotted to each varying.

As a reference, four psychiatry departments use the WHO International Classification of Diseases version 10 (ICD-10) (50%) (Portugal 1, Portugal 3; Mozambique 1, Mozambique 2). Two departments (25%) use a combination of the International Classification of Diseases version 10 and the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM V) (Portugal 2 and Brazil). One department (12.5%) uses the International Classification of Diseases version 11 (ICD 11) (Portugal 5). One department (12.5%) uses the American Classification of Mental Illness DSM V (Portugal 4) as presented in Table 3.

In terms of ethics topics taught, all departments cover ethics topics with the exception of departments 7 and 8 (Mozambique), namely ethics and mental illness, treatment and doctor–patient relationship, compulsory internment, ethics in care, bioethics, and ethics in research.

In the Table below, we can see that the socio-economic contents are also addressed, taking into account those that are most pressing in the countries enrolled:

Research in psychiatry and mental health

All departments carry out research in psychiatry, and the present work maintains that the research activities in psychiatry are a crucial factor for the development and updating of the teaching program and the improvement of the quality of training that brings about changes in the quality of professionals committed to the mental healthcare of the population, in accordance with the demands of contemporary society, respecting diversity and cultivating solidarity, inclusion, human values, and ethics and contributing to the formation of qualified citizens who, in turn, will promote sustainable development (14, 19).

Student performance evaluation

Departments use blended teaching methods to assess students' knowledge, skills, and attitudes that include clinical histories, class participation, and tests throughout the class period and at the end of the discipline/module (Table 5).

Discussion

Importance of the subject of psychiatry for the medicine degree

The teaching of psychiatry in schools of medicine has been evolving, and the last decades have brought great changes in the implemented delivery and assessment methods (4). Due to the increasing burden of mental illness globally, recognition of this specialty allows for better healthcare (9).

Students' experience of psychiatry at medical school will influence not only their career choices but also their lifelong attitudes toward people with mental health problems, whatever their specialty (20, 21). Medical education in psychiatry paves the way to gains from educational innovations although it has been slow on the uptake (22).

The control of quality of schools of medicine

The existence of entities to control higher education is one of the mechanisms to support the quality of higher education and the commitment of the schools to deliver the best education possible.

In the three countries mentioned below, the schools of medicine and the higher education system have regulatory bodies.

In Portugal, the Agency for the Assessment and Accreditation of Higher Education (A3ES) (23), through its regulatory framework, supervises higher education activities, with the agency having the decision-making independence in relation to certain procedures related with the curricula in force, while in Brazil, this responsibility belongs to the National Higher Education Assessment System (SINAES)[25]. In Mozambique, the National Council for the Assessment of Higher Education Quality CNAQ) accredits and certifies the institutions of higher education (24).

The European Association for Quality Assurance in Higher Education (25) and the Faculty of Medicine of the University of Geneva (2006) (26) in the process of reinforcing the quality of teaching promote evaluation mechanisms, namely self-evaluation, in which faculty students and administrative staff make a collective internal reflection on the institution's *status quo* and its practices that provide

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TABLE 3 Delivery of psychiatry teaching.

	Portugal 1	Portugal 2	Portugal 3	Portugal 4	Portugal 5	Brazil	Mozambique 1	Mozambique 2
Syllabus of the Psychiatry and Mental Health discipline	Major Psychopathological Syndromes	Main Psychiatric nosography	(Includes adults and child psychiatry): Clinical history and psychopathology + main nosologies + therapeutic approach	Psychopathology, clinical psychiatry and therapeutic methods	Psychiatric syndromes, clinical history, therapeutics in psychiatry	Psychological development throughout the life cycle, main psychiatric pathologies	Psychiatric nosography, clinical history, therapeutics in psychiatry	Major psychiatric syndromes.
Reference Classification of Mental Illness used	CID 10	CID10 and DSM V	CID 10	DSM V	CID 11 and DSM V	CID10 and DSM V	CID 10	CID 10
Specific topics of ethics and deontology in Psychiatry and Mental Health addressed	Ethics and Mental Illness, treatment and doctor-patient relationship	Patient autonomy, confidentiality, doctor-patient relationship, compulsive treatment	Consent, Mental Health Law, Compulsory internment, medical professionalism	Ethics in care, bioethics and ethics in research.	No specific topics	Ethics in psychiatry	No specific topics	No specific topics
Sociocultural aspects of the region and/or country with the most impact on the path of the population of your region	Employment, family relationships, rurality	Religion, family tradition, rural tradition	Socio-economic level, Health care system, Level of education	Violence, socio - economic and religion	Substance dependence (alcoholism, drugs of abuse)	Ethnic minorities, cultural minorities, migrants	Sorcery implicated in the cause of mental illness, Seek medical assistance after permission from the healer, Daughters-in-law need permission from mother-in-law to seek medical care	Mental illness Synonym of spell/evil spirits/punishment, Medical assistance conditioned by the permission of a healer, Contagious disease
Addressing traditional beliefs about mental illness	Yes	Yes	Yes	Yes	In the 3rd year, in the Medical Psychology module.	Yes	Yes	Yes

