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An insight into university medical and health science courses

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An insight into university medical and health science courses

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Table of contents

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Editorial: An insight into university medical and health science courses

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Editorial on the Research Topic
An insight into university medical and health science courses

Introduction

As emerging infectious diseases (EID) are expected to occur, healthcare personnel must prepare medical and health science majors on the effects of public health crises and the epidemiology of EID. The courses designed to increase interdisciplinary research competence are being developed by higher education institutions with the goal of reducing the disparities in education based on the level of socioeconomic development among countries (1). A greater understanding of environmental health determinants is emphasized in medicine (2), and crisis leadership has been required in public health education over the last 2 years of the coronavirus disease 2019 (COVID-19) pandemic (3).

However, optimistic interpretations of the mandatory application of online education as replacements for offline courses under COVID-19 exist. While online education is accessible from anywhere, it also has several limitations. Instructors lacked technological skills, such as experience with ZOOM or TEAMS, video-recording of presentations, educational experience with online education, how to keep the attention of online students, and so on. Environmental infrastructure and properly trained instructors are necessary to ensure effective, high-quality online education (4). Opportunities such as Internet access, educational material download, and two-way communication are assumed to be provided equally so that learners can share their experiences and ideas even with time barriers (5, 6). However, the effect of online education experienced by learners differs according to the national income level, infrastructure of the Internet, and information communication technology. To

supplement practice education, it is necessary to use a video display terminal in augmented reality technology or search for other alternatives (7). Unlike advanced countries such as the UK and US, which applied online education more than 10 years before the COVID-19 pandemic, most educational institutions and learners in developing countries such as Iran, Uganda, and Pakistan negatively evaluated online learning experiences and effects (5, 8). However, medical students in Belgium responded that the quality of education decreased, but self-directed learning competence developed during the pandemic (9, 10).

Fourteen articles were selected for publication. Most research findings have addressed medicine or public health curriculum and educational content improvement, the performance of public health degree programs, education to strengthen research capabilities, health education for specific diseases and subjects, and simulation education or augmented reality; however, only one study has examined the effect of online education during the COVID-19 pandemic. Five articles address pre-service education issues (Zhang et al.; Sun et al.; Syed et al.; Tu et al.; Yang et al.). One addresses in-service education issues (Yang et al.). Six articles are geared toward holistic or programmatic aspects (Zhang et al.; Rao et al.; Li et al.; Shete et al.; Dinov; Anitha et al.) with two disease or module-specific articles (Liu et al.; Jia et al.).

For this Research Topic, we received various types of articles, namely, original research, perspectives, brief research reports, mini-reviews, systematic reviews, curricula, instructions, and pedagogies. The authors' works are summarized according to the article type.

Contributions according to article type

Perspectives

As the public health crisis continues, the impact of environmental factors on health and the competencies of crisis management is reinforced to respond effectively to emerging infectious diseases in the future. Rao et al. argued that an understanding of the public health context and the impact of socio-ecological factors on health in medical education was necessitated by all types of undergraduate and special short-term courses in the United States. These expectations in medical education peaked throughout the COVID-19 pandemic because the role of clinical doctors was expanded to individual disease treatment and expert competencies in response to emerging infectious diseases. Recommendations for the reform of medical education were made on seven topics: premedical education, Medical College Admission Test, public health and nutrition course within the first 2 years of medical school, post-coursework or standardized licensure testing, research within training, clinical practice, and continuing education.

Original research

Healthcare personnel is essential to achieve sustainable development goals by 2030 and respond to the demand for health services during the public health crisis; therefore, higher education in medicine and health science should include the following: innovation in the course content, application of advanced and effective teaching and learning methods, quality management of the clinical practice, performance evaluation of programs, responsiveness to the provision of health services, and appropriate health education for communities.

Tu et al. conducted an online survey of 8,285 students of college level and higher from Jiangsu province, China, to identify their current knowledge, attitude, and sex education on Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome (HIV/AIDS). The authors determined the influencing factors of HIV/AIDS knowledge and students' health needs to be based on their knowledge using the structural equation model. Their findings indicate that HIV/AIDS health education has a significant effect on knowledge awareness and attitude, with standardized coefficients of 0.15 and 0.58, respectively. The authors concluded that timely sex education should be implemented to decrease the incidence rate of HIV/AIDS among young people. Syed et al. at King Saud University in Saudi Arabia examined undergraduate health science students' knowledge and perceptions of thyroid cancer development. The findings of their cross-sectional survey showed that female students had a significantly higher level of thyroid cancer knowledge and perception of the causes of the disease than male students ($p < 0.05$). More than half of the students (65%) were well aware of unexplained lumps or swelling as a warning sign of thyroid cancer. The authors concluded that the findings shed light on the understanding of pharmacology, nursing, and medical students' knowledge of thyroid diseases and highlighted the need for further repetitive qualitative studies that include participants from various institutions.

The COVID-19 pandemic played a role in advancing digital transformation by unexpectedly applying online education to university education, which had to prepare for innovative teaching and learning methods during the Fourth Industrial Revolution. In this regard, Sun et al. conducted a descriptive study using massive open online courses (MOOCs) platform data of course-taking students and official socioeconomic statistics in China. The relationship between socioeconomic factors and the number of participants during the COVID-19 pandemic was analyzed. The authors found a close relationship between the number of MOOCs course-takers and regions of China only during the COVID-19 pandemic. Their findings are important in understanding the inequality of access to MOOCs and the disparity of educational opportunities according to regional and socioeconomic status (i.e., the digital divide).

Simulation is applied at the level of modality in healthcare for education, assessment, research, and facilitating patient

safety. As hospital-based clinical training has been restricted to prevent social distancing and infection after the COVID-19 outbreak, simulation education to replace practice training in the simulation lab of nursing and medical schools has drawn attention. Zhang et al. identified the characteristics of virtual simulation (VS) and examined the trends in nursing research. The authors reviewed 677 articles from 1999 to 2021 with identifiers of authors, institutions, countries, journals, and network maps using bibliometric analysis. Their findings showed that the number of studies peaked exponentially in 2020 by authors from the US, Canada, and Australia. These studies were published mostly in three journals: *Clinical Simulation in Nursing*, *Nursing Education Today*, and the *Journal of Nursing Education*. The authors divided the four major themes into the following clusters: (i) virtual learning during the COVID-19 pandemic as Cluster 1, (ii) clinical nursing care using virtual reality as Cluster 2, (iii) education in nurse practitioners using vs. as Cluster 3, and (iv) education technology in vs. as Cluster 4. They concluded that further programs are required on training and evaluation outcomes using vs. for nursing students and faculty training on the use of VS.

Yang et al. examined the effects of a novel simulation curriculum on pediatric cardiovascular education for residents at a children's hospital in Hangzhou, China. The non-equivalent control group pre-and post-test design with the three segments of running, debriefing, and challenging task provision was applied only to the intervention group. The authors found that the assessment results of residents' knowledge ($p < 0.01$), skills ($p < 0.01$), professionalism ($p < 0.05$), and self-performance satisfaction feedback ($p < 0.05$) significantly increased in the intervention group only after simulation training. The authors concluded that qualified simulation training should be provided to the residents to enhance professionalism and pediatric cardiovascular knowledge and skills.

The mission of higher education institutions is to educate and produce quality health and medical personnel, as required by modern society. To pursue this goal, university education institutions should periodically identify and analyze changes in the health and medical environment to continuously improve the performance of educational programs. In this regard, Shete et al. conducted research on the outcomes of a university's training program in implementation science. For the implementation sciences, the training program of the University of California, San Francisco, revised domains into seven categories: team science, context identification, literature identification and assessment, community engagement, intervention design, and research implementation, evaluation of the effect of translational activity, and behavioral change communication strategies. The survey and academic productivity of the program participants in both in-person and online programs were assessed. The findings of this study showed that participants from both training programs had high to moderate confidence in all 12 competencies, with 181 publications. Only one competence in intervention evaluation was low because of the early stage in the career ladder. The authors concluded that a qualitative assessment with a larger sample size should be considered in future studies.

To identify graduates' distribution in the health employment industry, Li et al. examined the occupational situation of master's graduates in public health and preventive medicine in China. A cross-sectional survey was conducted to collect data from 2014 to 2018 (i.e., 5 years of program graduates). The findings of the study showed that most participants (95%) were employed in hospitals, and the jobs were not matched with their major and had a low initial salary. The rate of job maintenance was as high as 83%. The authors concluded that initial salary and job arrangement should be matched to their specialty by remodeling the programs and advocating for changes in employment policy.

In health sciences and medical education, graduates' proactive lead in research performance ability is considered an important achievement. Yang et al. conducted a study on the effectiveness of student-driven course-based undergraduate research experiences (CUREs) at a medical school in Shanghai, China. The authors identified the experience of general bacterial culture and gene amplicon sequencing under the guidance of instructors at the Shanghai Jiao Tong University School of Medicine. Their findings showed that CUREs contributed to the improvement of students' hard skills (research performance processes based on scientific theory, etc.) and soft skills (design, performing research, result in production, etc.). The authors concluded that CUREs were beneficial to scientific literacy skills and understanding instructors' roles from the student's perspective.

Intake of chronic disease medications among older adults in the community is an important issue in managing their healthy living without complications or aggravation of the disease. Considering one-third of older adults' medication non-adherence in Beijing, China, Jia et al. examined the relationship between health literacy and medication adherence among community older adults in Beijing, China, using a cross-sectional survey. The authors analyzed the association between the cognitive level of participants and sociodemographic factors on medication compliance. Their findings revealed that the lower the literacy rate, the higher the non-compliance with drug use (p 0.01); however, no relationship was observed between the two variables in the case of cognitive impairment. The authors concluded that medication adherence should be monitored with older adults' literacy ability after assessment of the cognitive level classified into normal and impairment levels.

Mini-review

Globally, the public health curriculum—as an undergraduate or master's degree program—has expanded

through the approval of programs or certified curriculum systems in advanced countries since 1990. Given the importance of public health education and its competencies, Anitha et al. analyzed 180 public health degree programs in seven South Asian countries (India, Bangladesh, Pakistan, Bhutan, Maldives, Afghanistan, and Sri Lanka), and they formed the South Asian Association for Regional Cooperation. Most countries, except India, still do not operate an educational accreditation or licensure system or regulations for public health education programs. Public health education in India is governed by a new national education policy that provides more research-based learning. However, public health professionals can play major roles in primary healthcare for universal health coverage and health literacy for communities in resource-scarce underdeveloped countries. Suggestions for the improvement of the enrollment of public health majors students and the accreditation system to evaluate the programs will contribute to the health workforce industry and the quality of public health programs in South Asia.

Brief research report

Meta-verse, the main technology of the fourth Industrial Revolution, is a three-dimensional virtual world, and the market has grown rapidly owing to the popularization of its use in realistic content.

The effectiveness of education has been proven through the meta-verse platform, augmented reality, and virtual reality education cases and the current use of video display terminals (VDT) is expected to continue to increase in clinical training for healthcare personnel and undergraduate simulation practicum.

Liu et al. analyzed the relationship between the total duration of daily VDT use, and the level of eye discomfort among medical students in a cross-sectional study in Kunming, Yunnan province of China. The study findings showed that the prevalence rate of VDT in medical students was significantly higher than that reported in 2016; however, the result may be affected by the COVID-19 pandemic and disruption of on-site clinical practice. A statistically significant positive relationship was observed between the total duration of VDT use and the severity of ocular discomfort among the participants ($p < 0.05$). The severity of eye discomfort symptoms was negatively affected by the total sleep duration and positively affected by the total VDT use duration ($p < 0.05$).

Curriculum, instruction, and pedagogy

Big biomedical data (as an enabler for a knowledge society) and data analytics (as an asset platform) are mandatory for health science professionals during the Fourth Industrial Revolution and digital transformation. Dinov reviewed advanced teaching and learning methods and the content of courses focused on the competence of analytics for doctoral programs in health science. Any doctoral program on health science majors, biomedical, informatics, and health analytics training should incessantly include the demand for big data literacy and analytics in their advanced curriculum framework. To meet these expectations, various courses on data quality, model interpretability with transparency, research ethics, information security and privacy protection, health policy overviews, and quantitative analysis should be incorporated. Recommendations on the areas of expected program graduates' competencies include algorithms and applications, data management, and analysis methods. The perspective of transdisciplinary efforts considers innovation-taking risk and uncertainty, but it is better than being ostracized by complacency.

Systematic review

The teaching and learning methods for nursing, medical, and public health majors were designed to provide more realistic practice opportunities because of patients' right to self-determinism and protection of patient privacy. Clear learner expectations of their teaching behaviors would be beneficial to clinical instructors. In this regard, Zhang et al. meta-reviewed nine articles based on the Joanna Briggs Institute Qualitative Assessment and Review Instrument (JBI-QARI). The three themes of good teaching literacy, solid professional competence, and harmonious relationships were synthesized using the JBI-QARI after category grouping. The good teaching literacy theme was synthesized from the categories of flexible teaching methods, a mature concept of education, and good personality characteristics. Solid professional competence was synthesized from the categories of excellent theoretical knowledge and operational skills, good professional attitude, and rich teaching experience. The harmonious faculty-student relationship was synthesized from the categories of the relationship of trust and objective evaluation. The authors concluded that qualitative analysis provided a better understanding of their relationship. They focused on awareness of nursing students' expectations during clinical practice to ensure effective students experience by clinical nursing teachers.

Conclusion

The studies highlighted herein provide insight into university medical and health science courses and have diverse contributions. Perspectives have been offered on training frontline healthcare personnel to fulfill the societal mandate in the era of the Fourth Industrial Revolution.

Original research reiterates the importance of university course reform in understanding students' outcomes and details how to achieve program performance through quality instructors; it also highlights the benefits of applying the advanced method of simulation and evidence-based research competence.

Author contributions

SK conducted the literature review and prepared the draft of Editorial in discussion with MG and HT. This work was carried out in collaboration with all authors. All authors read, revised, and approved the final manuscript.

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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References

1. Moradian N, Ochs HD, Sedikies C, Hamblin MR, Camargo CA, Martinez JA, et al. The urgent need for integrated science to fight COVID-19 pandemic and beyond. *J Transl Med.* (2020) 18:1–7. doi: 10.1186/s12967-020-02364-2

2. Ryan MS, Holmboe ES, Chandra S. Competency-based medical education: considering its past, present, and a post-COVID-19 era. *Acad Med.* (2022) 97:S90–7. doi: 10.1097/ACM.0000000000004535

3. Hertelendy A, Chekijian S, McNulty E, Mitchell C, Grimes J, Durneva P, et al. Crisis leadership: a case for inclusion in accredited Master of Public Health program curricula. *Public Health.* (2022) 209:14–8. doi: 10.1016/j.puhe.2022.05.012

4. Olum R, Kajjimu J, Kanyike AM, Chekwech G, Wekha G, Nassozi DR, et al. Perspective of medical students on the COVID-19 pandemic: survey of nine medical schools in Uganda. *JMIR Public Health Surveill.* (2020) 6:e19847. doi: 10.2196/19847

5. Abdull Mutalib AA, Md Akim A, Jaafar MH, A. systematic review of health sciences students' online learning during the COVID-19 pandemic. *BMC Med Educ.* (2022) 22:1–34. doi: 10.1186/s12909-022-03579-1

6. Puljak L, Civljak M, Haramina A, Mališa S, Cavić D, Klinec D, et al. Attitudes and concerns of undergraduate university health sciences students in Croatia regarding complete switch to e-learning during COVID-19 pandemic: a survey. *BMC Med Educ.* (2020) 20:1–11. doi: 10.1186/s12909-020-02343-7

7. Mukhtar K, Javed K, Arooj M, Sethi A. Advantages, limitations and recommendations for online learning during COVID-19 pandemic era. *Pak J Med Sci.* (2020) 36:S27–31. doi: 10.12669/pjms.36.COVID19-S4.2785

8. Li W, Gillies R, He M, Wu C, Liu S, Gong Z, et al. Barriers and facilitators to online medical and nursing education during the COVID-19 pandemic: Perspectives from international students from low-and middle-income countries and their teaching staff. *Hum Resour Health.* (2021) 19:1–14. doi: 10.1186/s12960-021-00609-9

9. Abbasi MS, Ahmed N, Sajjad B, Alshahrani A, Saeed S, Sarfaraz S, et al. E-Learning perception and satisfaction among health sciences students amid the COVID-19 pandemic. *Work.* (2020) 67:549–56. doi: 10.3233/WOR-203308

10. Olum R, Atulinda L, Kigozi E, Nassozi DR, Mulekwa A, Bongomin F, et al. Medical education and E-learning during COVID-19 pandemic: awareness, attitudes, preferences, and barriers among undergraduate medicine and nursing students at Makerere University, Uganda. *J Med Educ Curric Dev.* (2020) 7:2382120520973212. doi: 10.1177/2382120520973212

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CURRICULUM, INSTRUCTION, AND PEDAGOGY
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Modernizing the Methods and Analytics Curricula for Health Science Doctoral Programs

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This perspective provides a rationale for redesigning and a framework for expanding the graduate health science analytics and biomedical doctoral program curricula. It responds to digital revolution pressures, ubiquitous proliferation of big biomedical data, substantial recent advances in scientific technologies, and rapid progress in health analytics. Specifically, the paper presents a set of common prerequisites, a proposal for core computational and data analytic curriculum, and a list of expected outcome competencies for graduates of doctoral health science and biomedical programs. The manuscript emphasizes the necessity for coordinated efforts of all stakeholders, including trainees, educators, academic institutions, funding agencies, and policy makers. Concrete recommendations are presented of how to ensure graduates with terminal health science analytics and biomedical degrees are trained and able to continuously self-learn, effectively communicate across disciplines, and promote adaptation and change to counteract the relentless pace of automation and the law of diminishing returns.

Keywords: doctoral training, health science, graduate curricula, methods, analytics, data science, quantitative education

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BACKGROUND

Rapid advances in biomedical research and health science discoveries impact all human experiences. Further progress in this extremely interdisciplinary field requires reexamining policies, funding mechanisms, institutional organizations, graduate education, and training curricula, as well as financial incentives and distribution of limited health resources and services. Future graduates of quantitative biomedical and health science analytics graduate programs will play important roles in legislation, population-wide healthcare policies, and the economic, social, and behavioral determinants of human health. Recent computational, data science, and communication breakthroughs present an opportunity to review and enhance the terminal biomedical and health curricula by adopting modern scientific methods, embracing artificial intelligence analytical strategies, and emphasizing reproducible one-science computational protocols.

Graduates of doctoral biomedical and health science programs should be prepared to continuously self-learn, play active roles in research, participate in health policy, and engage in transdisciplinary collaborations. To be successful in these endeavors, a level of prerequisites is required prior to enrollment in the programs, and the expectations of freshly minted scholars should include technical competencies and transdisciplinary skills to ensure their long-term career success.

Key Points

- None of the health science disciplines (e.g., medicine, nursing, pharmacy, kinesiology, public health, bioinformatics, and genetics) are insular (1–3). Transdisciplinary training and inter-professional education are critical for ethical, collaborative, and reproducible research of complex biomedical and health conditions (4, 5).
- The digital revolution demands substantial quantitative skills, data-literacy, and analytical competence: health science doctoral programs need to be revised and expanded to build basic-science (STEM) expertise, emphasize team-science, rely on holistic understanding of biomedical systems and health challenges, and amplify dexterous abilities to handle, interrogate, and interpret complex multisource information (6–8).
- Exploratory, classification, and predictive Big Data analytics are all pivotally important and complementary to traditional hypothesis-driven confirmatory analyses (9–12).

Why Is Curriculum Redesign Important?

- Graduates of health science doctoral programs *may not be fully prepared* to participate in, or lead, transdisciplinary translational research projects involving complex information and heterogeneous observations (13–16).
- The range of *quantitative expertise* in computational and data sciences varies substantially within and between programs (17, 18).
- The NIH-wide 2016–2020 Strategic Plan calls for core data science training and the need for "*quantitative and analytical approaches, processes, and systems … to extract knowledge and insights from increasingly large and/orcomplex sets of data*" (https://datascience.nih.gov/sites/default/files/NIH_Strategic_Plan_for_Data_Science_Final_508.pdf).
- In health sciences, having a STEM foundation knowledge, possessing high technical skills, and having the abilities to gather, model, process, and interpret large amounts of heterogeneous, multi-source, and time-varying information is *gold*. The *golden rule* in advanced evidence-driven patient care, effective biomedical research, and transformative health science is simple: whoever has the gold will make the rules, control the direction of health science, and dominate the translational biomedical research impact. This golden rule is more pertinent to teams of investigators, rather than individual scientists, although the latter form the building blocks of all highly effective teams (19, 20).

Targeted Trainees

The extremely wide range of graduate biomedical, informatics, and health analytics training programs is a direct reflection of the disruptive nature of network-science based discovery, technological advances, and accelerated data-driven innovation (21–23). This manuscript addresses the need for educating and training a very specific cohort of data-savvy quantitative scholars pursuing terminal research-intensive degrees in biomedical and health sciences. Examples of such trainees include students enrolled in doctoral programs in health informatics, biomedical informatics, biostatistics, human genetics, data science, biomathematics, applied statistics, biomedical engineering, pharmacogenomics, and health analytics. This paper does not reflect on the curricular demands, or the quantitative training, of physicians, practicing clinicians, qualitative biosocial scholars, or licensed healthcare providers who are primarily focused on healthcare delivery. At the same time, some of the proposed technical training may be very appropriate for such practitioners as it will allow them to acquire additional skills, promote effective translation of STEM science and advanced analytics into clinical practice, and potentially improve health outcomes, job satisfaction, and patient experiences. Just like quantitative data scientists must possess dexterous artistic skills (8), it's reasonable to assume that exceptional clinicians will have functional quantitative abilities, and productive biomedical scholars would have basic anatomical and health training.

Big Biomedical and Health Data

Characteristics of Big Health Data

Over a decade ago, academic and IBM researchers introduced the qualifying notion of 3Vs of Big Data (volume, velocity, and variety), which later was expanded to 7Vs by adding veracity, variability, value, and visualization (24–26). This earlier framework provided a qualitative formulation expressing challenges related to the emergence and deluge of big biomedical and health data. Our more quantitative approach is formulated by examining dozens of challenging contemporary biomedical case-studies involving complex biomedical and healthcare datasets. There are seven dimensions of Big Biomedical and Health Data–size, format complexity, observation heterogeneity, incompleteness, spatiotemporal variability, multisource components, and multiscale resolution (9, 27). As a proxy of the underlying complex biological, physiological, and medical conditions, such data are important to understand the causes of morbid conditions, model associations between factors, predict risks of treatments, and forecast clinically relevant outcomes. Examples of big biomedical datasets include the UK Biobank (UKBB) (28–30), the Human Connectome Project (HCP) (31, 32), and the Alzheimer's Disease Neuroimaging Initiative (ADNI) (33, 34). UKBB represents a survey of a large population-based cohort including about 500 K individuals

Abbreviations: AdaBoost, Adaptive boosting (ensemble machine learning strategy); AD, Alzheimer's Disease; ADNI, Alzheimer's Disease Neuroimaging Initiative; API, Application Programming Interface; BANDIT, Bayesian ANalysis to determine Drug Interaction Targets; BDDS, Big Data Discovery Science; CDC, Centers for Disease Control and Prevention; CNN, Convolutional Neural Networks; CSCD, Center for Complexity and Self-management of Chronic Disease; DB, Database; DSPA, Data Science and Predictive Analytics; EDA, Exploratory Data Analysis; GB, Gigabyte; GFT, Google Flue Trends; HCP, Human Connectome Project; HTML5, Hypertext Markup Language (version 5); JSON, JavaScript Object Notation; MCI, Mild Cognitive Impairment; MIDAS, Michigan Institute for Data Science; MOOC, Massive Open Online Course; NIH, National Institutes of Health; NoSQL, non-SQL (database); NSF, National Science Foundation; OLAP, Online Analytical Processing; PHP, Hypertext Preprocessor; PIBS, Program in Biomedical Sciences; Q-Q, Quantile-Quantile (plot); R&D, Research and Development; SDSS, Sloan Digital Sky Survey; SOAP, Simple Object Access Protocol; SOCR, Statistics Online Computational Resource; SQL, Structured Query Language; STEM, Science, Technology, Engineering and Mathematics; SVM, Support Vector Machines; UKBB, United Kingdom Biobank; XML, Extensible Markup Language.

assessed at 22 UK medical centers in UK between 2006 and 2010. National Health Service recipients were invited to participate in UKBB and included individuals mostly between 40 and 69 years old (30, 35). HCP includes behavioral data, clinical phenotypes, and unprecedented high-resolution multimodal neuroimaging data for over 1,000 young adults (36). ADNI collected serial data for several thousands of participants including imaging (e.g., sMRI/fMRI, dMRI, PET), biological markers, clinical, genetics, cognitive, and neuropsychological assessment to measure the disease progression from normal aging to mild cognitive impairment (MCI) and early dementia (33). All of these large-scale studies face a number of challenges like balancing the (large) sample sizes with (small) effect sizes, incongruences, heterogeneity, time variability, and confounding effects. Once such datasets are represented as computable objects, data analytical strategies to extract valuable information and build actionable knowledge include model-based prediction vs. model-free inference, multiple comparison problems, and reproducibility (12, 27, 37).

Successes and Failures

Innovation is by definition uncertain and risky! The future of biomedical and health science discovery is bright and there are bound to be spectacular failures as well as breathtaking triumphs. Skeptics may point that major challenges of big data-driven transdisciplinary discoveries include communication barriers and the potential for bias inherent to dealing with complex and voluminous information. Others may argue that the quantity of observed data may obfuscate the key scientific questions transforming the traditional hypothesis-based (confirmatory) research based on a priori observations and inquiries into a new paradigm of data-driven inference, empirical knowledge derivation, and the formulation of novel hypotheses. The 2011 Google Flu Trends (GFT) report (38) was an example where GFT prediction problems were identified in 2013 (39) and partially attributed to overfitting. The GFT original report intended to predict future doctor office visits associated with influenza-like illness, which can be compared to the corresponding flu cases reported by the Centers for Disease Control and Prevention (CDC). In February 2013, independent investigators reported significantly higher GFT-predictions relative to the CDC forecast over the same period of time. The GFT model, which was built on 50-million web search terms over 1,152 data points, predicted increased likelihood of web-search terms matching the propensity of the flu. This may be explained by structurally unrelated queries that may have artificially inflated GFT predictions.

There have also been a number of mind-boggling reports representing successful transdisciplinary work that was only possible using enormous amounts of data interrogated by teams of scientists with broad and deep domain expertise using artificial intelligence (40). For instance, BANDIT (Bayesian ANalysis to determine Drug Interaction Targets), represents a novel data-driven paradigm for target identification and drug discovery using multisource big data in a Bayesian machine-learning framework (41). Applying BANDIT on 2,000 different small molecules, scientists identified likely targets and achieved predictive accuracy of 90%, which was an improvement of prior published target identifications. Similarly, a handful of small molecules with no known targets yielded 4,000 new molecule-target predictions. This target identification along with experimental validation using a set of microtubule inhibitors suggested three candidate compounds for cancer cells resistant to state-of-the-art clinical anti-microtubule treatment. Another example of successful biomedical and health application of transdisciplinary strategies to interrogate big data includes machine-learning techniques. To determine the top determinants of a health outcome, researchers discovered interesting combinations of indicators that affect health outcomes (e.g., life expectancy and anxiety disorders) and identified subpopulations representing analogous clinical phenotypes (42). A 2017 Kaggle Data Science Bowl competition offered $1M prize to a team that improved the specificity of automatic lung nodule characterization to improve screening mammography accuracy (43). Fusion algorithms and computational intelligence were used to efficiently process and visualize 40 GB of data in 10-min (44). Patient-centric eHealth ecosystems provide multi-layer architectures integrating connected devices, computing interfaces, and Cloud services to empower handling of complex data and ensure privacy (45).

Outside biomedical and health science, a recent data-driven discovery used partial differential equations to model large-scale time series measurements in Eulerian (spatially fixed sensors) or Lagrangian (dynamically moving sensors) frameworks. The model distinguishes between linear and Korteweg-de Vries equations, and enables discovery of the physical laws and the corresponding parametric spatiotemporal equations where derivations from first-principle derivations may be challenging (46).

ANALYTICS HEALTH SCIENCE CURRICULUM

Contemporary health science methods and analytics curricula are somewhat out of step with the accelerated scientific and technological advances in the twenty first century. Modernizing the graduate health science education and training will require substantial efforts to blend quantitative computational and data science methods with qualitative approaches, research ethics, and reproducible open science principles. The Data Science and Predictive Analytics (DSPA) course[1] provides one complete, openly-accessible, and technology-enhanced example of an advanced quantitative graduate course for health sciences.

Prerequisites

There are expected variations between different biomedical and health science doctoral programs. Student backgrounds, career interests, motivations, expectations, and learning styles present additional levels of anticipated disparities. Although neither necessary nor sufficient, the prerequisites listed in **Table 1** serve as a guideline of the foundational knowledge and prior experience that provide the basis for successful completion of

[1]http://DSPA.predictive.space

TABLE 1 | Examples of prerequisites for strong biomedical and health sciences quantitative doctoral programs.

Prerequisites	Skills	Rationale
Bachelor's degree or equivalent	Prior quantitative methods/analytics training and coding skills	Graduate programs require a basic minimum level of quantitative skills
Quantitative literacy	Undergraduate calculus, linear algebra, numerical methods, introduction to probability, statistics, or data science	These represent fundamentals that are required for most methods and analytics graduate health science courses
Some coding experience	Some academic, training or professional experience in programming or software development	Most practicing bioinformaticians and health analysts need substantial coding experience, e.g., Java, C/C++, HTML5, R, Python, Perl, PHP, SQL/DB
Strong motivation	Substantial current interest for emersion and motivation to pursue long-term quantitative data analytic applications	Dedication for prolonged and sustained immersion into hands-on practice, collaboration, and methodological health research is very important

a solid quantitative doctoral program in the biomedical and health sciences.

Potential trainees that have insufficient prior domain expertise, e.g., in college-level mathematics, numerical methods, probabilistic modeling, statistical analysis, or software programming, may need to complete relevant bootcamps or remediation coursework prior to matriculation. A wide range of MOOCs may provide the necessary prerequisites, e.g., Coursera, EdX, Khan Academy, Udacity. Examples of remediation courses provided to satisfy some of the Data Science and Predictive Analytics (DSPA) prerequisites are included in the DSPA self-assessment (pretest).

Core Curriculum

Indeed, each Institution and each quantitative biomedical or health sciences doctoral program will have their own customized curricula. At the same time, certain types of fundamental topics are expected to be common and share core principles, coverage, and methods. **Table 2** illustrates examples of types of computational and data science courses that graduate students[2] at any of the 12 disciplines part of the Program in Biomedical Sciences (PIBS)[3] at the University of Michigan choose from. Many of these courses have analogs at other Institutions and attract young scholars interested in data-intense transdisciplinary research, development, and training.

At the most basic level, graduates should receive analytical training in three complementary domains—mathematics, statistics, and engineering. The *mathematical foundations* should emphasize basic understanding of multi-variable calculus, complex variables and functions, linear algebra, matrix computing, differential equations, numerical methods, and optimization. Statistics knowledge should stress practical experience with at least a couple of different statistical computing software packages, understanding of probability theory, distribution functions, and Bayesian inference, as well as parametric and non-parametric statistical tests. Finally, it is important to enhance the graduates' engineering abilities, develop working knowledge of some compiled and interpreted programming languages, data ingestion, management, and visualization.

In addition to quantitative analytical training, all program graduates should be exposed to qualitative and common-sense human-intelligence training including data quality challenges, model interpretability, research ethics, privacy and security, health policy and regulatory guidelines, and implementation research.

- Data quality challenges are always present in big biomedical and health studies, this includes understanding the importance of tracking provenance and assessing data quality, "fitness for use," completeness, and complexity (47–49).
- Model interpretability and transparency is important to be understood, disclosed, and properly interpreted to contextualize the performance, bias, implementation approach, reported findings, potential limitations, and possible unintended consequences (50).
- Research ethics blends the individual scholar values, e.g., honesty and personal integrity, and treatment of other individuals involved in the research, e.g., informed consent, confidentiality, anonymity, and courtesy (51).
- Information security, and privacy protection training are absolutely necessary and will play a vital role throughout all professional activities of graduates (52).
- The landscape health policies are constantly created and updated to drive healthcare research and influence health achievements. Legislative and regulatory guidelines also impact biomedical and health research (53). These are intendend to standardize and control types of scholarly nad organizational behavior, monitor, and enforce policies and licensing, and accreditation.
- Implementation research amalgamates scienctific research and healthcare practice. It is focused on the creation knowledge that can be applied to improve health policies, clinical programs, medical practice, and the borader public health (54).

Due to substantial heterogeneities in institutional course offerings, depth and breadth of program coverage, and variations in individual backgrounds, learning-styles, and scholarly interests, "one-curriculum-plan-does-not-fit-all." It's difficult to prescribe one unique curriculum that includes a specific number of courses to complete, a concrete course-series ordering, and a single completion timeframe. In principle, each Health Science doctoral program will comprise a set of core courses, required for all trainees, a complementary set

[2]http://midas.umich.edu/certificate/approved-courses

[3]https://medicine.umich.edu/medschool/education/phd-programs/about-pibs/pibs-curriculum

TABLE 2 | Exemplary courses at the University of Michigan.

Courses	Descriptions	Types
HS853: Advanced scientific methods for health sciences	Covers a number of modern analytical methods for advanced healthcare research. Specific focus is on reviewing and using innovative modeling, computational, analytic and visualization techniques to address specific driving biomedical and healthcare applications. The course covers the 6 dimensions of Big-Data, statistical cross-validation, model-based, and model-free forecasting	Analytics/applications
HS650: Data science and predictive analytics	Concepts, techniques, tools, and services for managing, harmonizing, aggregating, preprocessing, modeling, analyzing, and interpreting large, multi-source, incomplete, incongruent, and heterogeneous data (Big Data). The focus will be to expose students to common challenges related to handling Big Data and present the enormous opportunities and power associated with our ability to interrogate such complex datasets, extract useful information, derive knowledge, and provide actionable forecasting	Analytics
PIBS503: Research responsibilities and ethics	Covers case-studies on fraud, fabrication, and plagiarism, data storage, ownership, and peer review, animal use and care, human subjects research and IRBs, conflict of interest, research in the global workplace, dual use issues, discussion about ethical practices particular to project/laboratory	Research ethics
BIOINF585: Machine learning for systems biology & clinical informatics	Focuses on machine learning methods and their applications in biomedical sciences. Topics include: (1) data management solutions for Big Data applications, (2) feature extraction and reduction methods, (3) clustering and classification methods, (4) testing and validation of models, (5) applications in systems biology and clinical informatics	Methods and apps
BIOINF527: Introduction to bioinformatics and computational biology	Introduces students to the fundamental theories and practices of Bioinformatics and Computational Biology via a series of integrated lectures and labs. These lectures and labs will focus on the basic knowledge required in this field, methods of high-throughput data generation, accessing public genome-related information and data, and tools for data mining and analysis	Methods and apps
BIOSTAT602: Biostatistical inference	Provides deep understanding of key concepts and analytics of statistical inference. Statistical inference methods are of critical importance for statisticians to properly process data and organize information to quantify uncertainty so to delivery adequate solutions to substantive questions	Methods and analytics
Math 571: Numerical linear algebra	Introduces numerical linear algebra as a core subject in scientific computing. Three types of problems are considered: (1) linear systems ($Ax = b$), (2) eigenvalues and eigenvectors ($Ax = \lambda x$), and (3) least squares problems ($\min_x \|Ax - b\|_2$). These problems arise in many scientific applications and we'll study the accuracy, efficiency, and stability of the methods developed for their solution	Methods and analytics
Stats 415: Data mining and statistical learning	Covers the principles of data mining, exploratory analysis and visualization of complex data sets, and predictive modeling. The presentation balances statistical concepts (such as over-fitting data, and interpreting results) and computational issues.	Methods and analytics
Stats 503: Applied multivariate analysis	Presents modern methods of multivariate data analysis and statistical learning, including theoretical foundations, and practical applications. Topics include principal component analysis and other dimension reduction techniques, classification (discriminant analysis, decision trees, nearest neighbor classifiers, logistic regression, support vector machines, ensemble methods), and clustering	Methods and analytics
NERS 590: Methods and practice of scientific computing	Develops the necessary skills to be effective computational scientists and how to produce work that adheres to the scientific method. A broad range of topics are covered including: software engineering best practices, computer architectures, computational performance, common algorithms in engineering, solvers, software libraries for scientific computing, uncertainty quantification, and validation	Methods
EECS 584: Advanced database management systems	Advanced topics and research issues in database management systems. Distributed databases, advanced query optimization, query processing, transaction processing, data models, and architectures. Data management for emerging application areas, including bioinformatics, the internet, OLAP, and data mining. A substantial course project allows in-depth exploration of topics of interest	Methods and analytics
EECS 545: Machine learning	Introduces computer algorithms that can learn from data or past experience to predict well on the new unseen data. In the past few decades, machine learning has become a powerful tool in artificial intelligence and data mining, and it has made major impacts in many real-world applications. This course gives a graduate-level introduction of machine learning and provide foundations of machine learning, mathematical derivation and implementation of the algorithms, and their applications	Methods and analytics
EECS 453: Applied data analysis	Theory and application of matrix algorithms to signal processing, data analysis and machine learning. Theoretical topics include subspaces, eigenvalue and singular value decomposition, projection theorem, constrained, regularized, and unconstrained least squares techniques and iterative algorithms. Applications include image deblurring, ranking of webpages, image segmentation and compression, social networks, circuit analysis, recommender systems, handwritten digit recognition	Methods and analytics

of specialization and elective courses, and alternative practical experiences (e.g., mentored lab rotations, internships, apprentice shadowing, hands-on capstone projects, etc.).

Table 3 outlines some hypothetical curriculum plans that may be customized and adopted in various quantitative graduate health science and analytical programs. The longitudinal flow (columns) and thematic variability (rows) are neither complete, not exhaustive, or mandatory.

Expected Competencies

In addition to their core area of specialization, graduating doctoral students should be expected to have moderate modeling,

TABLE 3 | Examples of hypothetical broad-scope 5-year program plans by specialization.

Broad thematic specializations	Common curricula, e.g., rotations, scientific rigor, reproducibility, and ethics	Annual progression (years)				
		Yr1	Yr2	Yr3	Yr4	Yr5
Bioinformatics	Discipline-specific courses.	Data science and predictive analytics	Advanced ML/AI	Inter-professional education, Trans-disciplinary collaborations Add-on certificates Electives, specialized courses	Domain-specific AI/ML applications Computational methods, protocol development, and Cloud computing	Data-driven dissertation-topic specific research
Professional schools (e.g., medicine, nursing, pharmacy, kinesiology)		Computing, statistics, math modeling	Data science and health analytics			
Public health, biostatistics		AI/ML techniques	Clinical decision support systems			
Biomathematics		Computational biology, bioinformatics	High-throughput precision health			
Neuroscience		Computational neuroscience, neuroimaging, brain mapping	Data science and predictive analytics			

computational, and analytic competency in at least two of each of the three competency areas listed in **Table 4**.

One important point to emphasize is that in addition to the proposed quantitative outcomes of any graduate biomedical and health training program, trainees should be expected to acquire a number of complementary qualitative skills. Such abilities include transitional science expertise, behavior change adoptability, and aptitude for identification of significant findings for clinical implementation. The focus of this specific manuscript is on the quantitative part of the training, i.e., the methods and analytics curricula for health science doctoral programs; however, soft skills, human intelligence, and artistic abilities are also important (8).

CONCLUSIONS

The role of continuous self-learning is paramount in the future on-demand economy, where rapid developments and technological advances quickly render static technical skills obsolete. One of the best lessons biomedical and health science doctoral program graduates should learn is the value of sustained lifelong commitment to learning, retooling, knowledge refreshing, and dynamic skill building. This is neither easy, quick, nor necessarily intuitive; however, it is absolutely essential for a perpetually successful career. The main factors driving the need for sustained self-learning include the relentless pace of automation (55), world-wide competition and the rise of the rest (56), the growth of network-based team science (57), the unrelenting anticipation of progress and increase of human well-being over time (58, 59), and the law of diminishing returns (60). The latter asserts that as equal efforts, resources or infrastructure are provided to support an R&D activity, the resulting output from these endeavors will initially increase monotonically with the input up to a certain point, after which, adding additional resources will result in steadily and disproportional decrease where the incremental additive outcome will tend to zero (61).

In addition to the technical, methodological, and analytical skills, there are other qualitative abilities skills that all premier graduate health and biomedical programs should emphasize. As health sciences are both deep and broad in scope, consideration needs to be made to improve inter-professional training and interdisciplinary collaborations (62, 63). Ability to communicate across disciplines is vital to establish, grow and sustain team science, crowdsourcing accomplishments, and citizen scholars, which recently demonstrated forward advances (57). For instance, the Galaxy Zoo project had over 250,000 contributors (Zooites) that completed about 200 million classifications of distance images from the Sloan Digital Sky Survey (SDSS), and over 200,000 users contributed to the Foldit project aiming to quickly enhance our understanding of protein folding via a computer game platform. Active and constructive participation in transdisciplinary teams will require well-rounded background with sufficient depth in specific scientific area and ability to broadly communicate with other experts.

It is undeniable that we need to reorganize the graduate health education and biomedical research training to keep up with the exponential increase of information, the broad knowledge field interactions, and the expeditious technological advances. The broader academic community needs to respond to this digital revolution challenge by balancing the need to preserve basic science rigor at the same time strongly emphasizing transdisciplinary network team-science. As no two programs are the same and there will be enormous progress ahead, there is a need for constant community-based revisions and expansions of the advanced quantitative health science analytics curriculum. All such programs will require environment-specific implementations and the need for contributions from all stakeholders (students, instructors, funding agencies, institutional leaders, and program directors).

It is hard to predict what specific recommendations may guarantee long-term success because the two key components of innovation are *uncertainty* and *risk*. However, aversion

TABLE 4 | Expected program graduate's competencies.

Areas	Competency	Expectation	Notes
Algorithms and applications	Tools	Working knowledge of basic software tools (command-line, GUI based, or web-services)	Familiarity with statistical programming languages, e.g., R or SciKit/Python, and database querying languages, e.g., SQL or NoSQL
	Algorithms	Knowledge of core principles of scientific computing, applications programming, numerical methods, API's, algorithm complexity, and data structures	Best practices for scientific and application programming, efficient implementation of matrix linear algebra and graphics, elementary notions of computational complexity, user-friendly interfaces, string matching
	Application domain	Data analysis experience from at least one application area, either through coursework, internship, research project, etc.	Applied domain examples include: computational social sciences, health sciences, business and marketing, learning sciences, transportation sciences, engineering, and physical sciences
Data management	Data validation and visualization	Curation, Exploratory Data Analysis (EDA) and visualization	Data provenance, validation, visualization via histograms, Q-Q plots, scatterplots (ggplot, Dashboard, D3.js)
	Data wrangling	Skills for data normalization, data cleaning, data aggregation, and data harmonization and registration. Experience with R notebook or Jupyter notebook	Data imperfections include missing values, inconsistent string formatting ("2016-01-01" vs. "01/01/2016," PC/Mac/Linux time vs. timestamps, structured vs. unstructured data, ASCII vs. binary format, compression, etc.
	Data infrastructure	Handling databases, web-services, Hadoop, multi-source data	Data structures, SOAP protocols, ontologies, XML, JSON, streaming
Analysis methods	Statistical inference	Basic understanding of bias and variance, principles of (non)parametric statistical inference, and (linear) modeling	Biological variability vs. technological noise, parametric (likelihood) vs. non-parametric (rank order statistics) procedures, point vs. interval estimation, hypothesis testing, regression
	Study design and diagnostics	Design of experiments, power calculations and sample sizing, strength of evidence, *p*-values, False Discovery Rates	Multistage testing, variance normalizing transforms, histogram equalization, goodness-of-fit tests, model overfitting, model reduction
	Machine learning	Dimensionality reduction, k-nearest neighbors, random forests, AdaBoost, kernelization, SVM, ensemble methods, CNN	Empirical risk minimization. Supervised, semi-supervised, and unsupervised learning. Transfer learning, active learning, reinforcement learning, multiview learning, instance learning

to either of these would virtually guarantee colossal failures. Coordinated efforts by policy makers, funding organizations, academic institutions, graduate biomedical, and health science curriculum committees, course instructors, and trainees will be vital to meet the demand for effective, fair, and consistent progress in improving human well-being and enhancing human experiences. Foundations and scholarly work funding agencies should diversify the pool of peer reviewers, embrace risky and unconventional approaches, reduce their multilevel bureaucracy (e.g., on-demand dynamic program staff selection and proposal formatting barriers), and acknowledge serendipity in scientific discovery (64).

There is an urgent need for strong commitment from all stakeholders to increase the availability of data, access to compute resources, open-science principles, and their embedding directly into all graduate program curricula. Improving the efficiencies of data acquisition, utilization of rich and diverse computational protocols, and research ethics training should augment the core program coursework. These burdens fall primarily on non-student stakeholders, e.g., instructors, advisors, curriculum committees, institutional administration, state and federal regulators, and policymakers. Careful planning and thoughtful implementation would be critical to avoid extreme and unreasonable policies, limit the unexpected consequences, and reduce unconstructive overregulation.

It is important to point out that curriculum design and its effective implementation are two separate aspects of equal importance. Deficiencies in either of these will strongly impact the final program and potentially lead to very different outcomes. The success of any graduate academic program redesign depends on many different factors including (1) the specific curriculum design plan, (2) sustained faculty engagement, (3) long-term financial support, (4) strong institutional backing, (5) appropriate trainee prescreening and selection, and (6) organizational infrastructure. It is impossible to make specific recommendations on the required levels of commitment for each of these vital components to "guarantee" successful launch and sustained programmatic triumph. Neither financial backing, infrastructure, expertise, or organization environment is by itself necessary or sufficient for establishing a successful program. The exact blend of these factors that leads to an exceptional quantitative graduate health science methods-and-analytics program will vary. In some institutions, funding may be more important than infrastructure. In others, existence of appropriate computational services or reliable lab equipment may be more influential than candidate prescreening. However, strengths in more than one of these six factors would certainly increase the likelihood of a successful and lasting curricula implementation. Finally, the role of the program teaching, research, and practice faculty, along with their continuing

(re)training, strategic recruitment, cultivation, and retention cannot be overestimated.

Federal, state and local public officials should enact egalitarian policies that stimulate research, innovation, development, and productization without compromising individual privacy, research ethics, or sensitive information. The academic institutions that embrace diverse financial endowments, without compromising impartiality, and implement strategies to democratize transdisciplinary collaborations will likely reap substantial benefits and chart the course forward. Individual instructors should adapt open-science principles in their courses, collaborate and share with others their learning modules, source materials, and champion direct connections to other courses, disciplines, techniques, or learning resources. Last but certainly not least, trainees represent the focal point and the future of the effort to enhance the capability and capacity of the biomedical and health workforce. Graduating students should realize that the era of the 9-to-5, long-term job-security, repetitive occupations, and stagnant knowledge career paths ended as the twentieth-century came to a close. Top graduate biomedical and health educational institutions will provide the fundamentals and train scholars how to self-learn, utilize Cloud-knowledge resources, and expand their know-how. The rest is up to individual researchers, their close scholarly networks, and the administrative staff that manages research, development, and translation activities. The lead article in a recent issue of the Economist, "Doctor You: How Data will transform Health Care" (65), predicts an upcoming health care digital revolution that will empower patients, improve diagnosis, lower costs, and introduce apps as alternatives to conventional drugs. However, this sea change is only possible when networks of well-trained researchers jointly design, implement, support, and continuously expand advanced clinical decision support systems.

The stakes of failing to restructure doctoral biomedical and health science education are high for two reasons. The first corresponds to failure of raising a cadre of computationally skilled and data-literate researchers to support the innovation backbone of future healthcare and biomedical discoveries. Second, there will be a very substantial loss-of-opportunity cost associated with lack of appreciation for the urgent need to change quantitative graduate biomedical education. In 1746, in his "Golden Rules" for "Young Tradesman," Benjamin Franklin wrote that "time is money" (66), referring to idleness as a direct loss. The analog for this eighteenth century work-lethargy loss of revenue, translates in the twenty first century as a societal deficit of equitable, effective, and progressive human health experiences, due to vegetative investment of resources or lackadaisical education vision. The golden rule for the future young biomedical and health science scholars may be "time is life."

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The author confirms being the sole contributor of this work and has approved it for publication.

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REFERENCES

1. Kreps GL, Maibach EW. Transdisciplinary science: the nexus between communication and public health. *J Commun*. (2008) 58:732–48. doi: 10.1111/j.1460-2466.2008.00411.x
2. Boyack KW, Klavans R, Börner K. Mapping the backbone of science. *Scientometrics*. (2005) 64:351–74. doi: 10.1007/s11192-005-0255-6
3. Pfau M, Epistemological and disciplinary intersections. *J Commun*. (2008). 58:597–602. doi: 10.1111/j.1460-2466.2008.00414.x
4. Korazim-Kőrösy Y, Mizrahi T, Bayne-Smith M, García ML. Professional determinants in community collaborations: interdisciplinary comparative perspectives on roles and experiences among six disciplines. *J Commun Pract*. (2014) 22:229–55. doi: 10.1080/10705422.2014.901267
5. Albert M, Paradis E, Kuper A. Interdisciplinary promises versus practices in medicine: the decoupled experiences of social sciences and humanities scholars. *Soc Sci Med*. (2015) 126:17–25. doi: 10.1016/j.socscimed.2014.12.004
6. Davies R, Trowsdale J. The value of instability: lessons from reviewing how and why creativity and the arts might interact with STEM education. *Eur J Curric Stud*. (2017) 4:584–600. Available online at: http://clok.uclan.ac.uk/21342
7. Leek JT, Jager LR. Is most published research really false? *Annu Rev Stat Appl*. (2017) 4:109–22. doi: 10.1101/050575
8. Dinov ID. Quant data science meets dexterous artistry. *Int J Data Sci Anal*. (2019) 7:81–6. doi: 10.1007/s41060-018-0138-6
9. Dinov ID. Volume and value of big healthcare data. *J Med Stat Inform*. (2016) 4:1–7. doi: 10.7243/2053-7662-4-3
10. Dinov I, Heavner B, Tang M, Glusman G, Chard K, Darcy M, Madduri R, et al. Predictive big data analytics: a study of parkinson's disease using large, complex, heterogeneous, incongruent, multi-source and incomplete observations. *PLoS ONE*. (2016) 1:e0157077. doi: 10.1371/journal.pone.0157077
11. Amirian P, van Loggerenberg F, Lang T, editors. *Data Science and Analytics*. In: *Big Data in Healthcare*. Cham: Springer (2017). p. 15–37. doi: 10.1007/978-3-319-62990-2_2
12. Dinov I. *Data Science and Predictive Analytics: Biomedical and Health Applications using R. Computer Science*. Cham: Springer International Publishing (2018). 800 p. doi: 10.1007/978-3-319-72347-1
13. Henly SJ, McCarthy DO, Wyman JF, Heitkemper MM, Redeker NS, Titler MG, et al. Emerging areas of science: recommendations for nursing science education from the council for the advancement of nursing science idea festival. *Nurs Outlook*. (2015) 63:398–407. doi: 10.1016/j.outlook.2015.04.007
14. Held ML, Mallory KC, Cummings S. Preparing social work students for integrated health care: results from a national study. *J Soc Work Educ*. (2017) 53:435–48. doi: 10.1080/10437797.2016.1269707

15. Bangasser DA, Rozensky RH, Fowler GA, Kraha A, Lopez AA, O'Connor M, et al. Psychology's core knowledge, scientific subfields, and health service specialization: preparing a competent workforce-recommendations from the Opening Doors Summit. *Train Educ Prof Psychol.* (2016) 10:84. doi: 10.1037/tep0000117
16. Fuhrmann CN, Halme DG, O'Sullivan PS, Lindstaedt B. Improving graduate education to support a branching career pipeline: recommendations based on a survey of doctoral students in the basic biomedical sciences. *CBE-Life Sci Educ*. (2011) 10:239–49. doi: 10.1187/cbe.11-02-0013
17. Pittayachawan S, Macauley P, Evans T. Revealing future research capacity from an analysis of a national database of discipline-coded Australian PhD thesis records. *J High Educ Policy Manage.* (2016) 38:562–75. doi: 10.1080/1360080X.2016.1196936
18. van Schalkwyk SC, Murdoch-Eaton D, Tekian A, van der Vleuten C, Cilliers F. The supervisor's toolkit: a framework for doctoral supervision in health professions education: AMEE Guide No. 104. *Med Teach.* (2016) 38:429–42. doi: 10.3109/0142159X.2016.1142517
19. Kim MJ, Park CG, McKenna H, Ketefian S, Park SH, Klopperet H, et al. Quality of nursing doctoral education in seven countries: survey of faculty and students/graduates. *J Adv Nurs.* (2015) 71:1098–109. doi: 10.1111/jan.12606
20. Rahbar MH, Dickerson AS, Ahn C, Carter RE, Hessabi M, Lindsell CJ, et al. Characteristics of biostatistics, epidemiology, and research design programs in institutions with clinical and translational science awards. *Acad Med.* (2017) 92:229–36. doi: 10.1097/ACM.0000000000001350
21. Sarkar IN. Biomedical informatics and translational medicine. *J Transl Med*. (2010) 8:22. doi: 10.1186/1479-5876-8-22
22. Sinche MV. *Next Gen PhD*. Cambridge: Harvard University Press (2016). doi: 10.4159/9780674974791
23. Kienholz ML, Crowleyet RS, Bergal JM, Levine AS. Transformative changes to embrace, manage, and exploit "Big Data" in: Wartman SA, editor. *The Transformation of Academic Health Centers*. Boston, MA: Elsevier (2015). p. 159–68. doi: 10.1016/B978-0-12-800762-4.00016-5
24. Treinish LA. *Scientific Data Models for Large-Scale Applications*. New York, NY: IBM TJ Watson Research Center (2004).
25. Poornima S, Pushpalatha M. A journey from big data towards prescriptive analytics. *ARPN J Eng Appl Sci.* (2006) 11. Available online at: http://www.arpnjournals.org/jeas/research_papers/rp_2016/jeas_1016_5099.pdf
26. Nunes MB. Understanding big data for industrial innovation and design: the missing information systems perspective. *J Data Inform Sci.* (2009) 2:1–6. doi: 10.1515/jdis-2017-0017
27. Dinov I. Methodological challenges and analytic opportunities for modeling and interpreting big healthcare data. *GigaScience*. (2016) 5:1–15. doi: 10.1186/s13742-016-0117-6
28. Zhou Y, Zhao L, Zhou N, Zhao Y, Marino S, Wang T, et al. Predictive big data analytics using the UK biobank data. *Sci Rep*. (2019) 9:6012. doi: 10.1038/s41598-019-41634-y
29. Sudlow C, Gallacher J, Allen N, Beral V, Burton P, Danesh J, et al. UK biobank: an open access resource for identifying the causes of a wide range of complex diseases of middle and old age. *PLoS Med*. (2015) 12:e1001779. doi: 10.1371/journal.pmed.1001779
30. Biobank U. *UK Biobank: Protocol For A Large-Scale Prospective Epidemiological Resource*. Cheshire: UK Biobank Coordinating Centre (2007).
31. Sporns O. The human connectome: origins and challenges. *Neuroimage*. (2013) 80:53–61. doi: 10.1016/j.neuroimage.2013.03.023
32. Van Essen DC, Ugurbil K, Auerbach E, Barch D, Behrens TE, Bucholz R, et al. The human connectome project: a data acquisition perspective. *Neuroimage*. (2012) 62:2222–31. doi: 10.1016/j.neuroimage.2012.02.018
33. Jack CR, Bernstein MA, Fox NC, Thompson P, Alexander G, Harvey D, et al. The Alzheimer's disease neuroimaging initiative (ADNI): MRI methods. *J Magn Reson Imaging.* (2008) 27:685–91. doi: 10.1002/jmri.21049
34. Moon S, Dinov ID, Kim J, Zamanyan A, Hobel S, Thompson PM, et al. Structural neuroimaging genetics interactions in Alzheimer's disease. *J Alzheimers Dis.* (2015). 48:1051–63. doi: 10.3233/JAD-150335
35. Mason KE, Pearce N, Cummins S. Associations between fast food and physical activity environments and adiposity in mid-life: cross-sectional, observational evidence from UK Biobank. *Lancet Public Health*. (2018) 3:e24–33. doi: 10.1016/S2468-2667(17)30212-8
36. Van Essen DC, Smith SM, Barch DM, Behrens TE, Yacoub E, Ugurbil K, et al. The WU-minn human connectome project: an overview. *NeuroImage*. (2013) 80:62–79. doi: 10.1016/j.neuroimage.2013.05.041
37. Smith SM, Nichols TE. Statistical challenges in "big data" human neuroimaging. *Neuron*. (2018) 97:263–8. doi: 10.1016/j.neuron.2017.12.018
38. Cook S, Conrad C, Fowlkes AL, Mohebbi MH. Assessing google flu trends performance in the United States during the 2009 influenza virus A (H1N1) Pandemic. *PLOS ONE*. (2011) 6:e23610. doi: 10.1371/journal.pone.0023610
39. Lazer D, Kennedy R, King G, Vespignani A. The parable of Google Flu: traps in big data analysis. *Science*. (2014) 343:1203–5. doi: 10.1126/science.1248506
40. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. *Nat Med*. (2019) 25:44–56. doi: 10.1038/s41591-018-0300-7
41. Madhukar NS, Khade PK, Huang L, Gayvert K, Galletti G, Stogniew M, et al. A new big-data paradigm for target identification and drug discovery. *bioRxiv*. (2017) 134973. doi: 10.1101/134973
42. Katsis Y, Balac N, Chapman D, Kapoor M, Block J, Griswoldet WG, et al. Big data techniques for public health: a case study. In: *2017 IEEE/ACM International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE)*. Washington, DC (2017).
43. Kruskal JB, Berkowitz S, Geis JR, Kim W, Nagy P, Dreyeret K, et al. Big data and machine learning-strategies for driving this bus: a summary of the 2016 intersociety summer conference. *J Am Coll Radiol.* (2017) 14:811–7. doi: 10.1016/j.jacr.2017.02.019
44. Chang V. Computational intelligence for medical imaging simulations. *J Med Syst.* (2018). 42:10. doi: 10.1007/s10916-017-0861-x
45. Farahani B, Firouzi F, Chang V, Badaroglu M, Constant N, Mankodiyaet K, et al. Towards fog-driven IoT eHealth: promises and challenges of IoT in medicine and healthcare. *Future Gener Comput Syst.* (2018) 78:659–76. doi: 10.1016/j.future.2017.04.036
46. Rudy SH, Brunton SL, Proctor JL, Kutzet JN. Data-driven discovery of partial differential equations. *Sci Adv*. (2017) 3:e1602614. doi: 10.1126/sciadv.1602614
47. Kahn MG, Callahan TJ, Barnard J, Bauck AE, Brown J, Davidson BN, et al. A harmonized data quality assessment terminology and framework for the secondary use of electronic health record data. *Egems*. (2016) 4:1244. doi: 10.13063/2327-9214.1244
48. Sahoo SS, Nguyen V, Bodenreider O, Parikh P, Minning T, Sheth AP, et al. A unified framework for managing provenance information in translational research. *BMC Bioinformatics*. (2011) 12:1. doi: 10.1186/1471-2105-12-461
49. Dinov I, Lozev K, Petrosyan P, Liu Z, Eggert P, Pierce J, et al. Neuroimaging study designs, computational analyses and data provenance using the LONI pipeline. *PLoS ONE*. (2010) 5:e13070. doi: 10.1371/journal.pone.0013070
50. Tonekaboni S, Joshi S, McCradden MD, Goldenberg A. What clinicians want: contextualizing explainable machine learning for clinical end use. *arXiv:1905.05134* (2019). Available online at: https://arxiv.org/abs/1905.05134
51. Walliman N. *Research Methods: the Basics*. Oxon: Routledge (2017).
52. Abouelmehdi K, Beni-Hessane A, Khaloufi H. Big healthcare data: preserving security and privacy. *J Big Data*. (2018) 5:1. doi: 10.1186/s40537-017-0110-7
53. Atasoy H, Greenwood BN, McCullough JS. The digitization of patient care: a review of the effects of electronic health records on health care quality and utilization. *Annu Rev Public Health*. (2019) 40:487–500. doi: 10.1146/annurev-publhealth-040218-044206
54. Theobald S, Brandes N, Gyapong M, El-Saharty S, Proctor E, Diaz T, et al. Implementation research: new imperatives and opportunities in global health. *Lancet*. (2018) 392:2214–28. doi: 10.1016/S0140-6736(18)32205-0
55. Rotman D. *The Relentless Pace of Automation.* MIT Technology Review (2017). Retreived from https://www.technologyreview.com/s/603465/the-relentless-pace-ofautomation (accessed February 2, 2020).
56. Zakaria F. The rise of the rest. *Newsweek*. (2008) 12:24–31. Available online at: https://www.jstor.org/stable/20032649
57. Franzoni C, Sauermann H. Crowd science: the organization of scientific research in open collaborative projects. *Res Policy*. (2014) 43:1–20. doi: 10.1016/j.respol.2013.07.005
58. Lange M. *Stanford Encyclopedia of Philosophy: Progress*. (2011). Available online at: http://plato.stanford.edu/archives/spr2011/entries/progress (accessed February 2, 2020).
59. Blackmar FW. *The Story of Human Progress*, Blackmar FW, editor. Leavenworth, WA: Press of Ketcheson & Reeves (1896).

60. Brue SL. Retrospectives: the law of diminishing returns. *J Econ Perspect*. (1993) 7:185–92. doi: 10.1257/jep.7.3.185
61. Shephard RW, Färe R. The law of diminishing returns. *Zeitschrift für Nationalökonomie*. (1974) 34:69–90. doi: 10.1007/BF01289147
62. Murphy JE, Liles AM, Bingham AL, Chamberlin KW, Dang DK, Hill LG, et al. Interprofessional education: principles and application. An update from the american college of clinical pharmacy. *J Am Coll Clin Pharm*. (2019) 1:e17–e28. doi: 10.1002/jac5.1025
63. Black EW, Blue AV, Davidson R, McCormack WT. Using team-based learning in a large interprofessional health science education experience. *J Inter Prof Educ Pract*. (2016) 5:19–22. doi: 10.1016/j.xjep.2016.09.002
64. Dinov I. Flipping the grant application review process. *Stud High Educ*. (2019) 1:1–9. doi: 10.1080/03075079.2019.1628201
65. Beddoes S. Doctor you: how data will transform health care. *Economist*. (2018) 426:9–10. Available online at: https://www.economist.com/news/leaders/21736138-welcome-doctor-you-revolution-health-care-coming
66. Franklin B. *Advice to a Young Tradesman*. Dublin (1820).

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The University of California San Francisco (UCSF) Training Program in Implementation Science: Program Experiences and Outcomes

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Purpose: We evaluated outcomes of trainees who have completed the Certificate program in Implementation Science at the University of California San Francisco.

Methods: All students who completed the in-person Certificate Program between 2008 and 2015 ($n = 71$), or the online Certificate Program between 2016 and 2017 ($n = 13$), were eligible for our study. We assessed the potential impact of the Certificate Program on the professional development of trainees, through participant surveys on their self-reported level of comfort with pre-defined competencies, and on academic productivity.

Results: Of eligible trainees, 54 in-person (77%) and 13 online (100%) Certificate Program participants completed surveys. In-person trainees reported a total of 147 implementation science-related publications in peer-reviewed journals (median 3 publications/trainee, IQR 1–15). Thirty-four trainees (63%) reported being a Principal Investigator (PI) of 64 funded implementation science-related grants (median 2 grants/trainee, IQR 1–4). Fifteen percent (15%, $n = 8$) of participants reported receiving an NIH grant on which they were the PI, including R01 or P01 level funding ($n = 4$, 7%) and K awards ($n = 3$, 6%). Both in-person and online trainees reported median high to moderate confidence for all 12 competencies assessed. Confidence waned in skills aligning with later stages of implementation research for all trainees.

Conclusion: The moderate to high confidence in all competencies assessed and reported high level of academic productivity support the benefits of intensive, graduate-level training focused on applied methods to support career development of implementation scientists.

Keywords: implementation science training, research education, implementation science competencies, curriculum evaluation, on-line education

CONTRIBUTIONS TO THE LITERATURE

- Methodological approach to evaluating implementation science training programs.
- Analysis and data interpretation that demonstrates the feasibility of an implementation science training program in achieving core competencies as measured by productivity and self-reported proficiency.
- Demonstration of the feasibility of online and in-person platforms for delivering high quality implementation science training that integrates didactics with longitudinal mentorship and project-based learning.

INTRODUCTION

Despite the growing body of research and evidence-based guidelines, there is still a significant lag in translating research into practice. Implementation science (ImS), the study of the methods used to design, implement, and evaluate strategies to increase uptake of evidence-based interventions, has never been more relevant (1). Researchers and policymakers around the world increasingly recognize the need for frameworks, theories, or models to design and evaluate interventions that address programmatic performance gaps in context-specific ways (2). Research funding agencies are now more often requiring frameworks, theories or models in grant proposals, and non-academic stakeholders involved in process planning and evidence translation are also using these tools (3). For these reasons, it is essential to ensure that physicians, researchers, public health practitioners, and others working to translate evidence into practice are trained in implementation science.