crucial information to the managers, course directors, and university professors about the institution's state that can lead to appropriate improvements.

Delivery of psychiatry contents

In the most of the curriculums, psychiatry is taught in the last years of medical school. However, early exposure to this vital specialty can be achieved through the integration of introductory psychology and psychiatry topics during the early college years into other specialties (27).

In the present study, we found that psychiatry and mental health programs in the eight schools of medicine have several common aspects in terms of the program syllabus, practical classes, internship, and the use of objective structured clinical examination.

The programs differ in the number of hours devoted to psychiatry and in the teaching methods used, which shows the importance that is given to psychiatry in different areas of the world.

Logistics and financial conditions for the improvement of teaching quality represent a commitment on the part of the institution to ensure that lecturers and students have

TABLE 4 Research at the department of psychiatry.

	Portugal 1	Portugal 2	Portugal 3	Portugal 4	Portugal 5	Brazil	Mozambique 1	Mozambique 2
Research on a Regular Basis	Yes	It is Encouraged	Depends on External Funding	Yes	Yes	Yes	It is Encouraged	Depends on External Funding
Research undertaken by Students	Yes	No	No	Yes	Yes	Yes	Yes	Yes

adequate means to perform their duties: indicating the way, not giving the answers, accompanying the students according to the objectives defined for the course and the student—to be able to develop skills to develop autonomy, self-learning, and critical thinking.

The study results presented several approaches to deliver psychiatry classes to undergraduate medical students in different settings which included seminars, theoretical classes, practices, and case analysis.

We consider that the success of the psychiatry and mental health program at schools of medicine depends a lot on the defined program content, way of implementation, as well as the selection of adequate and appropriate methods to assess knowledge, skills, and attitudes. Rather than the traditional lectures, it will be more effective to use role play, appropriate use of audio-visual aids, learning by doing, and asking questions to interest the students (21, 28). It is important that students have greater practical training, in a diversity of training scenarios that will allow them to progressively integrate their paths in hospitals to meet curriculum reform "based on health systems" (29).

Dale et al. (30) consider that the teaching of psychiatry should include the introduction of students to psychiatric phenomenology, and the ability to carry out a mental status examination for the diagnosis of major mental disorders, forensic psychiatry, cross-cultural psychiatry, intellectual handicap and mental health, gender aspects in psychiatry, religion, and spirituality in psychiatry (31) indicates that eventually the medical student, the future general practitioners, will not receive any other formal education in psychiatry and, after training in medical practice, will receive users from almost all areas of specialty. Due to the aspects mentioned, it is therefore important to have a basic education that covers a diverse range of pathologies.

Knowing that depression, anxiety, and schizophrenia are among the leading causes of burden worldwide (ranked 13th and 24th leading causes of DALYs, respectively) and the ongoing impact of the COVID-19 pandemic, it is likely that the global burden of mental disorders will increase (9, 32). Effective responses to this burden are achieved by reinforcing mental health interventions at all levels, including undergraduate teaching, to ensure that medical doctors that work at primary levels of healthcare facilities are capable of intervening by recognizing and treating these patients (33, 34).

Considerable discrepancies in content coverage, the delivery of ethics, and socio-cultural themes in psychiatry and in assessment methods were also found.

In this chapter, we make use of Culver et al. (35) who propose that the program of the discipline should not be limited only to the ethical aspects in psychiatry but must also include the religiosity of communities for a better understanding and perception of mental disorders, and on this matter, culture is increasingly becoming an issue for mental healthcare provider (36). Local practitioners and policymakers actively neglect cultural determinants in the mental health field (37). The imaginary of ethnic uniformity is a barrier to the implementation of culturally sensitive interventions (37). In Africa, the influence of traditional concepts is great. If certain conceptions and practices have proved their effectiveness in treating mental disorders, others, on the contrary, participate in promoting the emergence of mental health diseases. In this region, it is believed that witchcraft, sorcery, spells, and spirits can lead to mental illness (38, 39). Attention to psychosocial and socio-cultural aspects in mental health seeks to point out new paths in physical health and mental health that challenges training institutions, health managers, and research (40). Paying attention to these aspects allows for a better understanding of the *ego* of the individual who presents himself to physicians searching for assistance and care (17, 41, 42).