The field of implementation science has had its own "performance gaps" related to the availability of resources and training programs to acquire relevant knowledge and skills (4). To address these gaps, several types of programs have been developed that offer training in a variety of formats: degree granting programs, stand-alone certificate programs, short course mentored immersion programs, and workshops. Apart from our own University of California San Francisco (UCSF) Implementation Science Training Program (5), several other programs are affiliated and administered through academic institutions (6–8). Of these, several offer a multi-year, non-degree conferring fellowship experience to students that often includes longitudinal mentorship (6), while others use a shorter 1, 2 day workshop format as an introduction to the implementation science as a field of study (7). Additional training programs, such as the National Institutes of Health Training Institute for Dissemination and Implementation Research in Health (TIDIRH) (9, 10), have been developed and administered through national institutes, often in collaboration with multiple academic centers. These institutes have resulted from national prioritization of support for dissemination and implementation research and increase in funding mechanisms for implementation science proposals. TIDIRH and similar training programs are centered around core-competencies that reflect training priorities in implementation science (11, 12). The majority of implementation science training programs are offered in a short-course format (e.g., summer institute or 1, 2 week intensive course) and integrate a "practical" or project-based experience linked to close mentorship as part of their core curricula (13). While some of the shorter course programs are described as having led to additional training modules and potentially degree conferring curricula, the progress and results have not yet been published in the literature (7). While we focused here on programs with descriptions or outcomes published in the peer-reviewed literature, a more comprehensive list of training programs is available on the Society for Implementation Research Collaboration website (14).

We developed the UCSF Implementation Science Certificate program in 2008 to provide trainees with knowledge, skills and experience in applying implementation science methods. We have focused on developing a curriculum around competencies in implementation science processes rather than specific frameworks or theories. Frameworks are later introduced as tools to help facilitate the process of community engagement, intervention design, intervention evaluation, and policy translation (**Figure 1**). We have previously described the conceptual framework of this training program, which focused on three core principles: (1) behavior change among individuals and health care systems is fundamental to effectively translating evidence into practice; (2) engaging with a wide range of individuals and stakeholder organizations is essential for achieving effective and sustainable change; and (3) implementation and dissemination must be iterative and dynamic (5). These principles highlight that evidence is consumed by inter-related groups of stakeholders, delivery systems, and individuals.

The six, 10 week (equivalent to an academic quarter) long courses in the program focus on how to align priorities among and between players in these three domains and how to address barriers within each domain in order to successfully translate evidence into practice and ultimately into improved health (**Figure 1**). **Table 1** describes the six courses mapped to the key training domains and competencies that were included in the design of the program. The original training program was delivered in an in-person format either as a track within the UCSF Master's in Clinical Research (TICR) program or as a stand-alone Implementation Science Certificate Program. In 2016, we introduced an online format for the 6 courses to make both the courses and Certificate Program available to a wider audience within and outside the United States. Both the in-person and online courses (**Appendix Table**) are centered around didactics to convey key course content. In addition, each course uses learner-selected, project-based assignments to facilitate the learner's skill development and build personal research projects

Abbreviations: AHRQ, Agency for Healthcare Research and Quality; CI, Confidence Interval; HRSA, Health Resources and Services Administration; ImS, Implementation Science; IQR, Interquartile Range; NIH, National Institutes of Health; NIMH, National Institute of Mental Health; PCORI, Patient Centered Outcomes Research Institute; PI, Principal Investigator; TICR, Training in Clinical Research; TIDIRH, Training Institute for Dissemination and Implementation Research in Health; UCSF, University of California San Francisco; USAID, United States Agency for International Development; VA, Veteran's Administration.

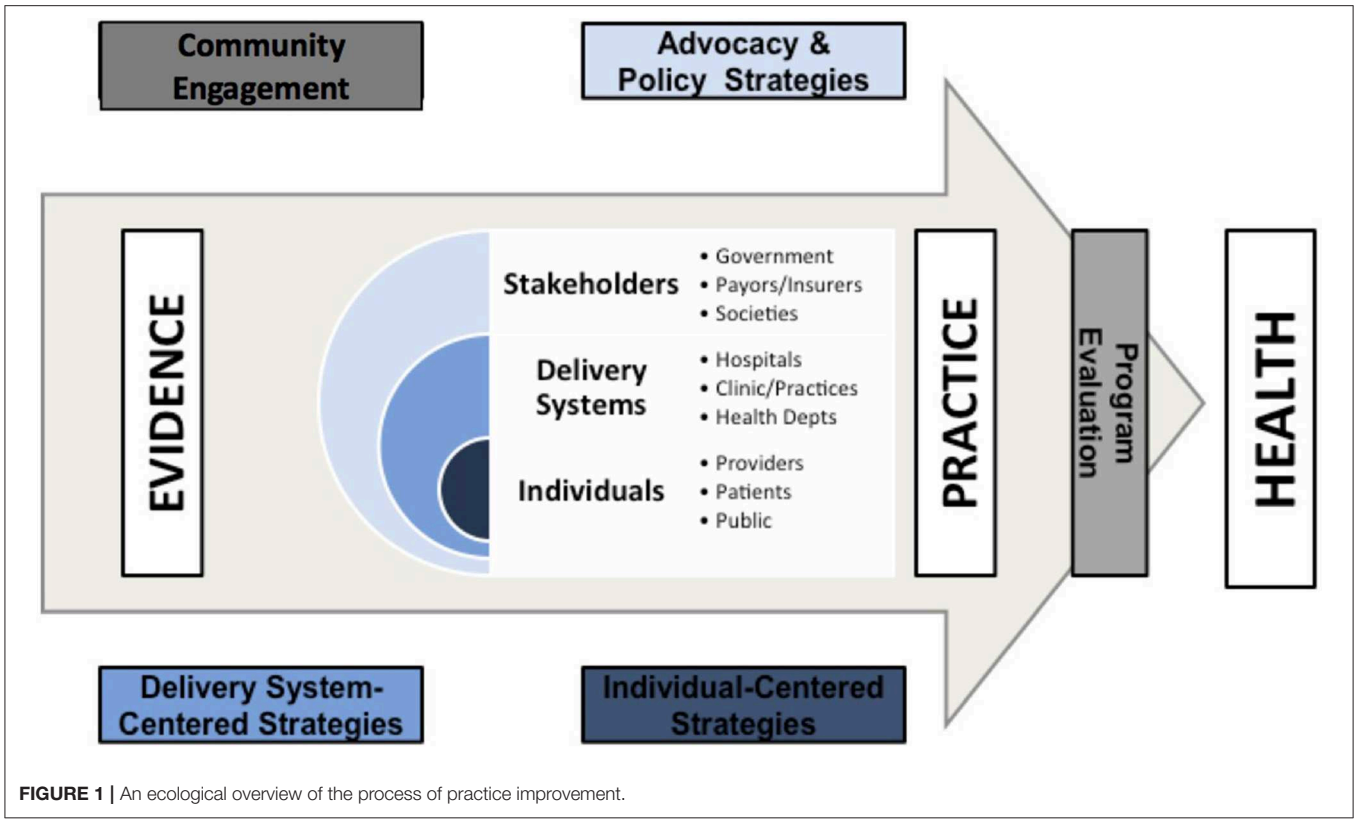

FIGURE 1 | An ecological overview of the process of practice improvement.

through the assignments, and the program provides longitudinal faculty-level mentorship for trainees enrolled in implementation science courses no matter their overall track. Implementation Science Certificate courses are credit- bearing and require tuition, paid through either a larger program of study such as the Masters in Clinical Research, through tuition for other graduate programs at UCSF, through participant grants, or through out of pocket payment. Our Certificate program provides a very "high touch" approach to implementation science training in which learners receive feedback from course faculty on a weekly basis on the application of concepts taught to their own projects. Most courses are taught by lead faculty in collaboration with 2–6 additional faculty as co-Instructors or small group facilitators. Each course anchors assignments to a longitudinal project that each learner come up with independently. This allows learners to apply newly-learned methods and skills to improve and develop their own projects.

Here, we sought to assess feasibility of our mutli-faceted implementation science training program by reviewing outcomes of trainees who have completed (1) the in-person UCSF Master's in Clinical Research Implementation Science Track; (2) the UCSF in-person Implementation Science Certificate Program; or (3) the UCSF online Implementation Science Certificate Program as of 2017. We focus on productivity in implementation science-related activities for the in-person Masters track and Certificate Program participants, and comfort level with implementation science-related competencies for all participants.

METHODS

Participants

Eligible participants included all students who completed 4 or more courses in the in-person Masters in Clinical Research Implementation Science Track or Implementation Science Certificate Program between 2008 and 2015, or the online Implementation Science Certificate Program in 2016–2017. An introductory course and a course on community engagement were required by all participants in the certificate program, while other certificate requirements could be filled by any of the courses available. Individuals who took a la carte courses but completed fewer than the 4 required to receive a certificate were excluded.

Procedures

In order to assess the potential impact of the training program on professional development, we conducted a cross-sectional study that surveyed participants on their self-reported competency with core components of implementation science training and on academic productivity.

Competency Questionnaire

We sent online surveys assessing comfort with implementation science competencies across 12 domains (see **Additional Files**) to all participants who completed either the Certificate Program regardless of mode of instruction (on-line or in-person). The competencies assessed were those identified using a Delphi process as key skills required for implementation science practitioners when developing our training program (5).

TABLE 1 | Revised domains and competencies for implementation sciences (ImS) training programs, with examples of relevant activities and courses offered by the training in clinical research program (TICR) at the University of California, San Francisco, 2011–2012.

Domain	Competency	Relevant activities	Relevant courses
Team Science	1. Develop a collaborative, multidisciplinary team that shares a common language, and promotes a transdisciplinary blending of disciplines. 2. Engage in collaborative writing, including the production of grants and manuscripts that meet the unique needs of sponsors of implementation and dissemination sciences.	- Small-group, multidisciplinary works in progress seminars - Grant applications and manuscript submissions - Mock study sections	Introduction to Implementation Science Theory and Design Designing Interventions to Change Organizational Behavior Community-Engaged Research Designing Individual-Level Implementation Strategies Translating Evidence into Policy Grant Writing Course (seminar)
Context Identification	3. Determine the range of factors—behavioral, social, ethical, institutional, political, economic, historical—that inform the research question, and design structure	- Small-group, multidisciplinary works-in-progress seminars - Field internship program - Multidisciplinary faculty mentorship	Community-Engaged Research Designing Individual-Level Implementation Strategies Designing Interventions to Change Organizational Behavior
Literature identification and assessment	4. Identify relevant theory, evidence, methods, ● and perspectives outside the clinical domain of the research program.	- Literature search and retrieval skills	All Clinical Research courses (TICR) available teach literature search skills All Implementation Science Courses
Community engagement	5. Build relationships with community members ● and community-based organizations, in order to engage multiple perspectives on the problem	- Field internship program - Individual research and implementation projects	Community-Engaged Research Translating Evidence into Policy
Intervention design and research implementation	6. Integrate diverse disciplinary, stakeholder and community perspectives into a cogent intervention design and/or implementation and dissemination strategy. 7. Utilize a comprehensive implementation framework to guide the integration of theory with specific intervention, evaluation, and dissemination activities	- Small-group, multidisciplinary works-in-progress seminars. - Biostatistical consultations	Introduction to Implementation Science Theory and Design Designing Individual-Level Implementation Strategies Designing Interventions to Change Organizational Behavior
Evaluation of effect of translational activity	8. Employ epidemiological methods in study designs, program evaluations and causal inference. 9. Gain facility with qualitative and quasi-experimental designs to plan, implement, and evaluate interventions and policy impact. 10. Determine and measure processes and outcomes that support iterative cycles of implementation and bidirectional flow of information.	- Epidemiology courses - Biostatistics courses (including quasi-experimental designs)	Translating Evidence into Policy Program Evaluation in Clinical and Public Health Settings
Behavioral change communication strategies	11. Disseminate research/program results to relevant stakeholders and communities in a manner that maximizes their influence and sustainability outside of the research paradigm 12. Ability to articulate Implementation Science as an innovative approach to clinical and community-based research.	- Field internship program	- Translating Evidence into Policy - Designing Individual-Level Implementation Strategies

Academic Productivity

Additionally, we sent online surveys assessing demographics and academic productivity to all participants. Program faculty contacted non-respondents once via email to encourage survey completion. Questions regarding academic productivity survey was limited to in-person students who completed the in-person Certificate Program because the online program only began in 2016–2017 (participants would not have had time to submit manuscripts or grant proposals and receive notice of outcome between completion of the training in mid 2017 and the time of the surveys in late 2017).

Measures

Competency was assessed using a questionnaire (see Online Supplement) that requested participants to rate their confidence in 12 implementation science-related competencies that represented the goals of the UCSF Implementation Science Training Program (5), with responses following a Likert scale

ranging from 1 (No Confidence) to 5 (Total Confidence). The questionnaire also had space for participants to clarify reasons behind their self-reported competency ratings. Included competencies were: developing a multi-disciplinary team for ImS-related research; collaborative writing for grants and publications; identifying multi-level influences across social, behavioral, economic, and historical spheres relevant to research topics; understanding and applying theories, evidence, and methods outside of the clinical research domain; building relationships with community members to engage in diverse perspectives on the research topic; integrate diverse perspectives into cogent intervention designs and/or implementation strategies; utilizing a comprehensive implementation framework to guide the integration of theory into interventions; applying epidemiological methods in design, evaluation, and causal inference; gaining facility in use of qualitative and quasi-experimental designs; selecting, and measuring process outcomes that can support an iterative approach to intervention design and evaluation; disseminating results in collaboration with relevant stakeholders outside of traditional research dissemination strategies; articulating implementation and dissemination sciences approaches as distinct from clinical research.

The demographic and academic productivity survey (see **Additional Files**) collected information on participant demographics (gender and race/ethnicity) and current job title and institutional affiliation. In addition, the survey asked in-person course participants to provide information on funded grants (as Principal Investigator or Co-Investigator), implementation-science related publications in peer-reviewed journals or publications in implementation science-related peer-review journals, and/or awards or honors received since completion of the Implementation Science Masters Track or Certificate Program.

Data Analysis

We described trainee characteristics, competency ratings, and productivity measures using either proportions and 95% confidence intervals (CI) or medians with inter-quartile ranges (IQR). Differences in median competency rating between in-person and online trainees were not evaluated due to small sample size of the online cohort. Qualitative data including optional comments provided by participants in the questionnaire were categorized according to competency. All surveys were created and disseminated using Survey Monkey (Survey Monkey, San Mateo CA). Data analysis was performed using Stata version 14 (Stata Corporation, College Station, TX), and Excel (Microsoft Corp, Redmond, WA).

RESULTS

Survey Participation

Of 71 eligible trainees who completed the in-person Certificate Program, 54 (77%) completed both the demographic and academic productivity survey and the post-training competency survey. Participation was similar for in-person trainees who completed the Master's in Clinical Research Implementation Science Track and the stand-alone Implementation Science Certificate Program (26/32, 81% vs. 28/39, 72%). All 13 eligible online Implementation Science Certificate Program trainees completed the demographic portion of the demographic and productivity survey and the post-training competency survey.

Demographic Characteristics

The majority (74%) of in-person trainees were female, 46% were non-Hispanic white and 40% were Asian (**Table 2**). Only 5 (9%) in-person trainees were from groups underrepresented in medicine, including 2 black or African American and 3 Hispanic trainees. The majority of in-person trainees (67%) reported their current position as academic faculty at the Assistant Professor or Associate Professor level and, as expected for an in-person program, most (78%) were currently based at UCSF. The characteristics of the online program trainees reflect a different demographic makeup of participants, with 84% being female, and 54% who identified as black or African American. Although the online trainee survey did not capture the specific job or academic title of participants, it did show that 6 (46%) had faculty appointments at the time of their ImS training, 4 (31%) were still trainees, and 2 (15%) were staff. Five (38%) of the online trainees were from outside of the US, and 5 of the 8 (63%) online trainees from the US were not based at UCSF (**Table 2**).

Productivity in Implementation Science for In-person Trainees

Trainees reported a total of 181 publications which included implementation science methods or focus areas (median 3 publications/trainee, IQR 1-15) (**Table 3**). Thirty-four trainees reported being a Principal Investigator (PI) of 64 implementation science-related grants (median 2 grants/trainee, IQR 1–4). Eight (15%) participants reported receiving an NIH grant on which they were the PI. These included R01 or P01 level funding ($n = 4$, 7%) and K awards ($n = 3$, 6%). Nine (17%) of participants were a PI of other federal grants including those administered by the Patient Centered Outcomes Research Institute (PCORI), Health Resources and Services Administration (HRSA), Veteran's Administration (VA), United States Agency for International Development (USAID), and Agency for Healthcare Research and Quality (AHRQ). Of the 34 participants who were a PI on implementation science-related grants, 19 (56%) reported successfully competing for 2 or more awards. Additionally, 20 trainees reported being co-investigators on 38 implementation science-related grants (median 1 grant/trainee, IQR 1–4) (**Table 3**).

Self-Reported Confidence With Implementation Science-Related Skills for In-person Trainees

The median level of competence was reported at 4 (high confidence) for 9 of the 12 competencies assessed, and at 3 or 3.5 (moderate confidence) for the remaining three (**Table 4**). No trainees reported having "no confidence" in any of the 12 competencies. Seven (13.5%) trainees reported having "low confidence" in Epidemiologic Methods (Competency 8). Five (9.6%) trainees reported having low confidence in the competencies for Qualitative and Quasi-experimental Designs (Competency 9) and Process and Outcome Measurement

TABLE 2 | Trainee demographics, current positions and institutions.

Characteristic	In-person trainees (*N* = 54) *N* (%)*	On-line trainees (*N* = 13) *N* (%)*
Gender		
Females	40 (74)	11 (85)
Males	14 (26)	2 (15)
Ethnicity		
Hispanic or Latino	3 (6)	1 (8)
Not Hispanic or Latino	51 (94)	12 (92)
Race		
American Indian or Alaskan Native	0	0
Asian	22 (41)	2 (15)
Black or African American	2 (4)	6 (46)
White	28 (52)	4 (31)
More than one race	2 (4)	0
Declined to answer	0 (0)	1 (8)
Education at time of ImS training		
MD	44 (82)	5 (38)
PhD	5 (9)	6 (46)
MPH, other Master's, or Bachelor's only	5 (9)	7 (54)
Current position		
Medical student	1 (2)	–
Post-doctoral fellow	7 (12)	–
Assistant professor	25 (4)	–
Associate professor	11 (2)	–
Professor	3 (5.5)	–
Clinician (non-academic)	3 (5.5)	–
Staff, lecturer or other	4 (7)	–
Institution of primary appointment		
UCSF	35 (65)	3 (23)
UCSF-affiliated delivery system	7 (13)	0
Other delivery system	3 (6)	0
US Universities other than UCSF	6 (11)	5 (38)
International	2 (3)	5 (38)
Other	1 (1)	0

**Percent may not equal 100% due to rounding.*

TABLE 3 | Academic productivity of in-person trainees (*N* = 54).

Implementation science-related publications in peer reviewed journals	*N* (%)
Total number of publications reported = 181	
None	20 (37)
1–5	26 (48)
6–10	4 (7)
11–15	3 (6)
16–40	0
>40	1 (2)
Implementation science-related grant funding	
Principal investigator	
Any ImS-related grant[a]	34 (63)
NIH ImS-related grant	8 (15)
NIH individual K award	3 (6)
NIH R03	2 (4)
NIH R21	2 (4)
NIH R01 or P01	4 (7)
Other federal ImS-related grant	9 (17)
PCORI grant	3 (6)
HRSA, VA, USAID, or AHRQ	6 (11)
UCSF intramural ImS-related grant	14 (26)
Foundation or other ImS-related grant	16 (30)
Co-investigator[b]	
Any ImS-related grant	26 (48)
NIH ImS-related grant	20 (37)
NIH R21	2 (4)
NIH R01 or PO1	6 (11)
Other federal ImS-related grant	
PCORI grant	3 (6)
HRSA,VA, USAID, or AHRQ	4 (7)
UCSF intramural ImS-related grant	4 (7)
Foundation or professional society	4 (7)

[a] *Nineteen respondents reported receipt of ≥2 grants as Principal Investigators across all mechanisms.*
[b] *Respondents could report receipt of multiple grants across all mechanisms.*

(Competency 10). No trainees reported having low confidence in any other competency.

Self-Reported Confidence With Implementation Science-Related Skills for Online Trainees

The median level of proficiency following certificate training was reported at 4 (high confidence) for 5 of the 12 competencies assessed, and at 3 or 3.5 (moderate confidence) for the remaining 7 (**Table 4**). Six trainees (46%) reported having "low confidence" in at least one competency. The number of participants who rated level of comfort as low for these competences ranged between 1 and 3, with the same individuals rating their confidence as "low" in multiple competencies: Determine Contextual Factors for Research (Competency 3) (n = 1, 8%); Theory and Perspectives (Competency 4) (n = 2, 15%); Implementation Frameworks (Competency 7) (n = 2, 15%); Epidemiologic Methods (Competency 8) (n = 2, 15%); Qualitative and Quasi-experimental Designs (Competency 9) (n = 2, 15%); Process and Outcome Measurement (Competency 10) (n = 1, 8%); Dissemination (Competency 11) (n = 2, 15%); Articulate ImS Approaches to Others (Competency 12) (n = 3, 23%).

Qualitative data from open comments in these surveys pointed to a trend toward lower confidence in some competencies due to not yet having the opportunity to apply the knowledge and skills acquired in projects. Representative comments to the open-ended question seeking additional comments about the trainee's confidence in implementation science-related competencies include:

> *"I feel that I have a lot of great knowledge learned from this certificate program, but now I need application practice in real life to increase my confidence in my abilities."*

TABLE 4 | Reported level of confidence in implementation science related competencies*.

Competency	In-person trainees (*N* = 52)	Online trainees (*N* = 13)
	Median (IQR)	Median (IQR)
1. Develop a collaborative, multidisciplinary team that shares a common language, and promotes a transdisciplinary blending of disciplines.	4 (3, 4)	4 (4, 4)
2. Engage in collaborative writing, including the production of grants and manuscripts that meet the unique needs of sponsors of implementation and dissemination sciences.	4 (3, 4)	4 (3, 4)
3. Determine the range of factors behavioral, social, ethical, institutional, political, economic, historical that inform the research question, and design structure.	4 (3, 4)	4 (3, 4)
4. Identify relevant theory, evidence, methods, and perspectives outside the clinical domain of the research program.	3 (3, 4)	4 (3, 4)
5. Build relationships with community members and community-based organizations, in order to engage multiple perspectives on the problem.	4 (3, 4)	4 (3, 5)
6. Integrate diverse disciplinary, stakeholder and community perspectives into a cogent intervention design and/or implementation and dissemination strategy.	4 (3, 4)	3 (3, 4)
7. Utilize a comprehensive implementation framework to guide the integration of theory.	4 (3, 4)	3 (3, 4)
8. Employ epidemiological methods in study designs, program evaluations, and causal inference.	3.5 (3, 4)	3 (3, 4)
9. Gain facility with qualitative and quasi-experimental designs to plan, implement, and evaluate interventions and policy impact.	4 (3, 4)	3 (3, 4)
10. Determine and measure processes and outcomes that support iterative cycles of implementation and bidirectional flow of information.	3 (3, 4)	3 (3, 4)
11. Disseminate research/program results to relevant stakeholders and communities in a manner that maximizes their influence and sustainability outside of the research paradigm.	4 (3, 4)	3 (3, 4)
12. Articulate ImS as an innovative approach to clinical and community-based research.	4 (3, 4)	3 (3, 4)

[Competencies ranked from no confidence (1) to total confidence (5)] ImS- Implementation Science.
**Medians based on data for 52 of 54 respondents for in-person trainees and 13/13 respondents for online trainees. Two in-person respondents did not complete this portion of the survey.*

> *"I have had an opportunity to gain understanding of the implementation science concepts and apply them in my day to day work and thought as I plan for my current and future research career and interests. [I] am currently providing guidance and mentorship in my region where the understanding of implementation science research is still very low."*
> *"I'm sure they will continue to grow, to the extent that my future work involves opportunities to apply them!"*

DISCUSSION

This assessment of the UCSF Implementation Science Training program demonstrates the feasibility and success of our approach of providing in-depth training along core implementation science-related competencies for biomedical and public health researchers. Trainees who completed the in-person training program report a high level of productivity and moderate to high confidence in all of the competencies assessed. While this may be related to the general culture of academic rigor and productivity at UCSF, where many in-person trainees were based, the specific nature of the productivity in terms of implementation science related papers and grants suggests an association with our training program. It is worth noting that these competencies, although developed originally in 2012 (5), share almost all core components with other educational competencies subsequently developed for dissemination and implementation research (11). These include competencies that reflect the skills and knowledge necessary for implementation-focused research, with some components being applicable to general clinical and translational research as well. Although productivity data are not yet available, a majority of trainees who completed the online training program also reported moderate to high confidence in all of the competencies assessed. These data confirm that in-depth training delivered either in-person or online can enable trainees from a wide range of backgrounds to apply core implementation science methods and skills.

There have been few evaluations of academic implementation science training programs that report productivity and skills-based competency assessments. The National Institute of Mental Health (NIMH) and Veteran's Administration (VA) co-funded Implementation Research Institute (IRI) training program has also reported high level of participant satisfaction with their curriculum. IRI is an interdisciplinary training program that provides didactic training, faculty mentoring (both local and distance), support and guidance for pilot research and grant writing through 2 2 week on-site training sessions followed by site visits and long-distance mentorship. Fellows in the program are established PhD or MD investigators in mental health with an interest in implementation science. The 31 participants in 3 cohorts surveyed have received 52 funded awards in implementation science and authored 208 publications (15). While these data may reflect the already advanced nature of this cohort, a subsequent study using social network analysis done 5 years later by IRI showed that continued longitudinal mentorship established by the training program

resulted in long-term impact in scientific productivity, including significantly more grant submissions, and publications (13). Results from an evaluation of the Mentored Training for Dissemination and Implementation Research in Cancer (MT-DIRC), based out of Washington University St. Louis, showed significantly improved implementation science skills as reported by trainees at 6 and 18 months post-training aligned to 43 competencies (16). MT-DIRC trains fellows and experienced investigators (junior to mid-level faculty) who are pivoting toward implementation science methods through an intensive 5 day course paired with longitudinal mentorship. Significant training is also available to improve mentorship for mentors in the program. The results of our evaluation of the UCSF Implementation Science Training Program parallel the results of these programs, especially those linked to high-quality longitudinal mentorship which is a hallmark of our program as well. Chambers and colleagues point out in their mapping of dissemination and implementation training needs, the effect of longitudinal mentorship on successful training depends in part of the experience of the learner, the goals of the training program, and the infrastructure to support research locally (17). While mentorship seems to be a unifying characteristics of successful training programs, one challenge in the field has been comparing programs that have been evaluated based on differing outcomes; not all evaluation studies report on the same or even similar productivity and competency outcomes those developed and used in our training program. Our program links mentorship, didactics and project-based learning to competencies, providing directed learning over longer periods of time.

The productivity of our graduates in a short amount of time is a testament to the overall effectiveness of our program in training implementation science researchers. However, our evaluation revealed some areas for improvement that other training programs may also be able to learn from. Competencies for which the majority of trainees reported low or low-moderate confidence were related to later stages of implementation research. For example, the competency related to Qualitative and Quasi-experimental Designs (Competency 9) and Process and Outcome Measurement (Competency 10) fall within the training domain, "Evaluation of effect of translational activity." We suspect this result is in part because most trainees were at an early stage of their career and were still in the process of developing interventions rather than conducting intervention evaluations. Nonetheless, these data point to the need for further training in study designs and measures for conducting evaluation of implementation interventions in real-world settings. In addition, self-rated competency was generally lower for online trainees. Potential reasons include that less time had passed, on average, between completion of the training and the competency assessment and that a higher proportion of online trainees were at an earlier stage of their career. Nonetheless, we are considering various methods to increase live contact between course faculty and online trainees to provide additional support (18). We have also developed courses that focus on these topics which launched this in Spring 2019.

Our results suggest that a hybrid model that combines didactics with focused, project based assignments and longitudinal mentorship is a successful model for implementation science training. Our results demonstrate the feasibility of both in-person and online training platforms for research training. Both training platforms effectively enhanced competency of learners in implementation science skills. This finding parallels other comparisons of online vs. in-person trainings (19, 20), in which the competency and skills delivered over the short- to medium term are approximately the same between modes of delivery. The longitudinal distance mentorship in our training program likely offset typical critiques of lack of personal interaction within online platforms. To adapt our in-person to an online program, didactics were video-recorded and available on our learning platform. All in-person content is available to online students, and assignments, were identical. We cultivated participant interaction through online small group sessions ("sync" sessions), moderated by faculty discussants who work with the same group of students through the semester. Finally, both in-person and online participants benefited from the availability of real-time discussion boards to facilitate knowledge sharing. These characteristics are particularly well-suited for implementation science training for early career investigators and seasoned academics who are pivoting their research portfolios (17).

In addition, as demonstrated by the diverse demographic of our online cohort as compared to our in-person cohorts, online training has a broader reach. Over 50% of our online trainees identified as Black African or African American compared to only 4% in our in-person program. This reflects high levels of enrolment from researchers in sub-Saharan African and students within our Research in Implementation Science for Equity program, which is a sponsored ImS training program for underrepresented in medicine (URM) junior faculty from all over to complete ImS training.

There are a few limitations of our program evaluation thus far. First, the sample size of participants surveyed is small overall, particularly for online trainees, making comparisons between online, and in-person cohorts difficult to interpret. Our online program is the newest addition to our training platform and, as should be a part of any continued program evaluation, we plan on further assessment of competencies and productivity as additional online trainees complete the Certificate Program. Second, a more in-depth qualitative assessment could have enabled identification of additional strengths and weaknesses, including reasons for low ratings by some trainees for some of the competencies. Further research is needed to determine whether short, intensive training programs alone, with or without follow-up longitudinal components, can achieve similar results, and whether there is significant variation in productivity and competency that arise as a result of different instructional platforms among different trainee populations. Finally, it is possible that our results on productivity or competency for in-person trainees may be skewed because of the non-response rate, if all non-responders were less productive with grant applications or publications. However, we had over 75% response rate, making such a bias unlikely.

In summary, this evaluation of our training program has validated the feasibility of our approach to competency-based implementation science training. Although it requires a significant time commitment from both faculty and trainees, the results of our "high-touch" program in terms of self-rated competence and academic productivity suggest that our approach is successful at developing implementation science researchers. Our program has the added benefit of mentorship aligned along core competencies through each course that focuses on project-based learning as a way to enhance sustainable scholarly productivity in implementation science.

CONCLUSIONS

Academic implementation science training through an intensive, graduate-level program can generate competent, productive implementation science researchers. A longitudinal training program using applied methods to support career development of implementation scientists can be delivered effectively in both an in-person and online learning format.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed in this study are not publicly available due to the personal nature of demographic and identifying information from course participants surveyed as part of a course evaluation, but are available from the corresponding author on reasonable request.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The UCSF Committee on Human Research a (IRB ##16-20323). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

PS and MH analyzed and interpreted the survey data regarding trainee demographics, productivity, and competencies. PS wrote the manuscript with major contributions from MH and AC. RG defined core training competencies. SA provided significant contribution in the design of surveys and in training program curriculum development. 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.2020.00094/full#supplementary-material

Additional File 1 | UCSF Implementation Science Training Program Academic Productivity Survey. This survey was administered to in-person Certificate Program participants to gauge their productivity in academic implementation science after completion of their training.

Additional File 2 | UCSF Implementation Science Training Program Skills and Competency Survey. This survey was administered to all Certificate Program participants to characterize their self-reported competency with skills and methods in implementation science after completion of their training.

Additional File 3 | STROBE Checklist.

Appendix Table | Courses included in UCSF Implementation Science Certificate Training Program.

REFERENCES

1. Madon T, Hofman KJ, Kupfer L, Glass RI. Public health. Implementation science. *Science*. (2007) 318:1728–9. doi: 10.1126/science.1150009
2. Handley MA, Gorukanti A, Cattamanchi A. Strategies for implementing implementation science: a methodological overview. *Emerg Med J*. (2016) 33:660–4. doi: 10.1136/emermed-2015-205461
3. Neta G, Sanchez MA, Chambers DA, Phillips SM, Leyva B, Cynkin L, et al. Implementation science in cancer prevention and control: a decade of grant funding by the National Cancer Institute and future directions. *Implement Sci*. (2015) 10:4. doi: 10.1186/s13012-014-0200-2
4. Tabak RG, Padek MM, Kerner JF, Stange KC, Proctor EK, Dobbins MJ, et al. Dissemination and implementation science training needs: insights from practitioners and researchers. *Am J Prev Med*. (2017) 52:S322–9. doi: 10.1016/j.amepre.2016.10.005
5. Gonzales R, Handley MA, Ackerman S, O'Sullivan PS. A framework for training health professionals in implementation and dissemination science. *Acad Med*. (2012) 87:271–8. doi: 10.1097/ACM.0b013e3182449d33
6. Osanjo GO, Oyugi JO, Kibwage IO, Mwanda WO, Ngugi EN, Otieno FC, et al. Building capacity in implementation science research training at the University of Nairobi. *Implement Sci*. (2016) 11:30. doi: 10.1186/s13012-016-0395-5
7. Morrato EH, Rabin B, Proctor J, Cicutto LC, Battaglia CT, Lambert-Kerzner A, et al. Bringing it home: expanding the local reach of dissemination and implementation training via a university-based workshop. *Implement Sci*. (2015) 10:94. doi: 10.1186/s13012-015-0281-6
8. Brownson RC, Proctor EK, Luke DA, Baumann AA, Staub M, Brown MT, et al. Building capacity for dissemination and implementation research: one university's experience. *Implement Sci*. (2017) 12:104. doi: 10.1186/s13012-017-0634-4

9. Meissner HI, Glasgow RE, Vinson CA, Chambers D, Brownson RC, Green LW, et al. The U.S. training institute for dissemination and implementation research in health. *Implement Sci*. (2013) 8:12. doi: 10.1186/1748-5908-8-12
10. Proctor EK, Chambers DA. Training in dissemination and implementation research: a field-wide perspective. *Transl Behav Med*. (2017) 7:624–35. doi: 10.1007/s13142-016-0406-8
11. Padek M, Colditz G, Dobbins M, Koscielniak N, Proctor EK, Sales AE, et al. Developing educational competencies for dissemination and implementation research training programs: an exploratory analysis using card sorts. *Implement Sci*. (2015) 10:114. doi: 10.1186/s13012-015-0304-3
12. Straus SE, Brouwers M, Johnson D, Lavis JN, Legare F, Majumdar SR, et al. Core competencies in the science and practice of knowledge translation: description of a Canadian strategic training initiative. *Implement Sci*. (2011) 6:127. doi: 10.1186/1748-5908-6-127
13. Luke DA, Baumann AA, Carothers BJ, Landsverk J, Proctor EK. Forging a link between mentoring and collaboration: a new training model for implementation science. *Implement Sci*. (2016) 11:137. doi: 10.1186/s13012-016-0499-y
14. Society for Implementation Research Collaboration. *Dissemination and Implementation Training Opportunity*. University of Washington (2018). Available online at: https://societyforimplementationresearchcollaboration.org/dissemination-and-implementation-training-opportunities/ (accessed November 20, 2019).
15. Proctor EK, Landsverk J, Baumann AA, Mittman BS, Aarons GA, Brownson RC, et al. The implementation research institute: training mental health implementation researchers in the United States. *Implement Sci*. (2013) 8:105. doi: 10.1186/1748-5908-8-105
16. Padek M, Mir N, Jacob RR, Chambers DA, Dobbins M, Emmons KM, et al. Training scholars in dissemination and implementation research for cancer prevention and control: a mentored approach. *Implement Sci*. (2018) 13:18. doi: 10.1186/s13012-018-0711-3
17. Chambers DA, Proctor EK, Brownson RC, Straus SE. Mapping training needs for dissemination and implementation research: lessons from a synthesis of existing D&I research training programs. *Transl Behav Med*. (2017) 7:593–601. doi: 10.1007/s13142-016-0399-3
18. Blood-Siegfried JE, Short NM, Rapp CG, Hill E, Talbert S, Skinner J, et al. A rubric for improving the quality of online courses. *Int J Nurs Educ Scholarsh*. (2008) 5:34. doi: 10.2202/1548-923X.1648
19. Jacob RR, Duggan K, Allen P, Erwin PC, Aisaka K, Yang SC, et al. Preparing public health professionals to make evidence-based decisions: a comparison of training delivery methods in the United States. *Front Public Health*. (2018) 6:257. doi: 10.3389/fpubh.2018.00257
20. Aggarwal R, Gupte N, Kass N, Taylor H, Ali J, Bhan A, et al. A comparison of online versus on-site training in health research methodology: a randomized study. *BMC Med Educ*. (2011) 11:37. doi: 10.1186/1472-6920-11-37

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The Evolving Role of Public Health in Medical Education

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Medical education in the twentieth century was largely influenced by the Flexner Report, with significant proportions of instruction dedicated to the molecular underpinnings of the pathologic pathways and minimal mention of the socio-ecological determinants of health. When examining the predominant diseases of the twenty first century landscape, widening health disparities, and significant changes in the United States healthcare system, it is imperative to view wellness and sickness in a broader public health context rather than a singular focus of the biomedical model. While undergraduate opportunities to study public health are on the rise in the United States, there is a parallel urgency for medical curricula to recognize the importance of the complex interrelated socio-ecological root causes of health, well-being, and illness. In order to reduce the risk of non-communicable diseases and increase health equity, it is necessary for medical education to integrate core public health knowledge and competencies. Contemporary health challenges require a public health approach, in addition to clinical skills, for physicians to provide equitable care. The COVID-19 pandemic further underscores the necessity to mitigate the effects of socio-ecological determinants of health. Seven key recommendations are presented from a training to practice timeline emphasizing the important linkages between medical education, socio-ecological influences on health, and public health. As the health challenges in society and communities shift, so too must training of future physicians. There is a need and an opportunity for medicine and public health to address the shared health challenges of our global society.

Keywords: education, public health, premedical, health equity, socio-ecological

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INTEGRATING SOCIO-ECOLOGICAL DETERMINANTS OF HEALTH IN MEDICAL EDUCATION

In 1910, Abraham Flexner's report on the state of American medical education provoked a dramatic revisiting of how young physicians should be trained. The importance of science as the foundation of medical training was emphasized, while aspects of what today we call socio-ecological determinants of health were reduced. In turn, many medical schools went through significant reorganization. As with many trends in education and training, changing societal circumstances and health burdens suggest the pendulum should shift toward the other direction today with a public health perspective playing a more prominent role in medical education. Some of the intertwined factors impacting health are the widening wealth gap, social, and economic environment, the physical environment, and individual behaviors (1).

While twentieth century medical education spent significant proportions of instruction dedicated to the fundamentals of anatomy, physiology, pathology, and biochemistry, other relevant disciplines, including elements of health economics, sociology of disadvantage, community-level forces such as violence and employment opportunities, and the socio-ecological contributors across the lifespan, received minimal mention (2). Many of these factors have been the core of medical anthropology and medical sociology, but their relevance to public health is notable. When examining predominant diseases of the twenty first century landscape (e.g., cardiovascular deterioration, malignancy, chronic inflammatory conditions), the vast amount of knowledge imparted on the molecular underpinnings of the pathologic pathway greatly exceeds the training on how to view wellness and sickness in a broader public health context. "One patient at a time" may be the appropriate mindset for diagnosing some rare genetic conditions or uncommon malignancies, but becomes an inefficient and futile approach in a setting where predictable patterns of disease impact millions.

The notion of integrating socio-ecological determinants of health into medical education and healthcare systems represents a cultural shift in this country; however, the enactment of the 2010 Patient Protection and Affordable Care Act (ACA) and the establishment of the Triple Aim have recognized key public health and health equity principles. Given the impetus for evidence-based decision making in health care, public health competencies are relevant in clinical practice now more than ever.

In fact, the changing landscape and evolution of the medical field has been significantly influenced by improvements in health attributed to advancements made in the public health field. The average lifespan in the United States (US) has increased by more than 30 years in the last century, of which 25 have been attributed to public health advancements, such as reductions in vaccine-preventable illnesses, injuries and death prevented by motor-vehicle safety, and reductions in infant and maternal mortality due to advancements in family planning (3). The aging population and increasing diversity of the US population further necessitates the role of a coordinated systems approach, understanding of socio-ecological determinants of health, and cultural competence in a comprehensive medical education, all of which are cornerstones of public health.

The COVID-19 pandemic underscores the necessity for a shift in thinking about role of equity in health. In the US, the pandemic compounds existing health inequities and has illustrated the inextricable connectedness and vulnerability of society. The disproportionate impact of COVID-19 on low-income and other high-risk communities will be recognized in a variety of health outcomes long after the efforts to reduce the spread of the virus have lifted. The pandemic is a global call to action to mitigate the effects of socio-ecological determinants of health and has exposed many inadequacies in the US healthcare system, particularly community-level preventative care, for the most vulnerable populations. Although we are in the midst of this moment in history, there are already lessons learned that can be applied immediately in the healthcare setting, as well as in medical and public health curricula. Addressing socio-ecological determinants of health is a primary approach to achieving health equity (4).

While there is conceptual overlap between some of the terms used in this discussion, each refers to a different scope of knowledge and practice. Socio-ecological determinants of health refers to the entire breadth of factors that do not pertain to genetically inherited conditions; these include considerations such as poor housing, poor air/water quality, limited availability of optimal foods, and the most intractable of economic and sociological burdens that result in deprivation, and alter or increase risk to develop disease (4). Public health pertains to the health outcome and measurements thereof, and often includes interventions at community-level to reduce risk and minimize cost of caring for chronic diseases that may be ameliorated by prevention (5). Equity, defined as both a process and an outcome to reduce disparities in health (6), remains a core value in public health. Health promotion refers to both the individual-level as well as the community/national initiatives that address the socio-ecological determinants of health in order to reduce the risk of disease and injury, in order to preserve and enhance health and well-being (7). Nutrition in this context refers to the reduction of risk of diet-related illnesses.

ACTIVITIES OF FUTURE HEALTHCARE PROVIDERS

As Westerhaus et al. (8) remarked, the current medical education system fails to "link the interplay of important biological processes with the social space their host inhabits." Cooke et al. (9) argue further that social aspects of health, the root causes of many conditions, have been neglected in U.S. medical education for the emphasis on context-free scientific knowledge, grounded in the basic sciences. The day-to-day experience of physicians certainly incorporates scientific problem solving requiring a strong understanding of the biological sciences. Complex patients may present with atypical symptoms or consequences of polypharmacy which can only be addressed with a thorough understanding of pathophysiology and pharmacology. However, the assumption that this is the majority of the physician's workload (i.e., using cognitive efforts to apply science to a patient's chief complaint) ignores the important opportunity to improve patient's well-being and reduce risks due to socio-ecological determinants.

Future physicians may ultimately take on three roles. First, they will continue their traditional duty to treat patients at the individual level. This encompasses their medical needs as well as emotional needs for compassion and empathy. Second, as highlighted by the COVID-19 pandemic, clinicians will serve as members of a broader response to emerging threats as members of the frontline during intense short-term crises. As part of ongoing efforts to reduce the impact of chronic and communicable diseases, a public health perspective will enhance the likelihood of data sharing and other collaborative initiatives to create an organized approach to reducing their burden. Finally, healthcare providers will be increasingly be part of the digitization of healthcare information in data collection, dataset

management, communication with administrative leaders, and involvement in statistical analysis. This requires quantitative rigor to examine individual health and community-level data, as well as a highly developed sense of empathy to recognize the impact of the socio-ecological determinants of health, particularly regarding inequities. Understanding statistical terminology and methodology underpins this capacity and is a core competency in public health.

SHIFTING TO PUBLIC HEALTH EDUCATION

Public health as an undergraduate degree is both a relatively new concept and rapidly growing option for premedical students. The rate of obtaining a bachelor's degree in public health increased by 662% between 2003 and 2015 (10). Additionally, over the past two decades, the number of institutions offering public health degrees at the undergraduate level has increased from 45 institutions in 1992 to 176 schools that offered undergraduate public health degrees in 2012 (11). If the diseases that current (and future) physicians encounter are largely attributable to societal factors, failures of institutions to educate individuals on beneficial health practices and risk reduction approaches will illustrate that the current medical education system is limited in its ability to train physicians to handle patients with such diseases.

The landscape of premedical studies has rapidly changed since the introduction of public health as an undergraduate degree. Premedical students, in particular, may be turning to public health as an undergraduate course of study as a means to address the multitude of complex challenges facing the US healthcare system. Components of a socio-ecological medical approach, from local to global levels, and preventative care through nutrition and health promotion principles, are integral in public health undergraduate curricula and advantageous to the premedical student.

The impressive trend in the number of undergraduate students pursuing public health majors, particularly among students who are pursuing premedical studies, indicates the interest and recognition of the role of public health in clinical practice. The recent changes to the Medical College Admissions Test (MCAT) to include behavioral and social sciences also recognizes the interplay between health and society (12). Intertwined with a public health perspective is the value of nutrition education as an integral component of most health issues (13). In the US, the approximately 140 accredited medical schools require a minimum of 25 h of nutrition education; three-fourths of these medical schools fail to meet the minimal requirements (14). As we gain a greater understanding of the significance of the socio-ecological determinants of health and wellness (1), it is imperative to incorporate training in public health and nutrition into medical school requirements and curricula as well.

Alongside the recent epidemiological transition from communicable to non-communicable diseases (i.e., the plethora of chronic diseases, such as type 2 diabetes, cancer and cardiovascular disease), factors impacting health that are outside the traditional biomedical scope of physiologic diagnosis must be acknowledged in medical education. These factors, including the socio-ecological determinants of health and nutrition, continue to blur the line between public health and medicine (15). It is important to note that a public health education also involves training in community organizing, stakeholder communications, working across disciplines and with government agencies toward strategic planning and logistics and innovation, all of which are relevant to clinical practice and have been integral, most recently, in the COVID-19 response. Public health terminology also includes significant overlap with military establishments (e.g., campaigns, mobilization, surveillance, deployment), which are rooted in wartime partnership efforts. Public health also emphasizes the ability to tell compelling stories with data through effective culturally-competent health communication.

The traditional medical curricula are well-aligned with the testing that follows, but not well-aligned with the disease/illness/suffering of patients encountered in practice. Current clinical training emphasizes the scientific analysis of pathophysiology (reinforced by testing of such content). Patients are served well when in advanced stages of complex diseases, but not in the reduction of risk of such diseases or the most common chronic diseases plaguing our society.

The IOM (16) and others (17, 18) have called for medical education to integrate basic public health competencies recognizing that the traditional biomedical model fails to address factors related to the multi-factorial societal context of health and well-being. There are notable positive examples among progressive medical schools across the country and there is increased attention in medical curricula on developing skills to work with patients to reduce the risk of disease (19, 20); however, most institutions are evaluated on the basis of molecular science curricula and student performance is assessed via standardized testing on molecular science. Incorporating a public health approach to medical education has been challenging, in spite of dedicated efforts such as the identification of training providers in public health as a key measure for improving population health by the World Health Organization (21) and Centers for Disease Control and Prevention (22) and the development of the Clinical Prevention and Population Health Curriculum Framework released through the Healthy People Curriculum Task Force (23). Consistent efforts to incorporate social-ecological perspectives, nutrition education, and prevention into medical school curricula is an important next step.

DISCUSSION AND RECOMMENDATIONS FOR REFORMING MEDICAL EDUCATION

To address the aforementioned limitations of current medical education and need for reform, seven proposals may warrant further discussion and pilot testing:

- *Premedical education*: Increase requirement of premedical students to include at least one semester of a public health course (covering disease prevention, health promotion and nutrition). In school that may not have public health department, this requirement could be fulfilled by a public

health related internship or other relevant experiential learning opportunity;
- *MCAT testing*: MCAT questions should also reflect knowledge and understanding of the socio-ecological determinants of health
- *Within the first 2 years of medical school*: Include a standalone required course on public health and in nutrition within the first 2 years of medical school, including socio-ecological determinants of health frameworks and behavior change strategies. This might expand the overall class hours or be a substitute for current coursework. Concepts from this standalone course are then connected in future courses and rotations throughout medical school (immunology, surgery, obstetrics/gynecology, pediatrics, internal medicine, geriatrics, etc.). Incorporate innovative team-based and project-based learning to improve knowledge and understanding of socio-ecological determinants, disease prevention, risk reduction, and health promotion (24);
- *Post-coursework/standardized licensure testing*: Increase the number of public health and nutrition questions, including knowledge key risk factors for leading causes of death on United States Medical Licensing Examinations;
- *Research within training*: Increase or reprioritize National Institutes of Health (NIH) research funding for student and residency research programs to place greater likelihood of awards for healthy equity research and social drivers of health. Establish mechanisms supporting public health practice and academic medicine partnerships;
- *Clinical Practice*: Develop innovative payer/reimbursement mechanisms such that risk-reduction practices are financially rewarded in primary care, acknowledging the initial steps of the Patient Protection and Affordable Care Act (ACA).
- *Continuing Education*: more specialties can offer Continuing Education Units (CEUs) for completing training in public health for physicians in wide variety of practices.

Each recommendation above merits longer discussion and consideration within the fields of medicine and public health, but for purposes here, the recommendations are presented along a training-to-practice timeline. Also, this sequence focuses exclusively on physician training while numerous other disciplines are part of the provider landscape and the clinical team (e.g., nurses, physical therapist, physician associate). This proposed model is specific to the US medical education system and may follow what many countries in the world already emphasize in their medical education. In other regions of the world, physicians are often practicing community-based health given the nature of healthcare systems.

The practice of medicine centers around accurate diagnosis of illness and effective treatment of disease; public health practice complements clinical practice as it centers around preventing illness, promoting population health, and reducing inequalities in health (25). We argue that incorporating core public health competencies in medical education will make better doctors and benefit both the clinical practice and the community served. Further, as the nation faces increasingly complex interdependent health concerns and widening health inequities, such as the case with the COVID-19 pandemic, it becomes an imperative.

The need for a greater emphasis on the socio-ecological aspects of healthcare and reform in medical training is clear (25, 26). Flexner himself acknowledged that medical education must adjust in response to changing scientific, social, and economic circumstances (2). That does not, however, imply that reform is a simple endeavor (27, 28). As the needs of society shift from acute disease treatment to chronic disease prevention and management, medical training must place greater emphasis on previously underrecognized influences including socio-ecological determinants of health.

This will require changes to medical education as well as mindset shifts in the role of clinicians. However, as access to health information has increased through social media and other technological advances (i.e., telemedicine), both physicians and patients can be empowered. As such, a primary source of valid and reliable health information may be coming from periodic visits to a healthcare provider. Rather than focus exclusively on the treatment of acute illness, there is an opportunity from which patients can learn principles of public health and health promotion from their physicians. This comprehensive approach falls to the healthcare provider, regardless of specialty, which further supports that prevention, promotion, and nutrition must be incorporated in the training of physicians. Of additional importance, and lacking adequate attention, is the relevance of nutrition education surrounding the health and wellness of physicians themselves. As the burnout rate among physicians continues to rise, the need for nutrition and wellness education among physicians has also risen (29).

Medical school curricula that focus on a diagnosis and treatment perspective alone, rather than examining the complex root causes of illness, are ill-equipped to comprehensively treat patients in today's society. Medical training, on the other hand, which focuses on the interaction of biological and social relationships in determining treatment, is the future of modern medicine and training effective physicians. With the shift in the prevalence of non-communicable diseases being greater than communicable diseases, it is crucial for physicians and future physicians to recognize the influence of the socio-ecological determinants of health and to continue to intentionally blur the line between public health and medicine.

AUTHOR CONTRIBUTIONS

TU and MH conceived of the presented idea. GG, GM, and CM reviewed the literature and contributed to the manuscript. RR wrote sections of the manuscript. All authors discussed and contributed to manuscript revisions. All authors read and approved the submitted version.

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REFERENCES

1. World Health Organization. Commission on Social Determinants of Health (CSDH), *Closing the Gap in a Generation: Health Equity Through Action on the Social Determinants of Health*. Final Report of the Commission on Social Determinants of Health, Geneva (2008).
2. Beck AH. The Flexner report and the standardization of American medical education. *JAMA*. (2004) 291:2139–40. doi: 10.1001/jama.291.17.2139
3. Centers for Disease Control and Prevention (CDC). Ten great public health achievements—United States, 2001-2010. *MMWR*. (2011) 60:619–23. Available online at: https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6019a5.htm
4. Braveman P, Gruskin S. Defining equity in health. *J Epidemiol Commun Health*. (2003) 57:254–8. doi: 10.1136/jech.57.4.254
5. Marmot MG, Wilkinson RG. *Social Determinants of Health*, 2nd ed. Oxford: New York, NY: Oxford University Press (2006).
6. U.S. Department of Health and Human Services, Office of Minority Health, National Partnership for Action to End Health Disparities. *Toolkit for Community Action*. Available online at: https://minorityhealth.hhs.gov/npa/
7. Hofrichter R, Bhatia R. (eds.). *Tackling Health Inequities Through Public Health Practice: Theory to Action*. New York, NY: Oxford University Press (2010).
8. Westerhaus M, Finnegan A, Haidar M, Kleinman A, Mukherjee J, Farmer P. The necessity of social medicine in medical education. *Acad Med*. (2015) 90:565–8. doi: 10.1097/ACM.0000000000000571
9. Cooke M, Irby D, Sullivan W, Ludmerer K. American medical education 100 years after the Flexner report. *N Engl J Med*. (2006) 355:1339–44. doi: 10.1056/NEJMra055445
10. Resnick B, Selig S, Riegelman R. An examination of the growing US undergraduate public health movement. *Public Health Rev*. (2017) 38:4. doi: 10.1186/s40985-016-0048-x
11. Tarasenko YN, Lee JM. Undergraduate education in public health: hot or not? *Front Public Health*. (2015) 3:71. doi: 10.3389/fpubh.2015.00071
12. Kaplan RM, Satterfield JM, Kington RS. Building a better physician: the case for the new MCAT. *N Engl J Med*. (2012) 366:1265–8. doi: 10.1056/NEJMp1113274
13. Seligman HK, Schillinger D. Hunger and socioeconomic disparities in chronic disease. *N Engl J Med*. (2010) 363:6–9. doi: 10.1056/NEJMp1000072
14. Baute V, Carr AD, Blackwell JN, Carstensen ER, Chhabra P, Porter LC, et al. Incorporating formal nutrition education into a medical school curriculum: a student-initiated lecture series. *Am J Med*. (2017) 130:623–5. doi: 10.1016/j.amjmed.2016.12.017
15. Kasper J, Green JA, Farmer PE, Jones DS. All health is global health, all medicine is social medicine: integrating the social sciences into the preclinical curriculum. *Acad Med*. (2016) 91:628–32. doi: 10.1097/ACM.0000000000001054
16. Institute of Medicine (US) Committee on Educating Public Health Professionals for the 21st Century. *IOM Report: Who Will Keep The Public Healthy?* Washington, DC: National Academy Press (2003).
17. Chamberlain LJ, Ewen Wang Nho ET, Banchoff AW, Braddock CH, Gesundheit N. Integrating collaborative population health projects into a medical student curriculum at Stanford. *Acad Med*. (2008) 83:338–44. doi: 10.1097/ACM.0b013e318166a11b
18. Simoyan O, Townsend J, Tarafder M, DeJoseph D, Stark R, White M. Public health and medical education: a natural alliance for a new regional medical school. *Am J Prev Med*. (2011) 41(Suppl. 3):S220–7. doi: 10.1016/j.amepre.2011.05.027
19. Allan J, Barwick TA, Cashman S, Cawley JF, Day C, Douglass CW, et al. Clinical prevention and population health: curriculum framework for health professions. *Am J Prev Med*. (2004) 5:471–6. doi: 10.1016/S0749-37970400206-5
20. Trevena LJ, Sainsbury P, Henderson-Smart C, Clarke R, Rubin G, Cumming R. Population health integration within a medical curriculum: an eight-part toolkit. *Am J Prev Med*. (2005) 3:234–9. doi: 10.1016/j.amepre.2005.05.008
21. World Health Organization. *Teaching of Public Health in Medical Schools*. Report of the Regional Meeting Bangkok, Thailand. WHO – Regional office of South East Asia (2009).
22. Centers for Disease Control and Prevention (CDC). *Healthy People 2010.* (2010). Available online at: https://www.cdc.gov/nchs/healthy_people/hp2010.htm
23. Maeshiro R. Medical and public health education. *J Public Health Manag Pract*. (2006) 12:493–5. doi: 10.1097/00124784-200609000-00018
24. Kershaw G, Grivna M, Elbarazi I, AliHassan S, Aziz F, Al Dhaheri AI. Integrating public health and health promotion practice in the medical curriculum: a self-directed team-based project approach. *Front Public Health*. (2017) 5:193. doi: 10.3389/fpubh.2017.00193
25. Wylie A. Health promotion in medical education. *Perspect Public Health*. (2011) 131:15–6. doi: 10.1177/1757913910391026
26. Ludmerer KM. Learner-centered medical education. *N Engl J Med*. (2004) 351:1163–4. doi: 10.1056/NEJMp048112
27. Whitcomb ME. Redesigning clinical education: a major challenge for academic health centers. *Acad Med*. (2005) 80:615–6. doi: 10.1097/00001888-200507000-00001
28. Leedham-Green K, Pound R, Wylie A. Enabling tomorrow's doctors to address obesity in a GP consultation: an action research project. *Educ Prim Care*. (2016) 27:455–61. doi: 10.1080/14739879.2016.1205459
29. Hanson C, Staskiewicz A, Woscyna G, Lyden E, Ritsema T, Norman J, et al. Frequency and confidence of healthcare practitioners in encountering and addressing nutrition-related issues. *J Allied Health*. (2015) 45:54–61.

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Using Employment Data From a Medical University to Examine the Current Occupation Situation of Master's Graduates in Public Health and Preventive Medicine in China

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Aims: The purposes of this study are (1) to understand the current employment situation of master's graduates in Public Health and Preventive Medicine (PHPM) and (2) to provide evidence for career guidance and training of competent PHPM personnel.

Methods: The master's graduates of the School of Public Health from the years 2014–2018 who majored in PHPM were chosen as research subjects. Questionnaires were distributed, and completed questionnaires were collected. The employment situation and characteristics of these graduates were analyzed based on the questionnaire data.

Results: The employment rate of these graduates was 95.45%. They were employed mainly in hospitals, followed by colleges and centers for disease control and prevention. The initial salaries were low. Graduates whose jobs barely or not at all matched their areas of specialization were 23.64 or 6.36%, respectively. Nevertheless, the percentage of students who had remained with their jobs since graduation was 82.73%. A total of 40% of the graduates were neutral about or dissatisfied with their jobs. Furthermore, 29% of them claimed that they were undervalued by their employers. Last, but not least, graduates were encouraged to gain experience in creativity, organizational or management skills, social networking experience, and interpersonal and professional skills.

Conclusion: Overall, the employment status of master's graduates in PHPM is good. Problems such as low initial salaries, jobs not matching graduates' areas of specialization, and feelings of being undervalued by employers were observed. It is necessary to improve employment outcomes by revising training models, formulating employment policies, and implementing training efforts.

Keywords: public health and preventive medicine, master graduates, employment status, existing problems, suggestions

INTRODUCTION

Public Health and Preventive Medicine (PHPM) is one of the fundamental curricula of modern medicine. As the most important component of medicine, its concept runs through the entire history of humans and diseases, and it has played a major role in the prevention and control of infectious diseases. The field and content of public health have developed considerably. However, new challenges have arisen in health promotion due to the changes in population structure, the ecosystem, and lifestyle (1). In 2002 and 2003, the outbreak and spread of SARS drew great attention to the field of public health and the prevention of infectious disease. It also emphasized the importance of the education and training of PHPM personnel to respond to such emergencies (2). *Healthy China 2030 Planning Outline*, issued by the CPC Central Committee, offers a blueprint for the construction of a healthy China and guidance for the development of the public health field, including the establishment of training programs for high-level personnel.

Public health has become an indispensable component of health education in China, due to the prevention-oriented policy of the Chinese government (3). The demands for both the quantity and the quality of personnel specialized in PHPM to adapt to the developing and future challenges of disease prevention and control have increased. Additional problems, such as aged teams and varying developments among regions, have been observed by the centers for disease control (CDCs) (4, 5). With the expanding scale of medical education and the increasing demand to address the core competencies of public health, the need to cultivate competent PHPM personnel has become more pressing. However, the scale of public health education has merely expanded, compared with the rest of the curricula (6). Accompanied by the rapid expansion of the graduate education scale across the country, the medical school in this study has increased the enrollment scale of PHPM graduates. Therefore, understanding the current situation of the PHPM employment outcome is of considerable importance for graduate education.

Extensive studies conducted on graduate education both domestically and internationally have focused mainly on the current education and cultivating models (7–10). However, few have investigated the employment outcome of the master's graduates. In this study, we collected and analyzed current employment outcome data of master's graduates majoring in PHPM at a medical University from the years 2014 to 2018. From the results gathered, we examined the existing problems and suggested corresponding measures to improve the quality of the personnel. Our study will provide evidence for the need for colleges to cultivate various talents in PHPM students.

METHODS

Graduates in five PHPM disciplines (epidemiology and health statistics, labor and environmental hygiene, nutrition and food hygiene, health toxicology, and maternal, child, and adolescent health) from the years 2014 to 2018 were chosen as research subjects. All graduates were from the same university, the Medical Center in the Western Taiwan Straits Economic Zone.

Based on the literature, we designed the questionnaire of employment outcomes for graduates majoring in PHPM. The questionnaire was further modified after consulting experts and teachers in the field. The questionnaire was then pilot tested by 30 master's graduates who graduated from 2012 to 2013 in the field, and revisions were made to the language.

The questionnaire consisted of 36 questions. There was a brief introduction to research design. Information was requested in three areas: (1) basic personal information; (2) employment information (the type of employer, administrative level of the employer, job duties); and (3) career development (salary levels, the stability of employment, occupational competency, and value of employees by the employers).

The questionnaire was imported to an online questionnaire platform for distribution. The cluster sampling method was used to choose 110 master's graduates in PHPM at a medical University from the years 2014 to 2018. The questionnaire was distributed by the class advisor through social media platforms such as WeChat and QQ, which the graduates continued to use after graduation. At this stage, an initial oral consent to participate in the study was obtained from each participant, using the voice function of QQ or WeChat. A total of 110 subjects returned a completed questionnaire, an overall response rate of 100%. Questionnaires were submitted anonymously and numbered according to the time submitted.

The data collected were used to create a database utilizing the Epi Data 3.0 program. The data were stored in a private off-line database owned by the university. Statistical analysis was performed using the SPSS 24.0 software package. The level of statistical significance was $P < 0.05$.

ANALYSIS OF RESEARCH RESULTS

Basic Information of Research Subjects

A total of 110 questionnaires were distributed and collected, with a recovery rate of 100%. All were valid. As shown in **Table 1**, 42 questionnaires, or 38.18%, were from male graduates The number of graduates were 13 (11.82%), 25 (22.73%), 24 (21.82%), 24 (21.82%), and 24 (21.82%), in the years 2014 to 2018, respectively. The number of subjects majoring in epidemiology and health statistics was the highest, 66 (60%), while the number majoring in maternal and adolescent health was the lowest, 3 (2.73%). Most of the subjects (95.45%) chose to find a job directly after graduation, while 3.64% decided to pursue postgraduate studies, both domestically and abroad.

Current Employment Situation

The type of employer is a key concern of graduates seeking jobs. As shown in **Table 2**, the master's graduates were mainly employed by hospitals (38.18%), followed by colleges (22.73%), then CDCs (21.82%). When analyzing administrative levels of the employers, provincial (47.92%), and municipal levels (37.5%) employed most of the graduates. More than half of the graduates (64.55%) were engaged in professional and technical work, while the remaining 35.45% occupied other positions.

TABLE 1 | Basic information for PHPM Master's graduates.

Item	Categories	*N* (persons)	Percentage (%)
Gender	Male	42	38.18
	Female	68	61.82
Graduation year	2014	13	11.82
	2015	25	22.73
	2016	24	21.82
	2017	24	21.82
	2018	24	21.82
Discipline	Epidemiology and health statistics	66	60.00
	Labor and environmental hygiene	15	13.64
	Nutrition and food hygiene	12	10.91
	Health toxicology	14	12.73
	Maternal, child, and adolescent health	3	2.73
Choice after graduation	Direct employment	105	95.45
	Pursue further studies	4	3.64
	Self-employed	0	0.00
	Other	1	0.91

TABLE 2 | Current employment situation of Master's graduates in PHPM.

Item	Categories	*N* (persons)	Percentage (%)
Type of employer	CDC	24	21.82
	Public health–related institutes other than CDCs	5	4.55
	Hospitals	42	38.18
	Colleges and universities	25	22.73
	Enterprises	7	6.36
	Other	7	6.36
Administrative level of employer	National	2	2.08
	Provincial	46	47.92
	Municipal level	36	37.50
	County (district) level	10	10.42
	Other	2	2.08
Job duty	Administration	27	24.55
	Professional	71	64.55
	Logistical	3	2.73
	Other	9	8.18

Career Development

Career development is a process that helps shape a person's work identity. Here, we investigated the career development status of the research subjects, such as their salary levels, employment stability, occupational competency, and their perception of how they were valued by employers.

Salary Levels

Salary is one of the key indices of the quality of employment. As **Table 3** shows, 30.84% of the graduates were paid <4,000 yuan as their initial salaries. Further investigation revealed that there was no significant difference in the initial salary of graduates regardless of discipline and type of work. However, working for different types of employers and for different administrative levels resulted in significant differences in the initial salaries.

Stability of Employment

Matching area of specialization to job is an important part of the fulfillment of human capital investment. As presented here, 70% of the subjects believed that their jobs matched their areas of specialization, while 30% claimed that their employment barely or not at all matched their specializations. Of the total research subjects, 82.73% did not change their employment after graduation. Those who made job moves declared that they did so because they "didn't have enough space to develop" (42.11%), were "looking for higher salaries" (26.32%), or "would like to change jobs or disciplines" (26.32%). Overall, 40% of the graduates were neutral about or dissatisfied with their jobs (**Table 4**).

Occupational Competency and Value by Employers

As shown in **Table 5**, 44.55 and 45.45% of the research subjects suggested they were either totally or mainly capable of performing their jobs. As to the abilities and qualities that help them quickly adapt to their jobs, the highest-ranked ability was "willing to go through hardships" (76.36%), followed by "outstanding professional skills" (65.45%), then "wide range of knowledge" (43.64%). However, 29, 2, and 1 person(s) claimed that they were merely, not, or considerably not valued by their employers, respectively. Regarding the qualities or abilities they believed they lacked, nearly half of them named creativity (48.18%), followed by organizational skills and management (43.73%), social networking skills (35.45%), interpersonal skills (30.00%), and professional skills (25.45%). A total of 25 subjects believed they lacked psychological sustainability.

DISCUSSION

The Employment Rate of Master's Graduates Remains at a Relatively High Level, but Many Are Working in Areas Unrelated to Their Majors

Most chose to start work immediately, and only a small number decided to pursue further studies. The employment area is mainly in the province where the University is located and concentrated in coastal cities. This may be due to the working environment, relatively high income level, and more job opportunities for highly educated employers. Due to the need to cultivate professional personnel in the PHPM field, the graduates belong to the specialist team (11). A majority of public health graduates are employed by CDCs, health inspection institutes, or hospitals in China (12, 13). However, in this study, the number working in CDCs ranked third, after colleges, and significantly lower than the numbers employed in hospitals (where the most graduates were employed). Nearly 35% of the graduates were doing administrative or logistical work unrelated to their specializations. Our results imply that this preference of hospitals and universities over CDCs leads to the loss of high-caliber personnel in the PHPM field. Interestingly, in the study

TABLE 3 | Initial salaries of PHPM Master's graduates.

Item	Categories	Initial salaries (yuans)				χ^2/P
		Below 3,000	3,000–4,000	4,000–6,000	Over 6,000	
Discipline	Epidemiology and health statistics	11	15	22	18	$\chi^2 = 12.224$
		(16.7%)	(22.7%)	(33.3%)	(27.3%)	$P = 0.428$
	Labor and environmental hygiene	2	1	5	6	
		(14.3%)	(7.1%)	(35.7%)	(42.9%)	
	Nutrition and food hygiene	1	1	10	3	
		(6.7%)	(6.7%)	(66.7%)	(20.0%)	
	Health toxicology	1	1	4	6	
		(8.3%)	(8.3%)	(33.3%)	(50.0%)	
	Maternal, child, and adolescent health	0	1	1	1	
		(0%)	(33.3%)	(33.3%)	(33.3%)	
Type of employer	CDC	7	7	8	2	$\chi^2 = 32.486$
		(29.2%)	(29.2%)	(33.3%)	(8.3%)	$P = 0.006$
	Public health—related institutes other than CDCs	1	2	1	1	
		(20.0%)	(40.0%)	(20.0%)	(20.0%)	
	Hospitals	5	7	14	16	
		(11.9%)	(16.7%)	(33.3%)	(38.1%)	
	Colleges and universities	2	3	15	5	
		(8.0%)	(12.0%)	(60.0%)	(20.0%)	
	Enterprises	0	0	1	6	
		(0%)	(.0%)	(14.3%)	(85.7%)	
	Other	0	0	3	4	
		(0%)	(0%)	(42.9%)	(57.1%)	
Administrative level of employer	National	1	0	0	1	$\chi^2 = 26.523$
		(50.0%)	(0%)	(0%)	(50.0%)	$P = 0.009$
	Provincial	9	8	21	8	
		(19.6%)	(17.4%)	(45.7%)	(17.4%)	
	Municipal level	3	10	14	9	
		(8.3%)	(27.8%)	(38.9%)	(25.0%)	
	County (district) level	2	1	2	5	
		(20.0%)	(10.0%)	(20.0%)	(50.0%)	
	Other	0	0	5	11	
		(0%)	(0%)	(31.3%)	(68.8%)	
Job duty	Administration	4	2	13	8	$\chi^2 = 11.311$
		(14.8%)	(7.4%)	(48.1%)	(29.6%)	$P = 0.255$
	Professional	9	15	25	22	
		(12.7%)	(21.1%)	(35.2%)	(31.0%)	
	Logistical	0	2	1	0	
		(0%)	(66.7%)	(33.3%)	(0%)	
	Other	2	0	3	4	
		(22.2%)	(0%)	(33.3%)	(44.4%)	

of the occupational situation of master's graduates in PHPM in Fudan University and Xuzhou Medical University (representing key University and average university) showed that 40–50% of the master's graduates were employed by hospitals, followed by CDCs and colleges, which was similar to our results (14, 15). According to J.P. Leider (16), since the vast majority of people are not engaged in government public health work, state and local health departments continue to report severe labor shortages, although the number of graduates in public health has increased. Moreover, a large number of the graduates were employed by provincial- or municipal-level institutions, which resulted in the relatively low education level in rudimentary CDCs.

Lower Salary May Distract Graduates From Working in CDC

Salary is one of the most important factors for job seekers. Along with medical reform, the income of medical staff in hospitals has increased. Nevertheless, as is the nature of a

TABLE 4 | Employment stability of PHPM Master's graduates.

Item	Categories	*N* (persons)	Percentage (%)
Extent of jobs matching specializations	Totally	33	30.00
	Mainly	44	40.00
	Barely	26	23.64
	Not at all	7	6.36
Number of job switches	Never	91	82.73
	Once	17	15.45
	Twice	2	1.82
	Three times or more	0	0.00
Reason for changing jobs	Limited opportunity for personal development	8	42.10
	Pursuit of higher salaries	5	26.32
	Seeking job or discipline changes	5	26.32
	Other	1	5.26
Satisfactory with employment	Very satisfied	16	14.55
	Satisfied	50	45.45
	Neutral	39	35.45
	Not satisfied	4	3.64
	Extremely disappointed	1	0.91

TABLE 5 | Occupational competency and value by employers of PHPM Master's graduates.

Item	Categories	*N* (persons)	Percentage (%)
Occupational competency	Totally capable	49	44.55
	Mainly capable	50	45.45
	Neutral	11	10.00
	Not capable	0	0.00
Adaption to jobs based on	Outstanding professional skills	72	65.45
	Willing to go through hardships	84	76.36
	Innovation and creativity	25	22.73
	Extensive interpersonal skills	30	27.27
	Wide range of knowledge	48	43.64
	Other	21	19.09
Value by employers	Extremely	10	9.09
	Relatively	68	61.82
	Not much	29	26.36
	Barely	2	1.82
	Not valued	1	0.91
Ability or skill that is lacking mostly	Professional or practical skills	28	25.45
	Social networking skills	39	35.45
	Creativity	53	48.18
	Interpersonal skills	33	30.00
	Team-working ability	13	11.82
	Organizing and management ability	47	42.73
	Psychological sustainability	25	22.73
	Other	12	10.91

public institution, the CDCs pay relatively low salaries based on standard and performance. Graduates could earn more in hospitals, colleges, and enterprises than in CDCs or other public health–related institutes, which could be one of the reasons that prevent them from working in disease prevention–related institutes. The initial salary of the master's graduates from various administrative levels varied. Only 30.91% of the graduates have a monthly income of over 6,000 yuan. Working in provincial or municipal cities with higher living expenses, the graduates often found their initial salaries merely met their expectations. Therefore, nearly 20% of respondents have changed jobs, and 26.32% of them are in pursuit of higher salaries. Owing to this, the satisfaction rate of staff in the CDCs and their passion for work were inevitably affected. Salaries are an important part of the recruitment and retention of public health personnel (15). Financial incentives may be important determinants of worker motivation and intention to leave (17–21). These results are consistent with previous studies of job satisfaction in the field of Public Health in settings elsewhere (22–25). Improving pay and benefits has become an urgent issue to be resolved in recruiting PHPM personnel.

It Is Worth Paying Attention to the Current Situation of Professional Mismatch and Job Dissatisfaction

Whether jobs fit graduate specializations is a superficial demonstration in terms of employment quality. Since PHPM is a field of strong professionalism, during the job-seeking processes, a majority of graduates would initially target the jobs in their areas of specialization. As a consequence, the jobs they found were generally in the PHPM field. Nevertheless, 30.00% of the graduates still claimed their jobs did not match their areas of specialization. It is believed that job satisfaction for health workers is important since it is related to internal motivation and overall job performance. Although 82.73% of health workers have not changed jobs, 40.00% of the subjects stated that they were not satisfied or barely satisfied with their current employment, suggesting that there is a gap between their expectations and current situations. Job dissatisfaction is caused by multiple factors, including salary and incentives, management and communication within the organization, and opportunities for training and promotion (22, 26). It is worth pointing out that the ideal major for many was clinical medicine, but due to the limited score and passive adjustment, they ended up in PHPM. These students were more likely to find a job irrelevant to PHPM as they were not satisfied with their major in the first place. Indeed, one study showed that ∼1–5th of graduates were unwilling to choose a career in the PHPM field in China (27).

Master's Graduates Are Qualified for the Job, but Some of Them Are Not Valued

As the findings of employment adaptation demonstrated, the graduates were mostly competent for their jobs. In addition, the determination to endure hardship, professional and practical skills, and a wide range of knowledge from University training contributed to solid foundations in employment. But improvements in creativity, organizational and management abilities, mental sustainability, social networking, and interpersonal skills are needed. Similarly, studies in the

United States and elsewhere strengthened the importance of embedding skill training in professional training, including leadership, project management, communication, problem-solving, planning, finance, and process improvement (28–31). Moreover, public health managers aiming to improve levels of job satisfaction should focus on workforce development and training efforts as well as adequate supervisory support, especially for new hires (24). As shown here, nearly 29% of the research subjects felt that they were merely valued by their employers. This sense of feeling undervalued, in turn, could lead to the dissatisfaction found by the questionnaire.

Based on the analysis above, we promoted the following political suggestions to improve the quality of employment of master's graduates in public health and preventive medicine. In formulating policies on talent recruitment, the appeal of salaries and benefits should be taken into account. Reasonable determinations of the compensation that reflects the value and professional contribution of public health personnel are required. Moreover, provincial governments should fully understand the importance of PHPM talent recruitment and cultivation, and provide adequate conditions for the introduction and preservation of personnel. This includes strengthening in various areas such as working environment, salary levels, personnel file management, training systems, continuing education, and promotion channels. For colleges and universities, a better understanding of the requirements of PHPM personnel from the developing society is of considerable importance. Colleges should formulate various training aims and methods to optimize the scale of education and cultivation system (32, 33). To increase sustainable development, the construction of curricula, the management of cultivation, and skill training should be stressed. Not only the research and innovation abilities should be cultivated, but also non-academic abilities such as teamwork, communication, and leadership are needed, so that the graduates can adapt to the diversified needs of the employment market (16, 20–24, 34). Furthermore, conducting a follow-up survey on the employment and career development of the master's in public health helps accurately grasp the development and utilization of graduates' employment orientation and employability, which in turn serves as feedback and guidance for the training of PHPM master's and employment services. Last, but not least, the employment departments and instructors of universities and public health institutions should (1) assist graduate students in career planning and job search guidance; (2) give full play to the role of academic associations, academic groups, and industry associations; and (3) build a master's employment information platform to promote the psychological and role transformation from schools to occupations.

CONCLUSION

In conclusion, the employment outcomes of public health master's graduates are in a good situation, with relatively stable employment and job satisfaction. However, problems have been observed, such as generally low initial salaries, poor fit of employments, and undervaluing of employees by the employers. In the context of expanding the scale of master's students and developing the career of public health, the promotion of high-quality employment of these graduates is of significant importance. To avoid waste of education resources and talent, we should make efforts to improve the cultivation model, to the benefit of both employers and employees.

DATA AVAILABILITY STATEMENT

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

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

HL, FZ, JZ, ZG, HY, CR, WZ, and SW made intellectual contributions to this study. HL, FZ, and JZ designed and wrote most of the paper and conducted the data analysis with assistance from SW. ZG, HY, CR, and WZ were major contributors to data collection and paper revision. All authors reviewed and approved the draft of the manuscript and ensured the accuracy and integrity of the work before submission.

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REFERENCES

1. The State Council of the People's Republic of China. *The CPC central Committee and the State Council's notification for the "The Healthy China 2030 Planning Outline"(EB/OL)*. (2016). Available online at: http://www.gov.cn/xinwen/2016-10/25/content_5124174.htm (accessed 25 Mar, 2018).
2. Fan R, Qiu Q, Zhong X. SARS and Public health education. *South China J Prev Med*. (2005) 31:67–68.
3. Hou J, Michaud C, Li Z, Dong Z, Sun B, Zhang J, et al. Transformation of the education of health professionals in China: progress and challenges. *Lancet*. (2014) 384:819–27. doi: 10.1016/S0140-6736(14)61307-6

4. Zhang X, Guo Li, Li Fei, Lv Y, Sha L, Zhou Y. The status and countermeasures of high-level talent construction in China Center for Disease Control and Prevention. *Chin Prev Med*. (2015) 16:394–6. doi: 10.3969/j.issn.1674-2982.2016.06.014
5. Su B, Cao W, Jia J, Wang Y, He Y, Zhang C, et al. Current situation of human resources and distribution equity in the Center for Disease Control and Prevention in China. *Chinese J Health Policy*. (2016) 6:75–80.
6. Hou J, Wang Z, Liu X, Luo Y, Sabharwal Sa, Wang N, et al. Public health education at China's higher education institutions: a time-series analysis from 1998 to 2012. *BMC Public Health*. (2018) 18:1471–2458. doi: 10.1186/s12889-018-5605-4
7. Karkee R. Public health education in South Asia: a basis for structuring a master degree course. *Front Public Health*. (2014) 2:2296–565. doi: 10.3389/fpubh.2014.00088
8. Odone A, PriviteraG, Signorelli1 C. Post-graduate medical education in public health: the case of Italy and a call for action. *Public Health Rev*. (2017) 38:24. doi: 10.1186/s40985-017-0069-0
9. Ren T, Li M, Song J, Qin X, Wu Y, Wang T, et al. Study on the current status of postgraduates training in Public Health and Preventive Medicine in China in 2016. *Chinese J Prev Med*. (2019) 53:625–7. doi: 10.3760/cma.j.issn.0253?9624.2019.06.016
10. Ren T, Wang X, Song J, Qin X, Zhu Y, Wu Y, et al. Investigation on the current status of the cultivation of the master of public health (MPH) in colleges in China. *Chinese J Prev Med*. (2019) 53:419–20. doi: 10.3760/cma.j.issn.0253-9624.2019.04.018
11. Deng F, Lv J, Gao J. Summary of the development and reform of China's disease prevention and control system. *Chinese J Public Health Manage*. (2019) 35:436–40.
12. Chen M. Analysis on the employment of 04-07 terms college graduates in preventive medicine. *China Higher Medical Educ*. (2009) 9:22–3. doi: 10.3969/j.issn.1002-1701.2009.09.012
13. Kong G, Meng L, Zhou CX, Zhang BL. Employment status of the preventive medicine graduates of Bengbu medical college from 2005 to 2009 and influencing factors. *J Bengbu Medical College*. (2010) 10:1056–8. doi: 10.3969/j.issn.1000-2200.2010.10.034
14. Mao L, Ge H, He N. Analysis of the employment destination of postgraduates majoring in public health and preventive medicine in Fudan University. *China Higher Medical Educ*. (2016) 6:119–20. doi: 10.3969/j.issn.1002-1701.2016.06.062
15. Li L, Gao DS. Analysis on the employment status of postgraduates majoring in medicine-taking Xuzhou Medical University for example. *Health Vocational Educ*. (2019) 37:52–5.
16. Leider JP, Harper E, Bharthapudi K, Castrucci BC. Educational attainment of the public health workforce and its implications for workforce development. *J Public Health Manag Pract*. (2015) 21(Suppl.6):S56–68. doi: 10.1097/PHH.0000000000000306
17. Yeager VA, Leider JP. The role of salary in recruiting employees in State and Local Governmental Public Health: PH WINS 2017. *Am J Public Health*. (2019) 109:683–5. doi: 10.2105/AJPH.2019.305008
18. Franco LM, Bennett S, Kanfer R. Health sector reform and public sector health worker motivation: a conceptual framework. *Soc Sci Med*. (2002) 54:1255–66. doi: 10.1016/S0277-9536(01)00094-6
19. Willis SM, Bidwell P, Thomas S, Wyness L, Blaauw D, Ditlopo P. Motivation and retention of health workers in developing countries: a systematic review. *BMC Health Serv Res*. (2008) 8:247. doi: 10.1186/1472-6963-8-247
20. Peters DH, Chakraborty S, Mahapatra P, Steinhardt L. Job satisfaction and motivation of health workers in public and private sectors: cross-sectional analysis from two Indian states. *Hum Resour Health*. (2010) 8:27. doi: 10.1186/1478-4491-8-27
21. Blaauw D, Ditlopo P, Maseko F, Chirwa M, Mwisongo A, Bidwell P, et al. Comparing the job satisfaction and intention to leave of different categories of health workers in Tanzania, Malawi, and South Africa. *Global Health Action*. (2013) 6:19287. doi: 10.3402/gha.v6i0.19287
22. Wang H, Li W, Lou Y, Song W, Tan C. Job satisfaction among staff in centers for disease control and prevention at different levels in Beijing municipality. *Chinese J Public Health*. (2019) 35:654–6. doi: 10.11847/zgggws1123613
23. Wang L, Zhang Y, Zhang L, Wu N, Qing J. Positive impact of performance-related pay on working enthusiasm among health workers in centers for disease control and prevention. *Chinese J Public Health*. (2014) 30:463–5. doi: 10.11847/zgggws2014-30-04-25
24. Deriba BK, Sinke SO, Ereso BM, Badacho AS. Health professionals' job satisfaction and associated factors at public health centers in West Ethiopia. *Hum Resourc Health*. (2017) 15:36. doi: 10.1186/s12960-017-0206-3
25. McCoy D, Bennett S, Witter S, Prond B, Baker B, Gow J, et al. Salaries and incomes of health workers in sub-Saharan Africa. *Lancet*. (2008) 371:675–81. doi: 10.1016/S0140-6736(08)60306-2
26. Elizabeth H, Brian CC, Kiran B, Katie S. Job satisfaction: a critical, understudied facet of workforce development in Public Health. *J Public Health Manage Pract*. (2015) 21:S46–55. doi: 10.1097/PHH.0000000000000296
27. Hou JL, Cai JY, Dong Z, Wang WM, Ke Y. Study on the sources and career preference of 6,129 healthcare undergraduate students. *Chinese J Medical Educ*. (2012) 32:826–30. Available online at: http://caod.oriprobe.com/articles/32057446/Study_on_the_sources_and_career_preference_of_6129_healthcare_undergra.htm
28. Munro D and Stuckey J. *The Need to Make Skills Work: The Cost of Ontario's Skill Gap*. Conference Board of Canada Report. (2013). Available online at: https://www.conferenceboard.ca/e-library/abstract.aspx?did=5563
29. Mason J, Johnston E, Berndt S, Segal K, Lei M, Wiest J. Labor and skill gap analysis of the biomedical research workforce. *FASEB J*. (2018) 30:2673–83. doi: 10.1096/fj.201500067R
30. Mathauer I, Imhoff I. Health worker motivation in Africa: the role of non-financial incentives and human resource management tools. *Hum Resour Health*. (2006) 4:24. doi: 10.1186/1478-4491-4-24
31. Wigington CJ, Colman LT, Sobelson RK, Young AC. Tracking Public Health workforce retention: observations from CDC's Public Health Associate Program. *Am J Public Health*. (2019) 109:1202–4. doi: 10.2105/AJPH.2019.305156
32. Zodpey SP, Evashwick CJ, Grivna M, Harrison RA, Finnegan JR. Editorial: educating the global workforce for Public Health. *Front Public Health*. (2018) 5:364. doi: 10.3389/fpubh.2017.00364
33. Tiwari R, Negandhi H, Zodpey SP. Health management workforce for India in 2030. *Frontiers in Public Health*. (2018) 6:227. doi: 10.3389/fpubh.2018.00227
34. Yang Y, Dai Y, Wang D, Cao P, Lei J, An D. On the cultivation of medical students' social adaptability and the improvement of employment ability. *Northwest Medical Educ*. (2016) 24:109–11. doi: 10.13555/j.cnki.c.m.e.2016.01.033

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Digital Divide in Online Education During the COVID-19 Pandemic: A Cosmetic Course From the View of the Regional Socioeconomic Distribution

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Objectives: During the pandemic, quarantine has led to the lockdown of many physical educational institutions. Thus, massive open online courses (MOOCs) have become a more common choice for participants. MOOCs are often flagged as supplemental methods to educational disparities caused by regional socioeconomic distribution. However, dissenters argue that MOOCs can exacerbate the digital divide. This study aimed to compare the participants' performance before and after the outbreak of COVID-19, analyze the impact of the epidemic on online education of cosmetic dermatology from the view of the regional socioeconomic distribution, and investigate whether MOOCs exacerbate the digital divide in the COVID-19 epidemic.

Methods: The study was conducted in participants of the MOOC course *Appreciation and Analysis of Cosmetics* from January 2018 to December 2020. Based on the platform data and official socioeconomic statistics, correlation of multivariate analysis was used to determine the factors related to the number of total participants. A panel regression model and stepwise least squares regression analysis (STEPLS) were employed to further analyze the relationship between GDP, population, number of college students and number of total participants in different years in the eastern, central and western regions of China.

Results: The number of total participants in 2020 surged 82.02% compared with that in 2019. Completion rates were generally stable in 2018 and 2019 before the COVID-19 pandemic and significantly decreased in 2020 after the outbreak of the pandemic. GDP was the most important socioeconomic factor that determined the total number of participants and it was positively related to the total number of participants before and after the outbreak of the pandemic. The number of college students was unrelated to the total number of participants before the epidemic, and after the outbreak of COVID-19 in 2020, the number became positively related in all regions of China.

Conclusions: This study shows that the epidemic pushes more people to choose MOOCs to study cosmetic dermatology, and online education could exacerbate rather than reduce disparities that are related to regional and socioeconomic status in the cosmetic field in the COVID-19 pandemic.

Keywords: COVID-19 pandemic, online education, MOOCs, digital divide, cosmetic, socioeconomic distribution

INTRODUCTION

COVID-19 is both highly contagious and transmissible. As the world is in an age of widespread global trade and travel, it causes the means for a rapid spread in the disease regardless of national borders. As of June 30th, 2020, a total of 10 million confirmed cases have been detected in 212 countries (1). Governments have responded by implementing self-isolation and physical distancing measures that billions of people have adopted into their daily routines that could potentially cause negative psychological effects (2). Being in quarantine is often an unpleasant experience and leads to negative emotions, including posttraumatic stress symptoms, confusion, anxiety and anger (3–5). During this period, it is a good choice to study independently by networking to eliminate negative feelings. Currently, little evidence exists on how people are self-learning during the pandemic. Meanwhile, Chinese universities had to suspend all on-site activities (6). With the closure of all campuses, 22 online course platforms, including MOOCs (massive open online courses), Wisdom Tree and xuetangX, were organized to develop and diversify a distance-learning solution by February 2, 2020, with over 24,000 online courses and 401 national virtual simulation-based courses available for universities to choose from (7, 8). Nevertheless, online education faces the problem of an unprecedented large scale.

Here, we provided an online course about cosmetic dermatology on the MOOC platform, aiming to provide high-quality online education while fighting the epidemic. In light of the course of *Appreciation and Analysis of Cosmetic*, it probes into some professional knowledge with cosmetic-associated dermatology and enhances a person's self-cultivation for the general public. Cosmetic products are closely associated with a series of dermatoses, such as sensitive skin, contact dermatitis, atopic dermatitis and rosacea (9, 10). While we all refrain from going outdoors, people have reduced the use of make-up during the pandemic. However, products for personal care and hygiene are still used daily, including soap, shampoo and face cream. Therefore, building the capability to select suitable cosmetic products for most people is a requisite protective strategy for certain dermatoses. However, the lack of access to professional knowledge makes it impractical (11–13). Fortunately, the popularity of online education in recent years has eased this problem. MOOCs allow the public to easily access thousands of professional fields, providing platforms for the public to conduct health education (14–16). With regard to this, the drawbacks of MOOCs, such as a high dropout rate and lack of actual practice, impact the effects of online courses on the spread of knowledge (16, 17). To virtually integrate cosmetics-associated dermatological knowledge into the daily routines of the widespread susceptible population, lowering the incidence of these dermatoses and preventing their recurrence, our team carried out an online course, *Appreciation and Analysis of Cosmetics*. Between 2014 and 2020, this course was inundated with more than 400,000 applications, which highlighted the importance of healthy-looking skin for many people.

Moreover, quarantine measures in the pandemic have profoundly impacted economic development throughout the world (2). Cosmetics represent an important industry worldwide (18). The cosmetic industry encompasses several environmental, social and economic impacts that are being addressed through searching for more efficient manufacturing techniques, the reduction of waste and emissions, and the promotion of personal hygiene, allowing it to contribute to the improvement of public health while providing employment opportunities (19). Currently, the cosmetic industry is faced with the enormous task of rebuilding the battered economy. It is known that China has a massive population, weak economic foundation and uneven regional development. At present, education inequality, especially in the field of higher education, exists in regional areas for different reasons. In the first years of the 2010s, researchers heralded the possibility that MOOCs can "democratize education." MOOCs are empirically characterized as remedies to educational disparities related to regional differences (20). "Digital divide," which was first proposed by Attewell (21), is an economic and social inequality with regard to access to, use of, or impact of information and communication technologies. It has been reported that pandemic-induced school closures have aggravated social inequalities and that the COVID-19 pandemic crisis is widening the gap in access to formal education (22). During an epidemic outbreak, the number of registrations and completions of online education participants related to the regional economy, education resource distribution and industrial distribution have sparked attention. Given this, we took advantage of the data collected from MOOC students who participated in the *Appreciation and Analysis of Cosmetics* course, aiming to compare the participants' performance before and after the outbreak of COVID-19, analyzed the impact of the epidemic on online education of cosmetic dermatology from the view of the regional socioeconomic distribution, and investigated whether MOOCs exacerbate the digital divide in the COVID-19 epidemic.

MATERIALS AND METHODS

Course Context

The *Appreciation and Analysis of Cosmetics* course was launched on a website named *MOOC* of Chinese Universities (https://www.icourse163.org/course/SCU-20012?tid=1206946235). The website is supported by the Ministry of Education of China and is free to the public. This 15-week course contained 15 lessons. Each lesson was divided into 3 to 5 videos, and each video was no more than 15 min.

The MOOC course comprised three main parts: manufacture of cosmetics, functions of common cosmetics and cosmetics-associated dermatology. Manufacture of cosmetics included 2 lessons: materials, formulations and processes. Functions of common cosmetics included 11 lessons: moisturizers, oil-control products, cleaning products, hair-care products, sunscreen, whitening products, anti-inflammation products, anti-aging products, perfumes, masque and make-up products. Cosmetics-associated dermatology included 4 lessons: capability building of differentiating skin types and choosing suitable products, adverse effects of cosmetics, and approaches to deal with adverse effects.

Evaluation of Participants

Participants were predicted to allocate 1.5 h per week on the course's contents and assignments. Participants who studied all the lessons and spent more than 1.5 h per week for 15 weeks were considered to complete the course. Final scores were determined by the grades of participants' homework (30%), quizzes (20%), the final exam (40%) and activities at the course forum (10%). With a score of more than 60, participants were considered to pass the course, and those who received more than 85 were considered to perform excellently in the course.

Data Acquisition

Data of the years of 2018, 2019 and 2020 were collected, respectively. Data of the year of 2018 and 2019 were considered to represent the situation before the outbreak of COVID-19, and those of 2020 were after the pandemic. The numbers of total participants, personal information (including age, gender, address, educational background) of the participants, completion rates, pass rates and rates of excellent performance of each year of the *Appreciation and Analysis of Cosmetics* course were obtained from the MOOC platform. Regional economic data, including gross domestic product (GDP), gross population, consumer price index (CPI) and numbers of higher institutions along with numbers of college students, were acquired from the National Bureau of Statistics of China (http://www.stats.gov.cn). We obtained the numbers and locations of cosmetic manufacturing companies that owned a production license from the National Medical Products Administration of China (https://www.nmpa.gov.cn).

Data Analysis

Stata 15.1 software (StataCorp, College Station, TX, USA) was used for data analysis. The differences in completion rates, pass rates and rates of excellent performance between 2018 and 2019, 2018 and 2020, 2019 and 2020 were compared by the Chi-square test. Correlations between the number of participants and socioeconomic factors were analyzed using Pearson correlation test. Data were divided into eastern, central and western regions for further analysis. Panel data regressive analysis and stepwise least squares regression analysis (STEPLS) from three regions were undertaken. For the chi-square test, $p < 0.01$ was considered significantly different. The stronger the tendency was, the larger the absolute value of the correlation coefficient (R value) in the Pearson correlation test. For panel data regressive analysis and STEPLS, $p < 0.1$ was significantly different, and the correlation coefficient value represented whether there was a positive or negative correlation but did not reflect the strength of the correlation between variables.

This study employed a panel regression model to analyze the relationship between the number of participants and regional socioeconomic distribution. Panel data have both temporal and cross-sectional dimensions. This method can overcome the interference of multicollinearity in time series analysis, ensuring that regression results are reliable. In this study, a random effect regression model acted as the reference for our theoretical framework.

This model can be written as Eq:

$$Y = \beta_0 + \beta_1 GDP_{it} + \beta_2 population_{it} + \beta_3 student_{it} + \varepsilon_{it}$$

where Y represents the number of participants; β_0 is a constant term; GDP, population and student represent GDP, population and number of college students in each region, respectively; β_1, β_2 and β_3 are the coefficients of the three explanatory variables; i represents individuals, i.e., each region; and *t* stands for years (2018, 2019 and 2020).

RESULTS

A total of 120,359 individuals were enrolled. 76.92% of the registered participants were female, and 23.08% were male. 15.69% got pre-university education, 52.27% were college students, 18.73% had a bachelor's degree and 13.32% had a master's degree. The majority of students lived in Jiangsu (15.34%), Henan (9.21%), Guangdong (8.67%), Zhejiang (5.94%), Beijing (5.87%) and Shandong (5.34%). There were 34,774 participants who took part in the course in 2018, 30,348 in 2019, and 55,237 in 2020. The number of total participants in 2020 surged 82.02% compared with that in 2019. Data from the MOOC platform also showed that there were never more than 250 new registered participants between December 9th, 2019, and January 24th, 2020. However, the number increased sharply on January 25th, 1 day after Wuhan told all nonessential businesses to close. The course was inundated with more than 600 participants a day after isolation measures were taken because of the COVID-19 pandemic, and there were 14,125 new participants in total from January 31 to February 14 of 2020 (**Figure 1**).

Performance of participants is shown in **Table 1**. A total of 2,757 (7.93%) participants completed the course in 2018, 2,377 (7.83%) completed it in 2019 and 3,056 (5.53%) completed it in 2020. Chi-square analysis documented that completion rates were generally stable in 2018 and 2019 ($\chi^2 = 0.190$, $p = 0.663$)

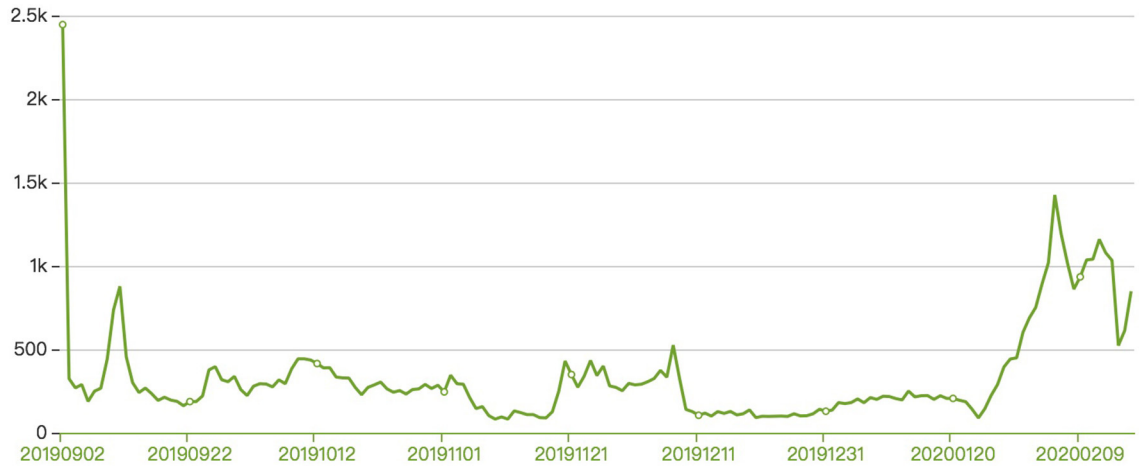

FIGURE 1 | Applications from January 31 to February 14 of 2020.

before the COVID-19 pandemic and significantly decreased in 2020 after the outbreak of the pandemic.

Participants were from 31 provinces of China. Correlations between the number of participants and socioeconomic factors of 31 provinces in 2018, 2019 and 2020 were analyzed using the Pearson correlation test. The results showed that all factors (GDP, population, CPI, number of certified cosmetic manufacturing companies, number of universities, number of college students) were positively correlated with the number of applicants (**Table 2**). For each year, GDP, population and number of college students were the top 3 factors mostly related to the number of participants.

The STEPLS was used to estimate the effects of the top 3 socioeconomic factors (GDP, population, and number of college students) on the number of participants in different regions of China in different years (**Table 3**). The results revealed that GDP was positively related to the number of participants in the whole region, no matter before (2018 and 2019) or after (2020) the outbreak of the COVID-19 pandemic, which was consistent with the Pearson correlation test results. The number of participants had a sustainable positive relationship with GDP in eastern China from 2018 to 2020, but in other regions, the numbers were not always associated with GDP. Before the pandemic in 2018 and 2019, the number of college students was not related to the number of course participants. However, after the outbreak of the pandemic in 2020, the number of college students had a positive correlation with the number of participants, especially in the central and western regions.

Table 4 presents the regression results in relation to the panel data. In general, the effects of the three main socioeconomic factors (GDP, population and number of college students) of the eastern region are consistent with those of the whole region. The correlation coefficient of the number of participants and GDP in the eastern region was significantly higher than those in the central and western regions, reflecting the effect of GDP on education inequality. The results demonstrated a negative correlation between the population of each region and the number of participants. The number of college students, population and GDP were all positively correlated with the number of participants in the eastern region. The results indicated that the quality of education and the economic level within the population exerted a positive effect on online courses in the east. The number of college students was positively correlated with the number of participants in the central and western regions, while population and GDP were negatively related.

TABLE 1 | Performance of course participants in different years.

	2018	2019	2020
Number of participants	34,774	30,348	55,237
Completion rate (number)	7.93% (,2757)	7.83% (2,377)	5.53% (3,056)
Pass rate (number)	1.65% (574)	1.25% (378)	1.25% (691)
Rate of excellent performance (number)	0.54% (188)	0.70% (212)	0.79% (463)

TABLE 2 | Correlation between the number of participants and socioeconomic factors across 31 provinces of China.

	2018 Coeff.	2019Coeff.	2020 Coeff.
GDP	0.8795	0.8400	0.8160
Population	0.7314	0.7604	0.6677
Number of college students	0.7212	0.7980	0.6777
Number of universities	0.6617	0.7254	0.5954
CPI	0.5531	0.3333	0.4043
Number of certified cosmetic manufacturing companies	0.5214	0.4829	0.4134

Coeff., correlation coefficient (R value); the stronger the tendency was, the larger the R value.

TABLE 3 | Effects of GDP, population, and number of college students on the number of participants in different regions of China in different years.

Year	Socioeconomic factor	Whole region Coeff.	Eastern region Coeff.	Central region Coeff.	Western region Coeff.
2018	GDP	0.0362***	0.0307***	N/A	0.0499***
	Population	N/A	N/A	0.204***	N/A
	Number of college students	N/A	N/A	N/A	N/A
2019	GDP	0.0313***	0.0367***	N/A	N/A
	Population	−0.288**	−0.356***	N/A	−0.564***
	Number of college students	N/A	N/A	18.40***	N/A
2020	GDP	0.109***	0.125**	N/A	N/A
	Population	−0.896**	−1.639*	N/A	N/A
	Number of college students	35.37*	74.85*	36.02***	7.041**

*Coeff., correlation coefficient; ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$; N/A, not available, uncorrelated.*

TABLE 4 | Results of the panel data regression analysis for different variables.

Socioeconomic factor	Whole region Coeff.	Eastern region Coeff.	Central region Coeff.	Western region Coeff.
GDP	0.0634***	0.0705***	−0.0684	−0.00215
Population	−0.529***	−0.862***	−0.297	−0.0889
Number of college students	24.01***	41.98***	56.23***	14.20**

*Coeff., correlation coefficient; ***$p < 0.01$; **$p < 0.05$.*

DISCUSSION

In recent years, online commerce, banking, and social networks have changed the way we shop, manage our lives, and meet and communicate with each other. Compared with the 2003 outbreak of severe acute respiratory syndrome (SARS), citizens were better equipped to cope with quarantine in an epidemic. Notably, we raise concerns regarding whether convenient network life and online learning can exacerbate rather than reduce disparities in resource distribution among regions related to socioeconomic status during the COVID-19 pandemic.

This study showed that the number of individuals enrolled in the cosmetic dermatology online course almost doubled after the outbreak of COVID-19. The COVID-19 pandemic indeed attracted more people to choose online courses as their way of learning. The COVID-19 pandemic has caused a lockdown situation impeding all educational institutions. This circumstance demanded online classes as an alternative strategy for the continuation of education. Many people who would not study on the internet turned to choose online education during the pandemic. Participants may choose MOOCs out of various reasons. Apart from the self-motivated reason, socioeconomic factors also play an important role in their decisions (20, 23, 24).

The completion rates were relatively low each year, which was consistent with data reported in the literature (23). Many factors may induce a low completion rate, such as the course length and design, the flexible learning form of MOOCs, the complicated background of participants and their ability to access the needed technology for MOOCs and so on (25). The completion rate in 2020 was significantly lower than those in 2018 and 2019. The current era of information overload, especially in the quarantine during a pandemic, can also create a multitude of distractions and obstacles for participants to complete an online course. Participants from a more diverse background after the outbreak of the COVID-19 pandemic tended to have less patience, and the ability to complete the course might also be a reason.

The unbalanced development of the regional economy is a common problem in all countries around the world, including China. With China's vast land and abundant resources, regional socioeconomic distribution has been driven by a boom in natural resources. The existing studies were based on individual socioeconomic status and educational attainment. A previous study conducted by Harvard and MIT between 2012 and 2014 reported that MOOC participants tended to live in more affluent and better-educated neighborhoods than the average U.S. resident (20). Studies have also reported that telemedicine could be helpful in the current pandemic, but organizational readiness to adopt telemedicine needs urgent attention (24, 26). Does digital divide exist despite broad accessibility of mobile tools and internet use in China? If it exists, does the COVID-19 pandemic increase it?

We evaluated regional economy (GDP, CPI), higher education distribution (number of higher institutions and college students), cosmetic industry distribution (number of certified cosmetic manufacturing companies) and population as potential confounders between the relationship with our cosmetic dermatology course participants in different years, including years before (2018 and 2019) and after the pandemic (2020). The results of the Pearson correlation test showed that all the above factors were positively correlated with the number of participants. GDP, population and the number of college students were the top 3 most related socioeconomic factors. Panel data regression analysis and STEPLS also revealed that

GDP and the number of college students were positively related to the number of participants in the whole region of China.

Population is an important socioeconomic factor. Inequalities exist between different populations depending upon their geographical locations. In rural areas with a small population, large investments and diminishing profits make building broadband infrastructure an unattractive investment (27). Online education could also be affected by population. The results of the Pearson correlation test of our study showed that the correlation between the number of students and the population was strongly positive each year. However, panel data regression analysis and STEPLS revealed the opposite result. Panel data have both temporal and cross-sectional dimensions. This method can eliminate the problems caused by strong correlation and collinearity between data. Thus, we think that the positive correlation between the population and the number of students is not reliable. The population may not be a suitable factor for the analysis of this study because the population is enormous and the number of participants of the MOOC course is too small.

GDP, the most commonly reported measure of aggregate output, is the market value of all final goods and services produced and is representative of the level of general welfare (28–30). Sometimes, GDP means that the government might give priority to regional construction in allocating education, economy and infrastructure resources (28). GDP is abetted in part by resource distribution and government decisions whose impact is considered by the population density. In other words, the economic future of most regional areas will be determined by the productivity of these burgeoning populations. It is necessary to provide demographic approval for the implementation of a higher education strategy in China from demographic and economic perspectives. Previous studies have demonstrated that MOOCs and similar approaches cannot "democratize education" as a change in structure within an individual's socioeconomic status (1, 3, 10, 31). The results of our study inferred that GDP might impact the number of MOOC participants. The majority of participants of our MOOC course were from Jiangsu, a developed province of coastal areas in China, with its people relatively richer and further educated (1, 3, 32). As a province with rapid economic development, Guangdong had the third most registered participants, holding the leading position in both GDP and financial revenue (33, 34). Taking into consideration China's large surface area and the uneven distribution of regional development, we further analyzed data from different regions (eastern, central and western), which might provide us with more information on the correlation of participants and socioeconomic factors. The eastern region is resource-poor, the central and western regions are resource-rich (32). Previous literature has consistently confirmed the negative impact of natural resource dependence on public education expenditure (35–37). The eastern region is better developed and tends to spend more education expenditure than other regions. Our study showed that the number of participants had a sustainable positive relationship with GDP in eastern China from 2018 to 2020, which was consistent with the results in the whole region. However, in other regions, the numbers were not always associated with GDP. We speculated that this was because participants from the eastern region predominated.

Education is a major factor contributing to economically sustainable development due to its potential for improving cognition and skill levels and therefore enhancing worker productivity. Our study showed that there was a positive correlation between the number of MOOC participants and the number of college students, which inferred that MOOCs could exacerbate the digital divide. MOOCs have been reported to favor participants with higher education (23). Previous studies have also found that MOOC students have the advantages of higher educational credentials (38) and that most MOOC students are graduates with a bachelor's degree, while the remainder are older "continuing learners" (16, 39–41). There are even some interesting studies suggesting that parents' literacy has an influence on the completion rates of MOOCs (20). This study revealed that economic conditions and education are explanatory factors with a seemingly greater significance and impact on online learning in provinces as well as other administrative regions with higher levels of economic development. The panel regression model and stepwise least squares regression analysis (STEPLS) also showed that before the pandemic in 2018 and 2019, the number of college students was not related to the number of course participants. However, after the outbreak of the pandemic in 2020, the number of college students had a positive correlation with the number of participants, especially in the central and western regions. It has been reported that online courses play an important role in student isolation at home (42). Our results further indicated that MOOCs had become a mainstream method for college students during the pandemic. The number of college students became positively related to the number of participants during the pandemic also implying that the pandemic could increase the digital divide.

CONCLUSIONS

In conclusion, this study investigated an online cosmetic dermatology course and compared data of course participants and socioeconomic factors before and after the COVID-19 pandemic. The results showed that the epidemic attracted more people to choose online courses. GDP was the most important socioeconomic factor that determined the total number of participants and it was positively related to the total number of participants in the whole region before and after the outbreak of the pandemic. The number of college students was unrelated to the total number of participants before the epidemic, and after the outbreak of COVID-19 in 2020, the number became positively related in all regions of China, which prompted MOOCs to become a mainstream study method for college students in the pandemic and implied that the pandemic increased the digital divide. Our study could enrich the public in regard to online education on cosmetic-associated

dermatological knowledge from the view of the regional socioeconomic distribution.

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

MS, LX, and YC: formal analysis. MS and LX: writing—original draught preparation. LL and YM: conceptualisation and project administration. LX, LL, JT, and WH: resources and data curation. YC and YM: writing—review and editing. 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.2021.796210/full#supplementary-material

REFERENCES

1. Ali ST, Wang L, Lau EHY, Xu XK, Du Z, Wu Y, et al. Serial interval of SARS-CoV-2 was shortened over time by nonpharmaceutical interventions. *Science.* (2020) 369:1106–9. doi: 10.1126/science.abc9004
2. Lades LK, Laffan K, Daly M, Delaney L. Daily emotional well-being during the COVID-19 pandemic. *Br J Health Psychol.* (2020) 25:902–11. doi: 10.1111/bjhp.12450
3. Brooks SK, Webster RK, Smith LE, Woodland L, Wessely S, Greenberg N, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *Lancet.* (2020) 395:912–20. doi: 10.1016/S0140-6736(20)30460-8
4. Kakaje A, Fadel A, Makki L, Ghareeb A, Al Zohbi R. Mental distress and psychological disorders related to COVID-19 mandatory lockdown. *Front Public Health.* (2021) 9:585235. doi: 10.3389/fpubh.2021.585235
5. Zhang Y, Bao X, Yan J, Miao H, Guo C. Anxiety and depression in chinese students during the COVID-19 pandemic: a meta-analysis. *Front Public Health.* (2021) 9:697642. doi: 10.3389/fpubh.2021.697642
6. Zhang C, Chen C, Shen W, Tang F, Lei H, Xie Y, et al. Impact of population movement on the spread of 2019-nCoV in China. *Emerg Microbes Infect.* (2020) 9:988–90. doi: 10.1080/22221751.2020.1760143
7. Bao W. COVID-19 and online teaching in higher education: a case study of Peking University. *Hum Behav Emerg Technol.* (2020) 2:113–5. doi: 10.1002/hbe2.191
8. Sun L, Tang Y, Zuo W. Coronavirus pushes education online. *Nat Mater.* (2020) 19:687. doi: 10.1038/s41563-020-0678-8
9. Soltani-Arabshahi R, Wong JW, Duffy KL, Powell DL. Facial allergic granulomatous reaction and systemic hypersensitivity associated with microneedle therapy for skin rejuvenation. *JAMA Dermatol.* (2014) 150:68–72. doi: 10.1001/jamadermatol.2013.6955
10. Steiling W, Almeida JF, Assaf Vandecasteele H, Gilpin S, Kawamoto T, O'Keeffe L, et al. Principles for the safety evaluation of cosmetic powders. *Toxicol Lett.* (2018) 297:8–18. doi: 10.1016/j.toxlet.2018.08.011
11. Barroso J, Pfannenbecker U, Adriaens E, Alépée N, Cluzel M, De Smedt A, et al. Cosmetics Europe compilation of historical serious eye damage/eye irritation *in vivo* data analysed by drivers of classification to support the selection of chemicals for development and evaluation of alternative methods/strategies: the Draize eye test Reference Database (DRD). *Arch Toxicol.* (2017) 91:521–47. doi: 10.1007/s00204-016-1679-x
12. Dréno B, Alexis A, Chuberre B, Marinovich M. Safety of titanium dioxide nanoparticles in cosmetics. *J Eur Acad Dermatol Venereol.* (2019) 33 Suppl 7:34–46. doi: 10.1111/jdv.15943
13. Pauwels M, Rogiers V. Human health safety evaluation of cosmetics in the EU: a legally imposed challenge to science. *Toxicol Appl Pharmacol.* (2010) 243:260–74. doi: 10.1016/j.taap.2009.12.007
14. de Jong PGM, Pickering JD, Hendriks RA, Swinnerton BJ, Goshtasbpour F, Reinders MEJ. Twelve tips for integrating massive open online course content into classroom teaching. *Med Teach.* (2020) 42:393–7. doi: 10.1080/0142159X.2019.1571569
15. Lau KHV, Farooque P, Leydon G, Schwartz ML, Sadler RM, Moeller JJ. Using learning analytics to evaluate a video-based lecture series. *Med Teach.* (2018) 40:91–8. doi: 10.1080/0142159X.2017.1395001
16. Chan MM, Barchino R, Medina-Merodio JA. de la Roca M, Sagastume F. MOOCs, an innovative alternative to teach first aid and emergency treatment: a practical study. *Nurse Educ Today.* (2019) 79:92–7. doi: 10.1016/j.nedt.2019.05.008
17. Jia M, Gong D, Luo J, Zhao J, Zheng J, Li K. Who can benefit more from massive open online courses? A prospective cohort study. *Nurse Educ Today.* (2019) 76:96–102. doi: 10.1016/j.nedt.2019.02.004
18. Kabri TH, Arab-Tehrany E, Belhaj N, Linder M. Physico-chemical characterization of nano-emulsions in cosmetic matrix enriched on omega-3. *J Nanobiotechnology.* (2011) 9:41. doi: 10.1186/1477-3155-9-41
19. Vecino X, Cruz JM, Moldes AB, Rodrigues LR. Biosurfactants in cosmetic formulations: trends and challenges. *Crit Rev Biotechnol.* (2017) 37:911–23. doi: 10.1080/07388551.2016.1269053
20. Hansen JD, Reich J. Democratizing education? Examining access and usage patterns in massive open online courses. *Science.* (2015) 350:1245–8. doi: 10.1126/science.aab3782
21. Attewell P. The first and second digital divides: a magazine of theory and practice. *Sociol Educ.* (2001) 74:252–9. doi: 10.2307/2673277
22. León-Nabal B, Zhang-Yu C, Lalueza JL. Uses of digital mediation in the school-families relationship during the COVID-19 pandemic. *Front Psychol.* (2021) 12:687400. doi: 10.3389/fpsyg.2021.687400
23. Goldberg LR, Bell E, King C, O'Mara C, McInerney F, Robinson A, et al. Relationship between participants' level of education and engagement in their completion of the understanding dementia massive open online course. *BMC Med Educ.* (2015) 15:60. doi: 10.1186/s12909-015-0344-z
24. Seifert A, Batsis JA, Smith AC. Telemedicine in long-term care facilities during and beyond COVID-19: challenges caused by the digital divide. *Front Public Health.* (2020) 8:601595. doi: 10.3389/fpubh.2020.601595
25. Yang X, Li D, Liu X, Tan J. Learner behaviors in synchronous online prosthodontic education during the 2020 COVID-19 pandemic. *J Prosthet Dent.* (2021) 126:653–7. doi: 10.1016/j.prosdent.2020.08.004
26. Gallistl V, Seifert A. Kolland F. COVID-19 as a "digital push?" research experiences from long-term care and recommendations for the post-pandemic era. *Front Public Health.* (2021) 9:660064. doi: 10.3389/fpubh.2021.660064
27. Reddick CG, Enriquez R, Harris RJ, Sharma B. Determinants of broadband access and affordability: an analysis of a community survey on the digital divide. *Cities.* (2020) 106:102904. doi: 10.1016/j.cities.2020.102904
28. Zhang M, Chen W, Cai K, Gao X, Zhang X, Liu J, et al. Analysis of the spatial distribution characteristics of urban resilience and its influencing factors: a case study of 56 cities in China. *Int J Environ Res Public Health.* (2019) 16:4442. doi: 10.3390/ijerph16224442

29. Lin JK, Moran AE, Bibbins-Domingo K, Falase B, Pedroza Tobias A, Mandke CN, et al. Cost-effectiveness of a fixed-dose combination pill for secondary prevention of cardiovascular disease in China, India, Mexico, Nigeria, and South Africa: a modelling study. *Lancet Glob Health.* (2019) 7:e1346–e58. doi: 10.1016/S2214-109X(19)30339-0
30. Wang B. Investigating network structure of cross-regional environmental spillover effects and driving factors. *J Air Waste Manag Assoc.* (2020) 70:243–52. doi: 10.1080/10962247.2019.1680460
31. Foo J, Rivers G, Allen L, Ilic D, Maloney S, Hay M. The economic costs of selecting medical students: an Australian case study. *Med Educ.* (2020) 54:643–51. doi: 10.1111/medu.14145
32. Sun HP, Sun WF, Geng Y, Yang X, Edziah BK. How does natural resource dependence affect public education spending? *Environ Sci Pollut Res Int.* (2019) 26:3666–74. doi: 10.1007/s11356-018-3853-6
33. Wang S, Xie Z, Wu R. Examining the effects of education level inequality on energy consumption: evidence from Guangdong Province. *J Environ Manage.* (2020) 269:110761. doi: 10.1016/j.jenvman.2020.110761
34. Wu N, Hou Y, Wang Q, Yu C. Intergenerational transmission of educational aspirations in Chinese families: identifying mediators and moderators. *J Youth Adolesc.* (2018) 47:1238–51. doi: 10.1007/s10964-018-0820-y
35. Gylfason T. Natural resources, education, and economic development. *Eur Econ Rev.* (2001) 45:847–59. doi: 10.1016/S0014-2921(01)00127-1
36. Douangngeune B, Godo Y, Wiemer C. Education and natural resources in economic development: Thailand compared with Japan and Korea. *J Asian Econ.* (2005) 16:179–204. doi: 10.1016/j.asieco.2004.12.004
37. Cockx L, Francken N. Natural resources: a curse on education spending? *Energy Policy.* (2016) 92:394–408. doi: 10.1016/j.enpol.2016.02.027
38. Ingolfsdottir K. Winds of change in higher education. *Trends Pharmacol Sci.* (2016) 37:990–2. doi: 10.1016/j.tips.2016.09.008
39. Pottier E, Boulanouar L, Bertrand M, Estrade A, Croiset A, Martineau C, et al. A MOOC about bariatric surgery improves knowledge and promotes patients' soft skills. *Obes Surg.* (2020) 30:1600–4. doi: 10.1007/s11695-019-04143-5
40. Lan M, Hou X, Qi X, Mattheos N. Self-regulated learning strategies in world's first MOOC in implant dentistry. *Eur J Dent Educ.* (2019) 23:278–85. doi: 10.1111/eje.12428
41. Meinert E, Alturkistani A, Car J, Carter A, Wells G, Brindley D. Real-world evidence for postgraduate students and professionals in healthcare: protocol for the design of a blended massive open online course. *BMJ Open.* (2018) 8:e025196. doi: 10.1136/bmjopen-2018-025196
42. Munshi F, Alsughayyer A, Alhaidar S, Alarfaj M. An online clinical examination for fellowship certification during the COVID-19 pandemic. *Med Educ.* (2020) 54:954–5. doi: 10.1111/medu.14267

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Global Trends and Hot-Spots in Research on Virtual Simulation in Nursing: A Bibliometric Analysis From 1999 to 2021

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Background: Virtual simulation has been widely used in nursing education and nursing training. This study aims to characterize the publications in terms of countries, institutions, journals, authors, collaboration relationships, and analyze the trends of virtual simulation in nursing research.

Methods: Publications regarding virtual simulation in nursing were retrieved from Web of Science core collection. Microsoft Excel 2010, VOSviewer were used to characterize the contributions of the authors, journals, institutions, and countries. The trends, hot-spots and knowledge network were analyzed by Citespace and VOSviewer.

Results: We identified 677 papers between 1999 and 2021. The number of publications grew slowly until 2019, after that, it got a sharp increase in 2020 and 2021. The USA, Canada and Australia were three key contributors to this field. Centennial College and University of San Paulo, University of Ottawa and Ryerson University were top major institutions with a larger number of publications. Verkuyl M was the most productive and highest cited author. Clinical Simulation in Nursing, Nurse Education Today, Journal of Nursing Education were the three productive journals. The foundational themes of virtual simulation research in nursing are "virtual learning during COVID-19, clinical nursing care, education in nurse practitioners, education technology".

Conclusion: Virtual simulation in nursing field has attracted considerable attention during COVID-19 pandemic. The research hotspot is gradually shifting from clinical nursing care to studies of nursing education using different virtual simulation technologies

Keywords: virtual simulation, nursing, bibliometric analysis, hot-spots, Citespace, VOSviewer

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INTRODUCTION

Virtual simulation (VS) is defined by a kind of computer simulation systems involving real people operating simulated systems, it could provide immersive, highly visual, 3D characteristics that allow the users to explore the role and changes within a seemingly real or physical world (1). Generally, it included three technologies [e.g., virtual reality (VR), augmented reality (AR), and mixed reality (MR)] (2, 3). In the last decades, with the adoption, application, and maturity of these technologies, nursing educators have increasingly used VS for nursing education and clinical training.

For example, Girao et al. (4) developed a serious virtual reality game for medication preparation and administration training. Weston and Zauche (5) conducted a virtual simulation with clinical practice for pediatric nursing students. Chao et al. (6) applied the immersive three-dimensional interactive video program to help nursing students better acquire nasogastric tube feeding skills. Compared to traditional teaching approaches, VS has the advantage of minimal requirement of medical equipments or consumables. What's more, the sense of immersion is enhanced by wearable displays, interactivity, and haptic devices. And users can practice it anywhere and anytime as long as the device is available (1). In 2018, Tiffany and Forneris (7) forecast that the adoption of VR in nursing education will from the current 10% use to 45% in the next 5 years. Specifically, The COVID-19 (coronavirus disease) pandemic has spurred a transition from face-to-face teaching to virtual learning (5, 8). As a burgeoning area, more and more educators and policymakers prefer using VS to assist teaching. To this end, there is an urgent need to investigate the performance (e.g., primary contributors and highly cited articles) and scientific map (collaborations, research themes, and trends) to show the past, present, and future direction in this field.

Bibliometric analysis is widely accepted for reviewing big data of articles in a field or publications in a journal using quantitative techniques (9, 10). It usually applies bibliometric tools (e.g., Bibliometrix R, Gephi, Pajek, CiteSpace, Leximancer, and VOSviewer) to analyze the publication trend, the top articles, primary contributors, and major theme and frontier topics in a given field (11–13). There are several existing bibliometric analysis about nursing topics (14–16). However, no study focused on bibliometric analysis to provide a state-of-the-art review for VS research in nursing field. Therefore, in this study, we utilized the popular bibliometric tools, Citespace and Vosviewer (17, 18), to comprehensively analyze VS research in nursing based on the Web of Science Core Collection (WoSCC). We hope this paper will uncover the following research questions (RQ).

RQ1. What is the publication trend for virtual simulation research in nursing?

RQ2. Which are the most influential articles and primary contributing authors, institutions, countries, journals for virtual simulation research in nursing?

RQ3. What are the potential collaborators (author, institutions, countries/regions) for virtual simulation research in nursing?

RQ4. What are the major themes and frontier topics for virtual simulation research in nursing?

MATERIALS AND METHODS

Aims

The aims of this study are as following: (1) to uncover the major contributors (e.g., countries, institutions, journals, authors, articles) in VS related to nursing research. (2) To analyze the co-operation relationships in this field. (3) To map the knowledge network and identify the frontier topics, and point the future directions in this field.

Design

A descriptive bibliometric analysis of publications in virtual simulation related to nursing research.

Sample/Participants

The data in this research were retrieved from Web of Science database, so no participants were involved.

Search Strategy

The advanced search was performed using Web of Science (Thomson Reuters, New York, USA) on March 15th, 2022. Formula: (((TS= ("virtual simulation" or "virtual realit*" or "virtual reality simulation" or "virtual learning" or "augmented realit*" or "mixed reality") and TS= ("nurs*")) AND DOP=(1999-01-01/2021-12-31)) AND DT=(Article OR Review)) AND LA=(English) was used to screen out publications associated with VS in nursing. Two team members (Qian Zhang and Jing Liu) searched and screened the database independently. Any discrepancies were resolved by discussion with Jia Chen until consensus was reached.

Inclusion Criteria

(1) Peer-reviewed articles involving VS related to nursing
(2) Original articles and review articles
(3) Written in English.
(4) Web of Science core collection (WoSCC).

Exclusion Criteria

(1) Unpublished papers
(2) Articles required a manual research.

Data Extraction and Analysis

The following bibliometric parameters were extracted, such as title, keywords, journal, publication year, citation counts, citations per paper, H-index, author, institution, country, and references. And then these data were imported into Microsoft Excel 2010 (Redmond, Washington, USA) to analyze the contributions of different countries, institutions, journals, and authors. VOSviewer (Leiden University, Leiden, the Netherlands) was applied to visualize the maps of coauthor-authorship, coauthor-institution, coauthor-country, co-citation references, and keywords co-occurrence. In the VOSviewer map, node size indicates the number of articles produced. The wider links between nodes means stronger cooperation strength. The color means the average publication year for the node. Blue represents the early and yellow represents the late. Citespce (Version 5.8. R1) was used to identify the keywords burst and co-cited references burst (18).

Abbreviations: WoSCC, Web of Science core collection; VS, virtual simulation; VR, virtual reality; AR, augmented reality; MR, mixed reality; IF, impact factor; CPR, cardiopulmonary resuscitation.

RESULTS

General Data

An initial research of the WoSCC identified 848 publications. After excluded meeting abstract, early access and limited English language, 677 articles were finally enrolled into analysis. Original article accounts for 86.1% of the total ($n = 583$) (**Figure 1**). These papers were published from 1999 to 2021. The timing of publication could be divided into three periods (Phase I, 1999–2008; Phase II, 2009–2019; Phase III, 2020–2021). 1999–2008, the number of articles per year was below 10 publications. 2009–2019, the annual output of this field has grown consistently to over 50 publications. The growth is evident since 2020, with more than 100 papers published each year (126 publications in 2020 and 217 publications in 2021). In other words, more than half of papers were published in these 2 years. The peak year was 2021 ($n = 217$) (**Figure 2A**). The total number of citations was 8885, with 13.1 citations per paper and 47 H-index. The annual year publications of the top 10 countries were shown in **Figure 2B**. The USA was the major contributor in this field, and almost leading this field since its inception.

Active Authors and Co-cited Authors

The top 10 prolific authors in this area were all from North America (**Table 1**). Of them, there were nine from Canada, and one from the USA. They published 84 papers and accounted for 12.4% of the total papers. Verkuyl M. from Centennial College was the most productive author in this scope with 15 publications. Followed by Luctkar-flude M from Queens University and Tyerman J from University of Ottawa with 12 papers. In terms of co-cited authors, Verkuyl, M, Hoffman HG, and Foronda, Cl were ranked the first three. **Supplementary Figure 1** showed the author cooperation

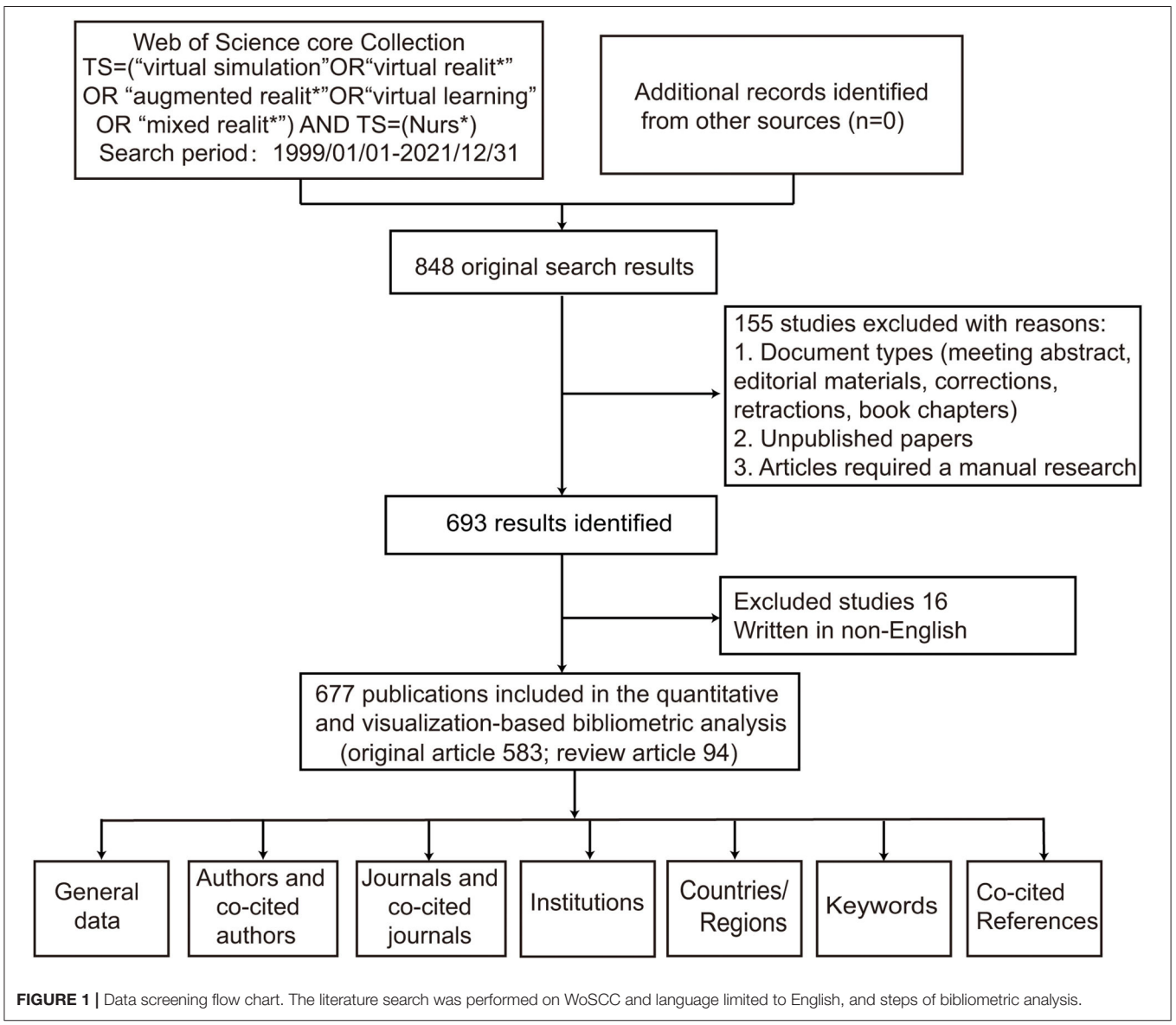


FIGURE 1 | Data screening flow chart. The literature search was performed on WoSCC and language limited to English, and steps of bibliometric analysis.