To classify the mental health disorders, there are two major diagnostic manuals: the International Classification of Diseases 10 and the Diagnostic and Statistical Manual of Mental Disorders, which provide classification systems which are relevant to public health, clinical diagnosis, service provision, and specific research applications (43, 44). The International Classification of Diseases 10 alone is the most used (50%), and in combination with the DSM V, it corresponds to 75% of the classification used in these schools of medicine. This is followed by DSM V, which corresponds to 50%, but in combination with ICD 10 or ICD 11.

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TABLE 5 Assessment.

	Portugal 1	Portugal 2	Portugal 3	Portugal 4	Portugal 5	Brazil	Mozambique 1	Mozambique 2
Assessment Methods, including the Mechanisms for Implementing each one, made known at the Beginning of the Classes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Assessment Based on the Clinical and Epidemiological Dimension of the Country, using Topics of Interest to Clinical Practice, or based on General Theoretical Topics	It is Fundamental the Knowledge of the Incidence of Mental Pathology	More Relevance is given to Prevalent Pathologies such as Dementia and Alcohol Use Disorders	It focuses on the Most Epidemiologically Relevant Nosologies	The Inter-relationship between Mental Disorders and the Different Clinics	There is Practical and Theoretical Assessment based on the Topics Delivered	Considered Clinical and Epidemiological Factors in the Country	Assessments are Carried out on the Basis of General Theoretical Topics	Assessments Carried out based on Theoretical Topics and Practical Classes
Calculation of Final Internship Grade	Written Test	Practical Assessment & Multiple-Choice Test & Final Clinical Skills Test	Continuous Assessment (20%) & Oral Exam (80%)	Through Written (40%) & Oral Test (60%).	Oral Test	Sum of Participation (30%), Report (30%) and Theoretical-Practical test (40%)	Task Grid (60%) & Continuous Assessment (40%)	Sum of Clinical History (40%) and Continuous Assessment (60%)
Assessment of students' skills	Clinical History, Use of OSCE	Practical Assessment & Multiple, Choice Test & Final Clinical Skills Test (OSCE)	Continuous Assessment in the Practical Internship, OSCE	Through Written and Oral Test	In Practical Classes, OSCE	Sum of Participation, Preparation of Report and Theoretical-Practical test, OSCE	Through Evidence in Terms of Knowledge, Skills and Attitudes	The Assessment of Students Skills is based on Evidence through a List of Previously Agreed Tasks with an Emphasis on Knowing how to do, Knowing how to be and being
Assignment of Final Grade of Psychiatry	Average Results of the Theoretical and Practical Evaluations	Average Results of the Theoretical and Practical Evaluations	Average Results of the Theoretical and Practical Evaluations	Average Results of the Theoretical and Practical Evaluations	Average Results of the Theoretical and Practical Evaluations	Average Results of the Theoretical and Practical Evaluations	Average Results of the Theoretical and Practical Evaluations	Average results of Average Results of the Theoretical and Practical Evaluations

Can *e-learning* be improved?

The challenge of using Information and Communication Technologies is pressing, and the pandemic caused by the SARS-CoV-2 virus has forced institutions to adopt hybrid teaching styles, favoring virtual laboratories, among others, and psychiatry is no exception. Undergraduate training programs in psychiatry can benefit if they are adapted to this new reality that requires the use of virtual learning and recommends that the schools enhance different aspects of the educational process that improves interactivity while using the virtual platform in teaching (45). It is worth mentioning creation of mechanisms that ensure that students have resources (computers, mobile phones, and Internet network) to access classes (46, 47).

Research in undergraduate psychiatry discipline

Loema (48) states that changes in psychiatry can only occur when they are based on scientifically proven assumptions that allow changes to be made for health promotion, prevention, and treatment of diseases, this being the pillar of medicine.

There is need to improve research in psychiatry and support its implementation to provide platforms for our better understanding and improvement of learning, teaching, and assessment methods that can be achieved with reforms that can increase financial support and resources to improveinfrastructures and recruit qualified staff that can motivate students (49) (Table 4).