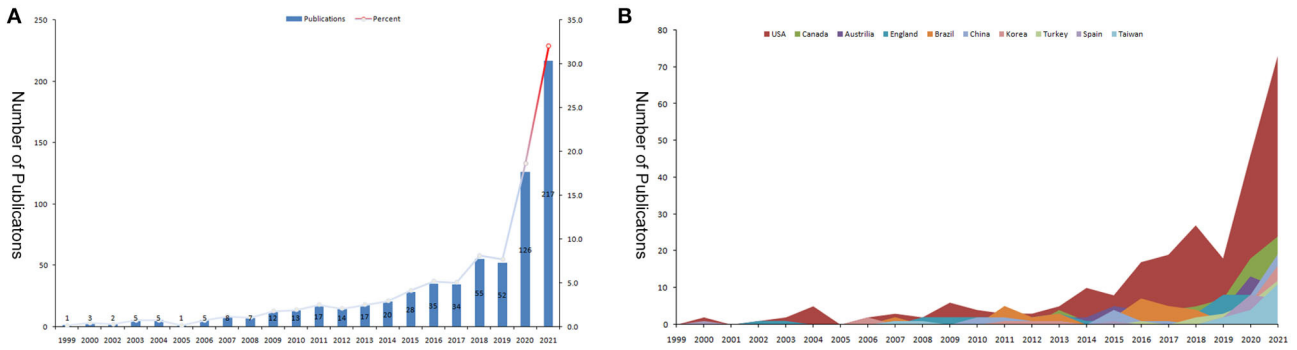


FIGURE 2 | The number of publications and total citations related to virtual simulation in nursing studies. **(A)** The number of papers published and total citations each year. **(B)** The top 10 countries/regions annual publications.

TABLE 1 | Top 10 prolific authors and co-cited authors on virtual simulation research in nursing.

Rank	Author	Publications	Citations	Country	Co-cited author	Co-citations	Country
1	Verkuyl, M	15	167	Canada	Verkuyl, M	128	Canada
2	Luctkar-Flude, M	12	33	Canada	Hoffman, Hg	124	USA
3	Tyerman, J	12	33	Canada	Foronda, Cl	90	USA
4	Hughes, M	8	95	Canada	Inacsl Stand, Comm	78	N/A
5	Lapum, JL.	7	79	Canada	Jeffries, Pr	77	USA
6	Mastrilli, P	7	117	Canada	Cook, Da	66	USA
7	Romaniuk, D	7	120	Canada	Foronda, C	66	USA
8	St-Amant, O	6	30	USA	Padilha, Jm	51	Portugal
9	Goldsworthy, S	5	7	Canada	World Health, Organization	49	N/A
10	Mcculloch, T	5	74	Canada	Cant, Rp	47	Australia

network and co-cited author network. There were scattered co-operations between them, and authors who work together have strong citation ties.

Active Journals and Co-cited Journals

The top 10 active and co-cited journals were identified by VOSviewer. Altogether, 269 journals contributed to VS in nursing. The top 10 most productive journals hosts 235 (34.7%) papers. Clinical Simulation in Nursing is the most productive journal (n = 89; 888 citations), followed by Nurse Education Today (n = 49; 584 citations), Journal of Nursing Education and Cin-Computers Informatics Nursing share the third position (n = 15). The top three co-cited journals were the same top three prolific journals, with 820, 667, 339 co-citations, respectively (**Table 2**).

Active Institutions

The top 10 most productive institutions were presented in **Figure 3A**. Among the top 10 institutions, there were five located in Canada, three in the USA, and one in Australia, Brazil, respectively. Centennial College and University of San Paulo were the most prolific institution (n = 15 publications), followed by University of Ottawa and Ryerson University (n = 14). In terms of total citations and citations per paper, University of Toronto (Canada, 595 citations, 54 citations/paper), University of Queensland (Australia, 383 citations, 38.3 citations/paper), University of Washington (Canada, 266 citations, 24.2 citations/paper) ranked in the top three. The co-authorship for organization module in VOSviewer was used to visualize the collaboration relationship among 38 institutions, which published at least five papers. As shown in **Figure 3B**, There were few and sporadic connecting lines between different institutions.

Active Countries/Regions

A total of 58 countries/regions participated in these publications. The top 10 were shown in **Figure 4A**. Obviously, the USA led in this field with 256 publications (37.8% of the total), followed by Canada (n = 73), Australia and England (n = 45). In terms of total citations, the USA ranked the first (4201), followed by Canada (1418) and England (816). In regard to citations per paper, Canada ranked first (19.4), followed by England (18.1) and the USA (16.4). The module of co-authorship for country in VOSviewer was used to map the countries' collaboration network. The smallest number of publications was settled as five, total link strength. Finally, 26 countries/regions meet our criterion. The USA, Canada, Australia, and England presented as the largest node. The strongest cooperation was between the USA and Canada and the USA and Australia (**Figure 4B**).

TABLE 2 | Top 10 prolific journals and co-cited journals on virtual simulation research in nursing.

Rank	Journal	Publications	Citations	IF*	Co-cited journal	Co-citations	IF
1	Clinical Simulation In Nursing	89	888	2.391	Clinical Simulation In Nursing	854	2.391
2	Nurse Education Today	49	584	3.442	Nurse Education Today	690	3.442
3	Cin-Computers Informatics Nursing	15	128	1.985	Journal of Nursing Education	278	1.726
4	Journal Of Nursing Education	15	116	1.726	Nursing Education Perspective	246	N/A
5	Nurse Educator	14	136	2.082	Computers & Education	225	8.538
6	Journal Of Medical Internet Research	12	219	5.428	Nurse Education In Practice	208	2.281
7	Nurse Education In Practice	12	206	2.281	Journal of Advanced Nursing	198	3.843
8	Journal Of Clinical Nursing	10	186	3.036	Journal of Medical Internet Research	197	5.428
9	Revista Latino-Americana De Enfermagem	10	74	1.886	Simulation in Healthcare-Journal of the Society for Simulation in Healthcare	194	1.929
10	Journal Of Advanced Nursing	9	97	3.843	Medical Education	176	6.251

Abbreviation for impact factor (Journal Citation Reports, 2020).

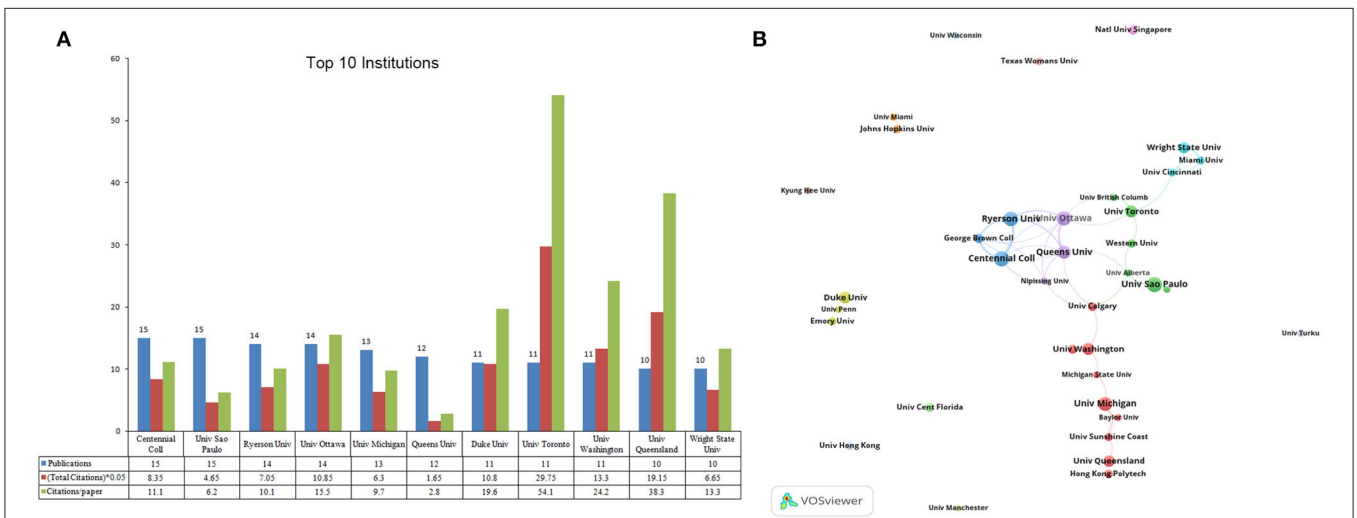


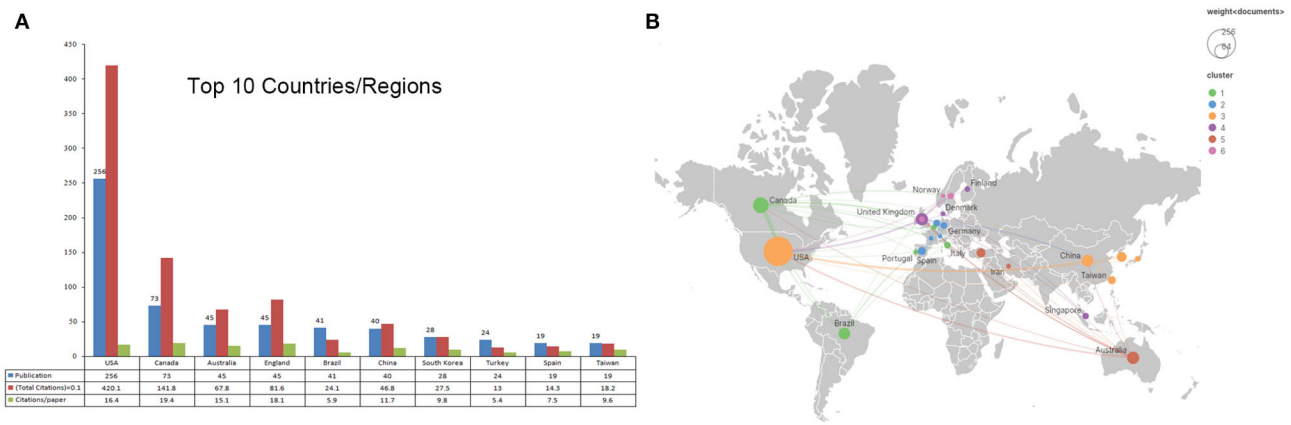
FIGURE 3 | The top 10 most productive institutions and inter-institution co-operation relationships on virtual simulation in nursing research. **(A)** The number of publications, total citations, and citations per paper in top 10 institutions. **(B)** The co-authorship network visualization map of institution for virtual simulation in nursing research. Node size indicated the number of articles produced. The distance between any two nodes positively associated with the cooperation strength.

Keywords

High-frequency keywords was usually used to describe hot-spots, and construct a knowledge map in a given field (19). We identified 1,540 keywords in total, 92 keywords occurred more than five times were enrolled into analysis. As shown in **Figure 5A**, the keywords were classified into nine clusters. The core keywords in the top five largest clusters, which ranked by the number of occurrences, are virtual reality (n = 183), simulation (n = 108), nurse education (n = 95), nursing (n = 92), virtual simulation (n = 88). As shown in **Figure 5B**, keywords were colored according to their average publication years. We observed although the concept of virtual simulation was built up early (colored by blue), there are lots of frontier topics spring up in recent years (colored by yellow), such as "nurse education, clinical simulation, augmented reality, and virtual learning". Also, Citespace burst module was used to identify the research trends and shift of center topics in a given field (20). The burst duration was set to 2 years. The blue and red bar indicated infrequently and frequently cited time. The top 22 keywords with strongest citation bursts were identified and displayed in **Figure 5C**. Among them, virtual reality simulation has the highest burst strength (n = 4.8). The topics gradually shifted from "distress, cancer, model, and technology" to "education, quality, clinical simulation, and student".

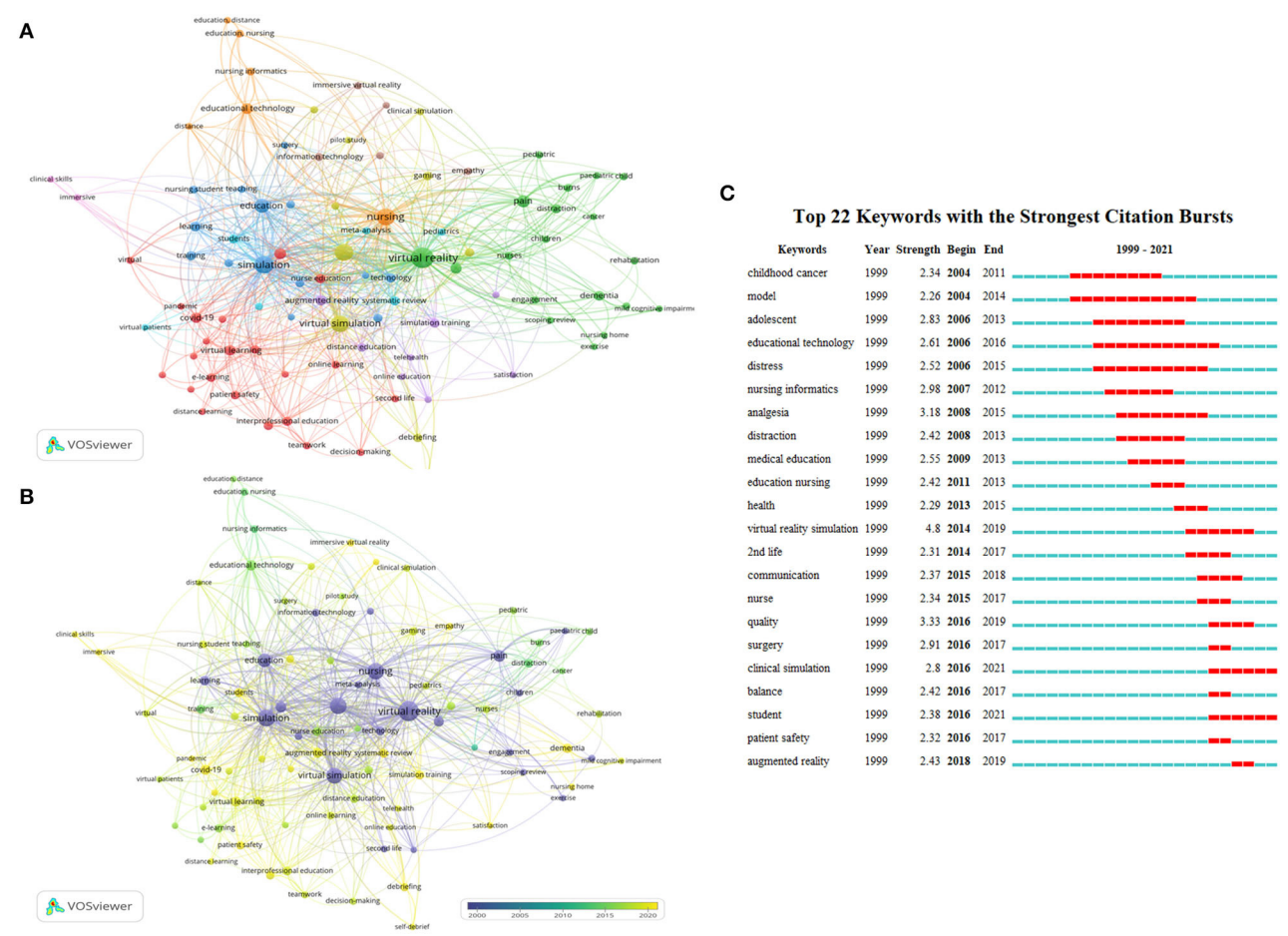
Top Cited Articles and Co-cited References

The top 10 most cited articles are listed in **Table 3**. The most cited article was produced by Gold et al. (21) published in



	USA	Canada	Australia	England	Brazil	China	South Korea	Turkey	Spain	Taiwan
Publication	256	73	45	45	41	40	28	24	19	19
(Total Citations)/0.1	420.1	141.8	67.8	81.6	24.1	46.8	27.5	13	14.3	18.2
Citations/paper	16.4	19.4	15.1	18.1	5.9	11.7	9.8	5.4	7.5	9.6

FIGURE 4 | The top 10 prolific countries/regions and inter-national collaboration network on virtual simulation in nursing research. **(A)** The number of publications, total citations, and citations per paper in top 10 countries/regions. **(B)** The co-authorship network visualization map of countries for virtual simulation in nursing research. Node size indicated the number of articles produced. The distance between any two nodes positively associated with the cooperation strength. The color indicated the average publication year for the author, The blue color represented for early stage and yellow color represented late stage.



Keywords	Year	Strength	Begin	End	1999 - 2021
childhood cancer	1999	2.34	2004	2011	
model	1999	2.26	2004	2014	
adolescent	1999	2.83	2006	2013	
educational technology	1999	2.61	2006	2016	
distress	1999	2.52	2006	2015	
nursing informatics	1999	2.98	2007	2012	
analgesia	1999	3.18	2008	2015	
distraction	1999	2.42	2008	2013	
medical education	1999	2.55	2009	2013	
education nursing	1999	2.42	2011	2013	
health	1999	2.29	2013	2015	
virtual reality simulation	1999	4.8	2014	2019	
2nd life	1999	2.31	2014	2017	
communication	1999	2.37	2015	2018	
nurse	1999	2.34	2015	2017	
quality	1999	3.33	2016	2019	
surgery	1999	2.91	2016	2017	
clinical simulation	1999	2.8	2016	2021	
balance	1999	2.42	2016	2017	
student	1999	2.38	2016	2021	
patient safety	1999	2.32	2016	2017	
augmented reality	1999	2.43	2018	2019	

FIGURE 5 | Analysis of keywords related to publications of virtual simulation in nursing field. **(A)** The co-occurrence network visualization map of keywords related to virtual simulation in nursing field. The keywords clustered into nine groups according to their color. Large nodes represented keywords with high frequency; **(B)** Keywords were colored according to the appearance for the average time. The blue color represented for early stage and yellow color represented late stage. **(C)** The top 22 keywords with the strongest citation bursts on virtual simulation in nursing field between 1999 and 2021. The red segment of the blue line denoted the burst duration of a keyword.

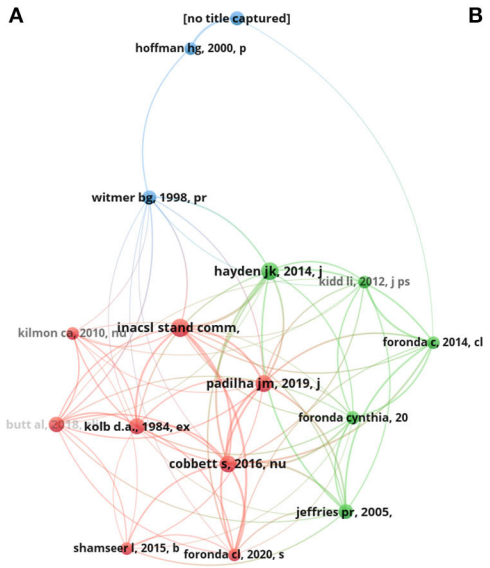
TABLE 3 | Top 10 most cited papers related to virtual simulation research in nursing.

Rank	Title	Journal	Document type	Corresponding author	Affiliation	Year	Citations
1	Effectiveness of virtual reality for pediatric pain distraction during IV placement	Cyberpsychology & Behavior	Article	Gold, JI	Univ So Calif,	2006	174
2	Mastery Learning for Health Professionals Using Technology-Enhanced Simulation: A Systematic Review and Meta-Analysis	Academic Medicine	Review	Cook, DA.	Mayo Clin	2013	168
3	Patient Outcomes in Simulation-Based Medical Education: A Systematic Review	Journal of General Internal Medicine	Review	Cook, DA.	Mayo Clin	2013	165
4	A pilot and feasibility study of virtual reality as a distraction for children with cancer	Journal of The American Academy of Child And Adolescent Psychiatry	Article	Gershon, J	Bradley Sch S Cty	2004	166
5	Current trends in stroke rehabilitation. A review with focus on brain plasticity	Acta Neurologica Scandinavica	Review	Johansson, BB	Lund Univ	2011	170
6	Evaluation of trauma team performance using an advanced human patient simulator for resuscitation training	Journal of Trauma-Injury Infection And Critical Care	Article	Holcomb, JB	Univ Texas	2002	161
7	Virtual reality pain control during burn wound debridement in the hydrotank	Clinical Journal of Pain	Article	Hoffman, HG	Univ Washington	2008	161
8	Interprofessional communication in healthcare: An integrative review	Nurse Education in Practice	Review	Foronda, C	Johns Hopkins Univ	2016	144
9	The Insertion and Management of External Ventricular Drains: An Evidence-Based Consensus Statement	Neurocritical Care	Review	Nathan, BR	Univ Virginia	2016	149
10	Effects of distraction on pain, fear, and distress during venous port access and venipuncture in children andAdolescents with cancer	Journal of Pediatric Oncology Nursing	Article	Windich-Biermeier, A	Childrens Med Ctr	2007	140

Cyberpsychology and Behavior by 2006 with 174 citations, entitled Effectiveness of virtual reality for pediatric pain distraction during IV placement. In this study, the author reported virtual reality's positive efficacy and suitability as a pain relief tool during the pediatric intravenous placement. The co-cited reference is the article which cited by the included papers of VS in nursing, which formed the knowledge base in this field. The top16 co-cited references were identified through 20,249 references which co-cited more than 20 times by the included 677 papers. As shown in **Figure 6A**, the article with highest co-citations ($n = 35$) was published by INACSL Stand Comm (22) in *Clinical Simulation in Nursing* in 2016, entitled INACSL Standards of Best Practice: Simulation (SM) Simulation Design. In this work, they provide a standard framework and guideline for developing effective simulation-based experiences. Similarly, CiteSpace citation burst could identify references focused by researchers in a specific period (17, 23). The burst duration was set to 2 years. At last, 20 references with strongest citation bursts were identified in **Figure 6B**. Among them, Foronda Cynthia, 2014, Nurse Educ Today, V34, P0 (24) has the highest burst strength ($n = 6.11$), entitled Use of virtual clinical simulation to improve communication skills of baccalaureate nursing students: A pilot study. There are eight articles with citation bursts ending in 2021 which means they were get more attention in recent years. They are "Caylor S, 2015, CLIN SIMUL NURS, V11, P163 (25)", "Smith PC, 2015, CLIN SIMUL NURS, V11, P52 (26)", "Shin S, 2015, NURS EDUC TODAY, V35, P176 (27)", "Irwin P, 2015, J NURS EDUC, V54, P572 (28)", "Cooper S, 2015, CLIN SIMUL NURS, V11, P97 (29)", "Rebenitsch L, 2016, VIRTUAL REAL-LONDON, V20, P101 (30)", "Butt AL, 2018, CLIN SIMUL NURS, V16, P25 (31)", "Padilha JM, 2018, CLIN SIMUL NURS, V15, P13 (3)".

DISCUSSION

The number of publications in a field reflects the activity and productivity over the years (23). We observed the overall trend of publication in this filed was upward, and could divided into three phases. Before 2008, the number of articles per year slightly increased. It may be restricted by technology such as internet access or computer popularity. Likewise, a previous study found before the year of 2005, the applications of virtual patient in medical education are small (32). Since 2020, the number of papers got a sharp increase to over 200 publications in 2021. We speculate several reasons account for this. First, because of



B

Top 20 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	1999 - 2021
Kilmon CA, 2010, NURS EDUC PERSPECT, V31, P314	2010	2.61	2012	2013	
Foronda Cynthia, 2014, Nurse Educ Today, V34, P0, DOI 10.1016/j.nedt.2013.10.007, DOI	2014	6.11	2014	2018	
Farra S, 2013, WESTERN J NURS RES, V35, P655, DOI 10.1177/0193945912471735, DOI	2013	3.55	2014	2018	
Kidd LI, 2012, J PSYCHOSOC NURS MEN, V50, P28, DOI 10.3928/02793695-20120605-04, DOI	2012	4.76	2015	2017	
Hayden JK, 2014, J NURS REGUL, V5, P0	2014	5.81	2016	2019	
Foronda C, 2014, CLIN SIMUL NURS, V10, P412, DOI 10.1016/j.ecns.2014.03.005, DOI	2014	3.86	2016	2019	
Caylor S, 2015, CLIN SIMUL NURS, V11, P163, DOI 10.1016/j.ecns.2014.12.003, DOI	2015	3.85	2016	2021	
Smith PC, 2015, CLIN SIMUL NURS, V11, P52, DOI 10.1016/j.ecns.2014.10.001, DOI	2015	4.29	2017	2021	
Ulrich D, 2014, CLIN SIMUL NURS, V10, P546, DOI 10.1016/j.ecns.2014.08.003, DOI	2014	4.16	2017	2019	
Foronda C, 2013, CLIN SIMUL NURS, V9, P0, DOI 10.1016/j.ecns.2012.05.005, DOI	2013	4.13	2017	2018	
Shin S, 2015, NURS EDUC TODAY, V35, P176, DOI 10.1016/j.nedt.2014.09.009, DOI	2015	3.57	2017	2021	
Foronda CL, 2016, CLIN SIMUL NURS, V12, P137, DOI 10.1016/j.ecns.2016.02.004, DOI	2016	2.95	2017	2018	
Decker S, 2013, CLIN SIMUL NURS, V9, P0, DOI 10.1016/j.ecns.2013.04.008, DOI	2013	2.95	2017	2018	
Lopreiato JO, 2016, HEALTHCARE SIMULATIO, V0, P0	2016	4.47	2018	2019	
Cant RP, 2014, NURS EDUC TODAY, V34, P1435, DOI 10.1016/j.nedt.2014.08.001, DOI	2014	2.79	2018	2019	
Irwin P, 2015, J NURS EDUC, V54, P572, DOI 10.3928/01484834-20150916-05, DOI	2015	3.71	2019	2021	
Cooper S, 2015, CLIN SIMUL NURS, V11, P97, DOI 10.1016/j.ecns.2014.10.010, DOI	2015	3.71	2019	2021	
Rebenitsch L, 2016, VIRTUAL REAL-LONDON, V20, P101, DOI 10.1007/s10055-016-0285-9, DOI	2016	2.77	2019	2021	
Butt AL, 2018, CLIN SIMUL NURS, V16, P25, DOI 10.1016/j.ecns.2017.09.010, DOI	2018	2.61	2019	2021	
Padilha JM, 2018, CLIN SIMUL NURS, V15, P13, DOI 10.1016/j.ecns.2017.09.005, DOI	2018	2.54	2019	2021	

FIGURE 6 | (A) The co-citation network visualization map of references on virtual simulation in nursing field between 1999 and 2021. **(B)** The top 20 references with the strongest citation bursts on virtual simulation in nursing field between 1999 and 2021. The blue line represented the time from its first appearance to 2021, the red line represented the burst time.

social isolation during the COVID-19 pandemic, it is difficult for students to enter clinical practice. In addition, educators were forced to change the way of program delivery (33). Numerous online programs has emerged during the COVID-19, such as virtual lab environments (34), three-dimensional virtual world (3DVW) (35), personal protective equipment (PPE) virtual simulation games (36). Such VS programs effectively enhanced nursing student interest and provided nurse educators with novel and engaging means of content delivery (33). Second, COVID-19 pandemic accelerated the demand for more nursing staff and higher quality nursing care. Indeed, not all nurses or medical staff have the opportunity to be in the frontline battle with such an pandemic. It is difficult to educate and train these back-ups with any physical touch. However, the greatest strength of VS could provide an almost real environment that simulated any emergency in COVID-19.

Without surprising, the USA leads the VS in nursing research, which requires the collaboration of multiple disciplines, such as medical informatics, education, computer science, and software engineering. Other areas displayed the similar leading position of the USA, such as radiation-induced lung injury (37), and human-computer interaction (38), etc. Interestingly, in terms of the number of productive authors and institutions, Canada ranked ahead of the USA. Extensively studies showed that collaborations tends to be stronger between institutions or countries with shorter geographical distances (15). We speculated the cooperation links between authors and institutions within Canada were stronger than that in the USA. As expected, **Supplementary Figure 1** and **Figure 4B** further corroborated our hypothesis. There are scattered links between numerous American authors and institutions, but relative close relationships between Canadian authors and institutions. Previous study reported studies with regional and international collaborations had a significantly higher mean number of citations than sole local collaborations. In fact, it suggested that collaborations among scholars can lead to improvements in research and contribute to greater clarity and richer insights in a field (39). Considering the scattered collaborations in this field, we hope there will be more inter-institutions and international research in the future.

Key journals, institutions, and authors provide the essential information for a given field. Clinical Simulation in Nursing, Nurse Education Today, and Journal of Nursing Education are the top three productive and co-cited journals. Researchers should continue to pay particular attention on them, because some frontier articles may be published in these journals. In addition, researchers could choose these journals for their draft submission. Institutions like University of Toronto, University of Queensland, University of Washington, and scholars like Verkuyl M, Luctkar-flude M, Tyerman J, Foronda, Cl, and Hoffman, HG should be followed and maybe the potential cooperation partner.

Keyword and reference analysis provides a graphical map of what knowledge existed and how they are interrelated in a given field. It facilitates researchers to get insight into a certain field quickly (18). The major themes generated from VOSviewer keyword co-occurrence characterize the body of knowledge structure of VS in nursing research. Specifically, the top four biggest clusters represent the whole body of this field.

Cluster 1 (Red): Virtual Learning During COVID-19 Pandemic

The largest cluster refers to virtual learning in COVID-19 pandemic, which accounts for 23.9% of the total keywords. The

primary keywords in this cluster are "nursing student ($n = 26$), virtual learning ($n = 19$), and COVID-19 ($n = 19$), nurse education ($n = 14$)" Under this cluster, researchers have explored the online virtual learning for nurse students (40–44). Studies showed their positive aspect of virtual learning. That is, virtual learning is essential at the height of the pandemic and may prove useful in other circumstances that limit clinical site availability (45, 46). Digital platforms strengthen the involvement of students (47). Herbert (48) reported their Augmented Reality (AR) app on heart failure for remote training of nursing students. Likewise, they find it could encourage students engagement during the learning process. Shamsaee et al. (49) reported virtual education had significant positive feedback on information-seeking skills and knowledge about search operators in nursing students. However, researchers also point out their worries. Amerson et al. (50) reports up to 94% of nursing students experienced a moderate level of stress in a time of virtual learning. Thus, he reminds the faculty must be attention to the mental health needs of nursing students in virtual learning during COVID-19. Also, another study discussed the negative comments regarding virtual learning from a personal level. It includes internet login and web conferencing logistics, lack of motivation to study, family difficulties, and faculty inexperience teaching in an online environment (8). Therefore, with the advent of widespread use of VS in nursing education, these problems should be fixed and pay more attention to psychological problems on students in the future.

Cluster 2 (Green): Clinical Nursing Care Using Virtual Reality

The second largest cluster refers to cure or clinical use for virtual reality. It includes 20.6% keywords of the total. The primary keywords in this cluster are "virtual reality ($n = 183$), pain ($n = 33$), anxiety ($n = 20$), dementia ($n = 18$), distraction ($n = 15$)." Under this cluster, researchers focused on its clinical applications. Studies from Nilsson et al. (51) and Gershon et al. (52) showed that VR could effectively relieve the needle-related procedural pain and distress in children and adolescents with cancer diseases. Also, studies reported VR could effectively reduce children's pain and distress during flu vaccinations (53) and burn wound care procedures (54). Apart from the applications for caring for children, older people also benefit from VR programs. Loggia et al. (55) reported the use of VR could help able-bodied older people to achieve physical activity recommendations, even with moderate cognitive impairments. Davis and Ohman (56) and Hannans et al. (57) reported VR could help persons with Alzheimer's disease find their way more effectively, help them maintain independence and enhance their cognitive and affective knowledge. Brimelow et al. (58) reported VR could reduce apathy and improve mood in aged care. Although many benefits may get from VR in older people's nursing, difficulties still exist in dementia older people caring, like less empathy in nurses. Previous studies show VR could enhance nursing students' effectiveness and interest in working with older people (59). Also, Campbell et al. (60) reported using a VR dementia experience system could increase nursing student awareness, knowledge, and sensitivity of Alzheimer's disease. Further exploration is how these VR programs translate into improved care for those older people.

Cluster 3 (Blue): Education in Nurse Practitioners Using VS

The third-largest cluster related to education in nurse practitioners using VS. It includes 15.2% keywords of the total. The primary keywords in this cluster are "simulation ($n = 108$), education ($n = 51$), learning ($n = 16$), training ($n = 15$)." Under this cluster, researchers focused on clinical education in nurse practitioners. Tsai et al. (61) developed a computer-assisted protocol using VR in performing Port-A catheter inserting. Results suggested it could reduce fear of performing the Port-A catheter technique, significantly reduce error rates and increase correct equipment selection in novice nurses. Samosornet al. (62) developed a VR airway Laboratory to teach difficult airway management skills to nursing students. For cardiopulmonary resuscitation (CPR), researchers explored the effects of VR (63) and AR (64) in training nursing students. Compared with the traditional teaching approach, VR and AR CPR training systems get positive feedback as experienced in a realistic environment. Again, studies report the 3D virtual environment such as 2nd Life laboratory is a good way to practice the students' experience of learning decision-making skills (65–68). Another virtual simulation program is virtual patients. It developed to provide a realistic standard clinical situation to train the ability of nursing students [e.g., clinical reasoning (69–71), communication skills (72–74) situation awareness, and teamwork capability (75)]. However, there are still lingering questions remain to elucidate. Currently, the predominant methods for assessing learning outcomes are combinations of paper-based exams and observations from clinical teachers (76), effective and objective assessment methods related to learning outcomes are still lacking (77–79). Thus, as a promising teaching approach, we call for nurse managers, policymakers, and nurse educators to develop more VS programs to train nursing students and build more reliable and objective assessment methods to validate learning outcomes.

Cluster 4 (Orange): Cluster 4 (Orange): Education Technology in VS

The fourth cluster associated with the education technology for nursing research, which consists of 6.3% keywords of the total. The primary keywords are "nursing ($n = 92$) and educational technology ($n = 24$)". Under this cluster, researchers focused on technologies on VS. The major virtual technologies used in nursing education are VR and AR. VR technologies have three common features: "(1) immersion, (2) perception to be present in an environment, (3) interaction with that environment." AR technologies have three defining characteristics: "(1) combines real and virtual, (2) interactive in real-time, (3) registered in 3D." The main difference between VR and AR is that AR merged the real world with virtual experience (80). Different terms [e.g., virtual learning spaces (81); virtual worlds (82); immersive three-dimensional (3D) interactive video program

(6)] have been used to refer to VR and AR technologies, and sometimes the distinction between VR and AR is unclear. Thus, there is a call to unify the definition of VR and AR (1). Contrary to being used with VR and AR in education, MR is less used, but recently got concerned. Wunder et al. (83) using an AR headsets to simulate fire in the operating room to train nurse anesthesia students. Although VR, AR, and MR provide a chance to revolutionize nursing education delivery, and promote student-centered learning (84). There are some shared challenges among the three virtual technologies. (1) Faculty and their institutions involved need to be able to invest significant time, money, and resources to successfully develop and launch VS technologies for nursing education. (2) Faculty need to be adequately trained before using VS technology to manage and prevent VR technology difficulties (e.g., poor video and sound quality, poor network connectivity, low fidelity of the virtual experience, or computer problems). (3) End-users for virtual technologies may experience cybersickness or digital motion sickness (e.g., feeling disoriented, dizzy, nauseous, and sore eyes). These issues warrant further research in the future.

LIMITATIONS

First, the papers on virtual simulation in nursing were searched based on the WoSCC. Although WoSCC is recognized as one of the most authoritative databases, PubMed, Scopus, and Google scholar are also widely accepted by scientists. Second, the number of citations and citations per paper are influenced by time and remain controversial as a comprehensive indicator of the quality of one paper or the author. Likewise, the larger number of publications was not the only indicator of influence for the journal, as other indicators (e.g., impact factor, SNIP, CiteScore, SJR) are widely used (85). Third, we included only English papers in this study, several papers with non-English languages were excluded, such as Chinese, Portuguese ($n = 8$), and Spanish ($n = 4$). Finally, database updates may result in discrepancies.

CONCLUSIONS

This bibliometric analysis identified major contributing authors, institutions, countries, journals and mapped the knowledge network of virtual simulation in nursing research. The research hotspot is gradually shifting from clinical nursing care to studies of nursing education using different virtual simulation technologies. Further research directions are as following: (1) Strengthen the co-operation between authors, institutions, and countries. (2) Reducing psychological problems and physical sickness of end-users. (3) Developing more VS programs to train nursing students and build more reliable and objective assessment methods to validate learning outcomes. (4) Strengthen the training of faculty abilities to VS technology to manage and prevent VS technology difficulties.

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

QZ conceived of the study, participated in its design, and drafted the manuscript. JL involved in study design, obtained data and contributed to interpretation, and helped to draft the manuscript. JC provided the theoretical frameworks and performed much of the editing of the manuscript. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

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Supplementary Figure 1 | Author co-operation network and co-cited author network on virtual simulation in nursing research. **(A)** Co-authorship network visualization map of authors for virtual simulation in nursing field. **(B)** Co-cited author network visualization map of virtual simulation in nursing field. Node size indicated the number of articles produced. The distance between any two nodes positively associated with the cooperation strength.

REFERENCES

1. Kardong-Edgren S, Farra SL, Alinier G, Young HM. A call to unify definitions of virtual reality. *Clin Simul Nurs.* (2019) 31:28–34. doi: 10.1016/j.ecns.2019.02.006
2. Kilmon CA, Brown L, Ghosh S, Mikitiuk A. Immersive virtual reality simulations in nursing education. *Nurs Educ Perspect.* (2010) 31:314–7.
3. Padilha JM, Machado PP, Ribeiro AL, Ramos JL. Clinical virtual simulation in nursing education. *Clin Simul Nurs.* (2018) 15:13–8. doi: 10.1016/j.ecns.2017.09.005
4. Girao ALA, Dos Santos MNO, Chaves EMC, Gomes EB, de Oliveira SKP, de Carvalho REFL. NurseVR: development of a serious virtual reality game for medication preparation and administration training. *Comput Inform Nurs.* (2021). doi: 10.1097/CIN.0000000000000820. [Epub ahead of print].
5. Weston J, Zauche LH. Comparison of virtual simulation to clinical practice for prelicensure nursing students in pediatrics. *Nurse Educ.* (2021) 46:E95–8. doi: 10.1097/NNE.0000000000000946
6. Chao YC, Hu SH, Chiu HY, Huang PH, Tsai HT, Chuang YH. The effects of an immersive 3d interactive video program on improving student nurses' nursing skill competence: A randomized controlled trial study. *Nurse Educ Today.* (2021) 103:104979. doi: 10.1016/j.nedt.2021.104979
7. Tiffany J, Forneris S. *The Forecast for Tech Usage and Growth in Nursing Education.* (2018). Retrieved from: https://nlnteq.org/2018/02/07/the-forecast-for-tech-usage-and-growth-in-nursing-education-part-4-of-the-

series-the-future-of-technology-in-nursing-education/ (accessed February 19, 2019).
8. Fogg N, Wilson C, Trinka M, Campbell R, Thomson A, Merritt L, et al. Transitioning from direct care to virtual clinical experiences during the COVID-19 pandemic. *J Prof Nurs.* (2020) 36:685–91. doi: 10.1016/j.profnurs.2020.09.012
9. Emich KJ, Kumar S, Lu L, Norder K, Pandey N. Mapping 50 years of small group research through small group research. *Small Group Res.* (2020) 51:659–99. doi: 10.1177/1046496420934541
10. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. *J Bus Res.* (2021) 133:285–96. doi: 10.1016/j.jbusres.2021.04.070
11. Cumming DJ, Kumar S, Lim WM, Pandey N. *Venture Capital and Private Equity Research: A Bibliometric Review and Future Research Agenda.* (2022). Available online at: https://ssrn.com/abstract$=$4034812 (accessed January 14, 2022).
12. Kumar S, Sahoo S, Lim WM, Dana L-P. Religion as a social shaping force in entrepreneurship and business: insights from a technology-empowered systematic literature review. *Technol Forecast Soc Change.* (2022) 175:121393. doi: 10.1016/j.techfore.2021.121393
13. Kumar S, Sharma D, Rao S, Lim W, Mangla S. Past, present, and future of sustainable finance: insights from big data analytics through machine learning of scholarly research. *Ann Operat Res.* (2022) 1–44. doi: 10.1201/9781003156291
14. Taskaya S, Aksoy A. A bibliometric analysis of workplace incivility in nursing. *J Nurs Manag.* (2021) 29:518–25. doi: 10.1111/jonm.13161
15. Yanbing S, Hua L, Chao L, Fenglan W, Zhiguang D. The state of nursing research from 2000 to 2019: a global analysis. *J Adv Nurs.* (2021) 77:162–75. doi: 10.1111/jan.14564
16. Jarden R, Narayanan A, Sandham M, Siegert R, Koziol-McLain J. Bibliometric mapping of intensive care nurses' wellbeing: development and application of the new iAnalysis model. *BMC Nurs.* (2019) 18:21. doi: 10.1186/s12912-019-0343-1
17. Chen CM. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *J Am Soc Inf Sci Technol.* (2006) 57:359–77. doi: 10.1002/asi.20317
18. van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics.* (2010) 84:523–38. doi: 10.1007/s11192-009-0146-3
19. Liao HC, Tang M, Luo L, Li CY, Chiclana F, Zeng XJ. A bibliometric analysis and visualization of medical big data research. *Sustainability.* (2018) 10:166. doi: 10.3390/su10010166
20. Dong J, Wei W, Wang C, Fu Y, Li Y, Li J, et al. Research trends and hotspots in caregiver studies: a bibliometric and scientometric analysis of nursing journals. *J Adv Nurs.* (2020) 76:2955–70. doi: 10.1111/jan.14489
21. Gold JI, Kim SH, Kant AJ, Joseph MH. Rizzo AS. Effectiveness of virtual reality for pediatric pain distraction during iv placement. *Cyberpsychol Behav.* (2006) 9:207–12. doi: 10.1089/cpb.2006.9.207
22. Comm IS, INACSL. Standards of best practice: simulation (SM) simulation design. *Clin Simul Nurs.* (2016) 12:S5–12. doi: 10.1016/j.ecns.2016.09.005
23. Chen D, Zhang G, Wang J, Chen S, Wang J, Nie H, et al. Mapping trends in Moyamoya angiopathy research: a 10-year bibliometric and visualization-based analyses of the web of science core collection (WoSCC). *Front Neurol.* (2021) 12:637310. doi: 10.3389/fneur.2021.637310
24. Foronda C, Gattamorta K, Snowden K, Bauman EB. Use of virtual clinical simulation to improve communication skills of baccalaureate nursing students: a pilot study. *Nurse Educ Today.* (2014) 34:e53–7. doi: 10.1016/j.nedt.2013.10.007
25. Caylor S, Aebersold M, Lapham J, Carlson E. The use of virtual simulation and a modified TeamSTEPPS (TM) training for multiprofessional education. *Clin Simul Nurs.* (2015) 11:163–71. doi: 10.1016/j.ecns.2014.12.003
26. Smith PC, Hamilton BK. The effects of virtual reality simulation as a teaching strategy for skills preparation in nursing students. *Clin Simul Nurs.* (2015) 11:52–8. doi: 10.1016/j.ecns.2014.10.001
27. Shin S, Park J-H, Kim J-H. Effectiveness of patient simulation in nursing education: Meta-analysis. *Nurse Educ Today.* (2015) 35:176–82. doi: 10.1016/j.nedt.2014.09.009
28. Irwin P, Coutts R. A. systematic review of the experience of using second life in the education of undergraduate nurses. *J Nurs Educ.* (2015) 54:572–7. doi: 10.3928/01484834-20150916-05
29. Cooper S, Cant R, Bogossian F, Kinsman L, Bucknall T, Team FAR. Patient deterioration education: evaluation of face-to-face simulation and e-simulation approaches. *Clin Simul Nurs.* (2015) 11:97–105. doi: 10.1016/j.ecns.2014.10.010
30. Rebenitsch L, Owen C. Review on cybersickness in applications and visual displays. *Virtual Real.* (2016) 20:101–25. doi: 10.1007/s10055-016-0285-9
31. Butt AL, Kardong-Edgren S, Ellertson A. Using game-based virtual reality with haptics for skill acquisition. *Clin Simul Nurs.* (2018) 16:25–32. doi: 10.1016/j.ecns.2017.09.010
32. Su W-S, Chang C-Y. Virtual patient in interactive learning environments: a review of 1989-2020 publications in selected SSCI journals. *Interact Learn Environ.* (2021) X:1–7. doi: 10.1080/10494820.2021.1879873
33. Saab MM, Hegarty J, Murphy D, Landers M. Incorporating virtual reality in nurse education: a qualitative study of nursing students' perspectives. *Nurse Educ Today.* (2021) 105:7. doi: 10.1016/j.nedt.2021.105045
34. Cantey DS, Sampson M, Vaughn J, Blodgett NP. Skills, community, and rapport: prelicensure nursing students in the virtual learning environment. *Teach Learn Nurs.* (2021) 16:384–8. doi: 10.1016/j.teln.2021.05.010
35. Liaw SY, Choo T, Wu LT, Lim WS, Choo H, Lim SM, et al. Wow, woo, win"- Healthcare students' and facilitators' experiences of interprofessional simulation in three-dimensional virtual world: a qualitative evaluation study. *Nurse Educ Today.* (2021) 105:6. doi: 10.1016/j.nedt.2021.105018
36. Tyerman J, Luctkar-Flude M, Baker C. Rapid development of a COVID-19 assessment and PPE virtual simulation game. *Clin Simul Nurs.* (2021) 56:125–32. doi: 10.1016/j.ecns.2021.03.002
37. Wang D, Li Z, Zhang Y, Li Y, Wang X, Wang S, et al. Bibliometric analysis of research relating to radiation-induced lung injury (2001-2020). *Ann Palliat Med.* (2021) 10:11166–76. doi: 10.21037/apm-21-1682
38. Wang J, Cheng R, Liu M, Liao P. Research trends of human-computer interaction studies in construction hazard recognition: a bibliometric review. *Sensors.* (2021) 21:6172. doi: 10.3390/s21186172
39. Annalingam A, Damayanthi H, Jayawardena R, Ranasinghe P. Determinants of the citation rate of medical research publications from a developing country. *Springerplus.* (2014) 3:140. doi: 10.1186/2193-1801-3-140
40. Smith TS, Holland AC, White T, Combs B, Watts P, Moss J, et al. Distance accessible education model: teaching skills to nurse practitioners. *J Nurse Pract.* (2021) 17:999–1003. doi: 10.1016/j.nurpra.2021.05.018
41. Zwart DP, Goei SL, Noroozi O, Van Luit JEH. The effects of computer-based virtual learning environments on nursing students' mathematical learning in medication processes. *Res Pract Technol Enhanc Learn.* (2021) 16:4. doi: 10.1186/s41039-021-00147-x
42. Castillo J, Gomar C, Rodriguez E, Trapero M, Gallart A. Cost minimization analysis for basic life support. *Resuscitation.* (2019) 134:127–32. doi: 10.1016/j.resuscitation.2018.11.008
43. MacRae D, Jara MR, Tyerman J, Luctkar-Flude M. Investing in engagement: integrating virtual learning experiences across an undergraduate nursing program. *Clin Simul Nurs.* (2021) 52:17–32. doi: 10.1016/j.ecns.2020.12.005
44. Dreifuerst KT, Bradley CS, Johnson BK. Using debriefing for meaningful learning with screen-based simulation. *Nurse Educ.* (2021) 46:239–44. doi: 10.1097/NNE.0000000000000930
45. Hinic K. Evidence-based virtual learning experiences for the clinical nurse leader capstone. *J Nurs Care Qual.* (2021) 36:E59–62. doi: 10.1097/NCQ.0000000000000552
46. Shea KL, Rovera EJ. Preparing for the COVID-19 pandemic and its impact on a nursing simulation curriculum. *J Nurs Educ.* (2021) 60:52–5. doi: 10.3928/01484834-20201217-12
47. Manakatt BM, Carson ZW, Penton RL, Demello AS. Virtual learning experiences in population health nursing course during the COVID-19 pandemic. *Int Nurs Rev.* (2021) 68:557–62. doi: 10.1111/inr.12725
48. Herbert VM, Perry RJ, LeBlanc CA, Haase KN, Corey RR, Giudice NA, et al. Developing a smartphone app with augmented reality to support

virtual learning of nursing students on heart failure. *Clin Simul Nurs.* (2021) 54:77–85. doi: 10.1016/j.ecns.2021.02.003
49. Shamsaee M, Mangolian Shahrbabaki P, Ahmadian L, Farokhzadian J, Fatehi F. Assessing the effect of virtual education on information literacy competency for evidence-based practice among the undergraduate nursing students. *BMC Med Inform Decis Mak.* (2021) 21:48. doi: 10.1186/s12911-021-01418-9
50. Amerson R, Fisher B, Bible J, Burgess L, Ravan L, Ward L. Nursing education amid a pandemic: mental health in a time of virtual learning. *Nurse Educ.* (2021) 46:255–60. doi: 10.1097/NNE.0000000000001039
51. Nilsson S, Finnstrom B, Kokinsky E, Enskar K. The use of virtual reality for needle-related procedural pain and distress in children and adolescents in a paediatric oncology unit. *Eur J Oncol Nurs.* (2009) 13:102–9. doi: 10.1016/j.ejon.2009.01.003
52. Gershon J, Zimand E, Pickering M, Rothbaum BO, Hodges L, A. pilot and feasibility study of virtual reality as a distraction for children with cancer. *J Am Acad Child Adolesc Psychiatry.* (2004) 43:1243–9. doi: 10.1097/01.chi.0000135621.23145.05
53. Beran TN, Ramirez-Serrano A, Vanderkooi OG, Kuhn S. Reducing children's pain and distress towards flu vaccinations: a novel and effective application of humanoid robotics. *Vaccine.* (2013) 31:2772–7. doi: 10.1016/j.vaccine.2013.03.056
54. Chan EA, Chung JW, Wong TK, Lien AS, Yang JY. Application of a virtual reality prototype for pain relief of pediatric burn in Taiwan. *J Clin Nurs.* (2007) 16:786–93. doi: 10.1111/j.1365-2702.2006.01719.x
55. Loggia G, Gauthier A, Lemiere F, Drigny J, Desvergee A, Leconte P, et al. Cycle more with virtual reality: a proof of concept study in an institutionalised able-bodied geriatric population. *Age Ageing.* (2021) 50:1422–5. doi: 10.1093/ageing/afab040
56. Davis R, Ohman J. Wayfinding in ageing and Alzheimer's disease within a virtual senior residence: study protocol. *J Adv Nurs.* (2016) 72:1677–88. doi: 10.1111/jan.12945
57. Hannans JA, Nevins CM, Jordan K. See it, hear it, feel it: embodying a patient experience through immersive virtual reality. *Inf Learn Sci.* (2021) 122:565–83. doi: 10.1108/ILS-10-2020-0233
58. Brimelow RE, Dawe B, Dissanayaka N. Preliminary research: virtual reality in residential aged care to reduce apathy and improve mood. *Cyberpsychol Behav Soc Netw.* (2020) 23:165–70. doi: 10.1089/cyber.2019.0286
59. Edwards H, Nash R, Sacre S, Courtney M, Abbey J. Development of a virtual learning environment to enhance undergraduate nursing students' effectiveness and interest in working with older people. *Nurse Educ Today.* (2008) 28:672–9. doi: 10.1016/j.nedt.2007.11.009
60. Campbell D, Lugger S, Sigler GS, Turkelson C. Increasing awareness, sensitivity, and empathy for Alzheimer's dementia patients using simulation. *Nurse Educ Today.* (2021) 98:104764. doi: 10.1016/j.nedt.2021.104764
61. Tsai SL, Chai SK, Hsieh LF, Lin S, Taur FM, Sung WH, et al. The use of virtual reality computer simulation in learning Port-A cath injection. *Adv Health Sci Educ Theory Pract.* (2008) 13:71–87. doi: 10.1007/s10459-006-9025-3
62. Samosorn AB, Gilbert GE, Bauman EB, Khine J, McGonigle D. Teaching airway insertion skills to nursing faculty and students using virtual reality: a pilot study. *Clin Simul Nurs.* (2020) 39:18–26. doi: 10.1016/j.ecns.2019.10.004
63. Keys E, Luctkar-Flude M, Tyerman J, Sears K, Woo K. The integration of virtual simulation gaming into undergraduate nursing resuscitation education: a pilot randomised controlled trial. *Clin Simul Nurs.* (2021) 54:54–61. doi: 10.1016/j.ecns.2021.01.013
64. Balian S, McGovern SK, Abella BS, Blewer AL, Leary M. Feasibility of an augmented reality cardiopulmonary resuscitation training system for health care providers. *Heliyon.* (2019) 5:e02205. doi: 10.1016/j.heliyon.2019.e02205
65. Jenson C, Forsyth D. Virtual reality simulation: using three-dimensional technology to teach nursing students. *Comp Informat Nurs.* (2012) 30:312–8; quiz 319–20. doi: 10.1097/NXN.0b013e31824af6ae
66. McCallum J, Ness V, Price T. Exploring nursing students' decision-making skills whilst in a Second Life clinical simulation laboratory. *Nurse Educ Today.* (2011) 31:699–704. doi: 10.1016/j.nedt.2010.03.010
67. Wiecha J, Heyden R, Sternthal E, Merialdi M. Learning in a virtual world: experience with using second life for medical education. *J Med Internet Res.* (2010) 12:e1. doi: 10.2196/jmir.1337
68. Bahrami M, Hadadgar A, Fuladvandi M. Designing virtual patients for education of nursing students in cancer course. *Iran J Nurs Midwifery Res.* (2021) 26:133–6. doi: 10.4103/ijnmr.IJNMR_327_20
69. Forsberg E, Georg C, Ziegert K, Fors U. Virtual patients for assessment of clinical reasoning in nursing – a pilot study. *Nurse Educ Today.* (2011) 31:757–62. doi: 10.1016/j.nedt.2010.11.015
70. Forsberg E, Ziegert K, Hult H, Fors U. Clinical reasoning in nursing, a think-aloud study using virtual patients - a base for an innovative assessment. *Nurse Educ Today.* (2014) 34:538–42. doi: 10.1016/j.nedt.2013.07.010
71. Everett-Thomas R, Joseph L, Trujillo G. Using virtual simulation and electronic health records to assess student nurses' documentation and critical thinking skills. *Nurse Educ Today.* (2021) 99:104770. doi: 10.1016/j.nedt.2021.104770
72. Shorey S, Ang E, Ng E, Yap J, Lau L, Chui C. Communication skills training using virtual reality: a descriptive qualitative study. *Nurse Educ Today.* (2020) 94:104592. doi: 10.1016/j.nedt.2020.104592
73. Shorey S, Ang E, Yap J, Ng E, Lau S, Chui C, et al. Virtual counseling application using artificial intelligence for communication skills training in nursing education: development study. *J Med Internet Res.* (2019) 21:e14658. doi: 10.2196/14658
74. Chapelain P, Morineau T, Gautier C. Effects of communication on the performance of nursing students during the simulation of an emergency situation. *J Adv Nurs.* (2015) 71:2650–60. doi: 10.1111/jan.12733
75. Peddle M, Mckenna L, Bearman M, Nestel D. Development of non-technical skills through virtual patients for undergraduate nursing students: an exploratory study. *Nurse Educ Today.* (2019) 73:94–101. doi: 10.1016/j.nedt.2018.11.008
76. Stayt L, Merriman C, Ricketts B, Morton S, Simpson T. Recognizing and managing a deteriorating patient: a randomized controlled trial investigating the effectiveness of clinical simulation in improving clinical performance in undergraduate nursing students. *J Adv Nurs.* (2015) 71:2563–74. doi: 10.1111/jan.12722
77. Cook DA, Triola MM. Virtual patients: a critical literature review and proposed next steps. *Med Educ.* (2009) 43:303–11. eng. doi: 10.1111/j.1365-2923.2008.03286.x
78. Ward R, Muckle T, Kremer M, Krogh M. Computer-based case simulations for assessment in health care: a literature review of validity evidence. *Eval Health Prof.* (2019) 42:82–102. doi: 10.1177/0163278717718609
79. Chen S, Huang T, Liao I, Liu C. Development and validation of the simulation learning effectiveness inventory. *J Adv Nurs.* (2015) 71:2444–53. doi: 10.1111/jan.12707
80. Mendez KJW, Piasecki RJ, Hudson K, Renda S, Mollenkopf N, Nettles BS, et al. Virtual and agumended reality: implication for the feature on nursing education. *Nurse Educ Today.* (2020) 93:104531. doi: 10.1016/j.nedt.2020.104531
81. Gdanetz LM, Hamer MK, Thomas E, Tarasenko LM, Horton-Deutsch S, Jones J. Technology, educator intention, and relationships in virtual learning spaces: a qualitative metasynthesis. *J Nurs Educ.* (2018) 57:197-+. doi: 10.3928/01484834-20180322-02
82. De Gagne JC, Oh J, Kang J, Vorderstrasse AA, Johnson CM. Virtual worlds in nursing education: a synthesis of the literature. *J Nurs Educ.* (2013) 52:391-+. doi: 10.3928/01484834-20130610-03
83. Wunder L, Gomez NAG, Gonzalez JE, Mitzova-Vladinov G, Cacchione M, Mato J, et al. Fire in the operating room: use of mixed reality simulation with nurse anesthesia students. *Informatics.* (2020) 7:40. doi: 10.3390/informatics7040040
84. Foronda CL, Alfes CM, Dev P, Kleinheksel AJ, Nelson DA Jr, O'Donnell JM, et al. Virtually nursing: emerging technologies in nursing education. *Nurse Educ.* (2017) 42:14–7. doi: 10.1097/NNE.0000000000000295

85. Mingers J, Yang LY. Evaluating journal quality: a review of journal citation indicators, and ranking in business and management. *Eur J Oper Res.* (2017) 257:323–37. doi: 10.1016/j.ejor.2016.07.058

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Association of Health Literacy With Medication Adherence Mediated by Cognitive Function Among the Community-Based Elders With Chronic Disease in Beijing of China

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Background: Although health literacy was considered to play a crucial role in non-communicable chronic disease (NCD) prevention and control, the relationship of health literacy and medication adherence has rarely given attention among older adult Chinese population in previous studies, especially considered that they might be with cognitive impairment.

Purpose: This study aimed to investigate the association between health literacy and medication adherence and mediation by cognitive ability among community-based older adults with chronic disease in Beijing of China.

Methods: The older adults aged 60 years old or over were recruited in a cross-sectional survey conducted in Beijing of China by using multistage, stratified sampling method. Of those, the participants with chronic disease and need to take long-term medicine were included in our study. The information about sociodemographic characteristics, health literacy, cognition ability, and medication adherence was collected by the questionnaire. The univariate and multiple logistic regression analysis were used to measure the association of health literacy and adherence medication, and mediate effect by cognitive ability.

Results: The total of 4,166 older adult populations (average age: 70.61 ± 7.38 years) was included in this study, 1,395 participants (33.49%) were non-adherence, 1,983 participants (47.60%) had two chronic conditions or more, and 1,459 participants (35.02%) screened as cognitive impairment. The health literacy was negatively associated with medication adherence. The lower total scores of health literacy were found with a high risk of non-adherence [$p < 0.01$, adjusted odds ratio (*OR*) = 0.988 per one point increase, 95% *CI*: 0.982–0.993] controlling other covariates. However, their association tended to be weakened or even disappeared among the older adults with cognitive impairment compared with the populations with normal cognitive.

Conclusion: Improving health literacy might be a public health strategy to increase the medication adherence of older adults, but need to first identify the potential target population based on their cognitive ability.

Keywords: health literacy, medication adherence, cognitive function, elder, chronic disease

INTRODUCTION

The older adults tends to suffer from chronic diseases. According to the surveillance data of chronic diseases, nearly 75% of the population aged 60 years and over had at least one chronic disease in China (1). Usually, most of the chronic diseases need long-term multiple medicines to improve symptoms or delay the progression of disease. Adherence is a passive behavior to follow treatment recommendations prescribed by their clinicians or healthcare providers (2). It was indicated that adherence has positive and significant effects on treatment outcomes and poor adherence could reduce the effectiveness of treatment and cause more economic losses (2, 3). Previous studies reported that about 5.1∼65.8% older adult patients of chronic diseases tend to have poor adherence to their medications in China, but varied by the types of chronic diseases or tools of adherence assessments (4–6). The interventions to improve the adherence were considered to make a far greater impact on the health than any improvement in specific medical treatments (2).

However, adherence was driven by many factors and these factors varied widely across the race of population, diseases, treatment regiments, and so on (7–9). Clearly and appropriately understanding the health information might be one of the essential core elements for patients to make health decisions that were closely related to adherence behaviors (9). Health literacy was defined as an ability to obtain, process, communicate, and understand the basic health information and services needed to make appropriate health decisions, which was considered to be one of the most promising and cost-effective approaches to overcome the non-communicable chronic disease (NCD) challenges (10). When patients were adequately informed and understand clearly what they were asked to do, they could actively participate in health decisions, which would help to improve their adherence to regimens (9). Therefore, improving health literacy might be an effective education and prevention strategy to improve treatment adherence. Until now, several studies had explored the association between health literacy and adherence among patients recruited from hospitals or primary health centers, but their findings were inconsistent (11–16) and their association were still ambiguity. Although health literacy was considered as a crucial role in NCD prevention and control in China, the relationship of health literacy and medication adherence has rarely given attention in the older adult Chinese population in previous studies.

Cognitive ability, which changed with aging, involved the abilities to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly, and learn from experience (17). Moreover, the older adults might experience subtle cognitive changes associated with aging, even those who might do not suffer from dementia or mild cognitive impairment (18). The lower cognitive function was found to be associated with poorer medicine adherence in healthy older adults (19). The study by Cho et al. reported that the decline in cognitive function worsened medicine adherence among the hypertensive patients (20). Previous studies reported that health literacy was significantly correlated with cognitive function (21–23). A cohort study by Wilson et al. found that the higher health literacy skills at baseline reduced the rate of cognitive decline in older adults (24). All of these suggested that cognitive function might be the important mediator of relationship between health literacy and medicine adherence. However, there is a lack of evidence till now, especially among the community-based population.

According to the results from the National Health Literacy Surveillance among the residents aged 15–69 years old, the health literacy among the Chinese population was still at a low level and had disparities between regions and groups (25). For the older adults 70 years old or above, the level of health literacy was still unknown in China, but might be even worse because of their low levels of education and high proportion of cognitive impairment. In this case, it was interested to know whether improving the health literacy was still an effective approach on medication adherence among the Chinese older population, and how the cognitive function mediated this effect of health literacy on adherence among the older adults in China.

Based on the above, this study aimed to investigate the association between health literacy and medication adherence among the community-based older adults with chronic disease in China. We hypothesized that the health literacy would be associated with the adherence of taking medicine, but its effect mediated by cognitive abilities.

MATERIALS AND METHODS

Sample and Setting

Data for this analysis came from the cross-sectional health survey. The survey was conducted in December 2020 and used a multistage, stratified sampling method to select a representative sample of community-based population aged 60 years or older in Beijing of China. The sampling process was stratified according to geographic regions and development status. At first, three central districts (such as DC, FT, and SJS) and five outer districts (such as CP, HR, MY, DX, and SY) were selected randomly among 16 districts. Then, total 100 street districts and 28 rural villages were randomly selected as study sites. About 48 persons in each study site were recruited to participate in the health survey, who were 60 years or older, lived in the current residence for at least 6 months and without mental illness, deaf blindness, or long-term bedridden. The study was approved by

the institutional review board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences (Project No. 064-2020). Written informed consent was obtained from each participant before data collection. A total of 6,160 persons participated in this survey, in which 5,829 (nearly 95% of all) were valid samples and 331 persons were eliminated for unqualified questionnaire with a lot of missing information or <60 years old. Among those, 4,166 participants who had self-reported at least one of the chronic diseases and needed to take long-term medicine were included in this analysis.

Self-completed questionnaires were used in this survey. For the older adults who were unable to complete the questionnaire by themselves owing to impaired vision, limited reading ability, or other such reasons, face-to-face inquiry by the staff from primary health center was used to collect the information. In that situation, the staffs were trained to complete the questions in a neutral fashion on the behalf of participants, and not to explain anything or help to answer questions. About 43% participants completed the questionnaire by themselves in our study.

Measures

The information about sociodemographic characteristics (such as age, gender, ethnicity, educational attainment, married status, medical cost last year, and medical payment), health literacy, cognition, and medication adherence were collected in the survey.

The Chinese version of the eight-item Morisky Medication Adherence Scale (MMAS-8) was used to assess the medication adherence (26–28). This scale included 7 items with "yes" or "no" answers and 1 item scored by an ordinal scale from 0 to 4. Items 5 and 8 of the questionnaire were transformed in accordance with the scoring algorithm, and all items were combined into a total score, ranging from 0 to 8 points. According to the scores, the older adult populations were divided into groups with low (<6 points), moderate (at least 6 points, but <8 points), and high (8 points) adherence to drug regimen. In our analysis, the low adherence was defined as non-adherence, moderate or high was defined as adherence. The Cronbach's α coefficient for the MMAS-8 was 0.76 in our study.

Health literacy was assessed by the Chinese Resident Health Literacy Scale (29). This scale contained 56 items with total scores ranging from 0 to 66 points and three dimensions: (1) knowledges and attitudes (28 points, Cronbach's α coefficient: 0.76); (2) behavior and lifestyle (22 points, Cronbach's α coefficient: 0.72); and (3) health-related skills (16 points, Cronbach's α coefficient: 0.66). The questions covered six aspects: scientific views of health (11 points); infectious diseases (7 points); chronic diseases (12 points); safety and first aid (14 points); medical care (14 points); and health information (8 points). The total scores reflected the health literacy level and the higher scores indicated higher health literacy, and vice versa.

The Ascertain Dementia 8 (AD8) questionnaire was used for screening the cognitive impairment in this study (30). AD8 is a brief informant-based measure that had only eight questions, such as domains of judgments, hobby/activity levels, repetitive conversations, learning abilities, memory in relation to date/appointments, finance, and daily thought processes. The AD8 had a good diagnostic accuracy in discriminating the cognitive impairment from normal cognition (31). The person with an AD8 score $\geq$2 was suspected to have cognitive impairment and need to be further definite diagnosis (30, 31). Cronbach's α coefficient of AD8 was 0.87 in our study.

Statistical Analysis

Descriptive statistics were calculated for all participant characteristics. Chi-square test, *t*-test, and ANOVA tests were conducted to compare demographic characteristics and health literacy scores between non-adherence and adherence. Taking non-adherence as the dependent variable, bivariate logistic regression analyses were performed to derive univariate, adjusted odds ratios (*OR*) and their respective 95% confidence intervals (*CI*s). Using the scores of health literacy, scores of knowledges and attitudes, scores of behavior and lifestyle, scores of health-related skills, scores of scientific views of health, scores of infectious diseases, scores of chronic diseases, scores of safety and first aid, scores of medical care, and scores of health information, respectively, as independent variable, the multiple logistic regression model was fit to estimate multivariate *OR*, controlling for developed status (urban or rural), age, gender, education attainment, married status, smoke, one or more of chronic disease, medical cost for last year, self-completed questionnaire, and cognitive impairment. The population was divided into cognitive impairment (AD8 scores at least 2 points) and normal cognitive, then in each subgroup, we also explored the association between health literacy and medication adherence after controlling other covariates. Furthermore, the scores were divided, respectively into four quartiles, e.g., Q1 (the lowest 25%), Q2 (50% or less), Q3 (75% or less), and Q4 (the highest 75%) to investigate the effect of modification by cognition on the association between health literacy and medicine adherence. The Cronbach's coefficient was calculated to examine the internal reliability of the scales or subscales used in this study. Statistical significance was accepted at $p < 0.05$ and all analyses were conducted using SAS 9.4 software (SAS Institute, Cary, NC, USA).

RESULTS

A total of 4,166 older adult populations with self-reported one or more chronic conditions were included in this study, and average age was 70.61 $\pm$ 7.38 years, ranging from 60 to 100 years old. Of those, 1,395 participants (33.49%) were identified as non-adherence (scores of MMAS-8 < 6 points), and 1,983 participants (47.60%) self-reported to have at least two chronic conditions or more, and 1,459 participants (35.02%) might be cognitive impairment screened by AD8 (scores of AD8 $\geq$ 2 points). The characteristics of the older adults are shown in **Table 1**.

The Association of Health Literacy With Medication Adherence

As shown in **Table 1**, participants who were living in urban areas, female, older adult, educated with illiterate or Primary school, as well as unmarried, divorced, or widowed tend to have a higher risk of non-adherence. The comorbidity, higher healthcare costs

TABLE 1 | Characteristics of study participants and comparison between adherence and non-adherence.

	Total (*N* = 4,166) *n* (%)	Adherence (*N*= 2 771) *n* (%)	Non-adherence (*N* = 1,395) *n* (%)	*P*-value*	Univariate OR (95%CI)#
Type of residence					
Urban	3,280 (78.73%)	2,261 (68.93%)	1,019 (31.07%)	<0.001	Reference
Rural	886 (21.27%)	510 (57.56%)	376 (42.44%)		1.636 (1.405–1.905)
Gender					
Male	2,025 (49.47%)	1,382 (68.25%)	643 (31.75%)	0.035	Reference
Female	2,068 (50.53%)	1,347 (65.14%)	721 (34.86%)		1.150 (1.010–1.310)
Subgroups of age					
60–69	1,988 (47.72%)	1,347 (67.76%)	641 (32.24%)	0.008	Reference
70–79	1,608 (38.6%)	1,077 (66.98%)	531 (33.02%)		1.036 (0.901–1.192)
≥80 or over	570 (13.68%)	347 (60.88%)	223 (39.12%)		1.350 (1.114–1.638)
Ethnicity					
Han	3,992 (96.05%)	2,663 (66.71%)	1,329 (33.29%)	0.173	Reference
Other	164 (3.95%)	101 (61.59%)	63 (38.41%)		1.250 (0.906–1.724)
Education					
Illiterate or primary school	1,135 (27.24%)	633 (55.77%)	502 (44.23%)	<0.001	Reference
Junior school	1,552 (37.25%)	1,085 (69.91%)	467 (30.09%)		0.543 (0.463–0.637)
High school, college, or graduate school	1,479 (35.50%)	1,053 (71.20%)	426 (28.80%)		0.510 (0.434–0.600)
Marital status					
Unmarried, divorced, widow	735 (17.92%)	455 (61.90%)	280 (38.10%)	0.002	Reference
Married	3,367 (82.08%)	2,284 (67.83%)	1,083 (32.17%)		0.771 (0.653–0.909)
Smoking condition					
Never smoking	2,670 (65.17%)	1,801 (67.45%)	869 (32.55%)	0.183	Reference
Smoking	790 (19.28%)	509 (64.43%)	281 (35.57%)		1.144 (0.969–1.352)
Smoked, but quit now	637 (15.55%)	413 (64.84%)	224 (35.16%)		1.124 (0.937–1.348)
Healthcare costs in last year					
<5000 Yuan	2,563 (61.52%)	1,748 (68.2%)	815 (31.80%)	0.004	Reference
≥5000 Yuan	1,603 (38.48%)	1,023 (63.82%)	580 (36.18%)		1.216 (1.066–1.387)
Medical insurance					
No	46 (1.11%)	26 (56.52%)	20 (43.48%)	0.153	Reference
Yes	4,086 (98.89%)	2,718 (66.52%)	1,368 (33.48%)		0.654 (0.364–1.176)
Suffering from chronic diseases					
Only one	2,183 (52.40%)	1,501 (68.76%)	682 (31.24%)	0.001	Reference
Multiple (2 or more)	1983 (47.60%)	1270 (64.04%)	713 (35.96%)		1.236 (1.086–1.406)
Cognitive ability					
Cognitive normal	2,707 (64.98%)	2,092 (77.28%)	615 (22.72%)	<0.001	Reference
Cognitive impairment	1,459 (35.02%)	679 (46.54%)	780 (53.46%)		3.908 (3.409–4.480)
Questionnaire filling method					
Self-completed	1,807 (43.37%)	1,150 (63.64%)	657 (36.36%)	<0.001	Reference
Face-to-face inquiry	2,359 (56.63%)	1,621 (68.72%)	738 (31.28%)		0.797 (0.700–0.907)
Total scores of health literacy (Mean±SD)	39.21 ± 12.71	40.38 ± 12.35	36.88 ± 13.07	<0.001	0.979 (0.974–0.984)
cores of three dimensions (Mean ± SD)					
Knowledges and attitudes	17.24 ± 5.53	17.67 ± 5.43	16.38 ± 5.62	<0.001	0.959 (0.948–0.97)
Behavior and lifestyle	12.81 ± 4.88	13.26 ± 4.76	11.90 ± 5.01	<0.001	0.944 (0.932–0.957)
Health-related skills	9.16 ± 3.57	9.45 ± 3.48	8.60 ± 3.69	<0.001	0.936 (0.919–0.953)
Scores of covering six aspects (Mean ± SD)					
Scientific views of health	6.74 ± 2.79	6.92 ± 2.74	6.37 ± 2.86	<0.001	0.932 (0.910–0.953)
Infectious diseases	4.44 ± 1.72	4.56 ± 1.68	4.20± 1.76	<0.001	0.886 (0.853–0.920)
Chronic diseases	6.64 ± 2.95	6.85 ± 2.91	6.23 ± 2.96	<0.001	0.931 (0.911–0.952)
Safety and first aid	9.49 ± 3.39	9.82 ± 3.26	8.84 ± 3.55	<0.001	0.919 (0.902–0.937)
Medical care	7.79 ± 2.83	8.03 ± 2.78	7.31 ± 2.88	<0.001	0.914 (0.894–0.936)
Health information	4.11 ± 2.10	4.20 ± 2.08	3.92 ± 2.12	<0.001	0.938 (0.909–0.967)

**p for chi-square test, t-test or ANOVA tests, $p < 0.05$.*

#Univariate bivariate logistic models with adherence as the dependent variable (event = "Non-adherence").

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TABLE 2 | Multivariable-adjusted odds ratios (*OR*s) for the association between the scores of health literacy and medication adherence.

	Model 1[#] OR (95%CI)	Model 2[##] OR (95%CI)	Model 3[###] OR (95%CI)
Total scores of health literacy	0.983 (0.978–0.989)	0.983 (0.977–0.988)	0.988 (0.982–0.993)
Cognitive impairment	N.A.	N.A.	3.464 (2.983–4.023)
Scores of three dimensions			
Knowledges and attitudes	0.971 (0.959–0.983)	0.968 (0.956–0.981)	0.979 (0.967–0.992)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.503 (3.017–4.067)
Behavior and lifestyle	0.952 (0.939–0.966)	0.953 (0.939–0.967)	0.963 (0.949–0.978)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.471 (2.989–4.030)
Health-related skills	0.952 (0.934–0.970)	0.947 (0.929–0.966)	0.964 (0.945–0.984)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.494 (3.009–4.057)
Scores of covering six aspects			
Scientific views of health	0.951 (0.928–0.974)	0.947 (0.924–0.971)	0.965 (0.940–0.99)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.529 (3.040–4.097)
Infectious diseases	0.910 (0.875–0.946)	0.917 (0.881–0.954)	0.937 (0.899–0.976)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.538 (3.049–4.106)
Chronic diseases	0.948 (0.926 - 0.969)	0.947 (0.925 - 0.969)	0.964 (0.941–0.988)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.522 (3.034–4.088)
Safety and first aid	0.936 (0.917–0.955)	0.934 (0.915–0.953)	0.953 (0.933–0.974)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.452 (2.972–4.010)
Medical care	0.928 (0.906–0.950)	0.922 (0.900–0.945)	0.941 (0.918–0.965)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.468 (2.987–4.027)
Health information	0.965 (0.935–0.996)	0.955 (0.924–0.987)	0.969 (0.936–1.003)
Cognitive impairment (ref = Normal)	N.A.	N.A.	3.569 (3.075–4.141)

[#]*Model 1: Bivariate logistic models those adherence was as the dependent variable (event = "Non-adherence"), and the scores of health literacy (or scores of knowledges and attitudes, or scores of behavior and lifestyle, or scores of health-related skills, or scores of scientific views of health, or scores of infectious diseases, or scores of chronic diseases, or scores of safety and first aid, or scores of medical care, or scores of health information, respectively) as independent variable, controlling for variables, such as type of residence, gender, age, and education.*

[##]*Model 2: Further adding variables of marital status, smoking condition, medical costs for last year, multiple chronic disease, as well as questionnaire filling method as covariates in Model 1.*

[###]*Model 3: Adding variable of cognitive impairment in Model 2.*

in last year, and cognitive impairment were also associated with the risk of poor medication adherence.

Moreover, health literacy was negatively associated with medication adherence. The lower total scores were found among the participants with non-adherence ($p < 0.01$, crude $OR = 0.979$ per one point increase, 95% *CI*: 0.974–0.984) when not controlling for any other covariates. The similar results were found in each dimension and each covering aspect of health literacy (as shown in **Table 1**).

In adjusted analyses (**Table 2**), the total scores of health literacy also associated with medication adherence when controlling other covariates (such as, type of residence, gender, age, education, marital status, smoking condition, healthcare costs in last year, comorbidity, and self-completed questionnaire) and adjusted *OR* was 0.983 (95% *CI*: 0.977–0.988), so did the scores of each dimension, as well as scores of each covering aspect of health literacy. Furthermore, when controlling the covariate of cognitive ability, the association of health literacy and adherence was still found (except the scores of health information).

Cognitive Condition Mediation Analysis

Then, the older adults were divided into cognitive normal and cognitive impairment according to AD8 scores. It was found the total scores of health literacy, the scores of each dimension, as well as the scores of each covering aspect were also negatively associated with non-adherence among the elderly with normal cognitive (**Table 3**). However, among the older adults with cognitive impairment, these associations were only found in total scores, the scores of behaviors and lifestyles, the scores of safe and first aid, as well as the scores of medical cares (**Table 3**).

Furthermore, according to the quantile of each score and cognitive normal/impairment, the participants were divided into eight subgroups. Compared with the subgroup with the lowest 25% scores and cognitive impairment, lower adjusted *OR* was found among the cognitive normal population in which adequate health literacy was still a positive factor of medication adherence, while the effects of health literacy on adherence were weakened or even disappeared among the older adults with cognitive impairments (as shown in **Figures 1**, **2**).

TABLE 3 | Multivariable-adjusted *OR*s for the association between health literacy and medication adherence among the participants with or without cognitive impairment.

	Participants without cognitive impairment	Participants with cognitive impairment
Total scores of health literacy	0.985 (0.977–0.993)	0.991 (0.982–0.999)
Scores of three dimensions		
Knowledges and attitudes	0.974 (0.957–0.991)	0.987 (0.967–1.007)
Behavior and lifestyle	0.958 (0.940–0.978)	0.969 (0.948–0.991)
Health-related skills	0.957 (0.931–0.984)	0.972 (0.943–1.003)
Scores of covering six aspects		
Scientific views of health	0.952 (0.919–0.986)	0.981 (0.944–1.020)
Infectious diseases	0.895 (0.846–0.946)	0.985 (0.926–1.048)
Chronic diseases	0.965 (0.934–0.996)	0.964 (0.928–1.001)
Safety and first aid	0.949 (0.922–0.977)	0.957 (0.928–0.988)
Medical cares	0.939 (0.908–0.972)	0.943 (0.907–0.980)
Health information	0.944 (0.902–0.988)	1.003 (0.950–1.059)

Bivariate logistic models those adherence was as the dependent variable (event = "Non-adherence"), and the scores of health literacy (or scores of knowledges and attitudes, or scores of behavior and lifestyle, or scores of health-related skills, or scores of scientific views of health, or scores of infectious diseases, or scores of chronic diseases, or scores of safety and first aid, or scores of medical care, or scores of health information, respectively) as independent variable, controlling for type of residence, gender, age, education, marital status, smoking condition, medical costs for last year, multiple chronic disease, as well as questionnaire filling method.

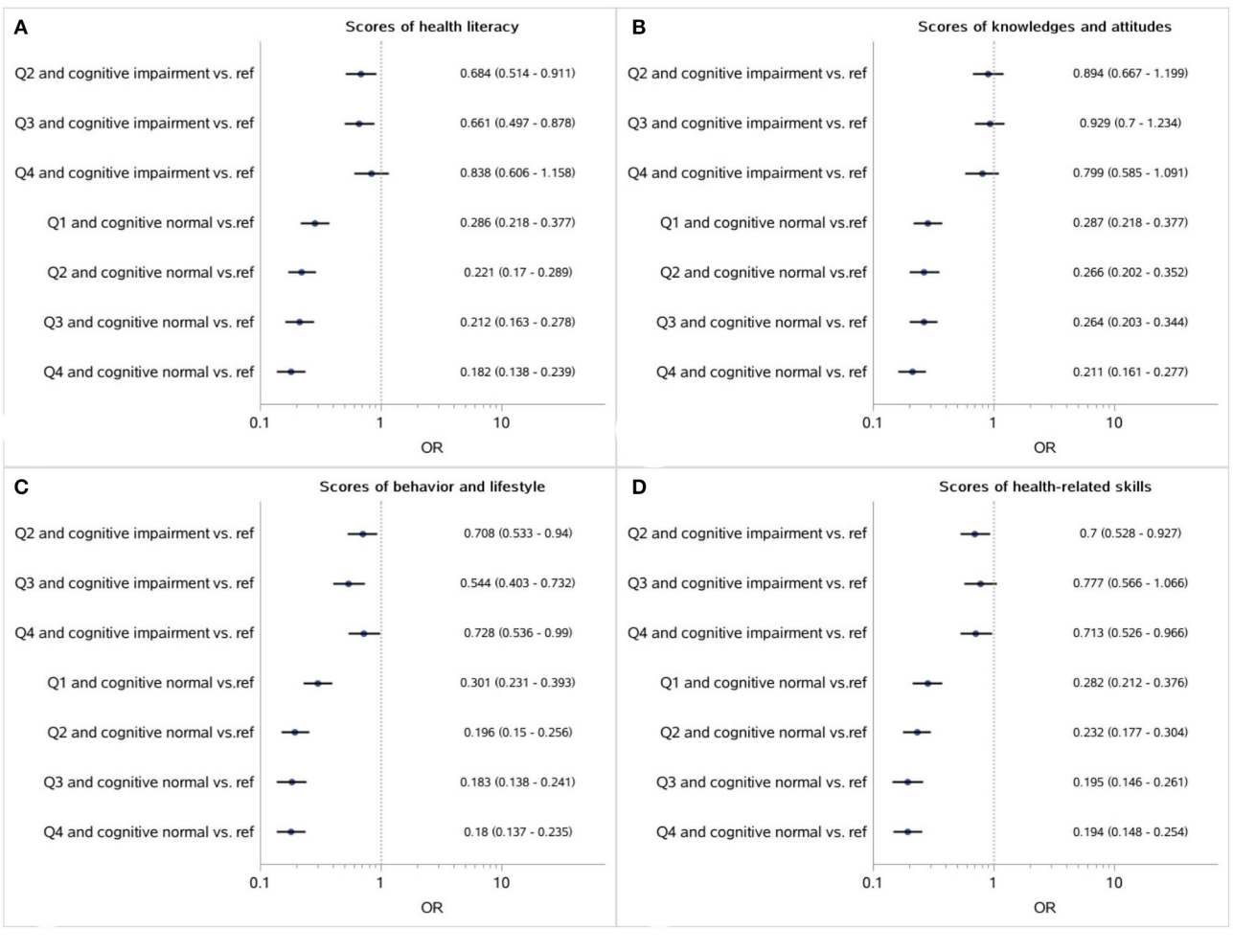

FIGURE 1 | Association between the respective scores of health literacy, as well as three dimensions (**A**: Healthy literacy; **B**: Knowledges and attitudes; **C**: Behavior and lifestyle; **D**: Health-related skills) and medication adherence mediated by cognitive impairment (Reference: participants with the lowest 25% scores and cognitive impairments).

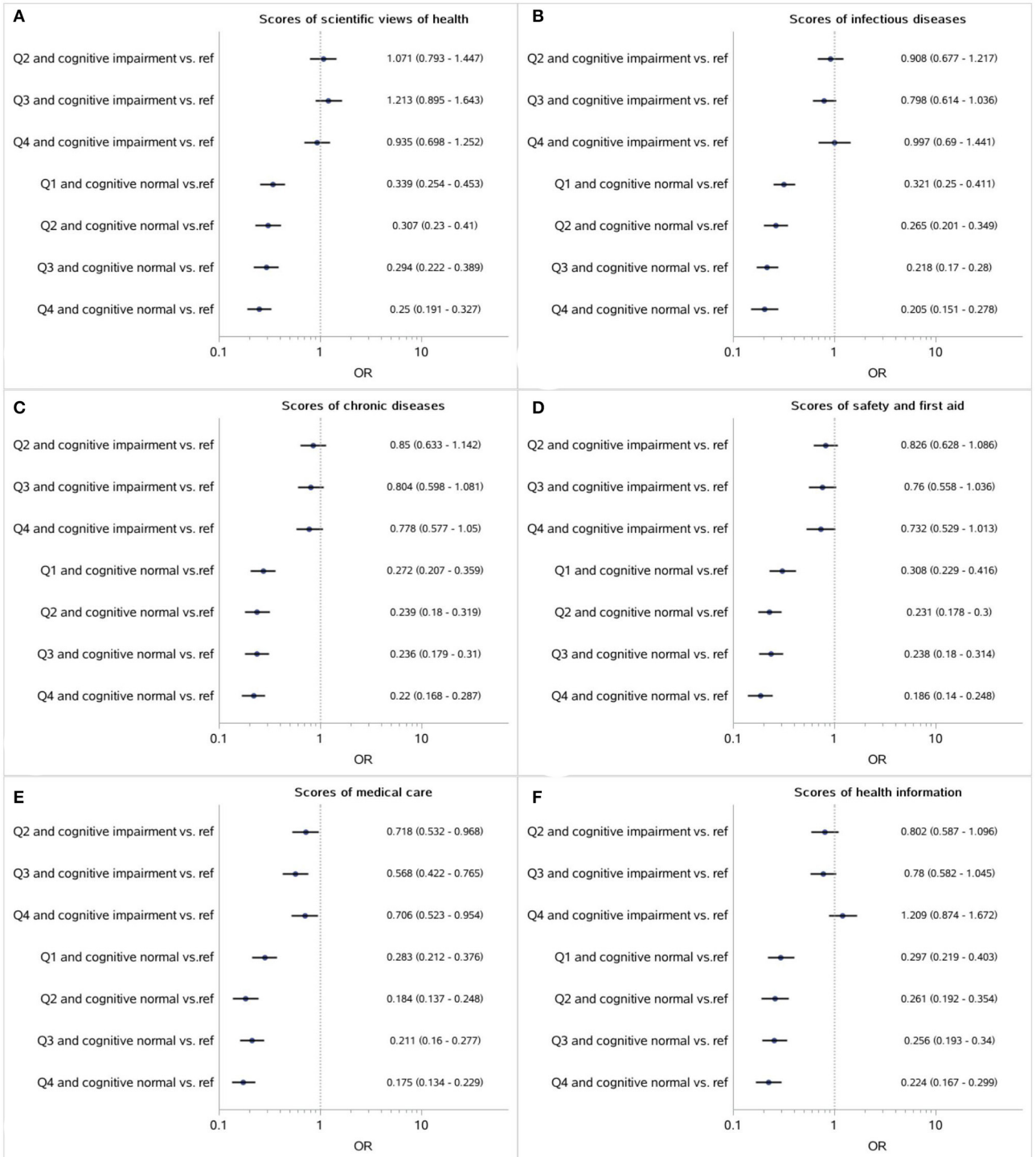

FIGURE 2 | Association between the respective scores of covering six aspects (**A**: Scientific views of health; **B**: Infectious diseases; **C**: Chronic diseases; **D**: Safety and first aid; **E**: Medical care; **F**: Health information) and medication adherence mediated by cognitive impairment (Reference: participants with the lowest 25% scores and cognitive impairments).

DISCUSSION

This study was focused on the relation of health literacy to medication adherence on the community-based older adults with one or more chronic conditions in Beijing of China. Of these older adults, nearly one-third were identified as non-adherence to medication and the higher scores of health literacy were found to be negatively associated with the risk of non-adherence in our study, especially among the older adults with normal function. In addition, we found that the cognitive function played an important mediator and the association of health literacy with adherence tended to be weakened or even disappeared among the older adults with cognitive impairment compared with those with normal cognitive.

In a meta study, Miller synthesized both correlation and intervention studies reported that health literacy was positively associated with adherence (8). Soones et al. indicated that health literacy had a direct and an indirect effect on adherence among the older adults with asthma (16). Our results in this study were similar to the findings in these previous studies. The association of health literacy with adherence might be bidirectional in this study. On the one hand, the individuals with poor health literacy had limited ability to obtain, process, and understand the health information, so that they had difficulty in understanding instructions rightly, even prone to develop fears about the side effect and addition of medication, and ultimately resulted in decreased adherence to taking medicine. On the other hand, non-adherence was found to be the worse health outcome (2, 3), which made them to actively obtain more information and understand instructions by communicating with the healthcare provider or by other channels (e.g., internet and televisions) so that they could make appropriate health decisions if needed, which, in turn, might improve health literacy.

The association between health literacy and adherence was not only affected by reading and numeracy, but also by the abilities necessary to actively learn and apply new information and crystallized abilities (such as, background knowledge), all of them were closely related to cognitive ability (23). Our findings suggested that the cognitive ability played an important mediator in these association. For the older adults with normal cognitive, improving health literacy might still be one of public health strategies to increase the medication adherence to deal with NCDs challenge, especially for the older adults with poor health literacy. However, some of the protective effects of improving health literacy might be offset by the larger impact of cognitive impairment with aging. The findings implied that the intervention among the older adults aimed at improving the health literacy need first to identify the sensitive population or potentially valuable targets and consider the active implementation of strategies according to their cognitive ability. The action programs for the improvement of health literacy for the older adults should incorporate cognitive science, which should design the easily understandable education materials, and decompose multi-steps or complex skills into small steps to teach, encourage the older population to repeat the information in their own words. Furthermore, for the older adult individuals with cognitive impairments, the strategies focused on the improvement of cognitive function might be more effective to improve their medication adherence, such as cognitive training, behavioral therapy, or administration of cholinesterase inhibitors.

This study was based on a representative sample of the older adult residents living in Beijing. In total, 4,166 participants suffering from one or more conditions reported by themselves were included in our analysis, which accounted for 71.47% of all the participants (4,166/5,829) in this community-based cross-sectional survey. This proportion were close to the proportion of 75% NCD previously reported in the Chinese older population (1). Our study first provided the evidence of adherence to medication from the general older adults in Beijing of China. In addition, our study found the effects of health literacy on adherence mediated by cognitive function among the Chinese older adults, which rarely reported previously. However, there were still limitations in our study. First, the cognitive impairment in our study was identified by AD8 scale which was just a screen tool and not a diagnosis tool. Although there was good accuracy (sensitivity: 92%; specificity: 46%) for AD8 scale, the potential misclassification (especially those of the older adult with normal cognitive misclassified as "cognitive impairment" identified by AD8) might lead to overestimate the effects of health literacy among the participants with cognitive impairment. Second, about 56.6% of participants provided the information by face-to-face inquiry owing to impaired vision, or limited reading ability or other such reasons, which might cause information bias especially for the measurement of health literacy. Although the type of questionnaire filled were put as covariate in the multiple models in our analysis, there might be still the potential residual confounding. Third, there were no widely recognized effective tools for assessing the level of health literacy mainly focused on the older adults in China. In our study, we used Chinese Resident Health Literacy Scale which was a commonly used measure among adults of 15–69 years older, but lack of evidence for 70 years old or over. Consider that the cut-off point (55 points, 80% of 66 points) for distinguishing adequate health literacy in this scale might be more rigorous for the older adults, especially the aged older adults, we used the scores and their quantile to assess the level of health literacy in our analysis.

CONCLUSION

In our study, we found that the one-third of the older adults with chronic diseases were non-adherence to the medication in Beijing of China and the association of health literacy to adherence mediated by cognitive ability. The findings suggested that improving health literacy might be one of the public health strategies to increase adherence to medication, especially for the older adults of poor health literacy. But, the priority to identify the potential target population is needed considering the cognitive ability.

DATA AVAILABILITY STATEMENT

The original data supporting the conclusions of this article will be provided by the authors, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board of the Institute of Basic Medical Sciences, Chinese Academy of Medical Sciences (Project No. 064-2020). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

YW and LW participated in the design of the study and organized the training of investigators. QJ and HW participated in data collection and quality control. QJ and YW drafted the manuscript, performed the statistical analysis, and revision of the manuscript. All authors contributed to the article and approved the submitted version.

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REFERENCES

1. Wang LM, Chen ZH, Zhang M, Zhao ZP, Huang ZJ, Zhang X, et al. Study of the prevalence and disease burden of chronic disease in the elderly in China. *Chin J Epidemiol.* (2019) 40:277–83. doi: 10.3760/cma.j.issn.0254-6450.2019.03.005
2. Dalfabbro AL. *Adherence to Long Term Therapies: Evidence for Action*. Geneva: World Health Organization. (2003).
3. Roebuck MC, Liberman JN, Gemmill-Toyama M, Brennan TA. Medication adherence leads to lower health care use and costs despite increased drug spending. *Health Aff.* (2011) 30:91–9. doi: 10.1377/hlthaff.2009.1087
4. Lu J, Zhang N, Mao D, Wang Y, Wang X. How social isolation and loneliness effect medication adherence among elderly with chronic diseases: an integrated theory and validated cross-sectional study. *Arch Gerontol Geriatr.* (2020) 90:104154. doi: 10.1016/j.archger.2020.104154
5. Qing W, Qi Z, Yao H, Xin J, Ying H. Elderly patients with hypertension self-perceived of aging status and compliance with medical behaviour. *Psychol Health Med.* (2020) 26:1206–18. doi: 10.1080/13548506.2020.1800056
6. Hou Y, Zhang D, Gu J, Xue F, Sun Y, Wu Q, et al. The association between self-perceptions of aging and antihypertensive medication adherence in older Chinese adults. *Aging Clin Exp Res.* (2016) 28:1113–20. doi: 10.1007/s40520-015-0516-z
7. Campbell NL, Boustani MA, Skopelja EN, Gao S, Unverzagt FW, Murray MD. Medication adherence in older adults with cognitive impairment: a systematic evidence-based review. *Am J Geriatr Pharmacother.* (2012) 10:165–77. doi: 10.1016/j.amjopharm.2012.04.004
8. Miller TA. Health literacy and adherence to medical treatment in chronic and acute illness: a meta-analysis. *Patient Educ Couns.* (2016) 99:1079–86. doi: 10.1016/j.pec.2016.01.020
9. Martin LR, Williams SL, Haskard KB, Dimatteo MR. The challenge of patient adherence. *Ther Clin Risk Manag.* (2005) 1:189–99.
10. Liu C, Wang D, Liu C, Jiang J, Wang X, Chen H, et al. What is the meaning of health literacy? A systematic review and qualitative synthesis. *Fam Med Community Health.* (2020) 8:e000351. doi: 10.1136/fmch-2020-000351
11. Mayo-Gamble TL, Mouton C. Examining the association between health literacy and medication adherence among older adults. *Health Commun.* (2018) 33:1124–30. doi: 10.1080/10410236.2017.1331311
12. Lu M, Ma J, Lin Y, Zhang X, Shen Y, Xia H. Relationship between patient's health literacy and adherence to coronary heart disease secondary prevention measures. *J Clin Nurs.* (2019) 28:2833–43. doi: 10.1111/jocn.14865
13. Thurston MM, Bourg CA, Phillips BB, Huston SA. Impact of health literacy level on aspects of medication nonadherence reported by underserved patients with type 2 diabetes. *Diabetes Technol Ther.* (2015) 17:187–93. doi: 10.1089/dia.2014.0220
14. Zhang NJ, Terry A, McHorney CA. Impact of health literacy on medication adherence: a systematic review and meta-analysis. *Ann Pharmacother.* (2014) 48:741–51. doi: 10.1177/1060028014526562
15. Shiyanbola OO, Unni E, Huang YM, Lanier C. The association of health literacy with illness perceptions, medication beliefs, and medication adherence among individuals with type 2 diabetes. *Res Social Adm Pharm.* (2018) 14:824–30. doi: 10.1016/j.sapharm.2017.12.005
16. Soones TN, Lin JL, Wolf MS, O'Conor R, Martynenko M, Wisnivesky JP, et al. Pathways linking health literacy, health beliefs, and cognition to medication adherence in older adults with asthma. *J Allergy Clin Immunol.* (2017) 139:804–9. doi: 10.1016/j.jaci.2016.05.043
17. Deary IJ. Intelligence. *Curr Biol.* (2013) 23:R673–6. doi: 10.1016/j.cub.2013.07.021
18. Singh-Manoux A, Kivimaki M, Glymour MM, Elbaz A, Berr C, Ebmeier KP, et al. Timing of onset of cognitive decline: results from Whitehall II prospective cohort study. *BMJ.* (2012) 344:d7622. doi: 10.1136/bmj.d7622
19. Hayes TL, Larimer N, Adami A, Kaye JA. Medication adherence in healthy elders: small cognitive changes make a big difference. *J Aging Health.* (2009) 21:567–80. doi: 10.1177/0898264309332836
20. Cho MH, Shin DW, Chang SA, Lee JE, Jeong SM, Kim SH, et al. Association between cognitive impairment and poor antihypertensive medication adherence in elderly hypertensive patients without dementia. *Sci Rep.* (2018) 8:11688. doi: 10.1038/s41598-018-29974-7
21. Serper M, Patzer RE, Curtis LM, Smith SG, O'Conor R, Baker DW, et al. Health literacy, cognitive ability, and functional health status among older adults. *Health Serv Res.* (2014) 49:1249–67. doi: 10.1111/1475-6773.12154
22. O'Conor R, Wolf MS, Smith SG, Martynenko M, Vicencio DP, Sano M, et al. Health literacy, cognitive function, proper use, and adherence to inhaled asthma controller medications among older adults with asthma. *Chest.* (2015) 147:1307–15. doi: 10.1378/chest.14-0914
23. Wolf MS, Curtis LM, Wilson EA, Revelle W, Waite KR, Smith SG, et al. Literacy, cognitive function, and health: results of the LitCog study. *J Gen Intern Med.* (2012) 27:1300–7. doi: 10.1007/s11606-012-2079-4
24. Wilson RS Yu L, James BD, Bennett DA, Boyle PA. Association of financial and health literacy with cognitive health in old age. *Neuropsychol Dev Cogn B Aging Neuropsychol Cogn.* (2017) 24:186–97. doi: 10.1080/13825585.2016.1178210
25. Yang J, Gao Y, Wang Z. Increasing health literacy in China to combat noncommunicable diseases. *China CDC weekly.* (2020) 2:987–91. doi: 10.46234/ccdcw2020.248
26. Morisky DE, Ang A, Krousel-Wood M, Ward HJ. Predictive validity of a medication adherence measure in an outpatient setting. *J Clin Hypertens.* (2008) 10:348–54. doi: 10.1111/j.1751-7176.2008.07572.x

27. Berlowitz DR, Foy CG, Kazis LE, Bolin L, Conroy LB, Fitzpatrick P, et al. Impact of intensive blood pressure therapy on patientreported outcomes: outcomes results from the SPRINT study. *N Engl J Med.* (2017) 377:733–44. doi: 10.1056/NEJMoa1611179
28. Bress AP, Bellows BK, King J, Hess R, Beddhu S, Zhang Z, et al. Cost-effectiveness of intensive versus standard blood pressure control. *N Engl J Med.* (2017) 377:745–55. doi: 10.1056/NEJMsa1616035
29. Shen M, Hu M, Liu S, Chang Y, Sun Z. Assessment of the Chinese resident health literacy scale in a population-based sample in South China. *BMC Public Health.* (2015) 15:637. doi: 10.1186/s12889-015-1958-0
30. Galvin JE, Roe CM, Xiong C, Morris JC. Validity and reliability of the AD8 informant interview in dementia. *Neurology.* (2006) 67:1942–8. doi: 10.1212/01.wnl.0000247042.15547.eb
31. Chen HH, Sun FJ, Yeh TL, Liu HE, Huang HL, Kuo BI, et al. The diagnostic accuracy of the Ascertain Dementia 8 questionnaire for detecting cognitive impairment in primary care in the community, clinics and hospitals: a systematic review and meta-analysis. *Fam Pract.* (2018) 35:239–46. doi: 10.1093/fampra/cmx098

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Student-Driven Course-Based Undergraduate Research Experience (CUREs) Projects in Identifying Vaginal Microorganism Species Communities to Promote Scientific Literacy Skills

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Objectives: We aim to build a students' own engagement in original microbiological course-based undergraduate research experience (CUREs) model served two research and teaching scientific purposes including students' scientific literacy skills and instructors' role, which could further be applied as contribution to broader scientific knowledge and conduct novel research in their future research experience and careers.

Methods: We describe a student-driven CUREs model on the microorganism species in female vaginal using general bacterial culture techniques and high-throughput 16S rRNA gene amplicon sequencing to enable students to center experimental research method under the direction of instructors. A total of 8 undergraduate students and 5 instructors from Shanghai Jiao Tong University School of Medicine participated in the project. The CUREs were divided in four operating scopes: project planning, implementation, summarizing and feedback phases. Instructors help students to develop learning research goals.

Results: This project helped students to gain "hard skills" experiences in scientific theoretical research process and technical practices. Students reached the conclusion that *Lactobacillus* species dominated the primary vaginal microbiota in reproductive-age women, 16S rRNA sequencing is a method widely applied for microbiology detection. CUREs also increased students' engagement in scientific experiments and promote 3 learning goals in "soft skills": (1) Develop students' self-study and efficacy ability, expression capability and professional research communication skills; (2) Strengthen students' motivation and ownership in science research, overcoming failure, benefitting persistence and patience, building professional science identity, competence, and confidence in collaboration, implement spirit of rigorous and carefulness;

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(3) Obtain authorship, independent and logical thinking capability, summarizing ability and confidence enhancement. Instructors proposed guiding research question for the students and determine evidence in achieving pedagogical goals in CUREs.

Conclusions: Our microbiological CUREs project served two scientific purposes: research and teaching, which increase students' engagement in promoting learning gains in scientific research skills, ownership, identity development, and spirit of motivation, self-efficacy, persistence, collaboration, communication, as well as opportunities to make relevant scientific discoveries. These abilities equipped them with essential foundation for the subsequent collaborative experiments and future scientific study.

Keywords: course-based undergraduate research experiences, student-driven, vaginal microorganisms, 16S rRNA gene amplicon sequencing, scientific literacy skills

INTRODUCTION

Course-based undergraduate research experiences (CUREs) are laboratory-learning lessons to investigate an original research question driven by students' authentic participate in novel scientific study based on their own interest and curiosity early in their college careers. It is an essential teaching model characterized by students obtaining science laboratory experiences with steps of involving discovery, conducting scientific practices, including relevant research questions and promoting collaboration in the research process, which is different from other science laboratories only relied on "cookbook labs" for student (1). Unlike traditional laboratorial based courses with outcomes known to the instructor. Instead, CUREs focus on student driven inquiry and active participation in the scientific process of experiments where the outcomes are often unknown to the instructors (2). CUREs benefit both the instructors and the students. The benefits to the students include ownership of the research project through developing their own research questions and hypotheses, effective at promoting students' research self-efficacy, science identity development, and persistence in the domain (3). Students designed an original research hypothesis, summarized content knowledge from literature, implemented a research plan, worked with teams, collected and analyzed data, concluded t novel scientific findings and discussed results with their peers and faculty members (4). Current evidence in biology education indicates that CURES is effective to develop students' science identity (3) through engagement in scientific research which promote students' self-efficacy and attitudes about learning, persistence, collaboration and networking (5, 6), thus lay the foundation for future basic medical research (2, 7). While benefits to the instructor include integrating research with teaching by training students to participate in independent research ability (8). CUREs instructors' key duty is to plan research instruction, choose suitable experimental tools and methods, assess CUREs outcomes and develop students' collaborative skills so that students can successfully apply their learning to conduct real research projects (9).

Since an essential goal for successful scientific education is offering opportunities for medical students to conduct research and realize real-world scientific experiences (6). CUREs topics addressed the aspect of microbiology, cell/molecular biology and genetics, immunology, histology and biotechnology (10). In recent years, microbiology has become a focus of research and is regarded as an important part of disease diagnosis and treatment with immediate "real-world" applications. The Human Microbiome Project (HMP) recommends characterizing the abundance and diversity of microorganisms using next-generation sequencing technology (11). Bacterial metabolism is an essential part of undergraduate microbiology education (12). For females, the vaginal microorganism environment includes a diverse set of species, constitute a biological barrier to pathogenic microorganisms (13), and protect Gynecologic Cancers (14).Beneficial bacteria, such as *Lactobacillus*, account for more than 80% of all vaginal bacteria and constitute the first line of defense against invasive microorganisms. The absence of *Lactobacillus* has been associated with disturbances in the vaginal microbiota, resulting in an inflammatory vaginal disease in ∼40% of healthy women and allowing infection through overgrowth of harmful anaerobes, such as *Gardnerella vaginalis* and *vulvovaginal candidiasis* (15, 16).

In this project, we employed general bacterial culture techniques and high-throughput 16S rRNA gene amplicon sequencing to explore vaginal microorganism species communities between premenopausal and postmenopausal women. Instructors were available for guidance and demonstrations of scientific technical skills and abilities. The specific focus questions guiding this exploratory study are:

1. What are the approaches used for microbiological CUREs?
2. What are the valuable skills and benefits for students by CUREs? And how did students evaluate their scientific literacy skills in the CUREs?
3. What is the instructors' role in the CUREs?

Abbreviations: ANOVA, Analysis of variance; CCA, correspondence analysis; COG, clusters of Orthologous Groups; CURES, course-based undergraduate research experiences; LEfSe, Linear discriminant analysis effect size; NMDS, non-metric multidimensional scaling; OTUs, operational taxonomic units; PCA, Principal Component; PCoA, Principal Co-ordinates Analysis; PERMANOVA, Permutational multivariate analysis of variance; RDA, gradient direct analysis; RDP, Ribosomal Database Project; SEER, sequence element enrichment analysis.

4. What is the effectiveness of CUREs education directly contributing to science ?
5. How did this CUREs project implied on other development research practices?

The purpose of our CUREs model was to engage students to participate in microbiome experimental study where they could associate theoretical knowledge to research practice through experimental repetition cycles and critical evaluation of data (17), and improve students' scientific literacy skill as critical thinking, problem solving skills and collaboration in scientific research, thus enhancing their innovation and self-authorship in scientific processes (18, 19).These essential technical abilities and spirits would equip them fitting well into other broader research-based courses and relevant to the scientific community at large, better preparing students for future careers.

MATERIALS AND METHODS

Study Design

This study was performed in Shanghai General Hospital affiliated with Shanghai Jiao Tong University School of Medicine. A total of 8 undergraduate students, identified as S1, S2, S3, S4 on grade 3 and S5, S6, S7, S8 on grade 4 in Shanghai Jiao Tong University School of Medicine, 3 clinicians (C1, C2, C3) and 2 experimental technician (T1, T2) as instructors with backgrounds in microbiological experimental research participated in the project. They were divided into 2 groups, S1, S2, S5, S6, C1, C2, and T1 as Group 1 (G1), the remaining researchers as Group 2 (G2). Both groups participate in determining the vaginal microorganism detection method and species distribution between premenopausal and postmenopausal women under the guidance of the instructors. A total of 597 women, including 124 postmenopausal women and 473 reproductive age women, were enrolled in this study as experimental research object, among which 30 vaginal discharge samples were subjected to identification of the microbial community abundance and diversity using high-throughput 16S rRNA gene amplicon sequencing. Our project was divided into four phases termed CURE #I to #IV (**Table 1**), where students engaged in planning, implementing, summarizing and providing feedback, respectively. Students averagely worked on the CURE project 1–2 h daily.

CURE #I: Planning phase, From January to February 2021 (Months 1–2), students referenced papers on pubmed (https://pubmed.ncbi.nlm.nih.gov) and derived a follow-up research plan, generated common research questions about culture bacterial community techniques and 16S rRNA gene amplicon sequencing to test the vaginal microbiome in vaginal discharge. They discussed experimental design approval and project strategies with instructors using video conferencing software like Tencent Communications (https://meeting.tencent.com) or wechat, and they prepared all materials needed to conduct the research.

CURE #II: Implementing phase: From March to June 2021 (Months 3–6), students collected vaginal secretion specimens for bacterial culture in the outpatient department twice a week. Then, they performed microorganism detection techniques according to their lab schedule under the guidance of the instructors and recorded and organized preliminary scientific data as the basis for research.

CURE #III: Summarizing phase: From July to October 2021 (Months 7–10), students focused on dissemination and communication of project findings, presented a brief feasibility analysis, and verified the data similarities and differences in results and interpretation.

CURE #IV: Feedback phase: From November to December 2021 (Months 11–12), both students and instructors conducted systematic reflection online to measure learning goals and settle problems. Recruitments and online analysis were gathered by Wen Juan Xing (https://www.wjx.cn). Each student was asked to provide their own role in facilitating the CUREs, how to resolve difficult issues, and make a short description in "hard and soft" skills with the self-evaluation score: Greatly improved: 3; Better improved: 2; General improved: 1; No improve: 0. Instructors were asked to provide assignments displayed by focus question regarded as instrument for program evaluation, analysis, ethical consideration (**Figure 1**).

Vaginal Sample Collection

Students collected vaginal samples using a cotton swab under the instruction of trained gynecologists. The samples were stored at room temperature for bacterial culture or at -40°C for 5 h until DNA extraction for the 16S rRNA Amplicon Library.

High-Throughput 16S rRNA Gene Amplicon Sequencing

NCBI's Sequence Read Archive (BioProject ID: PRJNA46877) was used as a control for vaginal microbiome 16S rDNA reference sequence analysis (20), and the generated contigs used the *Lactobacillus gasseri* (ATCC 9857) strain as the reference genome. Sequence element enrichment analysis (SEER) was used to analyze the annotated genomes for kmers of various lengths [47]. The resulting list of kmers was evaluated by likelihood-ratio p, and BLASTx and BLASTn yielded the top 50 hits. The clonal population structure of bacteria was estimated using Mash with default settings [48]. We used PCR primers that targeted the V3-V4 universal sequencing platform used 341F primers: CCCTACACGACGCTCTTCCGATCTG (barcode) CCTACGGGNGGCWGCAG and 805R primers: GACTGGAGTTCCTTGGCACCCGAGAATTCCA-GACTACHVGGGTATCTAATCC. All paired-end libraries were gathered into one lane and sequenced on the Illumina MiSeq^{TM} platform at the Biomicro Center (MIT, Cambridge, MA).

Statistical Analysis

Microorganism community distribution between premenopausal and postmenopausal women using general bacterial culture techniques were analyzed with Chi-square test. The statistical significance was set at $P < 0.05$. The students computed statistical analysis using R software version 3.2.0. The means of the flora variables were analyzed by two-tailed, paired *t*-tests (a = 0.05) using SPSS version 25.0. The filtered results for kmers used chi-square test of *P*-value <0.01.

TABLE 1 | Stage goals, activities, and focal skills associated with each phase of the project.

CUREs	Phase	Month	Activity	Details
#1	Planning	1–2 January to February 2021	Reading primary literature Propose hypotheses Experimental design Online science communication with instructors	Search suitable clinical and laboratory technology to detect vaginal microorganism species community. Study culture of microorganism community techniques and high-through 16S rRNA gene amplicon sequencing to identify vaginal microorganism species between premenopausal and postmenopausal women.
#2	Implementing	3–6 March to June in 2021	Collect vaginal samples in the outpatient department	
			General bacterial culture techniques	Identify the 10 most abundant vaginal microorganism genera between the premenopausal and postmenopausal groups.
			16S rRNA gene sequencing	PCR amplification, OTU and community taxonomy system analysis at the genus level, COG-based functional structure distribution to identify species classification and analysis of colony differences at genus level.
#3	Summarizing	7–10 July to October in 2021	Data interpretation	Describe the outcome of abundance and diversity of microbial communities through 16S rRNA analysis. Compare differences in microorganism diversity in female vaginal fluids between the premenopausal and postmenopausal group.
			Statistical inference	Mann-Whitney U-tests and Benjamini-Hochberg false discovery rate correction for non-parametric data; paired *t*-test, chi-square test and one-way ANOVA for parametric data
			Graphical inference	
			Collaborative writing manuscript	
#4	Feedback	11–12 November to December in 2021	For Students and instructors	Exposing feedback loops, facing obstacles, multiple connections among outcomes.

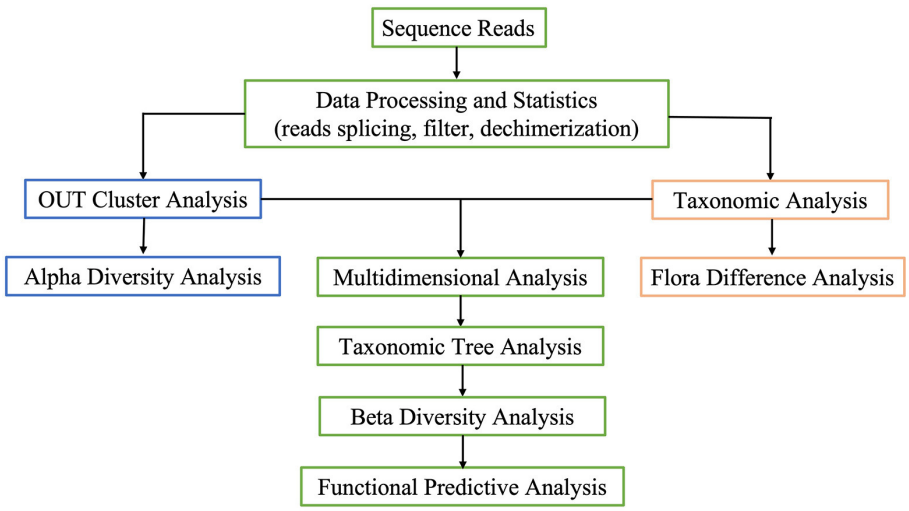

FIGURE 1 | CUREs project served two research and teaching scientific purposes including students' scientific literacy skills and instructors' role.

The operational taxonomic units (OTU) abundance difference between discrete categories was calculated using the Mann-Whitney U test and Benjamini-Hochberg false discovery rate correction. Hierarchical clustering and Wilcoxon tests were performed to compare genera classification. Linear discriminant analysis effect size (LEfSe), Anosim, Permutational multivariate analysis of variance (PERMANOVA) analysis and Analysis of variance (ANOVA) were carried out to compare differences in bacterial flora abundance between samples; Principal Co-ordinates Analysis (PCoA) analysis based on UniFrac was used to identify the similarities and differences in the vaginal microbial abundance matrix. Prism 8.0 was used to make the graphs.

RESULT

CUREs project served two research and teaching scientific purposes including students' scientific literacy skills and instructors' role was displayed in **Figure 1**. Framework in target,

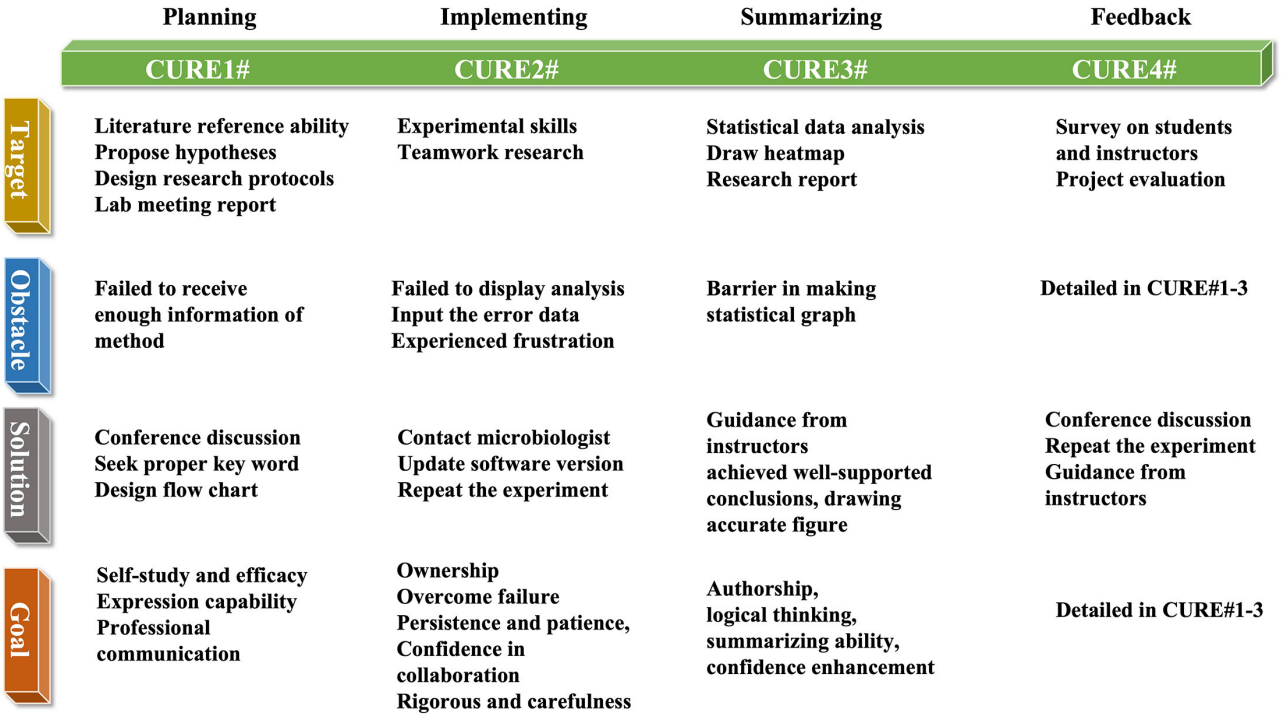

FIGURE 2 | Framework in target, obstacle, solution, and goal of CUREs students reach.

obstacle, solution and goal student reach was displayed in **Figure 2**.

CURE #I, Planning phase;

Learning Goal:

Hard skills (HS): Reserve foundational knowledge from primary literature, propose hypotheses, and design research protocols.

Soft skills (SS): Develop students' self-study and efficacy ability, expression capability, and professional research communication skills.

During the planning phase, instructors taught each group students the skills to seek open-access literature on web-based resources "pubmed" firstly, students began to link their research to summarize the recent findings and understanding of the vaginal bacterial microbiota. At the first week, students from Group 1 faced the obstacle on seeking the reference with accurate keywords, they first referenced with key word "vaginal bacteria, vaginal lactobacillus" but failed to receive enough information on experimental method, then they made a small conference on wechat with Group 2 students and obtained new key word "vaginal microbiome, high-throughput 16S rRNA gene amplicon sequencing, et al." from the reference they found so that they could seek more related reference (**Table 2**). On the next 2 weeks, the students became proficiency in the methods of retrieving literature basically, they gradually concluded vaginal microbiome plays an important role in human health and species of vaginal bacteria have been associated with reproductive disease.

In this part, students obtained "hard skills (HS)" of literature reference methods and "soft skill (SS)" of self-study and efficacy ability, as well as became familiar with the scientific practice of developing hypotheses: Vaginal microbial communities exist in a state of dynamic equilibrium and that homeostatic mechanisms exist to provide resilience. Lactobacilli are among the most dominant populations in the vaginal system (27) and provide protection against opportunistic and pathogenic bacteria. Lactobacillus species depletion associates with the increased risk of bacterial and HPV infection (28) as well as miscarriage (29), preterm birth (30).

Next both students and instructors attended online Tencent video conferencing for communication, discussions or debates, and summarizing 2 h each week. S1, S5 from G1 and S3, S8 from G2 reported literature summary by slide presentation, S2, S6 from G1 and S4, S7 from G2 proposed their experimental hypotheses and potential outcomes about research proposals. At the beginning, some students like S1, S3, S7 lack the confidence to contact research professors to ask about questions. The instructor C1 and C2 encouraged them to draft emails or communicate online thus helped them to overcome barrier of timid and shy. During lab meeting, instructors proposed guiding research question to determine evidence in achieving pedagogical goals like: Which scientific results are we aiming for? Which skills and competencies should students be able to demonstrate? After about 2 weeks, nearly all the students felt adeptly and became more confident to discuss and form their own scientific hypotheses as well as display their research plan designing. On the other hand, students from different grades help and gradually get acquainted with each other and accumulated friendship. Both groups of students

TABLE 2 | List of main associated literature in planning phase students prepared of Vaginal Microbiome.

Topic:	Key	References
The Structure and diversity of strain-level variation	Species-level diversity of vaginal microbiome communities change with respect to the reproductive stages of a woman. Vaginal microbial communities will differ in terms of number and strength of interspecies interactions, in turn have implications for the relative resistance and resilience of each community type to disturbances.	Eppinger et al. (21)
In Various Urogenital Disorders	VMB can impact the pathogenesis of urinary tract infection (UTI).	Yildirim et al. (22)
In vaginal infections and inflammatory conditions	Interplay between the cervicovaginal microbiota and the cell of immune system is determinant to prevent infections by external pathogens and to maintain an immuno-tolerant environment. Common vaginal strains as *L. gasseri* and *L. crispatus* have been used in recurrent BV.	Torcia (23)
In Gynecologic Cancers.	The vaginal microbiome, in addition to its role in common conditions such as vaginitis and HPV infection, may also have an impact on the development or prevention of gynecological cancers.	Champer et al. (24)
During pregnancy	Preterm birth is associated with increased vaginal microbiome instability compared to term birth High-risk vaginal microbiota linked to PPROM are observed closer to the time of membrane rupture, dominance of the vaginal microbiota by non-Lactobacillus spp. at any gestational age increases risk.	Stout et al. (25) Bennett et al. (26)
Vaginal Microbiome Techniques	high-throughput 16S rRNA gene amplicon sequencing.	Ricci et al. (31)

learned about how to generate high-throughput 16S rRNA gene amplicon sequencing (31) as a suitable laboratory technology to detect vaginal microorganism species community distribution theoretically. The instructors in group 2 organized group talks and summarize conference abstracts, instructors in group 1 and experimental technician T1 and T2 especially pointed out key experimental steps, such as DNA extraction, filtering OTUs, detect PCR primers targeted the V3–V4 sequencing platform and highlighting study limitations. After discussion with instructors and within groups, students carefully organized the experimental steps again and form preliminary study protocols. The instructors C2 and experimental technician provided guidance for students to ensure that the experimental strategies were well-designed and that the protocols and methods were technically feasible. In this section, students' expression capability, academic communication with team-member and instructors were improved.

Finally, they decided to identify differential vaginal microorganism species between premenopausal and postmenopausal women using general bacterial culture techniques widely used in the clinic and 16S rRNA gene amplicon sequencing used in the laboratory. G1 and G2 students were in charge of listing step 1–5 and 6–10 of detailed experiments separately, ultimately both groups made the protocols flow chart associated with statistical analysis of 16S rRNA gene amplicon sequencing under the direction of their instructors. Instructors C1 and T2 modified flow chart order students designed (**Figure 3**).

Steps of Flow Chart for 16S rRNA Gene Amplicon Sequencing

1. Sequence reads: data preprocessing and removal of chimeras and non-specific amplified sequences;
2. Data processing and statistics: reads splicing, filter and dechimerization;
3. OUT cluster analysis: cluster, distribution Venn diagram, number and cluster similarity value graph;
4. Alpha diversity analysis: Diversity index analysis, sparsity curve, Rank-abundance curve, specaccum species accumulation curve;
5. Taxonomic analysis: taxonomy, community structure composition map, single-sample multi-level species composition map, taxonomic and phylogenetic information visualization, species abundance heatmap, species abundance 3D histogram, clustering dendrogram based on species abundance samples, combined analysis of sample clustering tree and histogram, community taxonomy dendrogram;
6. Flora difference analysis: analysis of differences in bacterial flora abundance between samples, ternary plot graph, LEfSe analysis, Anosim analysis, PERMANOVA analysis, ANOVA analysis;
7. Multidimensional analysis: Principal Component (PCA) analysis, non-metric multidimensional scaling (NMDS) analysis, correlation analysis of OTU, species and environmental factors, gradient direct analysis (RDA) / correspondence analysis (CCA) analysis, network graph analysis, analysis of the relationship between microorganisms;
8. Taxonomic tree analysis: phylogenetic tree;
9. Beta diversity analysis: UniFrac analysis, multi-sample similarity tree analysis based on UniFrac, UniFrac-based heatmap, PCoA analysis based on UniFrac, UniFrac distance box plot;
10. Functional predictive analysis: PICRUSt functional analysis, functional component diagram, cluster map of samples based on functional abundance, functional abundance heatmap, combined analysis of sample clustering tree and functional histogram, function-Based PCA Analysis, feature-based NMDS Analysis, function cumulative curve, functional abundance differential analysis (**Figure 3**).

CURE #II: Implementing phase;
Learning Goal:

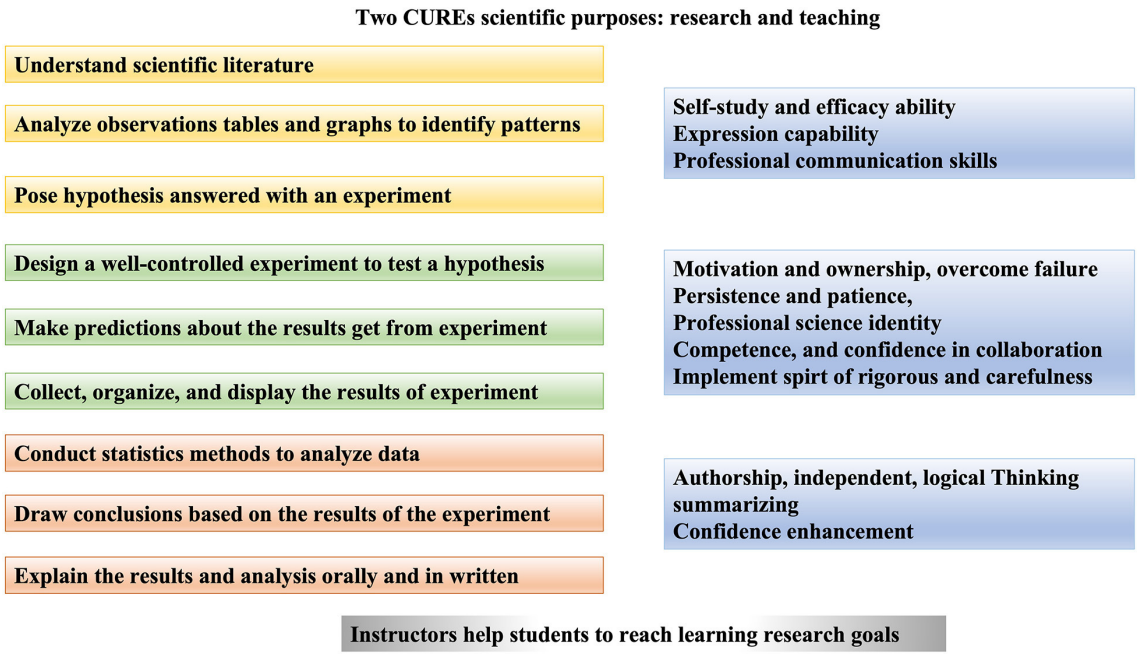

FIGURE 3 | Steps of flow chart for 16S rRNA gene amplicon sequencing.

Hard skills: Learn the foundational scientific research process and technique, conduct teamwork research under the direction of instructors.

Soft skills: Strengthen students' motivation and ownership in science research, overcome failure, benefit persistence and patience, build professional science identity, competence, and confidence in collaboration, implement spirit of rigorous and carefulness.

The implementation phase was carried out over Months 3–6, and students conducted lab projects under the guide of instructors on microbiological techniques. The workflow for microbiome projects involved students collecting vaginal discharge samples in the outpatient department and detecting the vaginal microorganism community using both general bacterial culture techniques (clinical) and 16S rRNA gene sequencing (laboratory), the latter including isolation of microorganism genomic DNA from vaginal discharge samples, PCR amplification using the Illumina MiSeq platform, identification of the relative abundance of microorganism taxa using OTU tables, and distinction of the bacterial diversity across different locations using bioinformatics analyses.

General Bacterial Culture Techniques

On the first month, students S1, S5 in G1 and S4, S8 in G2 collected vaginal discharge samples in the outpatient department to detect microorganism community distribution between premenopausal and postmenopausal women using general bacterial culture techniques by a laboratory physician and issued a report. Both group students were responsible for analyzing the results. A total of 597 women, including reproductive age women (n = 473, mean age 35 ± 7.07) and postmenopausal women (n = 124, mean age 35 ± 7.07), were enrolled in the study, among whom 41 were pregnant women and 432 were non-pregnant women. Students gathered the result that among the 20 genera identified across all samples in this study, the 10 most abundant vaginal microorganism genera between the premenopausal and postmenopausal groups were *Lactobacillus*, 56.03% vs. 77.42% (265/473 vs. 69/124); *Candida albicans* and *Streptococcus agalactiae*, 19.03% vs. 4.03% (90/473 vs. 5/124); no bacterial growth, 7.61% vs. 9.67% (36/473 vs. 12/124); *Escherichia coli* and *coagulase-negative staphylococci*, 9.73% vs. 8.87% (46/473 vs. 11/124); *Staphylococcus epidermidis*, 2.11% vs. 1.61% (10/473 vs. 2/124); *Enterococcus faecalis*, 1.90% vs. 2.42% (9/473 vs. 3/124); and other: *Proteus*, Gram-positive bacilli, *Staphylococcus aureus, hemolytic staphylococci*, *Klebsiella pneumoniae, Candida glabrata, Neisseria yellow, Neisseria gray, coagulase-negative bacillus, Streptococcus dysgalactiae,* and *Staphylococcus aureus*, 1.48% vs. 0.81% (7/473 vs. 1/124).

Combined with the vaginal secretion triple test, students found that the decrease in the proportion of *lactobacilli* led to an increase in the proportion of opportunistic infections, indicating that *lactobacilli* inhibit vaginal inflammation. *Candida albicans,* as the dominant bacterial population, was related to a higher positive rate of leukocyte esterase ($P < 0.05$) (**Figure 4A**) and poorer cleanliness ($P < 0.05$) (**Figure 4B**). *Staphylococcus epidermidis,* the main bacterial population, was related to reduced hydrogen peroxide content ($P = 0.0039 < 0.05$) (**Figure 4C**), while higher sialidase content existed in the *Enterococcus faecalis* population ($P = 0.0006 < 0.05$) (**Figure 4D**). Women carrying *Lactobacillus* as the main bacterial population were less susceptible to certain pathogens, such as *Candida albicans* ($P < 0.05$) (**Figure 4E**). There was no significant

difference in *Lactobacillus*, which accounted for the dominant bacteria, between the premenopausal and postmenopausal groups ($P = 0.9589 > 0.05$) (**Figure 4F**). There was also no significant difference in *Lactobacillus* as the dominant bacteria distributed during different menstrual cycles: the follicular phase accounted for 60% (36/60) and the luteal phase accounted for 51.10% (45/88) ($P = 0.2875 > 0.05$) (**Figure 4G**). Among them, Lactobacillus dominated 65.9% (27/41) of the pregnant women and 55.22% (307/556) of the non-pregnant people ($P = 0.1855 > 0.05$) (**Figure 4H**) (**Supplementary Table 1**). In this section, students self-mastered statistical methods of Chi-square test with two-sides and analysis the experimental data, they also learned about other statistical methods to lay the foundation for subsequent 16S experimental analysis. Instructors C1, C2, and C3 participated in verifying data.