Assessment of students

Last, but not least, the use of reliable and valid assessment methods IS prerequisites for allocating resources to faculty, based on the results of assessments (50, 51).

The formative and summative assessment methods must be in line with the program and teaching methodologies and allow testing of students' knowledge, skills, and competences, taking into account the objectives of each process and theme (52–54).

The use of methods such as the objective structured clinical examination and its adaptations has served as a basis for a critical assessment of the students' knowledge, skills, and attitudes, and its application has been increasing.

The School of Medicine of the University of Lisbon uses an annual and innovative method of assessment. This progress testing assesses students from the same curricular program but in different years. They are submitted to the same test that allows student self-assessment and gives the faculty of medicine information about the stage of knowledge of student positioning within their year as well as their placement in relation to the total number of students who took the examination (55).

Instrumentalization of evaluation makes it possible for the entire teaching–learning process to be also evaluated (56, 57).

Strengths and limitations and recommendations

The strength of the study was the possibility to explore the differences in three continents with the same language. In addition, the results may express the emphasis on psychiatry that is given by each school of medicine and provide the road maps on how to assure assistance in mental health.

Although we did not find a transcontinental study that can be comparable to this one, we consider that a bigger sample would bring more information to consolidate the findings.

Nevertheless, it is a starting point to promote the study of psychiatry programs and to find common points and differences that can lead to further studies in areas not addressed in the present study.

In the interest of developing a questionnaire that was brief but useful, a number of areas of interest were not explored, which included the topics and undergraduates chosen each year and how the departments prepare the classes and choose the assessment methods and topics as well as how to ensure that the same topic is approached in the same way by the different lecturers during internships and practicals. The impact of migration, war, and natural disasters and the stigma toward mental disorders were not addressed (58). These areas would be important and useful to investigate in the development of this work.

The limitations that we mention above can be used for further research and, above all, to improve the quality of medical assistance.

Conclusion

The undergraduate teaching of psychiatry as an independent discipline has been gaining more expression, with the reforms taking place in medical schools around the world.

Ensuring that these reforms continue will allow physicians to achieve the greatest possible degree of efficiency in their prophylactic and therapeutic roles and to cover a wider range of psychiatric conditions that are underdiagnosed. The fact that the discipline of psychiatry has a structure, albeit different in each undergraduate medical institution in Europe, South America, and Africa, allows us to continue working in the implementation of methods that improve the acquisition of knowledge, skills, and attitudes and toward the standardization of programs to the standards defined by international and national regulatory bodies. Many challenges in psychiatric education lie ahead.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

MP was involved in all aspects of the research project, design, conducting the research, data handling, exploratory analysis, and drafting and editing of the study. AP and MF assisted with the design of the study and in data interpretation and editing of the study. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.936177/full#supplementary-material

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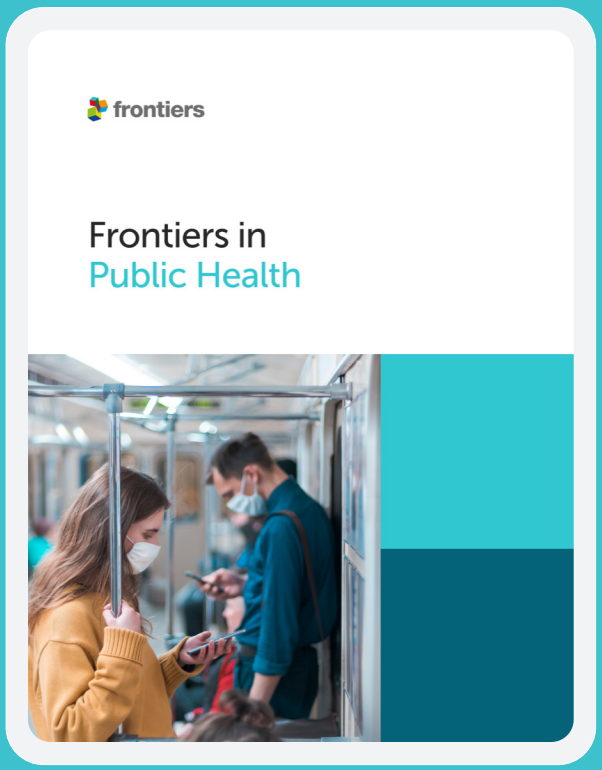
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