Identification of the Microorganism Species Community in Vaginal Discharge Using 16S rRNA Sequencing

Once students completed collecting a total of 30 vaginal discharge sample, they started to perform 16S rRNA sequencing analysis to evaluate the microbial community abundance and diversity since the second month of CURE 2#. Vaginal microbes were clustered by menopausal state, indicated as the premenopausal group, postmenopausal group, and both the premenopausal and postmenopausal groups. G1 and G2 students were in charge of conducting flow chart step 1–5 and 6–10 separately mainly under the direction of experimental technician T1, T2 and microbiologist in Shanghai Jiao Tong University School of Medicine. When G1 students encountered problems during the experiment, they discussed with students in the other group, and students in G2 assisted in reviewing literature again to find a solution and consulting experts, and vice versa. This ensures both groups of students can grasp all steps of the experiment and obtain effective allocation time.

Students in G1 used QIIME (Quantitative Insights Into Microbial Ecology, version 1.8.0) (32) to test Sequence read processing. A two-step 16S rRNA gene PCR amplicon approach was used to construct paired-end Illumina sequencing libraries (33). They followed the steps of the above flow chat to start the research under the guidance of the instructors. The raw image data files were transformed to the original sequencing sequence by Illumina MiSeq^{TM} (Phred quality score, Q_{phred}) and CASAVA base calling analysis (Sequenced Reads), and chimeras and non-specific amplified sequences were removed. Genomic DNA was measured using the Qubit 2.0 DNA Assay Kit with 10 ng per sample and a final sequencing concentration of 20 pmol for PCR. They observed a total of 2,212,345 raw sequences were produced from the varieties collected from the secretion of female vaginas. After trimming, quality filtering and chimera removal, a total of 2,099,122 sequences were maintained, with an average length of 423.72 bp (**Supplementary Figure 1A**) (**Supplementary Table 2**). Although steps 1 and 2 sequence reads, data processing and statistics were relatively progressing smoothly, students realized the latter steps were more complicated than expected and failed to display OUT cluster analysis with distribution Venn diagram and process alpha diversity or taxonomic analysis at the beginning. Students in G2 referenced the literature again to seek the reason and contact the microbiologist. Instructor C3 pointed out the 16S rRNA gene PCR amplicon approach greatly rely on the software database, after the students updated the version of NCBI Blast and R package, they could successfully progress the experiment. In this section, students' motivation and ownership in science research were greatly improved. Students also realized scientific research requires many repetitions to be succeed, they should be coped frustration with persistence and patience. Instructors helped them to buffer the difficult in actual research and reduce microbiology technological barriers in experiment.

Microbial Relationship Shared Multidimensional Analysis Based on OTU Cluster Analysis and Species Classification

To classify the community distribution, species diversity, richness of the strains and the genus sequences, it was necessary for the students to analyze the sequences of row clustering, which were divided into shared multidimensional analysis based on OTU cluster analysis species classification according to the similarity between sequences. Students in G1 tested their hypotheses that only OTUs with a relative abundance of at least 10^{-6} were maintained. Then student teams used BLAST to compare the operational taxonomic unit (OTU) sequence defined at 97% similarity and coverage to the corresponding database. The Ribosomal Database Project (RDP) was used for OTU taxonomic classification clusters of organisms with a confidence cutoff of 0.5 (34), which were grouped by DNA sequence similarity of a specific 16S rRNA taxonomic marker gene (33). RDP Naive Bayesian Classifier v.2.2 (35) filtered out the best alignment results of the OTU sequence by comparison (http://rdp.cme.msu.edu/misc/resources.jsp), while bacterial taxa with a relative abundance <1% were excluded.

Students concluded a total of 2,027,293 high-quality reads were clustered into 2,060 OTUs with 97% cutoff sequence similarity. Species with an abundance >1% or OTU information in the top 100 for bilateral testing were analyzed. Classification analysis of specific OTUs was ranked by mean decrease accuracy, and correlation analysis identified significant correlations, strong correlations, positive correlations, and negative correlations among microbial communities. Students observed differences in the bacterial communities in vaginal discharge between the premenopausal and postmenopausal groups and then selected the most abundant representative sequence under the guidance of their tutors. Both groups of students manufactured Wayne map in different colors together and considered the following diversity metrics by Mann-Whitney U test and Benjamini-Hochberg false discovery rate correction: overall counts of individual microbial OTU richness, effective counts of common and dominant OTUs, taxonomic composition, and relative abundances of classification (**Supplementary Figures 1B,C**)

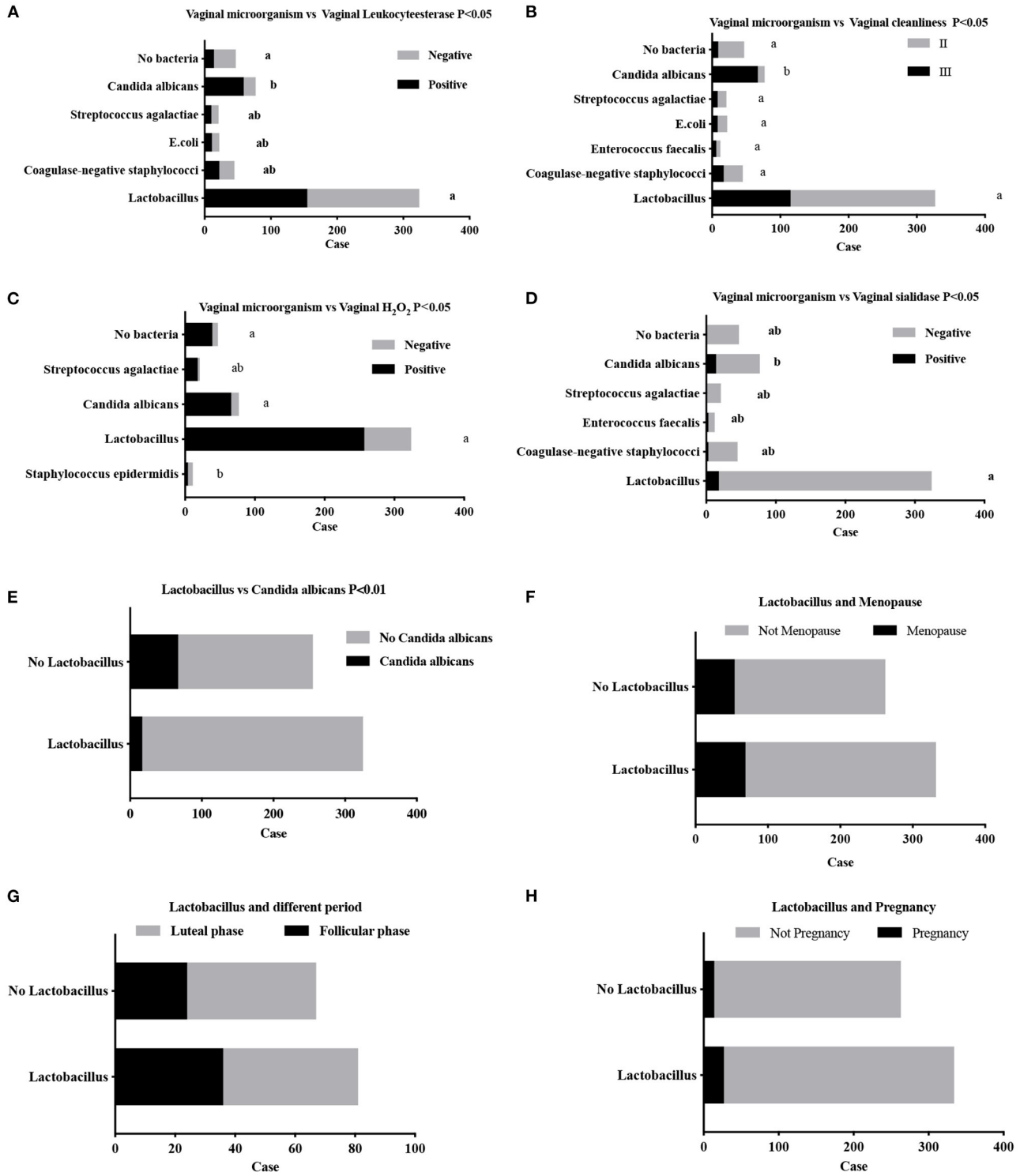

FIGURE 4 | Distribution of vaginal microorganisms in premenopausal and postmenopausal women using general bacterial culture techniques. **(A,B)** Vaginal secretion triple test: *Candida albicans,* the dominant bacterial population related to a higher positive rate of leukocyte esterase **(A)** and poorer cleanliness **(B)**. *Staphylococcus epidermidis, the* main bacterial population, was related to decreased hydrogen peroxide content **(C)**, a higher sialidase content existed in the *Enterococcus faecalis* population **(D)**. Women carrying *Lactobacillus* as the primary bacterial population were less susceptible to certain pathogens, such as *Candida albicans* **(E)**. There was no significant difference in *lactobacillus* as the dominant bacteria between the premenopausal and postmenopausal groups **(F)**. There was also no significant difference in *Lactobacillus,* as the dominant bacteria, distribution in different phases of the menstrual cycle **(G)**. Among them, Lactobacillus dominated 65.9% (27/41) in pregnant women and 55.22% (307/556) of non-pregnant women **(H)**.

(**Supplementary Table 3**). Students in G1 felt their professional science identity, competence, and confidence were promoted through collaboration with team members during the experimental process.

Composition and Differences in Vaginal Microbial Diversity

In order to identify the similarities and differences in the vaginal microbial abundance matrix revealed bacterial community diversity between premenopausal and postmenopausal groups, G2 students continue to construct PCoA based on the weighted UniFrac distance, and take the total variance of the principal components >80% as well as the covariance matrix diagonal value 1 as standard. On the routine lab meeting, G2 students reported there was no differences in the vaginal microbial abundance between the premenopausal and postmenopausal groups, which was inconsistent with literature reports. The instructors in G1 suggested to repeat step 7–9 multidimensional and beta diversity analysis again. They operated analysis again and identified student S4 input the error data. After correcting the data, G1 students concluded differences between the premenopausal and postmenopausal groups were statistically significant (**Supplementary Figure 1D**: eigenvalues = 1.96, var explained = 48%). The degree of similarity and relationship between the samples were imported through the distance heat map by the students and tutors (**Supplementary Figure 1E**). From the innermost circle to the outer circle, the composition of species was observed at the level of domain, phylum, gang, class, order, family, and genus. A single sample multilevel species composition was visually revealed from the inside out through a plurality of concentric circles at the taxonomic level (**Supplementary Figure 1F**) (**Supplementary Table 4**). Students summarized the spirit of rigorous and carefulness should be implemented throughout each procedure of the scientific research. Instructors encourage students not to get discouraged when they encounter setbacks

CURE #III: Summarizing phase;

Learning Goal:

Hard skills: Research summaries, including data interpretation, statistical and graphical inference and collaborative writing research report.

Soft skills: Obtain authorship, independent and logical thinking capability, summarizing ability, confidence enhancement.

In the summarizing phase, the students assembled their data into figures and tables, conducted bioinformatics analyses, summarized the research question, findings and results, and finally made conclusions in an original research manuscript. They need to learn SPSS and Prism as statistical and graphing software. G1 students were responsible for taxonomy and OUT analysis, while G2 students were in charge of orthologous group (COG)-based functional structure distribution and species classification. Student described their research question, proposed ideas, analyze practice data as pre-lab assignments, interpret and compare results and tried to write report papers. The instructors provided guidance, especially with thorough data analysis, achieved well-supported conclusions, drawing standard and accurate figure to enable students to facilitate the drafting process.

Community Taxonomy System at the Genus Level

Students were glad to realize that their experiment was supported by the literature, they revealed the taxonomic level for each single OTU displayed genus was calculated by the sequence probability value assigned at different levels within the V3–V4 region. V3 region amplicons of the 16S rRNA gene were analyzed on a high-throughput sequencing platform. They classified dominant species corresponding to each OTU dependent on Bergey's taxonomy using the RDP database (http://rdp.cme.msu.edu/misc/resources.jsp) (36). Similarity searches using the evolutionary relationships and abundance differences of dominant microorganisms in the sequenced samples were obtained from the entire classification system. The instructors told the students that the category name and its corresponding average abundance value were near the fulcrum, further, the microorganisms and their sequence numbers were known according to the similarity of the taxonomic composition analysis, including their relative abundance. According to the results of the taxonomy comparison of each sample, the students could visually determine the dominant flora community in the late proliferative and secretory phases of the menstrual cycle was Lactobacillus; instead of Lactobacillus, the bacteria/Shigella, Gardnerella, and Streptococcus were dominant bacteria in the postmenopausal group, analyzed by LEfSe, Anosim, PERMANOVA, and ANOVA (**Figure 5A**).

Clusters of Orthologous Group (COG)-Based Functional Structure Distribution Histogram

Next, S3 and S7 students in G2 concluded differences in abundance functional prediction between the premenopausal and postmenopausal groups through the clustered heat map. They found the more similar the distance of the sample flora, the closer their position in the cluster tree above the figure. Intuitively, the functional abundance values were represented by defined shades of color, and sample function information was clustered and rearranged. They characterized differences in functional prediction between the premenopausal and postmenopausal groups included intracellular trafficking, secretion, and vesicular transport ($P = 0.0272 < 0.05$); posttranslational modification, protein turnover, and chaperones ($P = 0.0353 > 0.05$); RNA processing and modification ($P = 0.0381 < 0.05$); inorganic ion transport and metabolism ($P = 0.0442 < 0.05$); and secondary metabolite biosynthesis, transport, and catabolism ($P = 0.0468 < 0.05$) (**Figure 5B**). The frequency of genera is displayed by a distribution bar plot graph (**Figure 5C**) mainly drawn by S7 with the guidance by instructors C3 (**Supplementary Table 5**).

Species Classification and Analysis of Colony Differences at the Genus Level

Ultimately, S4 and S8 students imported AUC analysis to assess the accuracy of the classification models to identify

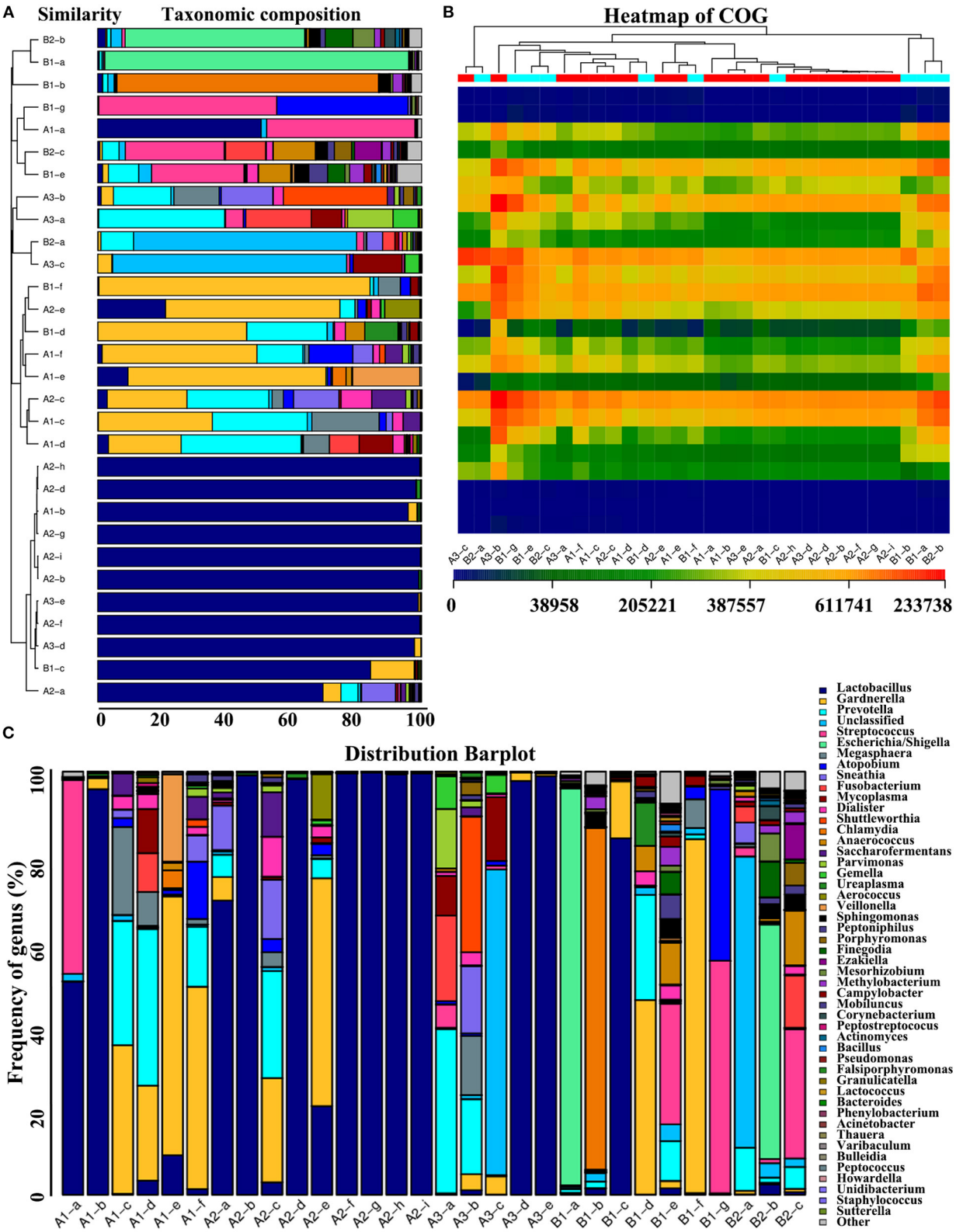

FIGURE 5 | Community taxonomy system at the genus level and COG-based functional structure distribution. **(A)** Taxonomic composition distribution graph showing the relative sample microorganism classification abundance. The horizontal or vertical axis is the sample number or relative abundance ratio. The width of different colors indicates the relative abundance ratio of different species at the taxonomic level. Left panel: Bray-Curtis-based sample clustering tree diagram; middle panel

(Continued)

FIGURE 5 | part: Histogram of species abundance of clustering order; right panel: Illustration of the species. **(B)** A functional abundance heat map based on COG was drawn using the functional abundance matrix. Each column represents a sample, the row represents the function, and the color block represents the functional abundance value. The redder the color is, the higher the abundance, and the more blue the color is, and the lower the distance. Samples from the same group have the same color. Sample distance is represented by the length of the branches. The more similar the samples are, the closer the branches of the same color in the figure are from the same group. (A) RNA processing and modification; (B) Chromatin structure and dynamics; (C) Energy production and conversion; (D) Cell cycle control, cell division, chromosome partitioning; (E) Amino acid transport and metabolism; (F) Nucleotide transport and metabolism; (G) Carbohydrate transport and metabolism; (H) Coenzyme transport and metabolism; (I) Lipid transport and metabolism; (J) Translation, ribosomal structure and biogenesis; (K) Translation, ribosomal structure and biogenesis; (L) Transcription; (M) Replication, recombination and repair; (N) Cell wall/membrane/envelope biogenesis; (O) Cell motility; (P) Post-translational modification, protein turnover, and chaperones; (Q) Secondary metabolites biosynthesis, transport, and catabolism; (R) General function prediction only; (S) Function unknown; (T) Signal transduction mechanisms; (U) Intracellular trafficking, secretion, and vesicular transport; (V) Defense mechanisms; (W) Extracellular structures; (Y) Nuclear structure; (Z) Cytoskeleton; **(C)** Distribution bar plot.

differences in microorganism diversity between premenopausal and postmenopausal group varieties in female vaginal discharge. They drawn a visual circle diagram in a colored pie chart which depicted the correspondence between samples and species reflected the proportion of dominant species and the distribution of dominant species among different samples. Different colors represent different samples, and the larger the fan area of the color is, the higher the abundance of the sample on the branch. The category name and its corresponding average abundance value are near the fulcrum. Sample clustering tree and histogram combination showed the community structure of 30 samples displayed in distribution of the flora in different menstrual cycles and on postmenopausal samples.

At first, S4 and S8 students tried to draw the species abundance heat map using a species abundance matrix, however they faced barrier in adjusting proper color and chromaticity ladder, instructor C3 suggested applying contrasting colors to show statistical differences. They learned about the information that only the top 10 samples and most abundant species classifications are shown in the graph (**Figures 6A,B**). Thus, their made their conclusion: The dominant flora in the premenopausal group according to the menstrual cycle (the early and middle stages of proliferation, late proliferative phase and secretory phase) compared to the postmenopausal group included *Lactobacillus* ($P = 0.0045$), *Gardnerella* ($P = 0.8088$), *Prevotella* ($P = 0.2619$), *Streptococcus* ($P = 0.0076$), *Escherichia/Shigella* ($P = 0.0757$), *Megasphaera* ($P = 0.8423$), *Atopobium* ($P = 0.8772$), *Sneathia* ($P = 0.2233$), *Fusobacterium* ($P = 0.0521$), *Diallster* ($P = 0.3904$), *Saccharofermentans* ($P = 1$), *Veilbnella* ($P = 0.2429$), *Chlamydia* ($P = 0.1566$), and *Anaerococcus* ($P = 0.0273$) (**Supplementary Table 6**). Both the students and instructors demonstrated the dominant flora in vaginal secretions changed before and after menopause. Lactobacillus was the primary flora present before menopause. The decrease in lactobacilli postmenopause leads to opportunistic pathogens becoming the dominant bacteria. A heatmap of genera from a tree diagram clustered the samples; the more similar the sample flora, the closer the distribution of the cluster tree (**Figures 6C–E**). In this part, students obtained authorship, independent and logical thinking capability.

Research Report Written by Students

Each student submitted a research summary report so that they could achieve summarizing ability and confidence enhancement. Below was a comprehensive summary report written by student S7:

Lactobacillus species including *L. crispatus*, *L. gasseri*, *L. jensenii*, and *L. iners,* dominated the primary vaginal microbiota have been associated with reproductive disease (15). 16S rRNA sequencing is a method widely applied for microbiology detection in the laboratory, while general bacterial culture is commonly implemented in clinical use (31, 37). Depending on iteration, revising and repeating experiments and troubleshooting problems to address challenges and enhance confidence, 16S rRNA sourced from a 1,500 bp gene existed in bacteria and composited with nine highly variable and species-specific regions (V1–V9) of the genome (31). Lactobacillus was the primary flora before menopause. Loss of Lactobacillus dominance promotes the colonization by anaerobic bacterial species with an increase in microbial diversity (15). The decrease in lactobacilli postmenopause leads to opportunistic pathogens, such as *Gardnerella*, *Prevotella*, *Streptococcus*, *Escherichia/Shigella* becoming the dominant bacteria.

Refer to 16S rRNA sequencing, comprehend OTU-based sample clustering tree diagram Wayne graph, PCoA graph, sample distance heat map representing multidimensional and species classification tree analysis. Taxonomic composition distribution graphs, distribution bar plots, COG functional abundance heat maps, and the dominant flora and heatmaps of genus form tree diagrams shown differences in microorganism diversity between premenopausal and postmenopausal women. In conclusion, maintain a stable vaginal microbiome becomes crucial for the health of a reproductive age woman (38). Lactobacillus species depletion and increased microbial diversity are characteristic of bacterial vaginosis (BV).

CURE #IV: Feedback phase;

Survey detailing both the instructors' and students' self-evaluation pinions in the research, as well as project evaluation, analysis, ethical consideration.

Learning Goal: Benefits and effect of CUREs for both students and instructors.

In the feedback phase, students self-reported their learning gains relative to the course elements and benefits. Students and instructors were anonymously surveyed on the effectiveness of the project and provided systematic reflection online. Recruitments were gathered by Wen Juan Xing (https://www.wjx.cn) and conducted by online analysis. Students' improvement in scientific literacy with "hard and soft" skills were evaluated with scores marked themselves covering aspect of skills in science

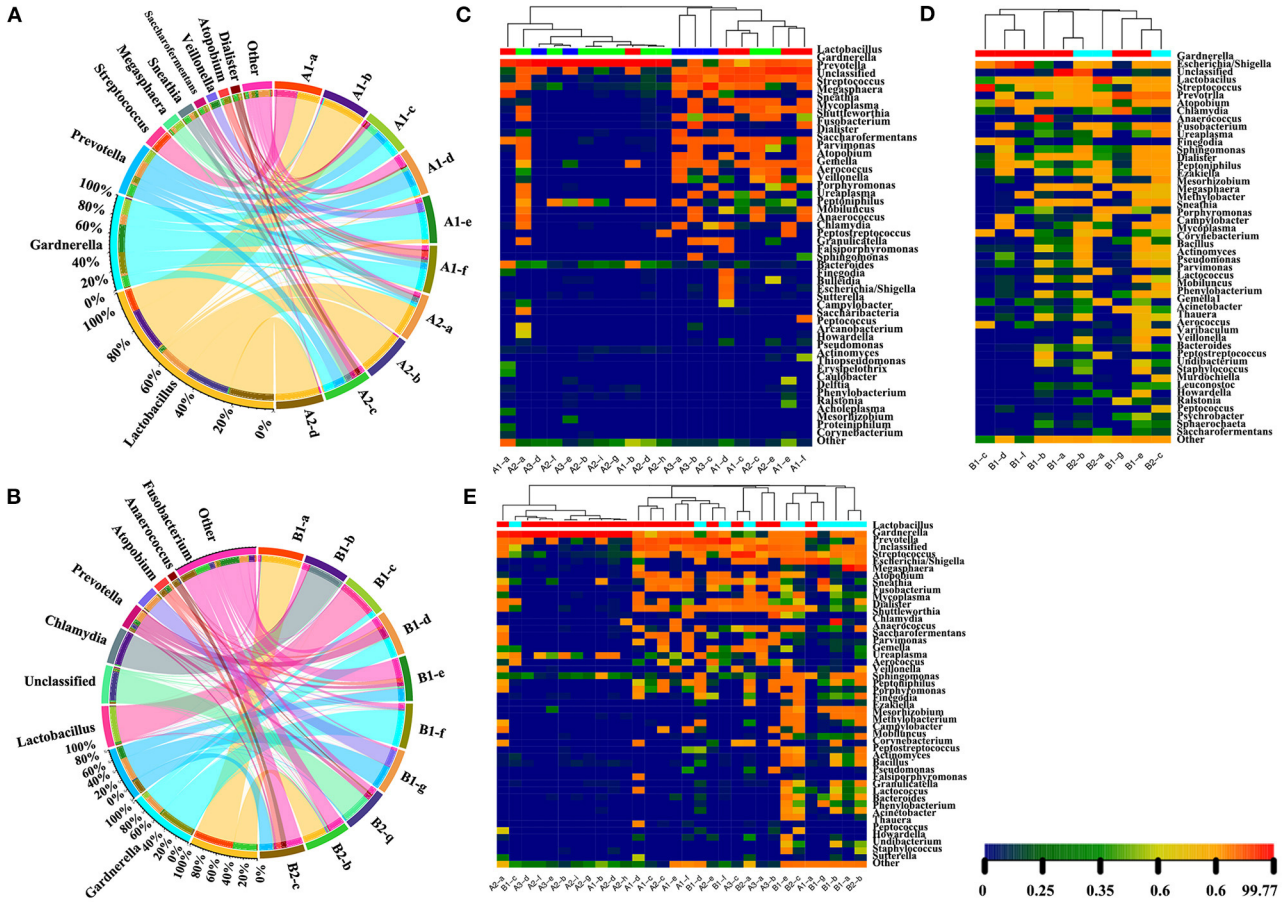

FIGURE 6 | The dominant flora and heatmap of genera from the tree diagram. The dominant flora in premenopausal **(A)** and postmenopausal **(B)** groups. The difference in abundance in samples on a branch is compared using a colored pie chart. Different colors represent different samples, and the larger the fan area of the color, the higher the abundance of the sample on the branch. The semicircle on the right indicates the species abundance composition of the sample, while the left semicircle indicates the proportion of different samples in the dominant species. The length and width represent the abundance and distribution ratio of species in the sample. Heat map of the top 50 species classifications at the genus-level species abundance matrix from a tree diagram. The distribution of flora in different phases of the menstrual cycle and postmenopausal women is shown in premenopausal women **(C)**, postmenopausal **(D)** and both **(E)** groups. The same sample group has the same color. Each column in the figure represents a sample, and the row represents the community structure. The color blocks represent relative species abundance values. The redder the color, the higher the relative abundance, while the bluer the color, the lower the relative abundance. The color shade reflects the abundance of the community distribution, and clustering reflects community similarities and different distributions at each classification level.

research: literature reading, objectivity, reporting, research design, technical conduction, data statistics; as well as spirit of ownership, authorship, motivation, collaboration, which can be found in **Table 3**. We also adopted assignments displayed by focus question, concluded comprehensive queries with the students and instructors' answers instrument for program evaluation, analysis, ethical consideration. We hypothesized that systematic reflections by students and instructors over CUREs courses would be valuable tools to measure positive effects on student confidence, great effects and teamwork spirits in scientific research (**Table 3**).

Focus question #I: What are the approaches used for microbiological CUREs?

Our students-driven course-based undergraduate research experience (CUREs) model based on original microbiology research. In planning phase, individual students gain the ability of utilizing primary literature by using precise keywords to search related literature on pubmed, learn research methods through previous research, summarizing the theme and result of the complicated literature. The implementation phase, students conducted real lab projects under the guide of instructors on microbiological techniques. In summarizing phase students learn how to seek novel discoveries, collect, analysis and statistics data, they all grasped the operation methods of SPSS version 25.0 and Prism 8.0 and improved statistical and computational proficiency. Finally two group of students cooperated to write the scientific lab reports, which provides the capability for students to develop their ideas, obtain the content necessary to conduct their own research project and present primary data.

TABLE 3 | Evaluation by students and instructors over CUREs project.

	Group 1					Group 2				
	Undergraduate students				Instructors	Undergraduate students				Instructors
Target	**S1**	**S2**	**S5**	**S6**	**C1, C2, T1**	**S3**	**S4**	**S7**	**S8**	**C3, T2**
CURE#1										
HS	Reference review	Reference review	Reference review	Reference review	Teach reviewing skills	Reference review	Reference review	Reference review	Reference review	Teach reviewing skills
E	2	2	3	2		3	1	3	3	
SS	Self-study and efficacy									
E	2	2	3	2		3	2	3	3	
HS	Report literature summary	Proposed experimental hypotheses	Report literature summary	Proposed experimental hypotheses	Ensure experimental strategies technically feasible	Report literature summary	Proposed experimental hypotheses	Proposed experimental hypotheses	Report literature summary	Organize and summarize conference
E	3	3	2	2		2	3	2	3	
SS	Expression capability, and professional research communication skills									
E	3	3	2	3		3	3	2	3	
HS	Design Flow chart step 1–5	Design Flow chart step 1–5	Design Flow chart step 1–5	Design Flow chart step 1–5	Modify flow chart	Design Flow chart step 1–5	Design Flow chart step 6–10	Design Flow chart step 6–10	Design Flow chart step 6–10	Modify flow chart
E	2	3	2	3		3	2	3	2	
CURE#2										
HS	Collect sample, Analysis results	Analysis results	Collect sample, Analysis results	Analysis results	Verify data	Analysis results	Collect sample, Analysis results	Analysis results	Collect sample, Analysis results	Verify data
E	3	3	3	3		2	3	3	3	
HS	Flow chart step 1–5; Reference, find solution	Flow chart step 1–5; Reference, find solution	Flow chart step 1–5; Reference, find solution	Flow chart step 1–5; Reference, find solution	Direct experiment step by step, reduce technological barriers	Reference, find solution; Flow chart step 6–10	Reference, find solution; Flow chart step 6–10	Reference, find solution; Flow chart step 6–10	Reference, find solution; Flow chart step 6–10	Direct experiment step by step reduce technological barriers
E	2	1	2	2		2	3	2	2	
SS	Motivation and ownership									
E	3	2	3	3		3	3	2	3	
SS	Overcome failure, benefit persistence and patience									
E	3	3	3	2		3	3	3	2	
SS	Professional science identity, competence, and confidence in collaboration									
E	3	2	3	3		2	3	3	3	
SS	Spirit of rigorous and carefulness									
E	3	3	3	3		3	2	3	3	

(Continued)

TABLE 3 | Continued

	Group 1					Group 2				
	Undergraduate students				Instructors	Undergraduate students				Instructors
Target	**S1**	**S2**	**S5**	**S6**	**C1, C2, T1**	**S3**	**S4**	**S7**	**S8**	**C3, T2**
CURE#3										
HS	Taxonomy and OUT analysis	Taxonomy and OUT analysis	Taxonomy and OUT analysis	Taxonomy and OUT analysis	Guidance on data analysis and statistical figure	COG functional distribution and species classification	COG functional distribution and species classification	COG functional distribution and species classification	COG functional distribution and species classification	Guidance on data analysis and statistical figure
E	2	1	2	2		1	2	2	3	
HS	Statistical analysis with SPSS and Prism	Statistical analysis with SPSS and Prism	Statistical analysis with SPSS and Prism	Statistical analysis with SPSS and Prism	Encourage drafting emails	Statistical analysis with SPSS and Prism	Statistical analysis with SPSS and Prism	Statistical analysis with SPSS and Prism	Statistical analysis with SPSS and Prism	Help them overcome barrier of shy
E	2	3	3	2		3	3	2	3	
SS	Obtain authorship, independent and logical thinking capability									
HS	Write search reports	Write search reports	Write search reports	Write search reports		Write search reports	Write search reports	Write search reports	Write search reports	
E	2	3	3	2		3	3	2	2	
SS	Achieve summarizing ability and confidence enhancement									
E	2	3	3	3		3	3	2	3	

HS, hard skills.
SS, soft skills.
E, evaluation, marked with self-evaluation score: Greatly improved: 3; Better improved: 2; General improved: 1; No improve: 0.

Focus question #II: What are the valuable skills and benefits for students by CUREs? And how did students evaluate their scientific literacy skills in the CUREs?

Students' improvement in scientific literacy skills were evaluated with scores marked themselves shown in **Table 3**. Regarding the scientific knowledge and technology students obtain. The CUREs increased students' scientific discoveries and content knowledge of microorganism species community in female vaginal fluids through understanding and generating primary scientific literature, 4 students felt greatly improved in the ability of reviewing reference and achieved self-study and efficacy spirit. Student S1, S2, S4, and S8 greatly improved their communication and collaboration skills through reporting and proposing hypotheses on lab conference with team members after the instructors help them to overcome barrier of timid and shy. Students team felt confidence in completing the team work project and this activity strengthened their understanding of the distribution of microorganism species communities. S2, S4 and S6 students especially felt their logical thinking and summarize skills have been enhanced by making protocol flow chart.

In addition, students experienced the messiness and failures of research and iterate their work through replication experiments to get success, like updating the version of database and correcting the error data. Students S1, S2, S3, S4, S5, and S6 feedback greatly progressed in overcoming failure and benefiting persistence and patience. Most of the students achieved motivation, ownership, professional science identity confidence and carefulness a lot. S1, S5, and S6 feedback that they had the opportunity to import the OUT sequences and metadata into different Figure Trees for the first time, which increased their analytical skills and enhanced science identity. S4, S7, and S8 students not only generated raw sequencing data, the weighted UniFrac distance PCoA, but also clustered OTU-based Wayne tree diagram and correlation matrix, sample distance clustering tree heat map on UniFrac, Taxonomic composition COG-based functional structure distribution graph, and the dominant genera heatmap. However, S2 and S3 students still felt different in grasping the methods of making the statistical graph. S2 and S6 felt more familiar with Chi-square test, the Mann-Whitney U test and Benjamini-Hochberg false discovery rate correction; S3 and S4 spent 1 week to grasp Hierarchical clustering and Wilcoxon tests method. S7 and S8 were mostly interested in LEfSe, Anosim, PERMANOVA, and ANOVA analysis to compare differences in bacterial flora abundance between samples. Student S7 felt greatly proud and excited since it was his first time to draw functional structure distribution heatmap successfully. Student S4 and S8 get success in making species abundance heat map after adjusting contrasting colors to show statistical differences. Most students rewarded the spirit of authorship, independent and logical thinking capability.

Focus question #IV: What is the instructors' role in the CUREs?

Instructors proposed guiding research question for the CUREs and determine evidence in achieving pedagogical goals. They acted as tutors to encourage student in discussion and motivated students to conduct microbiology laboratory techniques. They provided clear and comprehensive explanations when the students faced obstacles. For example, they taught students how to use PubMed to reference the primary literature, while before that, students had no experience in using reference tools on web. After students submitted the research abstract, instructors evaluate feasibility and help them to refine their experimental approach, keeping research questions a constant theme, discussing primary literature, evaluating early drafts of research questions and abstracts, and meeting with groups and ensure students would not get lost in designing their experiments. They helped student to gain skills for further education and eventual employment, provided clear and comprehensive explain. They instructed students to draw statistical figure trees with SPSS version 25.0 and Prism 8.0. Under the guidance of the instructors, students obtained positive interaction with peers and greatly felt their science identity development was improved.

DISCUSSION

CUREs offer research laboratory experiences to undergraduates, allowing individual students use scientific practices in a laboratory to relevant research questions, design studies, collect and analyze data on their own concern aspect (39). Multiple studies have reported the benefits of undergraduate participation in CUREs (2) including pursuing novel research questions with broad relevance and finding research opportunities (40), designing a self-directed approach to conduct experiments (18), improving scientific technical skills and persistence in science, and competitive internships, collaborating with instructors and team members (41).

Science-based CURE projects are a beneficial intervention to enable students to engage in a self-directed scientific approach and to set goals for discovery milestones (42) for research with unknown experimental outcomes (1). Currently, CURE courses cover the life science disciplines of molecular biosciences (43), biochemistry, recombinant DNA technology (44), protein expression and purification (45), molecular cell biology (46), microbiology, and genomics bioinformatics (47). Furthermore, microbiome studies are novel CURE topics integrating molecular biology (48), microbiology and phylogeny techniques (49), such as participating in answering family microbiome research questions (50), the Bean Beetle Microbiome CURE (51), students and general public volunteers mapping the gut (52), belly button (9) and oral microbiomes (53), and a CURE describing a fruit fly microbiome to assess influencing factors on the growth of Lactobacillus (54).

Our CUREs project served two scientific purposes: research and teaching. Undergraduate students were equipped with "hard skills" enabled them to create their own research proposals and hypotheses on vaginal microorganism species, conduct experiments and drive novel research, perform well relationships with team member and instructors, gain ownership of the statistical data and graph, summarize their results (55). By

referencing the literature, students developed hypotheses and learned about how to discovery approaches to address questions, they seek suitable technology to detect vaginal microorganism species community between premenopausal and postmenopausal women. Then students collaborated and worked in a group to solve a problem: the dominant flora of vaginal secretions changed before and after menopause. Finally, they conducted gathering, analyzing, and interpreting data and communicating the results to solve unknown questions in the scientific community. Students also learned about different statistical methods and charts to show differences in microorganism diversity between premenopausal and postmenopausal women. Students made self-test scientific literacy skills, they realized the spirit of rigorous, carefulness, failure overcoming, authorship, persistence and confidence should be implemented throughout each procedure of the scientific research. Most of the students exhibited increased interactive behaviors, such as posing questions and one-on-one talk to promote the active and research-driven nature of the course (56). Their "soft skills" such as communication skills, project management, and teamwork spirit within a lab group were also improved.

In the CURE project, instructors directed students to read the primary scientific literature regarding vaginal microbial diversity, drive the hypothesis of implementing general bacterial culture techniques and high-throughput 16S rRNA gene amplicon sequencing to identify vaginal microorganism species between premenopausal and postmenopausal groups, facilitate strategic decisions for significant lab protocol steps, handling lab supplies and equipment safely, and managing and analyzing data throughout the process (57). They acted as facilitators (58) to inspire and guide student initiative, science identity, and participation in laboratory experience. Students achieved successful and positive interaction with peers (59) according to the feedback inquiry.

Students in our biological CURE topics started from the beginning with developing a hypothesis, present primary literature, design research, collected specimens, conduct experiment, communicate with team members and instructors, analyze data, experience the messiness and failure of research, and finally producing research. Students eventually put the theoretical knowledge learned in statistical lesion into practice through this CURE, they improved statistical and computational proficiency, this greatly strengthened their computer technology which was essential in future scientific statistics. After these series of training, students not only experienced "hard skills" of scientific theoretical knowledge and technological practices, but also gain "soft skills" covering self-study, motivation, ownership, authorship, communication, overcoming setbacks, building persistence, identity, confidence in collaboration, rigorous and carefulness, independent, logical thinking, summarizing ability in science research. Students qualified with these technical abilities and spirits would better prepare them for future research and work. Possibly we would build an opportunity to share the experiences and advantage of this type of course at a professional conference, which might be implied on other development research practices.

CONCLUSIONS

Our microbiological CUREs issues made students to gain ownership of their research and data, which allowed them to be creative on what they were interested in, and offered them a more authentic research experience based on topics of their own interest and curiosity. Students acquired reading and scientific literature interpretation ability, designed scientific technical research, had the opportunity to do on the ground training, documenting observations, analyzing and interpreting data, and finally disseminating their research findings (60). Apart from the above promising advantages, obstacles still exist for CURE implementation with limited access to complex research methods for individual undergraduate students to conduct experiments. Since high-throughput 16S rRNA gene amplicon sequencing involved difficult steps including microorganism genomic DNA isolation, PCR primers design and amplification, OUT abundance identification, etc., which required technical staff with professional background. Students followed the complex produce with technicians together to operate certain experiments. Also, we conducted microorganism CUREs teaching project in a limited cohort of 8 students as a pilot. Further, it might be extended to a larger number of students in other development teaching course practices. We hope that experiences from our microorganism CUREs project may be helpful for other researchers to design educational CUREs projects.

DATA AVAILABILITY STATEMENT

The data presented in the study are deposited in the BioSample database repository, accession numberSUB11147188, BioProject ID: PRJNA826073. The project information will be accessible with the following link (http://www.ncbi.nlm.nih.gov/bioproject/826073), and submission (SUB11147188) has been released now on 2022- 04-15. BioSample accessions: SAMN27547963, SAMN27547964, SAMN27547965, SAMN27547966, SAMN27547967, SAMN27547968, Temporary SubmissionID: SUB11147188.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Shanghai General Hospital Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

YY and MW analyzed and interpreted the data regarding the CURE program. MW collected information and participated in teaching. YY, S-FW, WL, Y-YZ, and W-LS worked equally as major contributor in writing the manuscript. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

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Supplementary Figure 1 | Multidimensional and species classification tree analysis using 16S rRNA sequencing in premenopausal women, postmenopausal women, and both groups. **(A)** Raw sequencing data. **(B)** OTU-based sample clustering tree diagram by Wayne graph. Different samples (**A**- premenopausal group, **B**- postmenopausal group) are represented by different colors for specific or common OTUs. The ellipse size represents the absolute value of the correlation coefficient. The correlation of left or right oblique represents a positive or negative correlation, and the color changes with the right color scale. Only results with p-values <0.05 are shown in the figure. Correlations of OTU abundance with group, calculated using a two-sided t-test, are indicated as positive (blue, t statistic > 0 and p-value < 0.05), negative (red, t statistic < 0 and p-value < 0.05), and no correlation (gray, p-value > 0.05). **(C)** OTU-based correlation matrix. The corrplot package was used to draw the correlation matrix. The left or right oblique is positively or negatively correlated, and the color varies with the right gradation. Only the results with p-values <0.05 are shown in the figure. **(D)** PCoA represents the weighted UniFrac distance. **(E)** Sample distance heat map of the clustering tree based on UniFrac. The distance value is represented by the color block. The redder the color is, the closer the distance and the higher the similarity between the samples. The bluer the distance is, the further the distance. Error plot for comparison of differences. The left panel shows the abundance ratio of the different species classifications in the two groups, with the difference between the species abundance in the 95% confidence interval, and the right panel shows the p-value, $P < 0.05$. **(F)** Single sample multilevel species composition map. Circle size represents abundance. The outer ring is a heat map, and each ring represents a sample (group). Each sample corresponds to one color, and the depth of color changes with the abundance of the species.

Supplementary Table 1 | Abundant vaginal microorganism genera between the premenopausal and postmenopausal group.

Supplementary Table 2 | Vaginal microorganism raw sequences.

Supplementary Table 3 | Microbial relationship shared multi-dimensional analysis based on OTU cluster analysis and species classification.

Supplementary Table 4 | Composition and Differences of Vaginal Microbial Diversity.

Supplementary Table 5 | Clusters of Orthologous Groups (COG)-based functional structure distribution histogram.

Supplementary Table 6 | Species classification and analysis of colony differences at genus level.

REFERENCES

1. Heim AB, Holt EA. Benefits and challenges of instructing introductory biology Course-Based Undergraduate Research Experiences (CUREs) as perceived by graduate teaching assistants. *CBE Life Sci Educ.* (2019) 18:ar43. doi: 10.1187/cbe.18-09-0193
2. Auchincloss LC, Laursen SL, Branchaw JL, Eagan K, Dolan EL. Assessment of course-based undergraduate research experiences: a meeting report. *CBE Life Sci Educ.* (2014) 13:29–40. doi: 10.1187/cbe.14-01-0004
3. Olimpo J. Disease and the environment: a health disparities CURE incorporating civic engagement education. *Sci Educ Civic Engag.* (2019) 11:13–24. Available online at: https://www.researchgate.net/publication/332652829
4. Fey SB, Theus ME, Ramirez AR. Course-based undergraduate research experiences in a remote setting: two case studies documenting implementation and student perceptions. *Ecol Evol.* (2020) 10:12528–41. doi: 10.1002/ece3.6916
5. Corwin LA, Runyon CR, Eman G, Moriah S, Greg C, Palmer GC, et al. Effects of discovery, iteration, and collaboration in laboratory courses on undergraduates' research career intentions fully mediated by student ownership. *Cbe Life Sci Educ.* (2018) 17:ar20. doi: 10.1187/cbe.17-07-0141
6. Rodenbusch SE, Hernandez PR, Simmons SL, Dolan EL. Early engagement in course-based research increases graduation rates and completion of science, engineering, and mathematics degrees. *Cbe Life Sci Educ.* (2016) 15:ar20. doi: 10.1187/cbe.16-03-0117
7. Wang JTH. Course-based undergraduate research experiences in molecular biosciences-patterns, trends, and faculty support. *FEMS Microbiol Lett.* (2017) 364:fnx157. doi: 10.1093/femsle/fnx157
8. Oufiero CE. The organismal form and function lab-course: a new CURE for a lack of authentic research experiences in organismal biology. *Integr Org Biol.* (2019) 1:obz021. doi: 10.1093/iob/obz021
9. Mason CE, Garbarino J. The power of engaging citizen scientists for scientific progress. *J Microbiol Biol Educ.* (2016) 17:7–12. doi: 10.1128/jmbe.v17i1.1052
10. Diaz-Martinez LA, Hernandez AA, D'Arcy CE, Corral S, Bhatt JM, Esparza D, et al. Current approaches for integrating Responsible and Ethical Conduct of Research (RECR) education into course-based undergraduate research experiences: a national assessment. *CBE Life Sci Educ.* (2021) 20:ar38. doi: 10.1187/cbe.20-08-0179
11. Turnbaugh PJ, Ley RE, Hamady M, Fraser-Liggett CM, Knight R, Gordon JI. The human microbiome project. *Nature.* (2007) 449:804–10. doi: 10.1038/nature06244
12. Merkel S, Horak R, Chang A. The ASM curriculum guidelines for undergraduate microbiology: a case study of the advocacy role of societies in reform efforts. *J Microbiol Biol Educ.* (2015) 16:100–4. doi: 10.1128/jmbe.v16i1.915
13. De Seta F, Lonnee-Hoffmann R, Campisciano G, Comar M, Verstraelen H, Vieira-Baptista P, et al. The vaginal microbiome: III. The vaginal microbiome in various urogenital disorders. *J Low Genit Tract Dis.* (2022) 26:85–92. doi: 10.1097/LGT.0000000000000645
14. Ventolini G, Vieira-Baptista P, De Seta F, Verstraelen H, Lonnee-Hoffmann R, Lev-Sagie A. The vaginal microbiome: IV. The role of vaginal microbiome in reproduction and in gynecologic cancers. *J Low Genit Tract Dis.* (2022) 26:93–8. doi: 10.1097/LGT.0000000000000646
15. Tortelli BA, Lewis AL, Fay JC. The structure and diversity of strain-level variation in vaginal bacteria. *Microbial Genomics.* (2021) 7:mgen000543. doi: 10.1099/mgen.0.000543
16. Sirichoat A, Florez AB, Vazquez L, Buppasiri P, Panya M, Lulitanond V, et al. Antibiotic susceptibility profiles of lactic acid bacteria from the human vagina and genetic basis of acquired resistances. *Int J Mol Sci.* (2020) 21:2594. doi: 10.3390/ijms21072594
17. Baines K, Zarger RK. "It's Good to Learn about the Plants": promoting social justice and community health through the development of a Maya

environmental and cultural heritage curriculum in southern Belize. *J Environ Stud Sci*. (2017) 7:416–24. doi: 10.1007/s13412-016-0416-3
18. Cooper KM, Blattman JN, Hendrix T, Brownell SE. The impact of broadly relevant novel discoveries on student project ownership in a traditional lab course turned CURE. *CBE Life Sci Educ.* (2019) 18:ar57. doi: 10.1187/cbe.19-06-0113
19. Hurst-Kennedy J, Saum M, Achat-Mendes C, D'Costa A, Barrera A. The impact of a semester-long, cell culture and fluorescence microscopy CURE on learning and attitudes in an underrepresented STEM student population. *J Microbiol Biol Educ.* (2020) 21:25. doi: 10.1128/jmbe.v21i1.2001
20. Langille MGI, Zaneveld J, Caporaso JG, McDonald D, Knights D, Reyes JA, et al. Predictive functional profiling of microbial communities using 16S rRNA marker gene sequences. *Nat Biotechnol*. (2013) 31:814–21. doi: 10.1038/nbt.2676
21. Eppinger M, Mammel MK, Leclerc JE, Ravel J, Cebula TA. Genomic anatomy of *escherichia coli* o157:h7 outbreaks. In: *Proceedings of the National Academy of Sciences of the United States of America*. (2014). p. 2–7. doi: 10.1073/pnas.1107176108
22. Yildirim S, Shoskes D, Kulkarni S, Laguna P. Urinary microbiome in uncomplicated and interstitial cystitis: Is there any similarity? *World J Urol*. (2020) 38:2721–31. doi: 10.1007/s00345-020-03099-x
23. Torcia MG. interplay among vaginal microbiome, immune response and sexually transmitted viral infections. Int J Mol Sci. (2019) 20:266. doi: 10.3390/ijms20020266
24. Champer M, Wong AM, Champer J, Brito IL, Messer PW, Hou JY, et al. The role of the vaginal microbiome in gynaecological cancer. BJOG. (2018) 125:309-15. doi: 10.1111/1471-0528.14631
25. Stout MJ, Zhou Y, Wylie KM, Tarr PI, Macones GA, Tuuli MG. Early pregnancy vaginal microbiome trends and preterm birth. Am J Obstet Gynecol. (2017) 217:356.e1-e18. doi: 10.1016/j.ajog.2017.05.030
26. Bennett PR, Brown RG, MacIntyre DA. Vaginal microbiome in preterm rupture of membranes. Obstet Gynecol Clin North Am. (2020) 47:503-21. doi: 10.1016/j.ogc.2020.08.001
27. Matsumoto A, Yamagishi Y, Miyamoto K, Oka K, Takahashi M, Mikamo H. Characterization of the vaginal microbiota of Japanese women. *Anaerobe.* (2018) 54:172–7. doi: 10.1016/j.anaerobe.2018.10.001
28. Andrade Pessoa Morales J, Marconi C, El-Zein M, Ravel J, da Silva Pinto GV, Silveira R, et al. Vaginal microbiome components as correlates of cervical human papillomavirus infection. *J Infect Dis*. (2021) 10:1–14, jiab547. doi: 10.1093/infdis/jiab547
29. Shahid M, Quinlivan JA, Peek M, Castao-Rodríguez N, Mendz GL. Is there an association between the vaginal microbiome and first trimester miscarriage? A prospective observational study. *J Obstetr Gynaecol Res*. (2022) 48:119–28. doi: 10.1111/jog.15086
30. Pruski P, Correia G, Lewis HV, Capuccini K, Inglese P, Chan D, et al. Direct on-swab metabolic profiling of vaginal microbiome host interactions during pregnancy and preterm birth. *Nat Commun.* (2021) 12:5967. doi: 10.1038/s41467-021-26215-w
31. Ricci V, Carcione D, Messina S, Colombo GI, D'Alessandra Y. Circulating 16S RNA in biofluids: extracellular vesicles as mirrors of human microbiome? *Int J Mol Sci.* (2020) 21:1–14. doi: 10.3390/ijms21238959
32. Caporaso JG, Kuczynski J, Stombaugh J, Bittinger K, Bushman FD, Costello EK, et al. QIIME allows analysis of high-throughput community sequencing data. *Nat Methods.* (2010) 7:335–6. doi: 10.1038/nmeth.f.303
33. Preheim SP, Perrotta AR, Martin-Platero AM, Gupta A, Alm EJ. Distribution-based clustering: using ecology to refine the operational taxonomic unit. *Appl Environ Microbiol.* (2013) 79:6593–603. doi: 10.1128/AEM.00342-13
34. Wang Q, Garrity GM, Tiedje JM, Cole JR. Naive Bayesian classifier for rapid assignment of rRNA sequences into the new bacterial taxonomy. *Appl Environ Microbiol.* (2007) 73:5261–7. doi: 10.1128/AEM.00062-07
35. Claesson MJ, O'Sullivan O, Wang Q, Nikkila J, Marchesi JR. Comparative analysis of pyrosequencing and a phylogenetic microarray for exploring microbial community structures in the human distal intestine. *PloS ONE.* (2009) 4:e6669. doi: 10.1371/journal.pone.0006669
36. Nguyen NP, Warnow T, Pop M, White B. A perspective on 16S rRNA operational taxonomic unit clustering using sequence similarity. *Npj Biofilms Microbiomes.* (2016) 2:16004. doi: 10.1038/npjbiofilms.2016.4
37. Liang H, Cai R, Li C, Glendon OHM, Chengcheng H, Yan H. High-throughput sequencing of 16S rRNA gene analysis reveals novel taxonomic diversity among vaginal microbiota in healthy and affected sows with endometritis. *Res Vet Sci*. (2022) 143:33–40. doi: 10.1016/j.rvsc.2021.12.003
38. Deka N, Hassan S, Seghal Kiran G, Selvin J. Insights into the role of vaginal microbiome in women's health. *J Basic Microbiol.* (2021) 61:1071–84. doi: 10.1002/jobm.202100421
39. Corwin LA, Graham MJ, Dolan EL. Modeling course-based undergraduate research experiences: an agenda for future research and evaluation. *CBE Life Sci Educ.* (2015) 14:es1. doi: 10.1187/cbe.14-10-0167
40. Linn MC, Palmer E, Baranger A, Gerard E, Stone E. Undergraduate research experiences: impacts and opportunities. *Science.* (2015) 347:1261757. doi: 10.1126/science.1261757
41. Brownell SE, Hekmat-Scafe DS, Singla V, Chandler Seawell P, Conklin Imam JF, Eddy SL, et al. A high-enrollment course-based undergraduate research experience improves student conceptions of scientific thinking and ability to interpret data. *Cell Biol Educ.* (2015) 14:ar21. doi: 10.1187/cbe.14-05-0092
42. Cooper KM, Soneral PAG, Brownell SE. Define your goals before you design a CURE: A call to use backward design in planning course-based undergraduate research experiences. *J Microbiol Biol Educ.* (2017) 18:18.2.30. doi: 10.1128/jmbe.v18i2.1287
43. Sun E, Graves ML, Oliver DC. Propelling a course-based undergraduate research experience using an open-access online undergraduate research journal. *Front Microbiol.* (2020) 11:589025. doi: 10.3389/fmicb.2020.589025
44. Hargadon, Kristian M. A model system for the study of gene expression in the undergraduate laboratory. *Biochem Mol Biol Educ.* (2016) 44:397–404. doi: 10.1002/bmb.20958
45. Gray C, Price CW, Lee CT, Dewald AH, Cline MA, Mcanany CE, et al. Known structure, unknown function: an inquiry-based undergraduate biochemistry laboratory course. *Biochem Mol Biol Educ.* (2015) 43 :245–62. doi: 10.1002/bmb.20873
46. Byrd, Shere K. Apoptosis as the focus of an authentic research experience in a cell physiology laboratory. *Adv Physiol Educ.* (2016) 40:257–64. doi: 10.1152/advan.00176.2015
47. Brown, James AL. Evaluating the effectiveness of a practical inquiry-based learning bioinformatics module on undergraduate student engagement and applied skills. *Biochem Mol Biol Educ.* (2016) 44:304–13. doi: 10.1002/bmb.20954
48. Fuller KS, Torres Rivera C. A culturally responsive curricular revision to improve engagement and learning in an undergraduate microbiology lab course. *Front Microbiol.* (2020) 11:577852. doi: 10.3389/fmicb.2020.577852
49. Horvath JE, Council SE. Tools for citizen-science recruitment and student engagement in your research and in your classroom. *J Microbiol Biol Educ.* (2016) 17:38–40. doi: 10.1128/jmbe.v17i1.1018
50. Pérez-Losada M, Crandall KM, Crandall KA. Testing the "Grandma Hypothesis": characterizing skin microbiome diversity as a project-based learning approach to genomics. *J Microbiol Biol Educ.* (2020) 21:21.1.7. doi: 10.1128/jmbe.v21i1.2019
51. Zelaya AJ, Gerardo NM, Blumer LS, Beck CW. The Bean Beetle microbiome project: a course-based undergraduate research experience in microbiology. *Front Microbiol.* (2020) 11:577621. doi: 10.3389/fmicb.2020.577621
52. Xu Z, Vázquez-Baeza Y, Knight R, Debelius JW, Wolfe E, Mcdonald D. Turning participatory microbiome research into usable data: lessons from the american gut project. *J Microbiol Biol Educ.* (2016) 17:46–50. doi: 10.1128/jmbe.v17i1.1034
53. Hugenholtz P, Hall RA, Patil J, Daly JN, Tyson GW, Schembri MA, et al. Do you kiss your mother with that mouth? An authentic large-scale undergraduate research experience in mapping the human oral microbiome. *J Microbiol Biol Educ.* (2015) 16:50–60. doi: 10.1128/jmbe.v16i1.816
54. Skendzic E, Keler C. Fruit flies & the gut microbiome: redesign-your-bacteria lab exercise. *Am Biol Teach.* (2019) 81:47–51. doi: 10.1525/abt.2019.81.1.47

55. Reynolds HL, Kearns KD. A planning tool for incorporating backward design, active learning, and authentic assessment in the college classroom. *Coll Teach.* (2017) 65:17–27. doi: 10.1080/87567555.2016.1222575
56. Burmeister AR, Dickinson K, Graham MJ. Bridging trade-offs between traditional and course-based undergraduate research experiences by building student communication skills, identity, and interest. *J Microbiol Biol Educ.* (2021) 22: e00156–21. doi: 10.1128/jmbe.00156-21
57. Light C, Fegley M, Stamp N. Training program for Research Educators of sequential course-based undergraduate research experiences. *FEMS Microbiol Lett.* (2019) 366:fnz165. doi: 10.1093/femsle/nz165
58. Lee E, Hannafin MJ. A design framework for enhancing engagement in student-centered learning: own it, learn it, and share it. *Educ Technol Res Dev*. (2016) 64:707–34. doi: 10.1007/s11423-015-9422-5
59. Alkaher I, Dolan E. Integrating research into undergraduate courses: current practices and future directions. *Res Based Undergrad Sci Teach*. (2014) 1:1–41. Available online at: https://www.researchgate.net/publication/280735867
60. Estrada M, Hernandez PR, Schultz PW, Herrera J. A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. *Cbe Life Sci Educ.* (2018) 17:ar9. doi: 10.1187/cbe.17-04-0066

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Effective Teaching Behaviors of Clinical Nursing Teachers: A Qualitative Meta-Synthesis

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Objectives: To identify, appraise, and synthesize the available evidence exploring the effective teaching behaviors of clinical nursing teachers.

Design: The Joanna Briggs Institute (JBI) guidelines were followed, and a meta-synthesis was conducted.

Review Methods: Following databases were searched for relevant qualitative studies published in English and reporting primary data analysis, including experiences and perceptions of nursing students: PubMed, EBSCOhost, OVID, etc. Qualitative Assessment and Review Instrument were used to pool the qualitative research findings. Through the repeated reading of the original literature, the similar findings were combined and sorted into new categories, and then summarized into different synthesized themes.

Results: A total of nine articles were included. The review process produced 29 subcategories that were aggregated into seven categories. The categories generated three synthesized findings: good teaching literacy, solid professional competence, and harmonious faculty-student relationship.

Conclusions: The effective teaching behaviors of clinical nursing teachers are the driving force for the progress and growth of nursing students. In order to improve the effectiveness of clinical nursing teaching, nursing teachers should be fully aware of effective teaching behaviors for nursing students to master nursing theories and skills.

Keywords: clinical nursing teachers, effective teaching behaviors, qualitative research, meta-synthesis, nursing students

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INTRODUCTION

Nursing education includes both theoretical and practical educational aspects. Nursing students learn how to provide care in different settings, such as classrooms and clinic (1). Nursing education has a strong practicality, as it allows nursing students to better master theoretical knowledge, accumulate practical experience, and finally develop from nursing students to qualified professional nurses through clinical practice.

Clinical practice is an important stage for nursing students to complete the transformation of nurses' role in psychology and behaviors. As an important part of nursing education, high-quality teaching of clinical practice is very important to cultivate qualified clinical nursing students. A

previous study has shown that communication ability, health education ability, and professional psychological quality are relatively strong among nursing students, while their clinical scientific research, clinical management, and clinical teaching are relatively weak (2). In addition, according to the results of an interview with students on the soft environment evaluation of clinical nursing teaching, the teaching evaluation system of clinical nursing teachers needs to be further updated and improved; the working environment is harmonious, but opportunities for nursing students to participate in clinical practice are insufficient; teachers have a strong professional ability, but the teaching level needs to be further improved; teaching contents and methods are limited, and the learning effect is not ideal (3). Consequently, it is of urgent importance to improve the quality of clinical teaching.

The quality of clinical teaching does affect not only the future value orientation of nursing students but also the cultivation of their professional quality and career planning (4). In clinical teaching of nursing practice, nursing teachers have a leading role, and their teaching behaviors directly affect the quality of clinical teaching. In order to help nursing students become excellent nurses, clinical nursing teachers must use educational theories that are more in line with teachings from clinical practice to improve teaching methods, such as humanistic theory (5). Education should completely focus on nursing students and include teaching and learning activities that are consistent with the learning needs of nursing students so as to effectively improve the quality of clinical teaching.

Nursing students are the main focus of teaching activities, and nursing students tend to make different judgments on the effectiveness of clinical nursing teachers' behaviors based on their different learning motivations, learning strategies, cognitive styles, and family background (6). A previous study has shown that in the process of teaching, a full understanding of nursing students' learning characteristics by nursing teachers, cognitive style, and teaching effectiveness evaluation can effectively guide nursing teachers to adjust teaching methods and to teach activities to meet the teaching needs of different groups (7). Therefore, clinical nursing teachers should improve clinical teaching behaviors considering nursing students' perspective to cultivate high-quality nursing talents.

Teachers used theoretical and practical approaches in the process of teaching, which combined with their own qualities and teaching methods adopted in order to promote nursing students' learning and achieve their predetermined learning goals are considered to make up effective teaching behavior (8). The effective teaching behaviors of clinical nursing teachers can improve the clinical ability of nursing students and improve the effectiveness of clinical practice, thus ensuring the teaching quality (9). Therefore, in order to further improve the quality of clinical nursing teaching, it is very important to acquire an in-depth understanding of the effective teaching behaviors of clinical nursing teachers. The purpose of this study was to integrate the existing qualitative research results with meta-synthesis data in order to provide a reference for improving the quality of clinical nursing teaching.

THE REVIEW

Objective

The objective of this exploratory qualitative meta-synthesis was to determine the experience of nursing students and their perception of effective teaching behaviors of clinical nursing teachers. This review enabled us to make recommendations to further improve the effectiveness of clinical nursing teaching.

Design and Search Strategy

A systematic literature search according to the Joanna Briggs Institute (JBI) Reviewers' Manual (10) and a priori protocol (11) was performed. We initiated a three-step search strategy and followed a focused question. To guide the structure and identify the key aspects of the search, we adopted mnemonic for qualitative reviews. The target phenomenon was an investigation of nursing students' experiences and perceptions of effective teaching behaviors of clinical nursing teachers in their clinical practice, which has inspired the research question, the definition of the Population, the Phenomenon of Interest, the Context and the Type of study (PICoS) of the review. We searched PubMed, EBSCOhost, OVID, Embase, Scopus, Web of Science and ProQuest for qualitative studies on the effective teaching behaviors of clinical nursing teachers from the establishment of these databases to February 2022. CareSearch and Google Scholar were also utilized for searching the gray literature. The following keywords were included: clinical nursing, effective teaching, effective teaching behaviors, nursing students, qualitative research, qualitative study, interview, feelings, experience and perception. The systematic questions and search terms based on our PICoS are shown in **Table 1**. The qualitative research assessment and evaluation tool JBI-QARI online application software was used to evaluate the literature quality, extract the research results and comprehensive research results. This study met the requirements of the Helsinki Declaration.

Critical Appraisal

Before being included in the review, the two first authors independently assessed the validity of the literature using the Joanna Briggs Institute Qualitative Assessment and Review Instrument (JBI-QARI) (12, 13). The disagreements that arose between the two authors were resolved through discussion or by the third author.

Data Extraction and Synthesis

The data that were extracted from the papers using the JBI-QARI data extraction tool included specific details about nursing students' experiences and perceptions on effective teaching behaviors of clinical nursing teachers in their clinical practice. The researchers individually reviewed the nine studies and extracted the necessary information by using the JBI procedure for meta-synthesis (10). The similar findings were combined and sorted into new categories, and then summarized into different synthesized themes (12).

TABLE 1 | PICoS.

Types of participants (*P*)	Types of phenomena of interest (*I*)	Types of contexts (Co)	Types of studies (*S*)
This review will investigate nursing students.	This review will investigate nursing students' experiences and perceptions on effective teaching behaviors of clinical nursing teachers in their clinical practice.	This review will investigate nursing education in the practical process.	This review will focus on qualitative studies.
Systematic search terms are "nursing students, nurse students, student nurses, pupil nurses."	Systematic search terms are "effective teaching behaviors, effective teaching strategies, effective teaching, teaching effectiveness, effective teaching methods, nursing faculty, nurse faculty, nursing educator, nurse educator."	Systematic search terms are "clinical nursing, nursing education."	Systematic search terms are "qualitative research, qualitative study, interview, feelings, experience, perception."

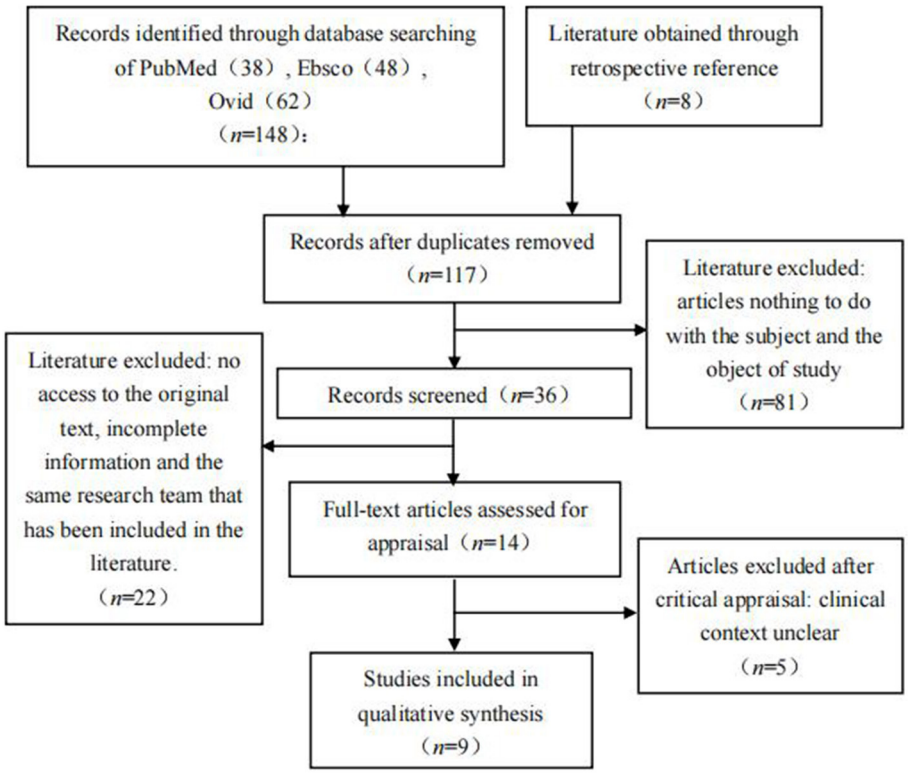

FIGURE 1 | PRISMA flowchart.

RESULTS

A total of 156 papers were retrieved from databases. Hundred and seventeen papers were screened for relevance based on subject and object after duplicates were removed, and 36 full-text papers were screened for eligibility. Twenty-two papers were excluded for the following reasons: no access to the original text, incomplete information, and the same research team that has been included in the literature. Among 14 papers that were assessed for appraisal, five were excluded. Of these, nine papers were included in the qualitative meta-synthesis. **Figure 1** shows the PRISMA flow diagram of the process of retrieval and selection of papers for inclusion (13).

The nine included studies used qualitative methodologies. They were conducted between 2006 and 2019 in eight different countries, and all were published in English. An illustration of the participants, designs, aims, methods of analysis, and key findings is presented in a meta-summary (**Table 2**).

Meta-Synthesis

This systematic review presented the following meta-synthesis: nursing students' experiences of effective teaching behaviors of clinical nursing teachers in their clinical practice. The meta-synthesis had three themes: (1) good teaching literature, (2) solid professional competence, and (3) harmonious faculty-student relationship. The three themes had seven synthesized categories (**Figure 2**) that were derived from 29 grouped study findings. The grouping of the findings into synthesized categories is illustrated in **Figure 3**. One of the three themes had a frequency effect size

TABLE 2 | Meta-summary of included studies.

Author (year) Country	Aim	Participants and design	Methods/analysis	Key findings
Pearson et al. (14) (2011) UK	To explore the perceptions of clinicians, clinical learners, and practice staff of key elements of being a teaching practice.	28 clinical learners, including postgraduate nurses and others Phenomenology	Individual face-to-face interviews or focus group interviews Inductive analysis	Two themes emerged: a positive learning environment (support for learning, excellence in teaching); learning culture (a passion for education).
Jiang et al. (15) (2018) PRC	To explore effective teaching methods in the emergency department from the perspective of Millennial nursing students in Shanghai.	16 nursing students from six colleges of nursing and five nursing high schools in Shanghai Qualitative study	Semi-structured interviews Colaizzi's seven-step data analysis	Three themes emerged: demonstrating harmonious faculty-student relationship, possessing professional competence, and being empathetic for teaching.
Lovrić et al. (16) (2017) Croatia	To explore what competencies BSc nursing students expect from their clinical faculties and whether their expectations changed.	34 BSc nursing students A two-phase, mixed-methods design	Reflections on the expectations Inductive analysis	Four themes emerged: a higher level of teaching ability; positive human qualities; clinical faculties' professional evaluation of the student; good interpersonal relations.
Harms et al. (17) (2019) Canada	To fill this gap by examining narrative comments from psychiatry faculty evaluations to understand learners' perceptions of educator effectiveness.	324 undergraduate and postgraduate learners from McMaster University A fundamental qualitative descriptive design	Narrative evaluation Inductive analysis	Four themes emerged: personal characteristics (learner-centered, supportive, engaging, good communicator, respectful, professional); relationships matter (learner security-the conditions for optimal learning, a spectrum of admiration); person as pedagogy (medical teachers themselves being the method of teaching); supervisors-more than medical experts (skills and qualities building upon their knowledge base).
Kelly (18) (2007) Canada	To elicit learner's views of what teacher characteristics and contextual influences impact them in clinical settings.	30 students at the end of second and third years Qualitative study	In-depth interviews Phenomenographic analysis	Three themes emerged: clinical teacher knowledge; feedback and communication skills (teacher's listening skills, a respectful, calm, co-learner, being straightforward and honest); environmental factors (ideal student-teacher ratios, welcoming students and trying to help them out, the importance of peer support).
Gustafsson et al. (19) (2015) Sweden	To describe and compare the clinical teacher's role in different models of clinical practice from the perspective of nursing students.	8 nursing students in the qualitative part of the study A mixed-method study A quantitative study with comparative design and a qualitative study with descriptive design	A mixed-method Inductive analysis	Three themes emerged: enabling integration of theory and practice; co-operation between placement staff and nurse teacher (being like a member of the nursing team, transmitting his or her pedagogical expertise to the clinical team); the relationship between student, mentor, and nurse teacher (The common meetings between myself, mentor and NT being comfortable experience, a climate of the meetings being congenial, focus on the meetings being in my learning needs).
McSharry et al. (20) (2017) Ireland	To explore the clinical teaching and learning within a preceptorship model in an acute care hospital in Ireland and identify when best practice principles occurred.	13 student nurses from 1st, 3rd, and 4th year from each of the four clinical sites A qualitative research study	semi-structured interviews Inductive analysis	Five themes emerged: continuity-foundation for effective teaching and learning relationship (within a relationship of mutual interest and respect); talking through practice; assessing practice-scaffolding learning (exploratory conversations); continuous assessment of the students understanding and performance; teaching clinical reasoning-preceptors' questions (the usefulness of critical questioning in developing student nurses' clinical reasoning skills in the context of clinical practice).
Yousefy et al. (21) (2015) Iran	To explore the environment of clinical baccalaureate nursing students' education.	54 nursing students and eight clinical educators from the four geographically diverse universities A qualitative study	Individual interviews, focus groups, and direct observations A content analysis	Two themes emerged: questions not being challenging and incentive to improve critical thinking in students; incompetency of clinical educators (not prepared and competent for being a role model practical setting).
Günay et al. (22) (2018) Turkey	To determine the transfer of theoretical knowledge into clinical practice by nursing students and the difficulties they experience during this process.	30 nursing students in a university located in the east of Turkey A qualitative research	Focus group interviews The method of content analysis	Three themes emerged: guidance and communication (inadequacy in receiving clinical guidance, lack of appreciation, cooperation); clinical evaluation (expectations changing based on the instructor, injustice in clinical grading); expectations (to be active in clinical education, love their profession and feel appreciated, to accompany them in the clinical area).

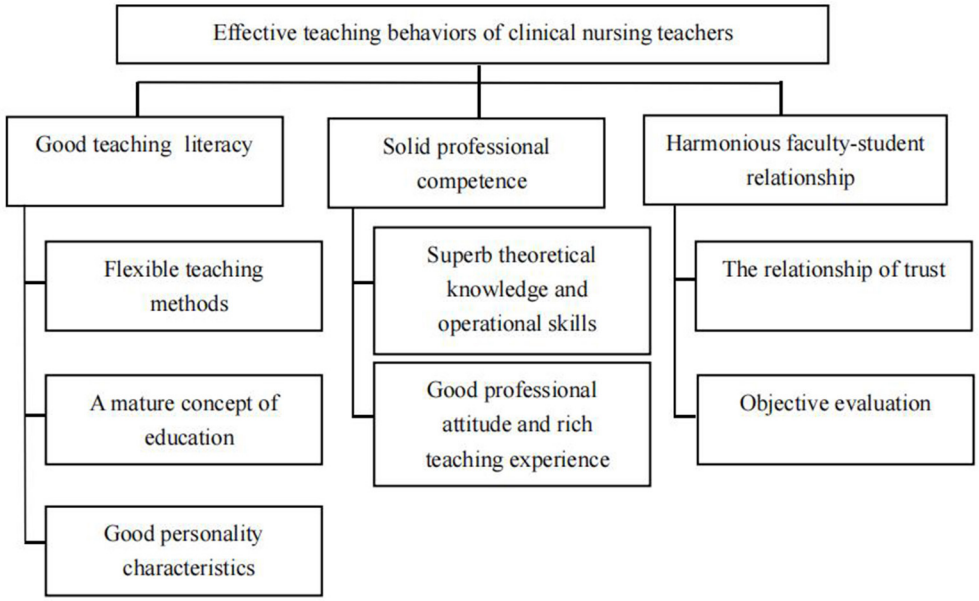

FIGURE 2 | The relation between meta-synthesis, themes, and categories in the review.

of 100% (23), while other themes had effect sizes of 89 and 78% (**Table 3**).

Good Teaching Literacy

Following themes were derived from 10 grouped study findings and three synthesized categories: flexible teaching methods, a mature concept of education, and good personality characteristics.

Category 1: Flexible Teaching Methods

Most clinical nursing teachers are well prepared for teaching. They can show clear teaching objectives and learning priorities and can apply flexible teaching methods to create a free learning environment. According to one student: "Good teachers make you do things. They're the ones that would assign you a patient and tell you what to do. They will be watching you if you have any problems." (20) (p78).

Teachers should take advantage of the opportunity of close contact with nursing students to stimulate their learning enthusiasm so as to fully tap into their full potential and realize the multi-dimensional interaction between teachers and students. Another student said: "We believe that this kind of questioning (such as how, why or what if) helped students to verbalize, and hence refine their knowledge." (20) (p79).

Category 2: A Mature Concept of Education

Clinical nursing teachers need to establish the educational concept of "humanism". Their teaching literature is the foundation of vocational teaching and the key supporting point of teaching activities, which has a significant impact on the teaching effect and the development of nursing students. The following quote described this reflective process, "One of the most engaging seminars I have participated in via video conference. This speaks highly of the teacher's ability to facilitate thoughtful discussion, present material, and also be conscious of how this transmits over technology. Superb!" (17) (p23).

At the same time, teachers need to be sympathetic, and nursing students often like teachers who show sustained enthusiasm for teaching. A student said, "They like to teach and they are willing to teach anybody who wants to listen…" (14) (p162).

Category 3: Good Personality Characteristics

The overall personality characteristics of clinical nursing teachers are good. They are showing enthusiasm, optimism, neatness, and modesty. They are active and creative thinkers, able to control their emotions, and having a strong ability to cope with setbacks and failures: a female student stated, "Deep down, I just want to be as a good nurse as she is…so gentle…and bringing warmth to the hopeless…" (15) (p223).

In short, teachers' charisma can improve the learning experience of nursing students. A student recalled, "The educator really soothed our anxiety levels…" (17) (p21).

Solid Professional Competence

The following themes were derived from 10 grouped study findings and two synthesized categories: superb theoretical knowledge and operational skills, and good professional attitude and rich teaching experience.

Category 4: Superb Theoretical Knowledge and Operational Skills

The good professional attitude and skills of clinical nursing teachers are the catalyst and activator of teaching effect that

Grouping the study findings into categories	Synthesized categories	Themes
Exploratory conversations Teaching clinical reasoning: preceptors' questions Critical and independent thinking climate	Flexible teaching methods	Good teaching literacy
A passion for education Person as pedagogy To be active in clinical education, love their profession and feel appreciated, to accompany them in the clinical area	A mature concept of education	
Being empathetic for teaching Positive human qualities Personal characteristics: learner-centered, supportive, engaging, good communicator, respectful, professional Feedback and communication skills: teacher's listening skills, a respectful, calm, co-learner, being straightforward and honest	Good personality characteristics	
Possessing professional competence A higher level of teaching ability Supervisors: more than medical experts Clinical teacher knowledge Enabling integration of theory and practice Prepared and competent for being a role model practical setting	Superb theoretical knowledge and operational skills	Solid professional competence
A positive learning environment: support for learning, excellence in teaching Continuity: foundation for an effective teaching and learning relationship Talking through practice Guidance and communication: adequacy in receiving clinical guidance, appreciation, cooperation	Good professional attitude and rich teaching experience	
Demonstrating the harmonious faculty-student relationship Good interpersonal relations Relationships matter: learner security, a spectrum of admiration Environmental factors: ideal student-teacher ratios, welcoming students and trying to help them out, the importance of peer support Co-operation between placement staff and nurse teacher: being as a member of the nursing team, transmitting his or her pedagogical expertise to the clinical team Relationship between student, mentor and nurse teacher: the common meetings between myself, mentor and nurse teacher being comfortable experience, a climate of the meetings being congenial, focus on the meetings being in my learning needs	The relationship of trust	Harmonious faculty-student relationship
Clinical faculties' professional evaluation of student Continuous assessment of the students understanding and performance Clinical evaluation: expectations changing based on the instructor, injustice in clinical grading	Objective evaluation	

FIGURE 3 | The meta-aggregative approach from grouping the study findings into categories and synthesizing the categories into themes.

further the development of students' ability. One student commented: "The thing that impressed me the most was her knowledge level and the way she incorporated it - put it into practice. She's got to be able to pull the whole thing together." (18) (p889).

The clinical skills, professional knowledge, professional responsibility and the attitude shown by clinical teachers set an example for nursing students. A student concurred, "You have to be ready to handle different unpredictable emergency situations in the ED. Sometimes you need to act like a senior supervisor…" (15) (p223).

Category 5: Good Professional Attitude and Rich Teaching Experience

Nursing students expect clinical nursing teachers to act as their role models and to influence nursing students through their

TABLE 3 | The effect size of themes.

References	Themes		
	Good teaching literacy	Solid professional competence	Harmonious faculty-student relationship
Pearson et al. (14)	x	x	
Jiang et al. (15)	x	x	x
Lovrić et al. (16)	x	x	x
Harms et al. (17)	x	x	x
Kelly (18)	x	x	x
Gustafsson et al. (19)		x	x
McSharry et al. (20)	x	x	x
Yousefy et al. (21)	x	x	
Günay et al. (22)	x	x	x
%	89	100	78

actions. A fourth-year student said, "Everyone is really friendly, and you share a staff room with them and stuff…they kind of chat with you as you were another member of staff really…" (14) (p161).

However, individual teachers also reprimand nursing students, which may increase the psychological burden in nursing students. A student stated, "If they appreciated us, we would like our profession and would be highly motivated." (22) (p83). This suggests that teachers should give more care to nursing students.

Harmonious Faculty-Student Relationship

The following themes were derived from nine grouped study findings and two synthesized categories: the relationship of trust and objective evaluation.

Category 6: The Relationship of Trust

Nursing students expect clinical nursing teachers to have an amiable attitude and give them full encouragement and respect. A student recalled the situation, "One day, I encountered my teacher from the ICU in the cafeteria of the hospital. I felt so excited and was deeply moved when she called my name…" (15) (p222).

This harmonious teacher-student relationship helps to provide nursing students with a good learning atmosphere, not only to practice and develop their clinical skills independently but also to get a sense of security from the stable relationship between teachers and students. A learner commented, "It fosters personal growth and motivates the learner to do better." (17) (p21).

Category 7: Objective Evaluation

Clinical nursing teachers are busy and cannot timely and effectively make an objective evaluation of nursing students, which has a role in motivating nursing students. Some students complained, "Some assistants try to look for our mistakes instead of helping us overcome our gaps in knowledge." (22) (p84).

Evaluation behaviors on behalf of the teachers is of vital importance, and can impact the effectiveness of clinical learning of nursing students. Therefore, clinical nursing teachers need to have rich teaching skills, which is of great significance for the motivation and growth of nursing students. A student recalled, "…My preceptor asked me 'so a patient is being discharged, what do you do?' I was so nervous…But then I answered and she was like 'well done, you've got the necessary knowledge. Now go and do it." (20) (p78).

DISCUSSION

The results of meta-syntheses, which are considered scientific and reliable, can complement qualitative research results (24). Compared with quantitative research, qualitative research can reflect more humanistic care, and it is becoming increasingly used in health care, health education, health service, and nursing (25). Herein, we conducted a systematic review of the qualitative research on the effective teaching behaviors of clinical nursing teachers. Through critical appraisal, the qualitative research results from nine articles were identified, summarized, and integrated by meta-synthesis, and the essence of the phenomenon was deeply explored. Seven categories were formed and synthesized into three themes so as to fully understand nursing students' experiences of effective teaching behaviors on behalf of clinical nursing teachers and find a comprehensive explanation for the consistencies between the results of various qualitative studies. The meta-synthesis process of this study was rigorous, and the results are reliable, which can be helpful for improving the quality of clinical nursing teaching and can be used as the application basis for evidence-based practice.

Cultivating good teaching literacy and strengthening teaching supervision is of essential importance. Clinical nursing teachers should establish their own role, not only as role models for clinical nurses, but also as knowledgeable and reliable teachers (26). The research shows that finding a role model is an important characteristic of effective teaching behaviors; thus, clinical teachers should nurture the characteristics of self-discipline, tolerance, self-improvement, politeness, and similar (27). Clinical nursing teachers should strive to create a good learning environment for nursing students, and their flexibility and openness might benefit nursing students a lot. Clinical teaching hospitals should strengthen cooperation with medical colleges and universities, make full use of their teaching advantages and carry out relevant training to help teachers improve their teaching abilities of clinical nursing. Teaching management departments should encourage clinical nursing teachers to participate in higher-level academic education and take courses such as psychology and pedagogy, which can help them master flexible teaching methods, own mature concepts of education, and enhance their awareness of professional development. The teaching management department should identify the necessary teaching qualifications of clinical nursing teachers and adopt the appointment system to strengthen teachers' responsibilities and abilities and ensure good teaching quality. The teaching management department can select students in accordance with their aptitude and strengthen the supervision of teaching quality so as to help nursing students make further achievements.

Paying attention to solid professional competence and advocating personalized teaching is of vital importance. In clinical nursing teaching, nursing students are the main focus of learning activities, and clinical nursing teachers are guides (28). The effective teaching behaviors of teachers are very important for the learning and growth of nursing students, which directly affects the effectiveness of teaching (29). Therefore, clinical nursing teachers should have superb theoretical knowledge and operational skills. At the same time, clinical nursing teachers should strengthen their professional attitude, have a positive attitude toward their clinical nursing teaching, and set an example for nursing students through words and deeds. Under the correct guidance of teachers with solid professional skills, nursing students can feel grounded and safe. Moreover, nursing students are more likely to admire the various professional skills of their teachers and their ability to communicate, thus being encouraged to study actively. The research shows that most nursing students recognize the theoretical knowledge and operational skills of clinical nursing teachers, but clinical teachers often ignore the differences between theoretical and practical courses learned by trainee nursing students from different schools, levels, and regions (30). Therefore, when arranging nursing teachers in clinical nursing teaching, the teaching management departments should fully consider the knowledge needs of nursing students with different backgrounds in clinical learning and pay attention to personalized and hierarchical teaching.

Establishing a harmonious faculty-student relationship and allocating teachers rationally are also essential factors. In addition to good teaching literature and solid professional competence, strong communication between teachers and students is very important to the clinical practice of nursing students (31). Some studies have shown that nursing students are faced with problems such as unfamiliar hospital environments, tense interpersonal relationships, and low self-identity in clinical practice (32). These problems could be solved by the encouragement of clinical nursing teachers in all aspects. Also, it is particularly important to establish a harmonious relationship between teachers and students. As clinical nursing teachers are most concerned about what nursing students have really learned, while nursing students pay special attention to whether teachers can evaluate them fairly (33), clinical nursing teachers should have the skills to evaluate nursing students and be able to guide them at any time. However, besides clinical teaching, clinical nursing teachers also undertake heavy clinical work. Therefore, many factors can cause great pressure on clinical nursing teachers, and the emergence of work fatigue can seriously affect their enthusiasm for nursing work. This requires teaching hospitals to establish a standardized evaluation mechanism for clinical teaching teachers and to rationalize the allocation of nursing human resources to prevent clinical nursing teachers from professional exhaustion and burnout. At the same time, teachers should also strive to maintain a good leading spirit in clinical nursing teaching.

Dewey put forward the teaching theory of "learning by doing," which requires nursing teachers and nursing students to build a harmonious faculty-student relationship. Teachers are the guides and leaders of nursing students' learning, rather than simple knowledge instillers and transmitters. As the instructor of nursing students, teachers are required to have good teaching literacy and solid professional competence in order to guide the study and life of nursing students and promote their all-round physical and mental development.

STUDY LIMITATIONS

The limitations of this review are related to the number of included literature and search strategies. Although the search strategy is extensive, some related literature may have been left out.

CONCLUSION

To sum up, compared with quantitative research, qualitative research can reflect more subjective aspects (34). The effective teaching behaviors of clinical nursing teachers greatly affect the nursing students, representing the driving force for nursing students' progress and growth. Clinical nursing teachers and teaching administrators should be fully aware of the value of effective teaching behaviors in guiding nursing students to master nursing theories and skills so as to improve the effectiveness of clinical nursing teaching further.

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

JJ and JZ: study design. JZ, FZ, JJ, XD, and XY: data collection, data analysis, and manuscript preparation. 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.2022.883204/full#supplementary-material

REFERENCES

1. Dinmohammada M, Jalali A, Peyrovi H. Clinical learning experiences of Iranian student nurses: a qualitative study. *Nurs Pract Today.* (2016) 3:31–9. Available online at: https://npt.tums.ac.ir/index.php/npt/article/view/132 (accessed February 15, 2022).
2. Sun L, Zhou C. Research progress on clinical ability training of nursing students. *Nurs Res Pract.* (2016) 13:14–6. doi: 10.3969/j.issn.1672-9676.2016.02.007
3. Zheng Y, Zhang C, Jiang J, et al. A survey of nursing undergraduates' evaluation of clinical teaching soft environment. *Chin Nurs Educ.* (2017) 14:939–43. doi: 10.3761/j.issn.1672-9234.2017.12.015
4. Toosi M, Modarres M, Amini M, Geranmayeh M, A. survey of midwifery graduates' opinions about midwifery education in Iran: a cross-sectional study. *BMC Med Educ.* (2021) 21:340. doi: 10.1186/s12909-021-02764-y
5. Jang MS, Kim S. [Person-centered relational care experienced by critical care nurses: an interpretative phenomenological analysis study]. *J Korean Acad Nurs.* (2019) 49:423–36. doi: 10.4040/jkan.2019.49.4.423
6. Khademi M, Mohammadi E, Vanaki Z, A. grounded theory of humanistic nursing in acute care work environments. *Nurs Ethics.* (2017) 24:908–21. doi: 10.1177/0969733016638140
7. McAllister M, Searl KR, Davis S. Who is that masked educator? Deconstructing the teaching and learning processes of an innovative humanistic simulation technique. *Nurse Educ Today.* (2013) 33:1453–8. doi: 10.1016/j.nedt.2013.06.015
8. Cayley WE Jr. Effective clinical education: strategies for teaching medical students and residents in the office. *WMJ.* (2011) 110:178–81.
9. Bocking J, Happell B, Scholz B, Horgan A, Goodwin J, Lahti M, et al. 'It is meant to be heart rather than head'; International perspectives of teaching from lived experience in mental health nursing programs. *Int J Ment Health Nur.* (2019) 28:1288–95. doi: 10.1111/inm.12635
10. Joanna Briggs Institute. *Joanna Briggs Institute Reviewers' Manual* (2014). Available online at: http://joannabriggs.org/assets/docs/sumari/ReviewersManual-2014.pdf (accessed October 20, 2021).
11. Kaldal MH, Kristiansen J, Uhrenfeldt L. Nursing students' experiences of professional patient care encounters in a hospital unit: a systematic review protocol. *JBI Database System Rev Implement Rep.* (2015) 13:30–9. doi: 10.11124/01938924-201513090-00005
12. Lockwood C, Munn Z, Porritt K. Qualitative research synthesis: methodological guidance for systematic reviewers utilizing meta-aggregation. *Int J Evid Based Healthc.* (2015) 13:179–87. doi: 10.1097/XEB.0000000000000062
13. Moher D, Liberati A, Tetzlaff J, Altman D. PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg.* (2010) 8:336–41. doi: 10.1016/j.ijsu.2010.02.007
14. Pearson D, Lucas B. What are the key elements of a primary care teaching practice? *Educ Prim Care.* (2011) 22:159–65. doi: 10.1080/14739879.2011.11493991
15. Jiang J, Zeng L, Kue J, Li H, Shi Y, Chen C. Effective teaching behaviors in the emergency department: a qualitative study with Millennial nursing students in Shanghai. *Nurse Educ Today.* (2018) 61:220–4. doi: 10.1016/j.nedt.2017.12.007
16. Lovrić R, Prlić N, Milutinović D, Marjanac I, Žvanut B. Changes in nursing students' expectations of nursing clinical faculties' competences: A longitudinal, mixed methods study. *Nurse Educ Today.* (2017) 59:38–44. doi: 10.1016/j.nedt.2017.08.013
17. Harms S, Bogie B, Lizius A, Saperson K, Jack S, McConnell M, et al. From good to great: learners' perceptions of the qualities of effective medical teachers and clinical supervisors in psychiatry. *Can Med Educ.* (2019) 10:e17–e26. doi: 10.36834/cmej.53156
18. Kelly C. Student's perceptions of effective clinical teaching revisited. *Nurse Educ Today.* (2007) 27:885–92. doi: 10.1016/j.nedt.2006.12.005
19. Gustafsson M, Kullén Engström A, Ohlsson U, Sundler AJ, Bisholt B. Nurse teacher models in clinical education from the perspective of student nurses–A mixed method study. *Nurse Educ Today.* (2015) 35:1289–94. doi: 10.1016/j.nedt.2015.03.008
20. McSharry E, Lathlean J. Clinical teaching and learning within a preceptorship model in an acute care hospital in Ireland; a qualitative study. *Nurse Educ Today.* (2017) 51:73–80. doi: 10.1016/j.nedt.2017.01.007
21. Yousefy A, Ar Y, Mohammadi S. Exploring the environment of clinical baccalaureate nursing students' education in Iran; A qualitative descriptive study. *Nurse Educ Today.* (2015) 35:1295–300. doi: 10.1016/j.nedt.2015.07.028
22. Günay U, Kilinç G. The transfer of theoretical knowledge to clinical practice by nursing students and the difficulties they experience: a qualitative study. *Nurse Educ Today.* (2018) 65:81–6. doi: 10.1016/j.nedt.2018.02.031
23. Sandelowski M, Barroso J, Voils CI. Using qualitative metasummary to synthesize qualitative and quantitative descriptive findings. *Res Nurs Health.* (2007) 30:99–111. doi: 10.1002/nur.20176
24. Chegini Z, Arab-Zozani M, Shariful Islam SM, Tobiano G, Rahimi S. Barriers and facilitators to patient engagement in patient safety from patients and healthcare professionals' perspectives: A systematic review and meta-synthesis. *Nurs Forum.* (2021) 56:938–49. doi: 10.1111/nuf.12635
25. Branger C, O'Connell ME, Peacock S. Protocol for a meta-integration: investigating positive aspects of caregiving in dementia. *BMJ Open.* (2018) 8:e021215. doi: 10.1136/bmjopen-2017-021215
26. Jung S, Greenberg J, O'Rourke AP, Minter R, Foley E, Voils C. Comparison of the perspectives of medical students and residents on the surgery learning environment. *J Surg Res.* (2021) 258:187–94. doi: 10.1016/j.jss.2020.08.070
27. Cruess SR, Cruess RL, Steinert Y. Role modelling–making the most of a powerful teaching strategy. *BMJ.* (2008) 336:718–21. doi: 10.1136/bmj.39503.757847.BE
28. Lana-Pérez A, Caamaño-Isorna F, Baltasar-Bagué A, Amezcua-Prieto C, Vives-Cases C, Davó-Blanes M. [Public health competencies and contents of Nursing degree programs in Spanish universities]. *Rev Esp Salud Publica.* (2018) 92:e201808064. Available online at: https://pubmed.ncbi.nlm.nih.gov/30197414/ (accessed February 15, 2022).
29. Gamage U, Mahesh P, Schnall J, et al. Effectiveness of training interventions to improve quality of medical certification of cause of death: systematic review and meta-analysis. *BMC Med.* (2020) 18:384. doi: 10.1186/s12916-020-01840-2
30. Alamrani MH, Alammar KA, Alqahtani SS, Salem OA. Comparing the effects of simulation-based and traditional teaching methods on the critical thinking abilities and self-confidence of nursing students. *J Nurs Res.* (2018) 26:152–7. doi: 10.1097/jnr.0000000000000231
31. Michael K, Dror MG, Karnieli-Miller O. Students' patient-centered-care attitudes: the contribution of self-efficacy, communication, and empathy. *Patient Educ Couns.* (2019) 102:2031–7. doi: 10.1016/j.pec.2019.06.004
32. Oh J. Effects of nursing students' empathy and interpersonal competence on ideal nurse attributes. *J Nurs Educ.* (2019) 58:130–5. doi: 10.3928/01484834-20190221-02
33. Koldestam M, Broström A, Petersson C, Knutsson S. Model for improvements in learning outcomes (MILO): development of a conceptual model grounded in caritative caring aimed to facilitate undergraduate nursing students' learning during clinical practice (Part 1). *Nurse Educ Pract.* (2021) 55:103144. doi: 10.1016/j.nepr.2021.103144
34. Dumenco L, Monteiro K, Collins S, Stewart C, Berkowitz L, Flanigan T, et al. A qualitative analysis of interprofessional students' perceptions toward patients with opioid use disorder after a patient panel experience. *Subst Abus.* (2019) 40:125–31. doi: 10.1080/08897077.2018.1546262

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BRIEF RESEARCH REPORT
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Investigation and Analysis of Eye Discomfort Caused by Video Display Terminal Use Among Medical Students Studying at High-Altitude Regions

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Objective: To investigate the use of video display terminal (VDT) in high-altitude regions by medical students and the resulted risk factors of eye discomfort.

Methods: A cross-sectional study was conducted in 686 medical students randomly selected from high-altitude regions, Kunming, Yunnan Province. The prevalence of video display terminal syndrome (VDTs) and related risk factors in medical students were analyzed by instructing students to fill in the eye discomfort symptom questionnaire [Ocular Surface Disease Index (OSDI) scale].

Results: There were 686 participants in this study, including 213 males (31.0%) and 473 females (69.0%). The results of questionnaire survey showed that 184 patients (26.8%) didn't have eye discomfort symptoms and 502 patients (73.2%) had eye discomfort symptoms. The comparison of demographic and ocular characteristics of eye discomfort symptoms group and no eye discomfort symptoms group showed that medical students in the group with ocular discomfort symptoms had longer total duration of video terminal use, longer duration of each VDT use, higher total scores of ocular discomfort symptom scores, and a higher percentage of the ocular discomfort severity group, all with statistically significant differences. There was no significant difference in the remaining parameters between the two groups of participants. The results of multivariate logistic regression model analysis showed that the relationship between total sleep time, total duration of VDT use and eye discomfort symptom score was statistically significant ($P < 0.05$). Besides, ordinal logistic regression was applied further to investigate related factors of the severity of eye discomfort. The model demonstrated that total sleep duration and total VDT using duration were significantly associated with the severity of eye discomfort symptom ($P < 0.05$).The severity of eye discomfort symptom was significantly negatively related to the increased total sleep duration and it was significantly positively related to the increased VDT use duration.

Conclusion: The prevalence of VDTs is high in medical students at high-altitude regions. The longer total duration of daily use of VDT and shorter sleep duration are risk

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factors associated with VDTs. The severity of eye discomfort symptom was significantly negatively related to the increased total sleep duration and it was significantly positively related to the increased total VDT using duration.

Keywords: video display terminal (VDT), medical students, high-altitude regions, dry eye, tear film distribution

INTRODUCTION

With the gradual advancement of social informatization and the widespread popularization of electronic products such as mobile phones, tablets, and computers, video display terminal (VDT) has infiltrated into every part of our life, study, and work, bringing various conveniences to our lives and improving our work efficiency, while video display terminal syndromes (VDTs) has become more and more common (1). These related eye diseases caused by frequent use of VDT are collectively referred to as VDTs, a clinical syndrome, which is mainly manifested as dry eyes, eye astringent, eye redness, eye pain, asthenopia, dizziness, blurred vision, diplopia, and other symptoms in some users after operating the computer or staring screen for a long time and at close distance, while some users are accompanied by different degrees of systemic symptoms such as shoulder and neck pain (2, 3).

The International Dry Eye Working Group in 2007 defined dry eye as a multifactorial ocular surface disease characterized by loss of intraocular homeostasis with tear film instability and hyperosmolarity, ocular surface inflammation and injury, and neurosensory abnormalities as ocular symptoms (4). Epidemiological research studies have shown that common risk factors for dry eye include female, age-related, prolonged contact-lens wearing, long-term use of hormones, irrational use of eye drops, vitamin A deficiency, prolonged use of VDT, excessive eye use, and so on (5). Currently, there is no standardized criteria for the diagnosis of VDTs as an important component of dry eye, but the presence of subjective symptoms of ocular discomfort is one of the necessary conditions for diagnosis (6, 7). The OSDI scale is the current common scale used internationally to assess the subjective symptoms of ocular discomfort symptoms (8). The scale consists of 12 questions, including the assessment of ocular symptoms, visual function and environmental factors and the severity of eye discomfort symptoms is classified and grouped according to different total scores: <6 as no eye discomfort symptoms, 6–20 as mild eye discomfort symptoms, 20–45 as moderate eye discomfort symptoms, and >45 as severe eye discomfort symptoms (9).

With the popularity of electronic medical records, the frequency of exposure to VDT among medical students enrolled in colleges and universities has also increased tremendously in proportion. It has been observed during internship process and follow-up clinic visits that many medical undergraduates have eye complaints, and there are relevant literature reports that symptomatic dry eye may be prevalent among medical students (10). Therefore, medical students in school were selected as the subjects of this study.

At the same time, high-altitude regions also affect the appearance of eye discomfort symptoms to varying degrees due to their very unique characteristics of natural environment and geographical conditions (11). Kunming, Yunnan Province in China, as one of the high-altitude areas, has an average altitude of about 1,890 m, an average annual temperature of about 12–22°C, an average annual relative humidity of about 62%, an annual total cloudiness of about 50%, an annual precipitation of about 900 mm, an annual average wind of 4 m/s, and an annual sunshine duration of about 2,500 h. In contrast, Chinese coastal cities such as Nanjing has an average altitude of 20–30 m, an average annual temperature of 13–22°C, an average annual relative humidity of about 72%, an annual total cloudiness of about 70%, an annual precipitation of about 1,200 mm, an annual average wind of up to 3 m/s, and an annual sunshine duration of about 1,500 h. Compared with coastal cities, the unique natural environment of high altitude areas, including long sunshine hours, low precipitation, strong wind and dryness, may have adverse effects on the human body, especially the eyes. In particular, the increase in altitude and the consequent increase in UV intensity is an important factor in aggravating eye discomfort (12, 13).

In view of the above reasons, 686 medical students majoring in medicine at Kunming University of Science and Technology and Kunming Medical University in Yunnan Province were selected as the survey subjects in this study and the ocular discomfort symptom questionnaire was filled out so as to analyze the prevalence and related risk factors of VDTs after using VDT in medical students at high-altitude regions. The survey results are reported as follows.

INFORMATIONS AND METHODS

Objects

A total of 686 medical students were randomly selected from colleges and universities in Kunming, Yunnan Province, including a total of 213 males and 473 females. The average age was (20.86 ± 4.33) years.

Inspection Method

Students were instructed to complete the eye discomfort symptom questionnaire under a uniform measurement standard. The questionnaire results were divided into 4 groups according to the total score: no eye discomfort symptoms: 0–5 points; mild eye discomfort symptoms: 6–20 points; moderate eye discomfort symptoms: 21–45 points; and severe eye discomfort symptoms: >45 points. In this study, the risk factors of VDTs in medical students in colleges and universities were further studied by adding the four questions of whether refractive surgery or other eye surgery was performed, whether contact lenses were worn for more than 2 h per day, the length of daily sleep, and the total

TABLE 1 | Description of the general clinical characteristics of the study subjects.

Variable	$N(\%)\sqrt{x \pm s}$
Gender	
Male	213 (31.0)
Female	473 (69.0)
Age	20.86 ± 4.33
Perform refractive surgery or other eye surgery	
Yes	29 (4.2)
No	657 (95.8)
Wearing contact lenses for more than 2 h per day	
Yes	67 (9.8)
No	619 (90.2)
Total sleep time (h)	
5	17 (2.5)
6	136 (19.8)
7	320 (46.6)
8	213 (31.0)
Total duration of daily VDT use (h)	3.77 ± 2.43
Duration of each VDT use (h)	2.60 ± 1.34
Total score	10.00 (4.00, 22.00)
Degree of eye discomfort	
Mild eye discomfort	311 (45.3)
No eye discomfort	184 (26.8)
Moderate eye discomfort	170 (24.8)
Severe eye discomfort	21 (3.1)
Eye discomfort	
Yes	502 (73.2)
No	184 (26.8)

duration of daily VDT use and the total duration of VDT use on the basis of the OSDI scale.

Statistical Methods

The statistical software R (Version 4.1.1; R Core Team, 2021) was used for statistical description and inference. Quantitative data were expressed as mean and standard deviation; qualitative data were expressed as frequency and percentage. Comparison among groups of quantitative data were conducted using independent sample *t*-test and test inspection for qualitative data. In addition, multivariate logistic regression models were used to further explore the influencing factors of the eye discomfort symptom score. Ordinal logistic regression was applied further to investigate related factors of the severity of eye discomfort. The test level was $\alpha = 0.05$, and the difference was considered statistically significant when $P < 0.05$.

RESULTS

General Clinical Characterization

A total of 686 subjects meeting the criteria were included in this study. The average age was 20.86 ± 4.33 years, including 213 (31.0%) males and 473 (69.0%) females. There were 184 patients (26.8%) in the group without eye discomfort symptoms, while 502 patients (73.2%) showed eye discomfort symptoms, as shown in **Table 1**.

Demographic and Ocular Characteristics, Eye Discomfort Symptoms Group vs. No Eye Discomfort Symptoms Group

The comparison of demographic and ocular characteristics between the group with ocular discomfort symptoms and the group without ocular discomfort symptoms showed statistically significant differences in the two groups of indicators: total sleep time, and total duration of daily VDT use. Shorter daily sleep duration and longer total duration of daily VDT use may have contributed to the presence of VDTs. The differences in the remaining indicators including gender, age, whether refractive surgery or other eye surgery was performed, and whether corneal contact lenses were worn for more than 2 h per day were not statistically significant and may not affect the occurrence of VDTs.As shown in **Table 2**.

Multivariate Logistic Regression Model of Factors Associated With Eye Discomfort Symptom Score

The above variables were further included in a multifactorial logistic regression model to create a multifactorial regression model of patients' eye discomfort symptom scores. The analysis showed that (1) Total daily sleep time: $OR_{\text{total sleep time}} = 0.768$, $P = 0.042$, indicating that for every 1 h increase in the patients' total daily sleep time, their likelihood of developing eye discomfort symptoms decreased by 23%; (2) Total duration of daily VDT use: $OR_{\text{Total duration of daily VDT use}} = 1.162$, $P = 0.001$, indicating that for every 1 h decrease in the patients' daily reduction in total duration of VDT, their likelihood of developing eye discomfort symptoms decreased by 16%. Total daily sleep time and total duration of daily VDT use were risk factors associated with dry eye symptom scores, and the effects of the remaining factors were not statistically significant. We can see the **Table 3**, **Figures 1**, **2** for the details.

ORDINAL LOGISTIC REGRESSION FOR RELATED FACTORS FOR THE SEVERITY OF EYE DISCOMFORT SYMPTOMS

Ordinal logistic regression was applied further to investigate related factors of the severity of eye discomforts. The model demonstrated that total sleep duration and total duration of daily VDT use were significantly associated with the severity of eye discomfort symptoms. $OR_{\text{Total sleep duration}} = 0.776$, $P < 0.05$, demonstrating that the severity of eye discomfort symptoms was significantly negatively related to the increased total sleep duration. $OR_{\text{Total duration of daily VDT use}} = 1.205$, $P < 0.001$, indicating that the severity of eye discomfort symptoms was significantly positively related to the increased total duration of daily VDT use, **Table 4**.

TABLE 2 | Single factor comparison eye discomfort symptoms group vs. no eye discomfort symptoms group.

Variables	Eye discomfort symptoms group (*N* = 502)	No Eye discomfort symptoms group (*N* = 184)	$t/Z/x^2$	*P*
Gender			3.379	0.066
Male	146 (29.1)	67 (36.4)		
Female	356 (70.9)	117 (63.6)		
Age	20.82 ± 4.30	20.97 ± 4.43	−0.402	0.688
Perform refractive surgery or other eye surgery			0.273	0.601
Yes	20 (4.0)	9 (4.9)		
No	482 (96.0)	175 (95.1)		
Wearing contact lenses for more than 2 h per day			0.327	0.567
Yes	51 (10.2)	16 (8.7)		
No	451 (89.8)	168 (91.3)		
Total sleep time (h)			8.028	**0.045**
5	12 (2.4)	5 (2.7)		
6	103 (20.5)	33 (17.9)		
7	246 (49.0)	74 (40.2)		
8	141 (28.1)	72 (39.1)		
Total duration of daily VDT use (h)	4.01 ± 2.45	3.12 ± 2.26	4.446	**<0.001**
Duration of each VDT use (h)	2.70 ± 1.36	2.35 ± 1.25	3.164	**0.002**
Total score	16.00 (10.00, 24.00)	2.00 (0.00, 4.00)	−20.130	**<0.001**
Degree of eye discomfort			686.000	**<0.001**
Mild eye discomfort	311 (62.0)	0 (0.0)		
No eye discomfort	0 (0.0)	184 (100.0)		
Moderate eye discomfort	170 (33.9)	0 (0.0)		
Severe eye discomfort	21 (4.2)	0 (0.0)		

The bold values indicate statistically significant values of $p < 0.05$.

TABLE 3 | Logistic regression model of factors associated with eye discomfort symptom score.

Variables	B	SE	Z	*P*	OR	LCL	HCL
Intercept	0.283	1.137	0.249	0.803	1.328	0.143	12.333
Gender	0.291	0.189	1.539	0.124	1.338	0.923	1.939
Age	−0.005	0.02	−0.234	0.815	0.995	0.958	1.034
Perform refractive surgery or other eye surgery	0.296	0.434	0.682	0.495	1.345	0.574	3.152
Wearing contact lenses more than 2 h a day	−0.143	0.314	−0.455	0.649	0.867	0.468	1.604
Total sleep time	−0.241	0.118	−2.036	**0.042**	0.786	0.623	0.991
Total duration of VDT use	0.150	0.045	3.304	**0.001**	1.162	1.063	1.270
Duration of each VDT use	0.095	0.08	1.187	0.235	1.099	0.940	1.285

The bold values indicate statistically significant values of $p < 0.05$.

DISCUSSION

Prevalence of VDTs

Through this survey, it was found that the prevalence of VDTs was high in the students of these two medical colleges in high-altitude regions, Kunming, reaching 73.2%. In 2016, Ling and others of Central South University found the prevalence of VDTs to be 57.3% in a questionnaire study of 1,350 general enrolled college students (14). Compared with this survey, the prevalence of VDTs in medical students in these two colleges in Kunming was significantly increased compared with the above studies. There are two reasons for consideration. Firstly, the respondents of this paper are medical students. As a reserve force of a special profession, medical students have been well-known for their high academic pressure and heavy tasks, but there is still a lack of attention to their health. In the process of learning in today's society, the use of VDT in various aspects such as learning and communication has also increased significantly. With the advent of the post-epidemic era, the learning mode of the Internet has been widely used and popularized, and in the era of information explosion, the ensuing series of adverse effects is increasingly being taken into account. Secondly, the

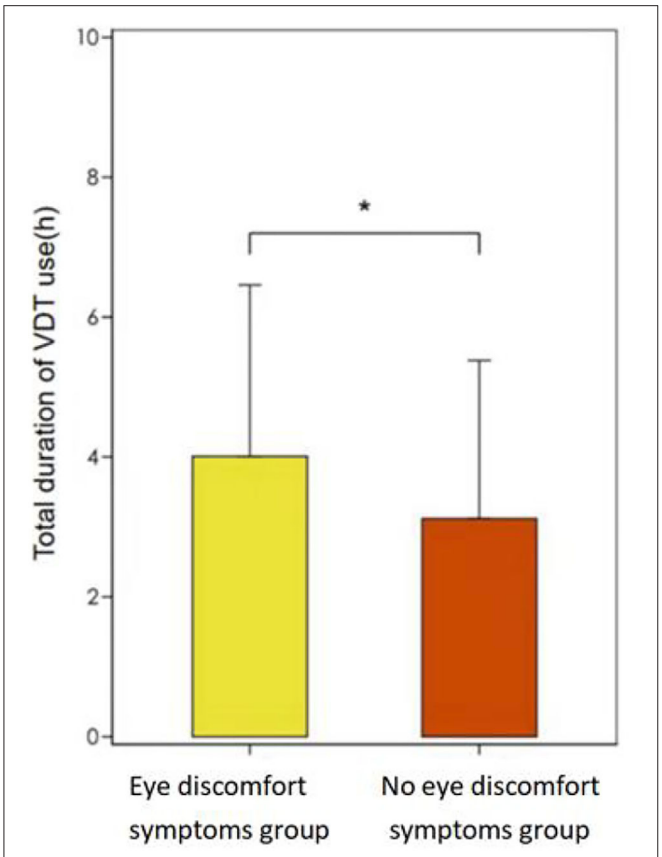

FIGURE 1 | Total duration of VDT use, eye discomfort symptoms group vs. no eye discomfort symptoms group. *means the difference between the two groups has statistically significant.

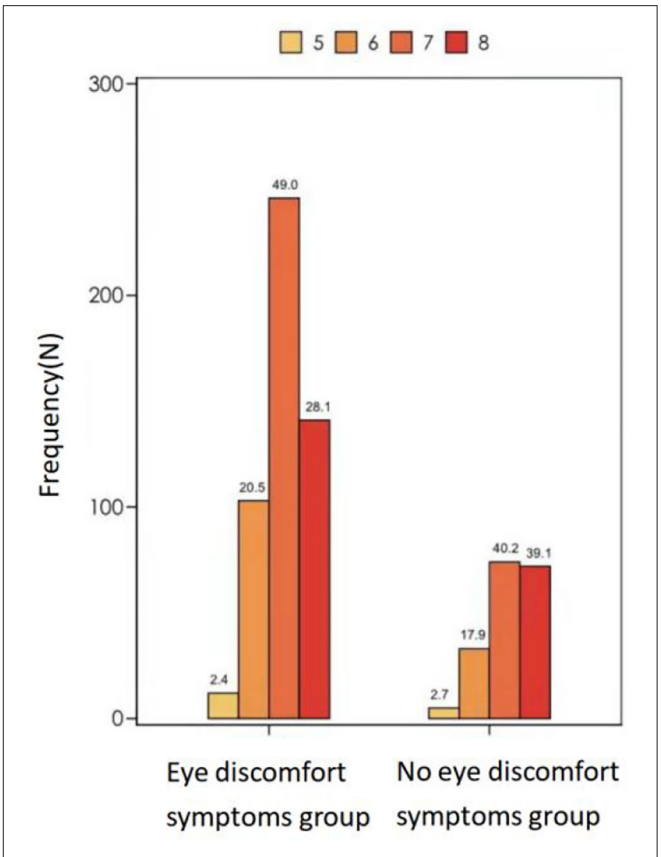

FIGURE 2 | Total sleep time, eye discomfort symptoms group vs. no eye discomfort symptoms group.

subjects of this paper were all from college students who had been studying in Kunming, a high-altitude area, for more than 1 year, while Zhongnan University is located in Hunan, China, a non-high-altitude area, which may lead to a higher prevalence of VDTs in the subjects of this paper due to the possible aggravation of dry eye symptoms at high altitude. The symptoms of VDTs, such as blurred vision and headaches, have significantly affected the quality of life and work of modern people, especially young people, and this has led to a significant increase in the number of patients seen for VDTs, making us sensitive to the fact that VDTs are a series of syndromes that cannot be ignored in our lives, that significantly affect the quality of life, and that may cause irreversible damage. Patients with these syndromes should be given more attention in our medical activities. In our medical activities, more attention should be paid to patients with such syndromes.

Influencing Factors of VDTs

The results of this questionnaire showed that total daily sleep duration as well as total daily VDT use were the influencing factors of VDTs. The severity of eye discomfort symptom was significantly negatively related to the increased total sleep duration and it was significantly positively related to the increased VDT use duration. This is consistent with the findings by Fjaervoll et al. (15) and others. They similarly concluded that prolonged VDT use and shortened sleep duration are closely related to the emergence of VDTs (16–18). Prolonged use of VDT is the cause of eye discomfort, which may include inappropriate operation methods, incorrect eye habits and so on. Most people may place the monitor high for comfort when using electronic products, which results in gazing at the screen with the line of sight facing upward, resulting in large exposure of the cornea to air and accelerated water evaporation, which to some extent affects the quality of the tear film, thus leading to a shorter tear film rupture time and causing ocular dryness and discomfort (3, 19). At the same time, due to long-term staring at the electronic screen, the significant reduction of blink rate and blink amplitude can likewise affect the tear film break-up time and the distribution of tear film, leading to the development of eye discomfort (20). This was investigated in a study by Cardona et al. (21) with a sample of 25 healthy young VDT users and found that a highly demanding visual task had an effect on flicker rate, flicker amplitude, and tear film integrity. The reason for the significant decrease in blink rate, on the other hand, may be due to the high level of concentration when operating

TABLE 4 | Ordinal logistic regression for related factors for the severity of eye discomfort symptoms.

Variables	Value	OR	SE	*t* value	*P*
Gender	0.318	1.374	0.216	1.469	0.142
Age	−0.015	0.985	0.023	−0.671	0.502
Surgery history	−0.333	0.716	0.479	−0.697	0.486
Contact lenses >2 h per day	−0.293	0.746	0.304	−0.963	0.336
Total sleep duration	−0.253	0.776	0.122	−2.069	**0.039**
Total VDT using duration	0.187	1.205	0.044	4.242	**<0.001**
Duration of each VDT use	0.046	1.047	0.078	0.594	0.553
Mild|Moderate	−0.366	0.693	1.262	−0.290	0.772
Moderate|Severe	2.406	11.085	1.273	1.890	0.059

The bold values indicate statistically significant values of p < 0.05.

electronic products, which produces excessive gaze, resulting in reduced lacrimal gland secretory capacity and uneven tear distribution, which can only be compensated by increasing blink frequency (22, 23).

Relationship Between VDTs and Duration of VDT Use, Eye Surgery, Wearing Contact Lenses, and Gender

The results of multivariate regression analysis in this paper showed that the duration of each VDT use, whether contact lenses were worn for more than 2 h, and gender were not sufficient to affect the occurrence of eye discomfort symptoms. This may be related to the possibility that long-term use of contact lenses may cause damage to the corneal nerve tissue, manifested in part as reduced sensitivity to discomfort symptoms. It has also been clearly reported in a study of Malcolm that the use of contact lenses decreases corneal sensitivity (24). In addition, the gender indicator may be affected by the uneven proportion of male and female students enrolled in medical schools. At the same time, the sex ratio of the observational study participants included in this paper is also unbalanced, so the sex in this paper is not included in the risk factor analysis of whether it is the risk factors for the disease of video terminal syndrome of medical students in high altitude areas.

As VDT gradually becomes an increasingly inseparable part of people's daily life, especially in the context of VDT users gradually tending to be younger, it is important to study the characteristics of the disease in the population used and the health hazards that may be complicated during use to ensure the healthy development of each of us. This investigation and analysis of VDT use and ocular symptoms of high-altitude regions in medical students has certain representativeness, which is helpful to understand the VDT exposure of contemporary college students and young people, so as to formulate reasonable prevention and control measures for this current situation and reduce or avoid property and health losses caused by incorrect use of VDT.

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 Ethics Committee of Human Research in The First People's Hospital Yunnan Province. Participants provided their verbal informed consent.

AUTHOR CONTRIBUTIONS

BL and ZC planned and designed the study. SJ, YW, ZL, and DZ contributed to data collection, data analysis, and data interpretation. BL played a leading role in writing the manuscript. ZC revised the manuscript. All authors read and approved the final manuscript.

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REFERENCES

1. Qu X, Chu R. Take high of the study of VDT related eye symptoms. *Chin J Ophthalmol.* (2005) 41:8–10. doi: 10.3760/j:issn:0412-4081.2005.11.002
2. Qu X, Chu R, Wang L, Yao P, Liu J. Effects of short-term VDT usage on visual functions. *Chin J Ophthalmol.* (2005) 41:31–4. doi: 10.3760/j:issn:0412-4081.2005.11.007
3. Blehm C, Vishnu S, Khattak A, Mitra S, Yee RW. Computer vision syndrome: a review. *Surv Ophthalmol.* (2005) 50:253–62. doi: 10.1016/j.survophthal.2005.02.008
4. Craig JP, Nichols KK, Akpek EK, Caffery B, Dua HS, Joo C-K, et al. TFOS DEWS II definition and classification report. *Ocul Surf.* (2017) 15:276–83. doi: 10.1016/j.jtos.2017.05.008
5. Clayton JA. Dry Eye. *N Engl J Med.* (2018) 378:2212–23. doi: 10.1056/NEJMra1407936
6. Thulasi P, Djalilian AR. Update in current diagnostics and therapeutics of dry eye disease. *Ophthalmology.* (2017) 124:S27–33. doi: 10.1016/j.ophtha.2017.07.022
7. Schein OD, Muñoz B, Tielsch JM, Bandeen-Roche K, West S. Prevalence of dry eye among the elderly. *Am J Ophthalmol.* (1997) 124:723–8. doi: 10.1016/S0002-9394(14)71688-5
8. Zhang M, Liu Y. Interpretation of dry eye examination in 2017 Dry Eye Expert Consensus of International Association of Tear Film and Eye Surface. *Chin J Ophthalmol.* (2018) 54:87–9. doi: 10.3760/cma.j.issn.0412-4081.2018.02.003
9. Satitpitakul V, Kheirkhah A, Crnej A, Hamrah P, Dana R. Determinants of ocular pain severity in patients with dry eye disease. *Am J Ophthalmol.* (2017) 179:198–204. doi: 10.1016/j.ajo.2017.05.009
10. Hyon JY, Yang HK, Han SB. Dry eye symptoms may have association with psychological stress in medical students. *Eye Contact Lens.* (2019) 45:310–4. doi: 10.1097/ICL.0000000000000567
11. Chinese Branch of Asian Dry Eye Association, Ocular Surface and Tear Disease Group of Ophthalmology Professional Committee of Cross-Strait Medical and Health Exchange Association, Dry Eye Group of Ophthalmologist Branch of Chinese Medical Doctor Association. Chinese expert consensus on dry eye: definition and classification 2020. *Chin J Ophthalmol.* (2020). 56:418–22. doi: 10.3760/cma.j.cn112142-20200316-00190
12. Hu J, Liu X. Adverse environmental factors and dry eye disease. *Chin J Ophthalmol Otorhinolaryngol.* (2017) 17:283–7. doi: 10.14166/j.issn.1671-2420.2017.04.016
13. Lu P, Chen X, Liu X, Yu L, Kang Y, Xie Q, et al. Dry eye syndrome in elderly Tibetans at high altitude: a population-based study in China. *Cornea.* (2008) 27:545–51. doi: 10.1097/ICO.0b013e318165b1b7
14. Ding L, Kai W, Wang L, Shang P, Zhou W. Prevalence of dry eye and its related factors among undergraduates in Central South University. *Pract Prev Med.* (2017) 24:1534–8. doi: 10.3969/j.issn.1006-3110.2017.12.037
15. Fjaervoll H, Fjaervoll K, Magno M, Moschowits E, Vehof J, Dartt DA, et al. The association between visual display terminal use and dry eye: a review. *Acta Ophthalmol.* (2021) 1–19. doi: 10.1111/aos.15049
16. Ahn JM, Lee SH, Rim THT, Park RJ, Yang HS, Kim TI, et al. Prevalence of and risk factors associated with dry eye: the Korea National Health and Nutrition Examination Survey 2010-2011. *Am J Ophthalmol.* (2014) 158:1205–1214.e7. doi: 10.1016/j.ajo.2014.08.021
17. Uchino M, Yokoi N, Uchino Y, Dogru M, Kawashima M, Komuro A, et al. Prevalence of dry eye disease and its risk factors in visual display terminal users: the Osaka study. *Am J Ophthalmol.* (2013) 156:759–66. doi: 10.1016/j.ajo.2013.05.040
18. Rosenfield M. Computer vision syndrome: a review of ocular causes and potential treatments. *Ophthalmic Physiol Opt.* (2011) 31:502–15. doi: 10.1111/j.1475-1313.2011.00834.x
19. Mowatt L, Gordon C, Santosh ABR, Jones T. Computer vision syndrome and ergonomic practices among undergraduate university students. *Int J Clin Pract.* (2018) 72:1–7. doi: 10.1111/ijcp.13035
20. Portello JK, Rosenfield M, Chu CA. Blink rate, incomplete blinks and computer vision syndrome. *Optom Vis Sci.* (2013) 90:482–7. doi: 10.1097/OPX.0b013e31828f09a7
21. Cardona G, García C, Serés C, Vilaseca M, Gispets J. Blink rate, blink amplitude, and tear film integrity during dynamic visual display terminal tasks. *Curr Eye Res.* (2011) 36:190–7. doi: 10.3109/02713683.2010.544442
22. Tsubota K. Tear dynamics and dry eye. *Prog Retin Eye Res.* (1998) 17:565–96. doi: 10.1016/S1350-9462(98)00004-4
23. Schlote T, Kadner G, Freudenthaler N. Marked reduction and distinct patterns of eye blinking in patients with moderately dry eyes during video display terminal use. *Graefes Arch Clin Exp Ophthalmol.* (2004) 242:306–12. doi: 10.1007/s00417-003-0845-z
24. Kates MM, Tuli S. Complications of contact lenses. *JAMA.* (2021) 325:1912. doi: 10.1001/jama.2020.20328

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Structural Equation Model Analysis of HIV/AIDS Knowledge, Attitude, and Sex Education Among Freshmen in Jiangsu, China

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Background: The study of acquired immunodeficiency syndrome (AIDS) related knowledge, attitude, and sex education status of Jiangsu freshmen was conducted, which can provide data support directionally for the prevention work of HIV/AIDS among this population.

Methods: Male students (4,006) and female students (4,279) were selected from 20 universities or colleges in the Jiangsu province. The knowledge, attitudes, and sex education of freshmen were conducted with an online questionnaire. The log-binomial regression model was used to analyze the influencing factors of HIV/AIDS knowledge. In addition, a structural equation model was used to analyze students' health needs that affect knowledge awareness and knowledge mastery.

Results: The overall awareness rate of AIDS knowledge was 87.4%. The students in undergraduate colleges (OR = 2.523, 95% CI=2.223∼2.864) and independent colleges (OR = 1.389, 95%CI = 1.172∼1.646) were more likely to have a higher awareness compared with the students in junior colleges. In this study, 2,011 freshmen approved of premarital behavior, 4,921 freshmen insisted on using condoms when having sex, and 8,138 freshmen were willing to take HIV antibody test when they suspected they were infected. In total, 4,703 freshmen believed that sexual health education was necessary for colleges and universities, and most of them (57.2%) hoped that sex education in schools should be improved. The direct effect of sex education on knowledge awareness and attitude is 0.15 and 0.58. The mediation effect test found that the pass ability knowledge path of sex education indirectly affected sexual attitudes (0.05).

Conclusion: The awareness rate of HIV/AIDS among Jiangsu freshmen has not reached the national standard. Health education has a significant positive effect on knowledge awareness and attitude; however, students' needs in terms of time, place, and degree of sex education have not been met in time. It is necessary to strengthen the HIV/AIDS health education of college students in multiple ways.

Keywords: acquired immunodeficiency syndrome (AIDS), human immunodeficiency viruses (HIV), structural equation model, knowledge attitude and sex education, freshmen

INTRODUCTION

As one of the vastest countries that contains a quarter of the world's population, China had faced various complex challenges in its fight against HIV/AIDS. The epidemic of HIV/AIDS in China mainly experienced three stages: sporadic cases (1985–1988), endemic outbreaks (1989–1994), and expansion phase (1995 to present). China has made remarkable achievements in HIV preventions and controls during the past three decades (1). The previous studies had indicated that higher risk existed among the young- and middle-aged populations, especially for the population who are aged between 30 and 40 years (2), MSM is the highest-risk group for HIV infection in the country (3), and people of lower socioeconomic status, unemployed populations, business workers, and rural labors are usually considered as the groups which had the highest opportunity be affected by HIV/AIDS frequently (4).

Despite substantial progress in understanding and treating HIV/AIDS (5), HIV remains a major global concern (6), HIV/AIDS has become one of the main causes of death among teenagers. Over 300 children and adolescents die every day from AIDS-related causes (7). Although China's HIV/AIDS epidemic remains low-prevalence level, the number of young students who are infected with HIV still keeps rising (8). From 2010 to 2019, China has reported a total of over 140,000 cases of HIV infection among young students between 15 and 24 years (9). In the corresponding years, the proportion of the total population of infected young students had increased from 8.5% in 2010 to 21.7% in 2019 (10), which shows HIV/AIDS prevention situation among young students is severe.

Recently, increased HIV infections among college students is one of primary challenges for the overall HIV prevention strategies in China (11). As an important educational center, Jiangsu province has a total of 168 higher education institutions and almost 2.25 million students, which ranking the first of all the Chinese provinces. Spatial analysis had shown geographic variations of HIV infection among young population in China, and the cumulative number of new HIV diagnoses among young students in Jiangsu province ranks in the top three in China from 2010 to 2019 (9). Although the Jiangsu government announced an implementation plan for preventing the spread of HIV/AIDS in the province (2019–2022) (12), there is still much space for improvement in the terms of adolescent HIV/AIDS prevention and health education (13). Meanwhile, due to the lack of self-motivation for prevention and treatment among the target population, departments of education and health require to work together in policy making for HIV prevention and care among college students on campus (14).

With the rapid development of social economic culture, young students tend to open sexual concepts gradually, and sexual behaviors become pervasive. They are likely to be imitation and conformity (15). However, inadequate sexual knowledge and some risky sexual behaviors (i.e., reduced use of the condom, especially with casual partners, and sexual intercourse with unknown persons) are quite diffused among young people (15).

There is good evidence from many countries that comprehensive sex education programs lead to safer sexual behaviors. However, the implementation of sex education in China is still inadequate (16). In light of the increased prevalence of HIV/AIDS among young students, preventive education is an integral and basic part of an effective and comprehensive combination HIV prevention program. Hence, effective knowledge and education programs should be mainstreamed across universities and schools to prevent new HIV infections (17).

Empirical evidence suggests mixed reports regarding the level of HIV/AIDS knowledge, attitude, and practice among university students (18), previous studies on students' HIV/AIDS knowledge, attitudes, and behaviors among undergraduates university and college students (19–21), and few studies have conducted HIV-/AIDS-related KAP survey among the freshmen. The purpose of this study is to understand the knowledge, attitudes, and sex education of freshmen from the Jiangsu colleges and universities, we also analyzed factors affecting the overall awareness rate of knowledge about HIV/AIDS and explore the relationship between sex knowledge, attitudes, and education. To our knowledge, this is the first study in a province-wide survey of a large sample, helping to provide a theoretical basis for the further development of HIV/AIDS prevention among college and university students.

METHODS

Ethics Approval and Consent to Participate

This study was reviewed and approved by the Human Research Ethics Committee of the Zhongda Hospital affiliated to the Southeast University, China (approval ID: 2017ZDKYSB045). All the participating subjects received written detailed information on the study, and signed consent forms for the interview and the processing of sensitive personal data, if the participants were younger than 18 years, parental informed consent was obtained. The procedure of the study was performed following the guidelines outlined in the Declaration of Helsinki.

Participants

Freshmen who come from the class of 2020 are incorporated as the research objects. In total, 20 universities and colleges in the Jiangsu Province are randomly selected through stratified clusters (including three independent colleges, 12 undergraduate universities, and five technical colleges). Second, 10–13 classes were selected randomly from the freshman of each university. Finally, 16–18 male and female students of the Jiangsu domicile were randomly selected from each class as the research object. A total of 8,580 students were selected and 8,285 valid questionnaires were collected. The effective rate is 96.6%.

Data Collection

A self-made structural questionnaire was applied, and the content of the survey include: (1) basic demographic characteristics, including age, gender, school, region, parental education, family income, living style, etc.; (2) AIDS-related knowledge, which was designed refer to 8 basic AIDS prevention knowledge of young students in China. Awareness is judged by answering 6 or more questions

TABLE 1 | Single factor analysis of the overall awareness rate of AIDS knowledge among freshmen with different demographic characteristics.

Demographic indicators	Number of awareness *n*(%)	χ^2 Value	*P*-Value
Gender		4.291	0.038
Male($n = 4006$)	3532(88.2)		
Female($n = 4279$)	3708(86.7)		
School		265.579	<0.001
Junior college($n = 1850$)	1416(76.5)		
Undergraduate college($n = 5130$)	4679(91.2)		
Independent college($n = 1305$)	1145(87.7)		
Region		7.315	0.026
Southern Jiangsu($n = 3102$)	2750(88.7)		
Central Jiangsu($n = 1931$)	1669(86.4)		
Northern Jiangsu($n = 3252$)	2921(87.4)		
Only child		24.593	<0.001
Yes($n = 5005$)	4447(88.9)		
No($n = 3280$)	2793(85.2)		
Father's education level		38.796	<0.001
Junior high and below($n = 3543$)	3013(85.0)		
High school($n = 2362$)	2078(88.0)		
College/undergraduate or above($n = 2380$)	2149(90.3)		
Mother's education level		53.554	<0.001
Junior high and below($n = 4176$)	3554(85.1)		
High school($n = 2331$)	2082(89.3)		
College/University and above($n = 1778$)	1604(90.2)		
Family monthly income		27.268	<0.001
<1000($n = 205$)	175(85.4)		
1000∼3000($n = 871$)	740(85.0)		
≥3000($n = 7209$)	1681(85.0)		
Living style		21.336	0.001
Live with parents($n = 4308$)	3828(88.9)		
Others($n = 3977$)	144(82.3)		

correctly; (3) AIDS-related sexual attitudes, including sexual behaviors and sexual education; (4) current status of AIDS health education.

Quality Control

Producing standardized electronic questionnaires, and conducting online surveys through the health data management system for freshmen in the universities of Jiangsu Province. Professionals from the health departments of various universities served as quality controllers. They were uniformly trained before the survey, the training that required them to clarify survey requirements, be familiar with the process, and stress the standard of an effective questionnaire which should include complete demographic data, no outliers, and less than four missing items of principal part. During the survey, the respondents were gathered by counselors in a computer lab, and filled out an online questionnaire anonymously.

Statistical Analysis

The SPSS 22.0 statistical software (SPSS Inc. Chicago IL, USA, 2013) was used for data analysis, chi-square test was used for rate comparison. In cross-sectional studies, when the incidence of outcome is high (e.g., >10%), the correlation strength between outcome and factors may be overestimated if logistic regression model is used to calculate odds ratio (odds ratio, OR). In this case, log-binomial regression model should be used to calculate the prevalence ratio (prevalence ratio, PR) and carry out multivariate analysis with the test level of 0.05. The structural equation model was constructed by the SPSS AMOS 25.0 software.

RESULTS

Basic Demographic Information

Among 8,285 survey subjects, 4,006 were men (48.4%). The age distribution ranged from 15 to 25 years old, more than 65% of the participants were 18 years old or younger. There are 1,850 (22.3%) from the technical colleges, 5,130 (61.9%) from undergraduate universities, and 1,305 (15.8%) from independent colleges. According to the geographical location of the cities under the jurisdiction of the Jiangsu Province, this study divides the Jiangsu Province into Southern Jiangsu (Nanjing, Zhenjiang, Changzhou, Wuxi, Suzhou), Central Jiangsu (Nantong, Taizhou, Yangzhou), and Northern Jiangsu (Yancheng, Huai'an, Lianyungang, Xuzhou and Suqian), among all the participants, 3,102 (37.4%) are from South Jiangsu, 1,931 (23.3%) are from Central Jiangsu, and 3,252 (39.3%) are from North Jiangsu.

Awareness of Sexual Knowledge Among Freshman Students

In the total eight questions, "After high-risk behaviors (sharing needles, drug use, unsafe sex, etc.), should actively seek HIV testing and counseling" has the highest awareness rate, which is 98.0%; "At present, whether the main mode of transmission of AIDS among young students in our country is male homosexual behavior, followed by heterosexual behavior" has the lowest awareness rate, which is 60.9%. The total awareness rate of AIDS knowledge among 8,285 participants is 87.4%. There are statistically significant differences about the awareness rate of AIDS knowledge among different genders, schools, regions, whether they are or not only child, parent education level,

TABLE 2 | Log-binomial regression analysis of total awareness rate of AIDS knowledge among freshmen.

Independent variable	β Value	Standard value	95%*Wald* Confidence interval	Hypothetical test			Exp(β)	95%Exp(β)*Wald* Confidence interval
				Wald χ^2 Value	df	P Value		
School								
Junior college	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Undergraduate college	0.925	0.065	(0.799∼1.052)	205.198	1	<0.001	2.523	(2.223∼2.864)
Independent college	0.329	0.087	(0.159∼0.498)	14.395	1	<0.001	1.389	(1.172∼1.646)

family monthly income, and residence style ($P < 0.05$), see **Table 1**. By adopting AIDS knowledge awareness rate (know = 1, do not know = 0) as a dependent variable, and the aforementioned statistically significant ($P < 0.05$) factors as independent variables, a log-binomial regression model was constructed. The results show that the overall awareness rate of AIDS among freshmen of undergraduate universities is higher than that of junior colleges (OR = 2.523, 95% CI=2.223∼2.864), and independent colleges are higher than junior colleges as well (OR = 1.389, 95%CI = 1.172 ∼1.646); see **Table 2.**

Freshman Sexual Attitudes

Attitudes About Sexual Behaviors

Among 8,285 survey respondents, 2,011 (24.2%) students are in favor of premarital sex, and 4,921 (59.4%) are willing to insist on using condoms during sexual behaviors, 8,138 (98.2%) students are willing to be tested for HIV antibodies when they suspect they are infected. The aforementioned sexual attitudes have statistically significant differences in gender, school, and family monthly income/person (all $P < 0.05$). According to chi-square segmentation pairwise comparison, students who come from the undergraduates' college are more likely in favor of premarital sex than junior college students, students who come from the Southern Jiangsu areas are more likely in favor of premarital sex than students come from the Northern Jiangsu areas. Compared with junior college students, undergraduate college students are more willing to insist on using condoms and taking HIV antibody test if they suspect they had been infected. Students who come from the Southern Jiangsu areas are more willing to insist on using condoms and taking HIV antibody tests if they suspect they had been infected (all *P*-values<0.05). The results of the rest pairwise comparison is shown in **Table 3.**

Attitudes of Sexual Education Development

Among the 8,285 survey participants, 3,441 (41.5%) freshmen believe that the reasonable time to conduct sexual health education is during junior high school, 4,703 (56.8%) freshmen believe that colleges and universities must carry out sexual health education, and most of them (57.2%) hope that the intensity of sex education in schools should be improved. In addition, 2,238 (27.0%) freshmen believe that school should conduct sex education in multiple ways by offering special, elective courses and additional lectures, increasing activity promotions, distributing brochures or other methods; 1,391 (16.8%) freshmen believe that in addition to publicizing AIDS prevention knowledge, it is necessary to comprehensively add sexual physiology and psychology knowledge, sexual ethics and sexual crimes knowledge, heterosexual and contraceptive knowledge, and how to avoid being sexually assaulted relevant knowledge.

Sex Education Status of Freshmen

Among 8,285 survey participants, 3,092 (37.3%), 2,881 (34.8%), and 2,301 (27.8%) freshmen indicated that they just received general sexual education from school and parents. Nearly half (49.9%) of the freshmen believe that they have only received sexual education at the general level; see **Figure 1.**

The Relationship Between Sex Knowledge, Attitudes, and Education

Taking sex knowledge, attitude, and education as latent variables, through exploratory factor analysis, the observation variables in **Table 4** are incorporated to construct a structural equation model. The Cronbach's α coefficient of this model is 0.696, the KMO value is 0.708, the approximate chi-square value of the Bartlett sphericity test is 17,649.686, the df is 78, and the *P*-value is <0.001.

According to the value of the revised index MI, the model has proceeded with the second correction, and the paths are increased one by one: e9⇔e10, e10⇔e11. The Root Mean Square Error of Approximation (RMSEA) of the corrected model is 0.059 (<0.080), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), Incremental Fit Index (IFI), Comparative Fit Index (CFI) is 0.968, 0.951, 0.901, and 0.901 (both>0.900), which matches the requirements of model testing and goodness-of-fit. It shows that the overall fitting effect of the model is acceptable. Path analysis of the model shows that sex education has a significant positive effect on sex knowledge and attitudes, of which the direct effect value is 0.15, and 0.58, respectively. By using the Bootstrap method to test the intermediary effect, it is found that sexual education can indirectly affect sexual attitudes through the sexual knowledge path, and the indirect effect value is 0.05, 95% CI = 0.04∼0.07, P<0.001, which could prove intermediary effect is significant. See **Table 5** and **Figure 2.**

DISCUSSION

This study found that the awareness rate of AIDS knowledge among freshmen of Jiangsu who came from the class of 2020

TABLE 3 | Different demographic characteristics of freshmen attitudes about sexual behaviors.

Items	Accept premarital sex			Insist on using condom during sexual behaviors			Willing to do HIV antibody test		
	Constituent ratio *n*(%)	χ^2 value	*P* value	Constituent ratio *n*(%)	χ^2 value	*P*-value	Constituent ratio *n*(%)	χ^2 value	*P*-value
Gender		499.009	<0.001		491.891	<0.001		30.058	<0.001
Male	1408(35.1)			1884(47.0)			3902(97.4)		
Female	603(14.1)			3037(71.0)			4236(99.0)		
School		6.900	0.032		63.001	<0.001		13.588	0.001
Junior college	411(22.2)			971(52.5)			1802(97.4)		
Undergraduate college	1292(25.2)[a]			5060(98.6)[a]			3212(62.6)[a]		
Independed college	308(23.6)			738(56.6)			1276(97.8)		
Region		12.674	0.002		48.592	<0.001		1.724	0.422
Northern Jiangsu	738(22.7)			1809(55.6)			3202(98.5)		
Central Jiangsu	454(23.5)			1124(58.2)			1894(98.1)		
Southern Jiangsu	819(26.4)[c]			3042(98.1)			1988(64.1)[bc]		
Family monthly income		6.642	0.036		10.418	0.005		11.662	0.003
<1000	48(23.4)			110(53.7)			195(95.1)		
1000∼3000	181(20.8)			481(55.2)			857(98.4)[d]		
≥3000	1782(24.7)[f]			4330(60.1)[f]			7086(98.3)[e]		
Living style		6.145	0.013		33.470	<0.001		0.328	0.567
Living with parents	1094(25.4)			2688(62.4)			4235(98.3)		
Others	917(23.1)			2233(56.1)			3903(98.1)		

By pairwise comparison of chi-square method, "a" means P < 0.01 when junior college compares to undergraduate college; "b" means P < 0.01 by comparing southern Jiangsu areas to central Jiangsu areas, "c" means P < 0.01 by comparing southern Jiangsu to northern Jiangsu; "d" means P < 0.01 by comparing family monthly income of 1000—3000 RMB with income of 1000 RMB or less, "e" means family monthly income of 1000 yuan or less compared with 3000 yuan or more, P < 0.01, "f" means P < 0.01 by comparing family monthly income of 1000—3000 RMB with income of 3000 RMB or more.

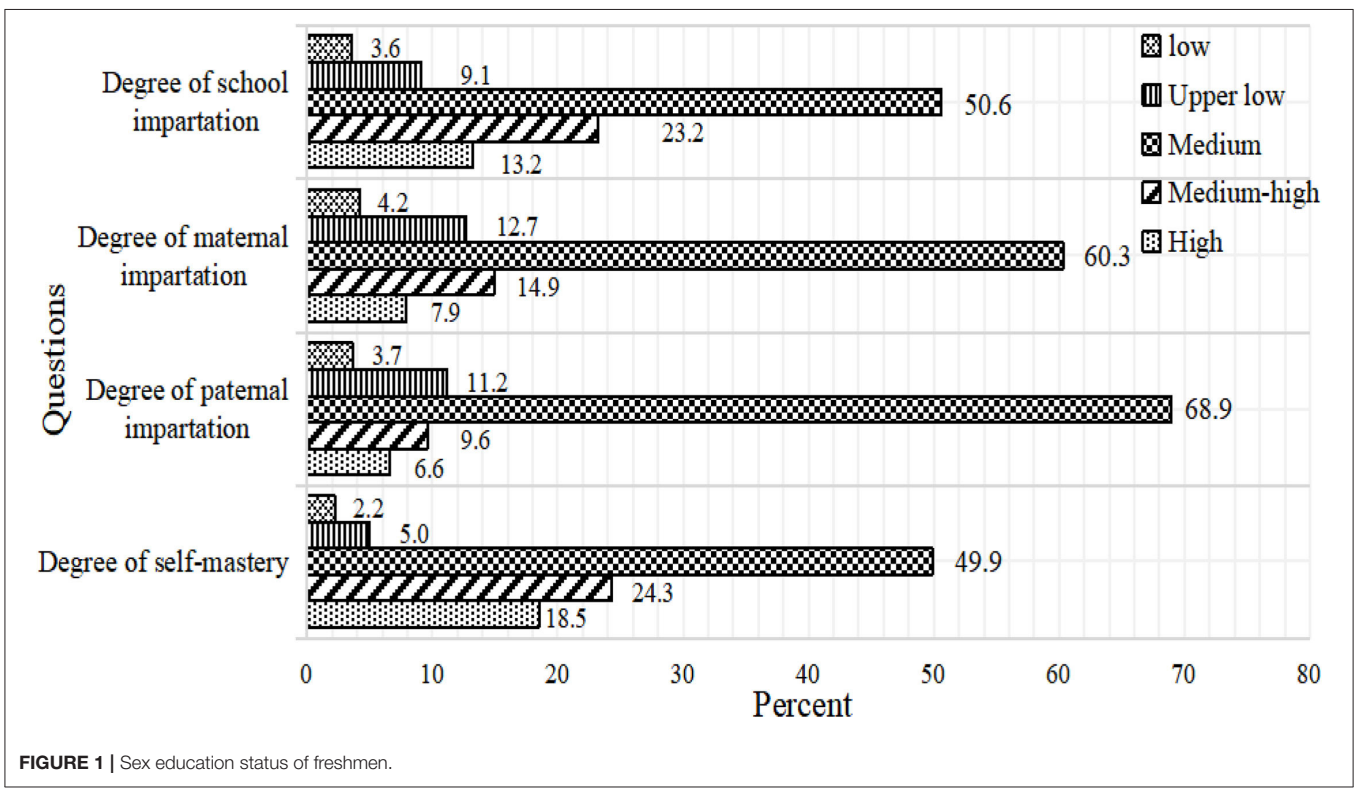

FIGURE 1 | Sex education status of freshmen.

TABLE 4 | Latent variable and observational variable.

Latent variable	Observational Variable
Sexual education	Q1 What do you think the level of sexual education that your school taught you
	Q2 What do you think about the level of sex education you have received
	Q3 What do you think the level of sexual education that your father taught you
	Q4 What do you think the level of sexual education that your mother taught you
Sexual knowledge	Q5 Can insist on using condoms correctly reduce the risk of infect and spread HIV?
	Q6 Does the use of new-type drugs increase the risk of AIDS?
	Q7 Should we actively look for HIV testing and counseling after high-risk behaviors?
	Q8 Are the rights of HIV-infected patients in marriage, employment and school enrollment protected by the laws of our country?
Sexual attitude	Q9 Is it necessary to carry out sexual and reproductive health education in high school?
	Q10 Is it necessary for colleges and universities to carry out sexual and reproductive health education?
	Q11 Do you think the sexual and reproductive health education in your high school needs to be further improved?
	Q12 Are you willing to use condoms when you have sex with your partner?
	Q13 If you suspect that have been infected HIV, will you go for an antibody test immediately?

TABLE 5 | Model results of each path.

Paths	Coefficient	Standardized coefficients	S.E.	C.R.	*P*-value
Sexual knowledge <- Sexual education	0.07	0.15	0.01	9.10	<0.001
Sexual attitude <- Sexual education	0.35	0.58	0.02	23.26	<0.001
Sexual attitude <- Sexual knowledge	0.46	0.35	0.04	13.34	<0.001
Q1 <– Sexual education	1.00	0.56	–	–	–
Q2 <– Sexual education	0.47	0.36	0.02	27.55	<0.001
Q3 <– Sexual education	1.48	0.80	0.03	48.07	–
Q4 <– Sexual education	1.54	0.85	0.03	48.01	<0.001
Q8 <– Sexual knowledge	1.00	0.48	–	–	–
Q5 <– Sexual knowledge	0.05	0.08	0.01	5.76	<0.001
Q6 <– Sexual knowledge	0.91	0.57	0.04	24.61	<0.001
Q7 <– Sexual knowledge	0.50	0.60	0.02	24.33	<0.001
Q9 <– Sexual attitude	1.00	0.47	–	–	–
Q10 <– Sexual attitude	0.48	0.31	0.03	16.43	<0.001
Q11 <– Sexual attitude	0.60	0.37	0.03	48.07	<0.001
Q12<– Sexual attitude	0.27	0.23	0.02	13.82	<0.001
Q13<– Sexual attitude	0.05	0.16	0.01	10.15	<0.001

is 87.4%, which is lower than that of Shanghai (92.1%) (22), Wenzhou (96.38%) (23), Nanning (96.78%) (24), and other regions (25). The result shows the awareness rate of prevention and control knowledge for young- and middle-aged students has not reached the requirement yet, which is 90% or more than "China's 13th Five-Year Plan for Containment and Prevention of AIDS" indicates. Our study revealed that significant number of freshmen have poor knowledge regarding HIV. This suggests that the current HIV/AIDS-related health education in middle school, high school, and the entrance section of university need to be further strengthened. This can help boost the level of HIV/AIDS knowledge as well as increase HIV testing and skills for HIV prevention (26).

"At present, the prevalence of AIDS among young students in our country is showing a rapid growth trend. The main mode of transmission is homosexuality, followed by heterosexuality" has the lowest awareness rate among eight topics, only 60.9%, and that is consistent with some published reports in China (27, 28). It reminds that students' understanding of the current epidemic trend and transmission routes of AIDS is still on the surface, and it is necessary to focus on adjusting and improving the direction of AIDS knowledge publicity by increasing the strength and depth of publicity and education for weak parts. As game-based learning and gamification were used to improve the sexual health education of adolescent students (29). The results of log-binomial regression analysis which affects the awareness rate of AIDS suggest undergraduate college students are better than junior colleges and independent colleges. This reflects the factors such as students' cultural literacy, sexual education investment, and attention in school have a positive significance in prevention of AIDS. In this study, the awareness rate of AIDS did not differ by gender, schools, whether they are or not only child, parent education level, family monthly income, and residence style, this finding conflicts with some earlier researches (30, 31). Future studies may wish to assess a wider range of influence factors to better understand which affects the awareness rate of AIDS.

Previous studies have found positive correlations between HIV attitude and behavior (32). However, in the current study, the participants in this survey are university and college freshmen who have a relatively conservative attitude toward premarital sex, the percentage of respondents who are willing to insist on using condoms during sex is relatively low (59.1%). People with a longer duration of premarital sex had higher odds of HIV and other STIs and were more likely to report multiple sexual partners (33). It prompts the urgent need to increase the awareness of self-protection among freshmen by popularizing AIDS-related protective measures.

Compared with women, men are more likely to have more permissive perceptions about sex (34). Our previous study

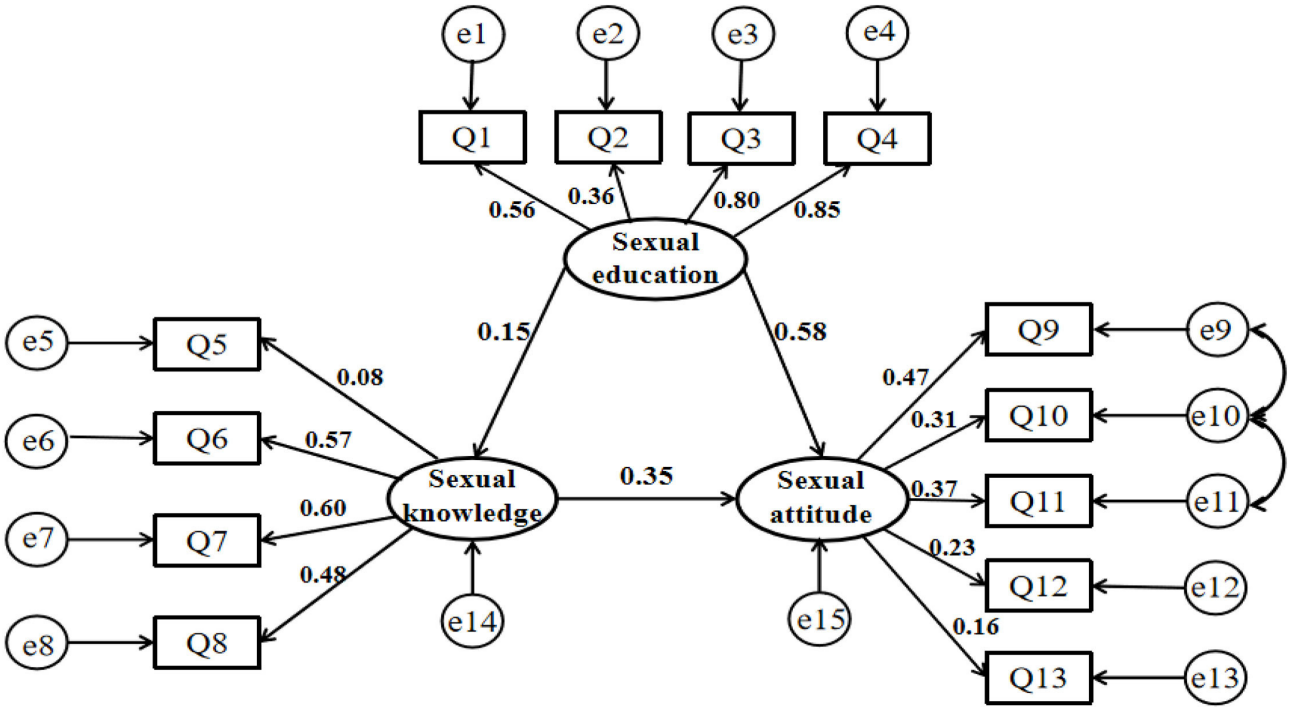

FIGURE 2 | Diagram of structural equation model.

demonstrated that only 62.5 and 66.3% of HIV-positive college male students who used condoms consistently during sexual intercourse with regular and casual partners, respectively (35). Meanwhile, the willingness of HIV antibody testing among male students if they suspect that they have been infected with HIV was lower than women (36). These findings are supported by the previous studies (13, 37), this may be because of the openness of men's sexual viewpoints. HIV education services in the Chinese colleges and universities should be designed and provided comprehensively taking into consideration the needs of male undergraduates (38).

Although undergraduate students are more likely to have premarital sex compared with the junior colleges, students who come from the Southern Jiangsu are more likely to have premarital sex than middle and Northern Jiangsu's students as well, all of them are more willing to insist on using condoms and taking HIV antibody testing when having sex. This finding shows that there are big differences in the effects of sexual education between schools and regions. The imbalances in the cultivation and guidance of ideas, education services, information resources, and economic development among schools or regions should be fully considered, and should appropriately increase investment in educational resources of junior colleges and Northern Jiangsu regions.

Some researchers have pointed out that to reduce the risk of infection among young students, the most important thing is to promote comprehensive sexual education (39). The structural equation model shows that sexual education can directly have a significant positive effect on sexual knowledge (0.15) and sexual attitudes (0.53). It can also indirectly influence sexual attitudes (0.05) through the sexual knowledge pathway. However, the survey shows that more than half of the students believe that the main responsible body for reproductive and sexual health education are parents and schools, and the level of sexual education obtained from parents and schools is just the modest and nearly half of students believe that their level of sexual education is far from enough. It shows the students' needs about the duration, place, and degree of sexual education have not been satisfied in time. This not only reveals the importance and urgency of carrying out sexual education, but also reminds us when we carry out AIDS health education, we should focus on combining the function of individuals, families, and schools to make their respective advantages to jointly promote prevention work. It recommends that the duration of sexual education should be moved forward, not just slogans. Colleges and universities can organize lectures for the parent by offering sexual health education for parents first, and parents should be guided on how to conduct sexual health education for their children in the family. Meanwhile, increasing channels for students to understand HIV/AIDS-related knowledge, such as opening professional lecture and elective courses, making full use of new media network platforms (40), conducting knowledge competitions, expert interviews, and other activities to meet the needs of students in all aspects of sexual education, grasp relevant knowledge in time and ultimately guide young adults to develop positive sexual attitudes and healthy sexual behaviors.

Proceeding a survey about the status of sexual education for universities and colleges, freshmen can objectively understand

the level of sexual education that high school graduates received and the situation of sexual education at the middle school stage. According to that, correct direction for effective sexual education at the university stage can be provided, and it plays a forward role in epidemic prevention and control. Many pieces of national policy of school-based health education programs on HIV/AIDS have been advocated for a long time in China (30). HIV/AIDS education was found effective in promoting positive behavior change related to HIV/AIDS prevention (41), while policy's ability to structure implementation was at a moderate level (42). In summary, the work of HIV/AIDS health education for university and college students in the Jiangsu Province needs to be strengthened. It is necessary to develop school-based culturally relevant comprehensive sexual health education programs according to various characteristics of freshmen (43). By focusing on strengthening popularization of HIV/AIDS epidemic situation and self-protection measures, establishing a personal–family–school–social relationship combining prevention and control mechanisms to effectively train university and college students' ability in the HIV/AIDS prevention field.

CONCLUSION

The awareness rate of HIV/AIDS among the Jiangsu freshmen has not reached the national standard. Health education has a significant positive effect on knowledge awareness and attitude; however, the students' needs in terms of time, place, and degree of sex education have not been met in time. It is necessary to develop school-based culturally relevant comprehensive sexual health education programs according to various characteristics of freshmen.

Strengths and Limitations of This Study

The number of young students infected with HIV is still rising in China, and HIV/AIDS has become one of the leading causes of death among young people. Therefore, we chose the student population as the research object. From a regional perspective, the Jiangsu province, with its rapid economic development, convenient information exchange, frequent population mobility, and active employment in other places has created conditions for the spread of HIV. It is also an important hot spot for young people infected with HIV. The large sample size across the various cities presents us with an opportunity to determine disparities in prevalence within a province. From the perspective of methodology, the log-binomial method is reasonably used in our study, which is different from the logistic regression method used in most studies in terms of multi-impact factor analysis. For the first time, we use the structural equation model to better understand the students' health needs that affect knowledge awareness and knowledge mastery. Finally, in the terms of research significance, our study focuses on the relationship between sex education and knowledge and attitude, which is different from the common research purpose of knowledge, belief, and behavior. There are several limitations to our study. At first, the information was collected using a self-administered questionnaire. Second, the honesty and the seriousness of the respondents to the questions are difficult to access and validate. Third, we did not investigate the education level of students in high school, but we believe that the region of students can reflect the education level of their high school, Southern Jiangsu, central Jiangsu, and northern Jiangsu represents three levels of education high, medium, and low, respectively. Lastly, we did not investigate the regional origin (urban and rural), sexual orientation of the respondents, the bias may occur in the results.

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 this study was reviewed and approved by the Human Research Ethics Committee of the Zhongda hospital affiliated Southeast University, China (approval ID: 2017ZDKYSB045). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

FT: methodology, software, formal analysis, and writing. RY: conceptualization, project administration, and writing. RL: data curation. GD: writing. YL: methodology. WL and PW: conceptualization, supervision, and writing. All authors contributed to the article and approved the submitted version.

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REFERENCES

1. Xu JJ, Han MJ, Jiang YJ, Ding HB Li X, Han XX, et al. Prevention and control of HIV/AIDS in China: lessons from the past three decades. *Chin Med J.* (2021) 134:2799–809. doi: 10.1097/CM9.0000000000001842
2. Qiao YC, Xu Y, Jiang DX, Wang X, Wang F, Yang J, et al. Epidemiological analyses of regional and age differences of HIV/AIDS prevalence in China, 2004-2016. *Int J Infect Dis.* (2019) 81:215–20. doi: 10.1016/j.ijid.2019.02.016
3. Ding Y, Ma Z, He J, Xu X, Qiao S, Xu L, et al. Evolving HIV epidemiology in mainland China: 2009-2018. *Curr HIV/AIDS Rep.* (2019) 16:423–30. doi: 10.1007/s11904-019-00468-z

4. Xu Y, Yang G, Liu H, Li X, Song L, Li Y, et al. Epidemiologic features of AIDS in China, 2004-2013. *Clin Infect Dis.* (2015) 60:167–9. doi: 10.1093/cid/ciu753
5. Bekker L-G, Tatoud R, Dabis F, Feinberg M, Kaleebu P, Marovich M, et al. The complex challenges of HIV vaccine development require renewed and expanded global commitment. *Lancet.* (2020) 395:384–8. doi: 10.1016/S0140-6736(19)32682-0
6. Ghosn J, Taiwo B, Seedat S, Autran B, Katlama C. Hiv. *Lancet.* (2018) 392:685–97. doi: 10.1016/S0140-6736(18)31311-4
7. UNICEF. *Over 300 Children and Adolescents Die Every Day From Aids-Related Causes.* (2019). Available online at: https://www.unicef.org/press-releases/over-300-children-and-adolescents-die-every-day-aids-related-causes
8. Wu Z, Chen J, Scott SR, McGoogan JM. History of the HIV Epidemic in China. *Curr HIV/AIDS Rep.* (2019) 16:458–66. doi: 10.1007/s11904-019-00471-4
9. Cai C, Tang H, Chen F, Li D, Lv F. Characteristics and trends of newly reported HIV infection in young students in China, 2010-2019. *Chin J Epidemiol.* (2020) 41:1455–9.
10. Chuai Z, Zhang Y, Zhao Y, Yan J, Sun Z, Wang Y, et al. Latest AIDS epidemic in global and China. *J Infect Dis.* (2020) 33:501–3.
11. Chen W, Yang J, Jiang J, He L, Xu Y, Zheng J, et al. A spatial analysis of the epidemiology of HIV-infected students in Zhejiang province, China. *BMC Infect Dis.* (2021) 21:43012. doi: 10.1186/s12879-021-06033-7
12. Jiangsu Comission Health. *Notice on Printing and Distributing the "Implementation Plan for Preventing the Spread of AIDS in Jiangsu Province (2019-2022)" (Su Health Disease Control* [2019] No. 53). (2020). Available online at: http://wjw.jiangsu.gov.cn/art/2020/1/3/art_7312_8900191.html. Chinese
13. Ruan L, Zhao R, Ong JJ, Fu X, Xiong Y, Chen Y, et al. A national survey of HIV knowledge, sexual practices and attitude towards homosexuality for HIV elimination among young people in China. *Sex Health.* (2021) 18:64–76. doi: 10.1071/SH20122
14. Li G, Jiang Y, Zhang L, HIV. upsurge in China's students. *Science.* (2019) 364:711. doi: 10.1126/science.aay0799
15. Caltabiano M, Castiglioni M, De-Rose A. Changes in the sexual behaviour of young people: introduction. *Genus.* (2020) 76:38. doi: 10.1186/s41118-020-00107-1
16. Lyu J, Shen X, Hesketh T. Sexual Knowledge, Attitudes and Behaviours among Undergraduate Students in China-Implications for Sex Education. *Int J Environ Res Public Health*. (2020) 17:6716. doi: 10.3390/ijerph17186716
17. Haroun D, El Saleh O, Wood L, Mechli R, Al Marzouqi N, Anouti S. Assessing knowledge of, and attitudes to, HIV/AIDS among University Students in the United Arab Emirates. *PLoS ONE.* (2016) 11:e0149920. doi: 10.1371/journal.pone.0149920
18. Gemeda TT, Gandile AU, Bikamo DS. HIV/AIDS Knowledge, attitude and practice among Dilla University students, Ethiopia. *Afr J Reprod Health.* (2017) 21:49–61. doi: 10.29063/ajrh2017/v21i3.4
19. Sallam M, Alabbadi AM, Abdel-Razeq S, Battah K, Malkawi L, Al-Abbadi MA, et al. HIV knowledge and stigmatizing attitude towards people living with HIV/AIDS among medical students in Jordan. *Int J Environ Res Public Health.* (2022) 19:745. doi: 10.3390/ijerph19020745
20. Jin CX, Meng YC, Du WZ, Pei DD Li A. Knowledge of infection prevention and attitudes towards HIV/AIDS among Chinese dental bachelor interns: an appeal for educational intervention. *Oral Health Prev Dent.* (2020) 18:485–92. doi: 10.3290/j.ohpd.a44686
21. Tesfaye Y, Agenagnew L. Knowledge, attitude, and practices of jimma teacher training college students toward risky sexual behaviors, Jimma, Ethiopia. *Sex Med.* (2020) 8:554–64. doi: 10.1016/j.esxm.2020.04.006
22. Liu J, Yang H, Pan X, Gu C, Qian J, Guo X, et al. Results of AIDS sentinel surveillance of young students in Songjiang district of Shanghai, 2011-2015. *Chin J AIDS STD.* (2019) 25:1067–10701 + 084. doi: 10.13419/j.cnki.aids.2019.10.21
23. Wang D, Zhao S, Ye Z, Zhao L, Zhang H, Su D, et al. Results of sentinel surveillance on HIV/AIDS among young students in Wenzhou from 2010 to 2018. *Pre Med.* (2021) 33:165–7. doi: 10.19485/j.cnki.issn2096-5087.2021.02.014
24. Lin Q, Nong Q, Li S, Ceng P, Chen S, Nong L. The Analysis of AIDS Sentinel Surveillance Among Students in Nanning from 2011 to 2015. *Chin J Derm Venereol.* (2018) 32:795–8. doi: 10.13735/j.cjdv.1001-7089.201711018
25. Luo Y, Zhao G, Li X, Jin J, Wu H, Zhang X, et al. AIDS knowledge,attitudes and practices among freshmen of a university in Hangzhou. *J Prev Med.* (2019) 31:673–7. doi: 10.19485/j.cnki.issn2096-5087.2019.07.007
26. Kingori C, Nkansah MA, Haile Z, Darlington KA, Basta T. Factors associated with HIV related stigma among college students in the Midwest. *AIMS Public Health.* (2017) 4:347–63. doi: 10.3934/publichealth.2017.4.347
27. Wang J, Chen Q, Han M. Survey on AIDS knowledge awareness of male college students in 7 universities in China. *Chin J AIDS & STD.* (2020) 26:493–5. doi: 10.13419/j.cnki.aids.2020.05.10
28. Liu T, Wang G, Zhang X, Mu Y, Xing Y, Kan Z, et al. Survey on sexual behavior characteristics and AIDS knowledge among male college students in Fangshan District, Beijing. *Chin J of AIDS & STD.* (2019) 25:516–5175 + 23. doi: 10.13419/j.cnki.aids.2019.05.22
29. Haruna H, Hu X, Chu SKW, Mellecker RR, Gabriel G, Ndekao PS. Improving sexual health education programs for adolescent students through game-based learning and gamification. *Int J Environ Res Public Health*. (2018) 15:2027. doi: 10.3390/ijerph15092027
30. Liu Y, Lu L, Wang YY, Wilkinson MR, Ren YM, Wang CC, et al. Effects of health education on HIV/AIDS related knowledge among first year university students in China. *Afr Health Sci.* (2020) 20:1582–90. doi: 10.4314/ahs.v20i4.10
31. Zhang L, Yu H, Luo H, Rong W, Meng X, Du X, et al. HIV/AIDS-related knowledge and attitudes among Chinese college students and associated factors: a cross-sectional study. *Front Public Health.* (2021) 9:804626. doi: 10.3389/fpubh.2021.804626
32. Youssef L, Hallit S, Sacre H, Salameh P, Cherfan M, Akel M, et al. Knowledge, attitudes and practices towards people living with HIV/AIDS in Lebanon. *PLoS ONE.* (2021) 16:e0249025. doi: 10.1371/journal.pone.0249025
33. Ghebremichael MS, Finkelman MD. The effect of premarital sex on sexually transmitted infections (STIs) and high risk behaviors in women. *J AIDS HIV Res.* (2013) 5:59–64.
34. Zuo X, Lou C, Gao E, Cheng Y, Niu H, Zabin LS. Gender differences in adolescent premarital sexual permissiveness in three Asian cities: effects of gender-role attitudes. *J Adolesec Health*. (2012) 50(3 Suppl):S18–25. doi: 10.1016/j.jadohealth.2011.12.001
35. Li W, Chu J, Zhu Z, Li X, Ge Y, He Y, et al. Epidemiological characteristics of HIV infection among college students in Nanjing, China: a cross-sectional survey. *BMJ Open.* (2020) 10:e035889. doi: 10.1136/bmjopen-2019-035889
36. Moore MP, Belgrave F. Gender differences in predictors of HIV testing among African American young adults. *J Racial Ethn Health Disparities.* (2019) 6:189–96. doi: 10.1007/s40615-018-0513-y
37. Tesfaye G, Dessie Y, Berhane Y, Assefa N, Semahegn A, Canavan CR, et al. HIV/AIDS awareness and testing practices among adolescents in eastern Ethiopia. *Trop Med Int Health.* (2020) 25:111–8. doi: 10.1111/tmi.13337
38. Xu H, Xie J, Xiao Z, Xiao H, Li X, Goldsamt L, et al. Sexual attitudes, sexual behaviors, and use of HIV prevention services among male undergraduate students in Hunan, China: a cross-sectional survey. *BMC Public Health.* (2019) 19:250. doi: 10.1186/s12889-019-6570-2
39. Chi X, Hawk ST, Winter S, Meeus W. The effect of comprehensive sexual education program on sexual health knowledge and sexual attitude among college students in Southwest China. *Asia Pac J Public Health.* (2015) 27:Np2049–66. doi: 10.1177/1010539513475655

40. Taggart T, Grewe ME, Conserve DF, Gliwa C, Roman Isler M. Social Media and HIV: a systematic review of uses of social media in HIV communication. *J Med Internet Res.* (2015) 17:e248. doi: 10.2196/jmir.4387
41. Gao X, Wu Y, Zhang Y, Zhang N, Tang J, Qiu J, et al. Effectiveness of school-based education on HIV/AIDS knowledge, attitude, and behavior among secondary school students in Wuhan, China. *PLoS ONE.* (2012) 7:e44881. doi: 10.1371/journal.pone.0044881
42. Zheng Y, Zhang X, Sun X, Shi Y, Chang C. Evaluation of the college-based HIV/AIDS education policy in Beijing, China: a mixed method approach. *Environ Health Prev Med.* (2020) 25:50. doi: 10.1186/s12199-020-00890-5
43. Andres EB, Choi EPH, Fung AWC, Lau KWC, Ng NHT, Yeung M, et al. Comprehensive sexuality education in Hong Kong: study protocol for process and outcome evaluation. BMC Public Health. (2021)21:197. doi: 10.1186/s12889-021-10253-6

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Evaluation of a Novel Simulation Curriculum With the Segmented Model in Pediatric Cardiovascular Education

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Objective: The need to develop the full range of knowledge, skills, and professionalism poses new challenges for pediatric cardiovascular education. This study aimed to investigate the effectiveness of a novel simulation curriculum with the segmented model for pediatric cardiovascular residents.

Materials and Methods: First, the simulation course was designed according to a prior survey and based on a human patient simulator setting. Then, another 55 residents were randomly selected and assigned to participate in a simulation course (about acute fulminant myocarditis in children), either in the experimental group or the control group. Taking full advantage of the simulation education, the simulation case in the experimental group was divided into three segments and included a micro-debriefing at the end of each segment. The three segments were independent but together formed the whole case. It was designed through three cycles of running and debriefing, and more challenging tasks were gradually proposed to residents. The case in the control group was not split and included only one case running and debriefing. The assessments of the residents' knowledge, skills, professionalism performance, and satisfaction feedback from residents were analyzed to evaluate the effectiveness of the course.

Results: In total, 44 residents completed the whole experimental period, including 23 participants in the experimental group and 21 participants in the control group. The pre-course knowledge assessment scores of the two groups were comparable, while the mean post-course score in the experimental group was 82.61 ± 17.38, which was significantly higher than that in the control group (50.48 ± 18.57, $p < 0.01$). The mean skills assessment score of residents in the experimental group was 84.17 ± 6.01, which was significantly higher than the control group (54.50 ± 5.72, $p < 0.01$). In terms of the professionalism assessment, the residents in the experimental group achieved better performance than those in the control group in all aspects (respect, privacy, communication, responsibility, and cooperation) ($p < 0.05$). Satisfaction feedback from residents showed that self-confidence regarding knowledge mastery in the experimental

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group was significantly higher than that in the control group ($p < 0.05$), while there were no significant differences in the evaluations of the teacher's performance ($p > 0.05$).

Conclusions: The novel simulation curriculum with the segmented model helps residents achieve better performance in terms of knowledge, skills, and professionalism while improving self-confidence. It has some value in pediatric cardiovascular education and is worthy of further promotion.

Keywords: pediatric cardiovascular specialty, simulation education, residency training, novel model, teaching effectiveness

INTRODUCTION

There is an irreversible trend of pediatric cardiovascular doctors needing to provide high-quality care to children, which means that developing a full range of knowledge, skills, and professionalism is necessary (1). Deficiencies in any one of these aspects will dramatically affect the outcomes for pediatric cardiovascular patients. However, in some developing countries, reports from both teachers and residents show that there is a big gap between goals and reality. The mastery, retention, and application of knowledge and skills among residents are lower compared to senior doctors due to their relatively short clinical working time. The cultivation of professionalism depends more on personal contact with the clinical environment. The relatively low level of knowledge and skills among residents leads to their lack of self-confidence in dealing with clinical problems, which further limits their abilities in all aspects. The need for an effective educational model that can simulate the real medical environment with high-fidelity is urgent. In recent years, simulation-based medical education (SBME) has been applied to pediatric teaching to improve this situation in some developed regions of China and was reported to be effective (2). SBME uses simulators or humans as substitutes for real patients and provides an educational environment for educators to use—a real but well-controlled clinical experience, simulating real-life patient care (3). It was reported to be well suited for both high-risk and low-volume clinical scenarios, such as pediatric cardiovascular medicine (3). The knowledge and skills required in these scenarios are rarely practiced during clinical care and can instead be practiced frequently in simulation scenarios without endangering patients. The key to a simulation curriculum is the integration of the most compatible model, which has been a major challenge for pediatric SBME for the past 20 years. A compatible model will improve the effectiveness of the simulation curriculum, while an inappropriate teaching model will result in a waste of time and resources. The two main features of the SBME facility's effective teaching are providing debriefings and repeated practices, according to the findings of a recent system analysis (4). Debriefings are fairly important, and various studies have shown that they can improve learning efficiency and memory retention in SBME (5, 6). SBME with repeated practices is better than those without them in skills acquisition (7). Our study tried to combine the two merits of SBME in a novel model to make full use of them.

Acute fulminant myocarditis (AFM) is rare inflammatory heart disease. The overall incidence of acute myocarditis was 1.4–2.1 per 100,000 children, and 22.8–44.1% of acute myocarditis was classified as AFM, according to a study from 2007 to 2016 conducted in Korea and a study from 2012 to 2018 conducted in Japan (8, 9). However, a significant increase has been found in the incidence rate of AFM over time (8). In particular, AFM in children has been reported to lead to a higher mortality rate than in adults (10). A retrospective observational study of children showed that the mortality related to AFM was 24.1%, which is 41.3 times higher than that of non-fulminant myocarditis (9). AFM has a sudden onset and rapidly develops into heart failure, cardiogenic shock, fatal arrhythmia, or multi-organ failure. Its early symptoms are non-specific, including abdominal pain, vomiting, fatigue, syncope, and convulsions (11), often leading to misdiagnoses (12). The targeted history collection, physical examination, and laboratory tests and imaging (myocardial injury biomarkers, electrocardiogram, echocardiography, cardiac magnetic resonance, etc.) are helpful for early identification and differential diagnosis (11). The management strategy of AFM is to maintain stable hemodynamics and adequate organ perfusion. Even with active medications (intravenous immunoglobulin or glucocorticoids) and supportive therapy (fluid resuscitation or anti-arrhythmic treatment), some patients will still present lactic acidosis and low peripheral perfusion. The only way to improve the survival rate is to maintain the children's circulation with extracorporeal membrane oxygenation (ECMO). According to data from the Extracorporeal Life Support Organization in 2018, AFM had the highest survival rate among all disease types supported by ECMO (up to 76%) and a short hospitalization duration (8 days). The long-term cardiac function of these children during follow-up was satisfactory (13).

We can see that AFM is a disease that is easily misdiagnosed. Early diagnosis and targeted therapy will, thus, significantly improve patients' prognoses. Appropriate management of a child with AFM requires doctors to have related knowledge, skills, and professionalism (communication, cooperation, and so on). However, the chance for residents to understand AFM in clinical practice is very low due to its low incidence rate. Therefore, taking AFM in children as an example, our team developed a novel simulation course with the segmented model characterized by providing debriefings and repeated practices and applied it to the education of residents. The main aim was to build a bridge between pediatric cardiovascular residents and clinical diseases.

MATERIALS AND METHODS

Simulation Course Design

A survey of the simulation course about AFM in children was conducted. Ten third-grade pediatric cardiovascular residents in the Children's Hospital of Zhejiang University Hospital (Hangzhou, China) were randomly selected from May 2021 to June 2021 to complete the survey. Contents chosen by over 70% of residents were included in the course according to the survey. The course was designed based on a human patient simulator setting (PediaSim ECS from Tellyes Scientific Company, Tianjin, Hebei, China) according to the results of the survey. Taking full advantage of the simulation education, the simulation case in the experimental group was divided into three segments and included a micro-debriefing at the end of each segment. The three segments were independent but related to each other and arranged in order, together forming the whole case. It was designed through three cycles of running and debriefing, and more challenging tasks were gradually proposed. The case in the control group was not split, and the main content was continuously displayed, including only one case running and debriefing.

Simulation Course Practice

Another 55 third-grade pediatric cardiovascular residents from the Children's Hospital of Zhejiang University School of Medicine were randomly selected to participate in the simulation course practice. Participants were subsequently assigned into two groups randomly: the experimental and the control groups.

Participants were scheduled to spend 8 weeks completing the experimental period. On the first day of the first week, they were given the same preview materials (including textbooks, clinical guidelines, expert consensus, pictures, videos, etc.). One-to-one supervision was conducted to ensure that all residents had the same preview time before the course. On the first day of the second week, both groups of residents were scheduled to complete the pre-course test. In the control group, a 48-min simulation course practice was conducted on the first day of the third week to complete the whole case. In the experimental group, a 16-min simulation course practice was conducted on the first day of each week from the third to the fifth week to complete the three segments of the case, respectively. The same teacher guided the practice in both groups. The residents participated in the course practice by role-playing as doctors or nurses. Every five residents were assigned to a team, playing the role of a junior cardiovascular pediatrician, a senior cardiovascular pediatrician, an ECMO physician, and two cardiovascular nurses, respectively. During this period, the two groups of residents were given clinical practice and bedside teaching of no difference. On the first day of the ninth week, both groups of residents underwent the post-course test, followed by satisfaction feedback.

Effectiveness Evaluation

The evaluation of the simulation course's effectiveness included three parts: knowledge, skills, and professionalism assessment. The knowledge tests were carried out before and after the course, randomly selected from the same examination question bank. Skills and professionalism assessments were conducted after the course. Both knowledge and skills were assessed by scores with the highest possible score being 100. Professionalism was assessed by level: dissatisfied, average, and satisfied. The satisfaction feedback from residents included two parts: their own performance and that of the teachers, ranked by level: very dissatisfied, dissatisfied, average, satisfied, and very satisfied. The data from any participant who didn't complete the whole simulation course practice, the entire knowledge, skills, and professionalism assessment, or the satisfaction feedback portion, were excluded while evaluating the simulation course's effectiveness.

Statistical Analysis

Categorical data were expressed as numbers and percentages (n, %) and were compared using the χ^2-test between groups. Continuous data with normal distribution were expressed as $\mathrm{X} \pm \mathrm{S}$ and were compared with a t-test. Continuous data with a non-normal distribution were expressed as a percentile (M, P_{25}, and P_{75}) and were compared using a two-sided Mann-Whitney U test between two independent groups, as well as a Wilcoxon signed test between two paired groups. Ranked data were expressed as numbers and percentages (n, %), and were compared by a two-sided Mann-Whitney U test for two independent groups, and a two-sided Friedman test for more than two related groups. All above statistical analyses were performed using Microsoft Office Excel 2000 (Microsoft Corporation, Redmond, Washington, the Unite State) and SPSS 23.0 (International Business Machines Corporation, Armonk, New York, the Unite State). The sample size was estimated using the Power and Sample Size online calculator (http://www.powerandsamplesize.com). A $p < 0.05$ was considered statistically significant.

Ethic

This study was approved by the ethics committee of the Children's Hospital, School of Medicine, Zhejiang University (2021-IRB-183). All residents have read the written notification of the study and given their oral informed consent prior to participation.

RESULTS

Design of a Simulation Course about Acute Fulminant Myocarditis in Children

The mean age of the 10 third-grade pediatric cardiovascular residents was 25.70 ± 0.82 years old and the ratio of male to female was 1:9. All of them reported to expect a simulation curriculum, 60% had heard about a simulation curriculum before, and 40% had participated in a simulation curriculum through other ways. Survey results of the simulation course about AFM in children is shown in **Figure 1**. Knowledge (diagnostic criteria, early identification, differential diagnosis, complications, medications, and indications for ECMO), skills (oxygen therapy, emergency labs and imaging, defibrillator usage), and professionalism (respect, privacy, communication, responsibility, and cooperation) were selected as the content of the course according to the survey. The details of the teaching

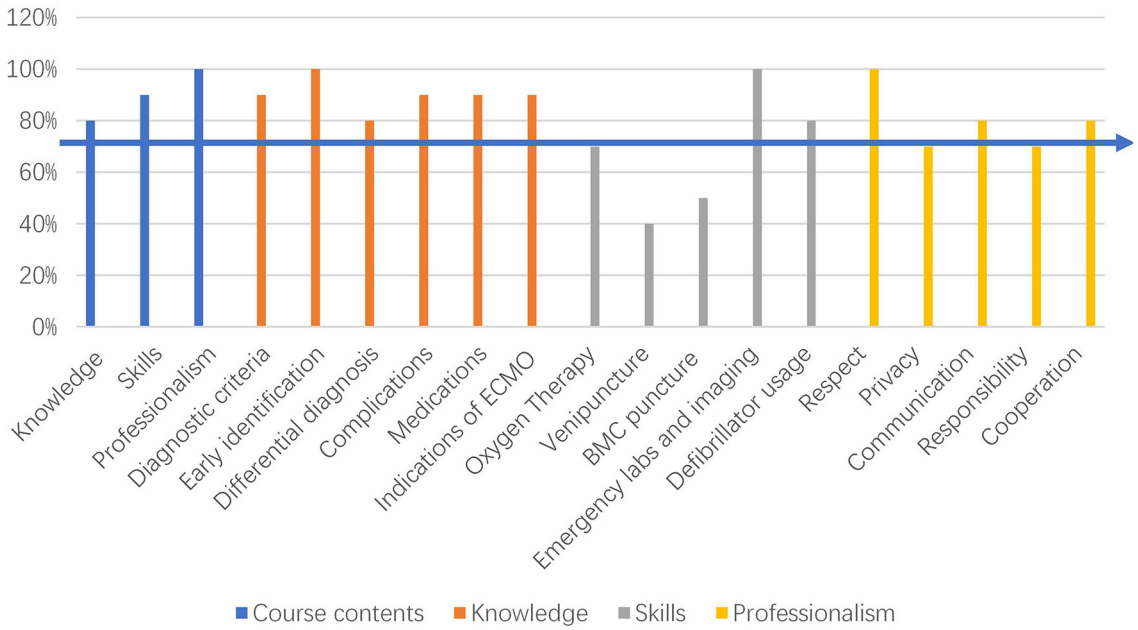

FIGURE 1 | Survey results of the simulation course about acute fulminant myocarditis in children.

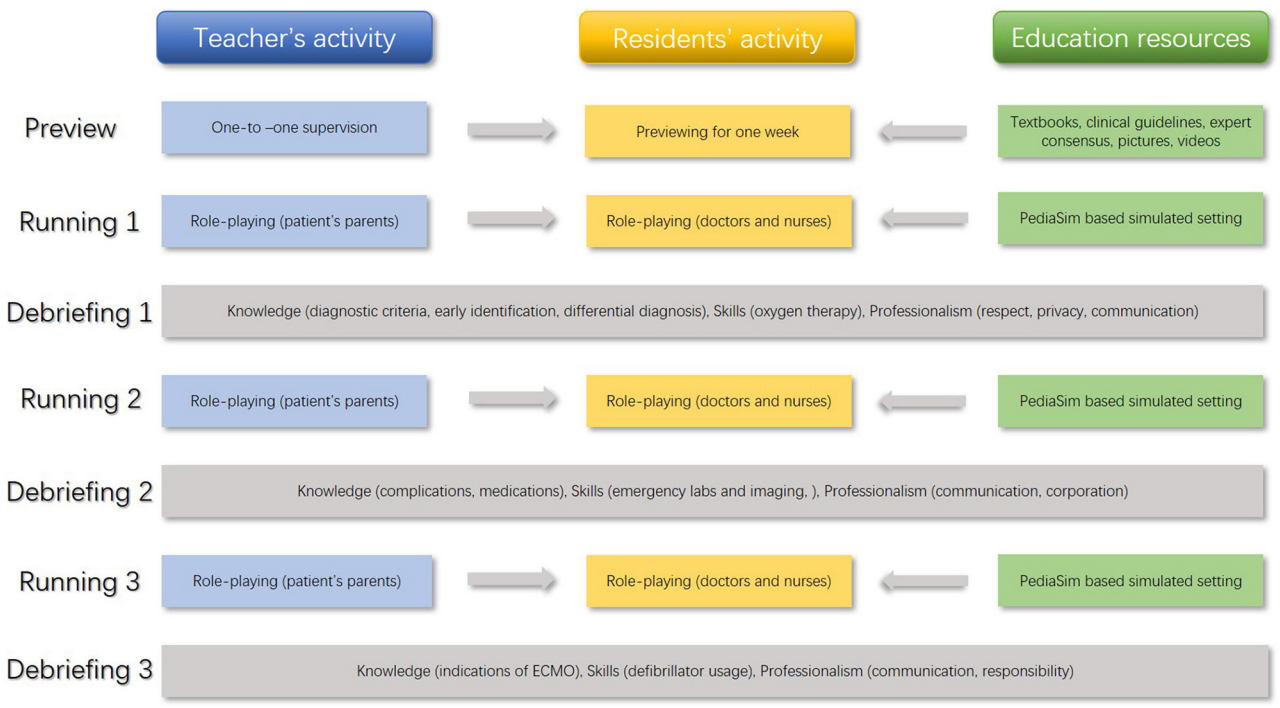

FIGURE 2 | Teaching schedule of the novel simulation course with the segmented model (acute fulminant myocarditis in children).

schedule of the novel simulation course with the segmented model are shown in **Figure 2**.

Figure 1 shows the residents' demands for each specific type of course content. The horizontal arrow represents the 70% level, and any content above the 70% level was selected for the course. ECMO, Extracorporeal Membrane Oxygenation; BMC, Bone Marrow Cavity.

Figure 2 shows the teaching schedule of the novel simulation course, including a preview and three cycles of running and debriefing. The content marked in blue represents the teachers' activities, yellow represents the residents' activities, green represents education resources, and gray represents the specific teaching content in each segment. All teachers' activities and education resources served the residents. ECMO, Extracorporeal Membrane Oxygenation.

Simulation Course Practice

A total of 55 residents completed the whole simulation course practice, including 30 in the experimental group (6 teams) and 25 in the control group (5 teams). Among them, 23 residents in the experimental group and 21 residents in the control group also completed the entire knowledge, skills, and professionalism assessment and satisfaction feedback. Of the 44 residents, the male to female ratios of residents in the experimental and control groups were 0.35:1 and 0.316:1, respectively, and there was no significant difference between the two groups ($\chi^2 = 0.03$, $p = 0.570$). The time distribution of the two groups is shown in **Table 1**.

TABLE 1 | Time distribution of the experimental and control groups.

	Control group (min)	Experimental group (min)
Pre-course test	10	10
Introduction	5	5
Case practice		
Running 1	24	8
Debriefing 1	24	8
Running 2	0	8
Debriefing 2	0	8
Running 3	0	8
Debriefing 3	0	8
Post-course test	15	15

Effectiveness Evaluation

Residents' Knowledge Assessment Results

The mean pre-course knowledge assessment score of the residents in the experimental group was 53.04 ± 17.69, while the mean score in the control group was 55.24 ± 28.92, and there was no significant difference between the two groups ($t = -.0300$, $p = 0.766$). The mean post-course knowledge assessment score of the residents in the experimental group was 82.61 ± 17.38, while the mean score in the control group was 50.48 ± 18.57, which was significantly lower than that in the experimental group ($t = -5.93$, $p < 0.01$). The mean post-course knowledge assessment score of the residents was significantly higher than that of the pre-course in the experimental group ($t = -6.314$, $p < 0.001$), while the mean post-course score of the residents was not significantly different from that of pre-course in the control group ($t = 0.653$, $p = 0.521$).

Residents' Skills Assessment Results

The mean skills score of residents in the experimental group was 84.17 ± 6.01, which was significantly higher than that in the control group (54.50 ± 5.72, $t = 8.365$, $p < 0.001$).

Residents' Professionalism Assessment Results

The residents' professionalism assessment included respect for patients and families, protection of patient privacy, communication with others, responsibility for patients, and cooperation with the team. The professionalism assessment of residents in the experimental group was higher than that in the control group in all aspects (**Table 2**).

Residents' Satisfaction Feedback

Self-Performance Evaluation

The self-performance evaluation showed that residents in the experimental group were significantly more confident regarding their knowledge mastery than those in the control group ($p = 0.039$), and there was no significant difference between the two groups in other aspects ($p > 0.05$) (**Table 3**).

Teacher's Performance Evaluation

The teacher's performance evaluation included simulation design, simulation running, and debriefings. No significant differences between the two groups were found, as shown in **Tables 4A–C**.

DISCUSSION

Although there is still a long way to go in the training of cardiovascular pediatricians, particularly in developing countries such as China, we have been working hard to cultivate qualified pediatricians in three areas: knowledge, clinical skills, and professionalism (14). This is necessary to provide qualified patient care. The ultimate goal of this education is to improve the health statuses of the patients and the community (14). There are common obstacles among some pediatric cardiovascular residents regarding the retention of knowledge, application of clinical skills, and embodiment of professionalism, which brings great challenges to the pediatric cardiovascular residents' training program. The ideal teaching mode should transfer knowledge, skills, and professionalism in the process of medical education in order to fully develop these aspects. The emergence of SBME has brought a new dawn, but the best teaching model is still being explored (3). We tried a novel simulation curriculum with a segmented model, hoping to improve the teaching effectiveness.

First, qualified pediatric cardiovascular doctors must have rich professional knowledge and proficient clinical skills. For example, to manage children with AFM well, pediatric cardiovascular doctors need to master the disease's incidence rate, etiology, clinical features, management, and prognosis. Our course focused on the knowledge related to the diagnosis and therapy of AFM and the related clinical skills. There were significant differences in the focus areas of the three segments. At the knowledge level, the first segment focused on the early recognition of AFM in children, the second segment focused on the preliminary emergency management, and the third segment focused on the indications for ECMO. At the skill level, the first segment focused on the oxygen therapy strategy, the second

TABLE 2 | Residents' professionalism assessment in the experimental and control groups.

Indicators	Control group ($n = 5$) (n, %)			Experimental group ($n = 6$) (n, %)			p	Z
	1	2	3	1	2	3		
Respect	3 (60.0)	2 (40.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (100.0)	0.004	-3.028
Privacy	2 (40.0)	3 (60.0)	0 (0.0)	0 (0.0)	1 (16.7)	5 (83.3)	0.009	-2.659
Communication	4 (80.0)	1 (20.0)	0 (0.0)	0 (0.0)	1 (16.7)	5 (83.3)	0.004	-2.856
Responsibility	2 (40.0)	3 (60.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (100)	0.004	-3.028
Cooperation	3 (60.0)	2 (40.0)	0 (0.0)	0 (0.0)	3 (50.0)	3 (50.0)	0.030	-2.345

1, 2, and 3 represent dissatisfied, average, and satisfied, respectively.

TABLE 3 | Evaluation of the residents' self-performance.

Indicators	Control group ($n = 21$) (n, %)					Experimental group ($n = 23$) (n, %)					p	Z
	1	2	3	4	5	1	2	3	4	5		
Knowledge mastery	0 (0.0)	1 (4.8)	6 (28.6)	6 (28.6)	8 (38.1)	0 (0.0)	0 (0.0)	1 (4.3)	8 (34.8)	14 (60.9)	0.039	-2.065
Skills development	0 (0.0)	0 (0.0)	0 (0.0)	8 (38.1)	13 (61.9)	0 (0.0)	0 (0.0)	0 (0.0)	9 (39.1)	14 (60.9)	0.944	-0.070
Professionalism training	0 (0.0)	0 (0.0)	0 (0.0)	5 (23.8)	16 (76.2)	0 (0.0)	0 (0.0)	0 (0.0)	8 (34.8)	15 (65.2)	0.431	-0.788
Careful thinking	0 (0.0)	0 (0.0)	3 (14.3)	6 (28.6)	12 (57.1)	0 (0.0)	0 (0.0)	0 (0.0)	12 (52.2)	11 (47.8)	0.905	-0.119
Active suggestions	0 (0.0)	0 (0.0)	3 (14.3)	5 (23.8)	13 (61.9)	0 (0.0)	0 (0.0)	0 (0.0)	10 (43.5)	13 (56.5)	0.957	-0.054
Proactive questioning	0 (0.0)	0 (0.0)	0 (0.0)	7 (33.3)	14 (66.7)	0 (0.0)	0 (0.0)	0 (0.0)	11 (47.8)	12 (52.2)	0.334	-0.965

1, 2, 3, 4, and 5 represent very dissatisfied, dissatisfied, average, satisfied, and very satisfied, respectively.

TABLE 4A | Evaluation of the teacher's performance (simulation design).

Indicators	Control group ($n = 21$) (n, %)					Experimental group ($n = 23$) (n, %)					p	Z
	1	2	3	4	5	1	2	3	4	5		
Adequate preparation	0 (0.0)	0 (0.0)	0 (0.0)	6 (28.6)	15 (71.4)	0 (0.0)	0 (0.0)	0 (0.0)	5 (21.7)	18 (78.3)	0.605	-0.517
Clear objectives	0 (0.0)	0 (0.0)	0 (0.0)	5 (23.8)	16 (76.2)	0 (0.0)	0 (0.0)	0 (0.0)	7 (30.4)	16 (69.6)	0.626	-0.487
Sufficient information	0 (0.0)	0 (0.0)	0 (0.0)	5 (23.8)	16 (76.2)	0 (0.0)	0 (0.0)	0 (0.0)	8 (34.8)	15 (65.2)	0.431	-0.788
Appropriate threads	0 (0.0)	0 (0.0)	0 (0.0)	4 (19.0)	17 (81.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (26.1)	17 (73.9)	0.582	-0.550

1, 2, 3, 4, and 5 represent very dissatisfied, dissatisfied, average, satisfied, and very satisfied, respectively.

segment focused on various emergency labs and imaging, and the third segment focused on the use of defibrillators. SBME is a powerful tool for acquiring knowledge and improving skills, and previous studies have shown its ability in the training of pediatricians (15, 16). In our course, we organically integrated these contents into different segments and delivered focused knowledge and skills training in each segment. From the teacher's point of view, the simulation design was more focused, the simulation running was more purposeful, and the debriefing was timelier. From the residents' point of view, the training was shorter, there was less consent, and quicker feedback was also preferable. The design was in line with the teaching principle of moving along step-by-step. Although the content, teachers, pre-course preview were the same, the knowledge and skill assessment outcomes of the two groups were significantly different. The gap in the knowledge and skill scores between the two groups was as high as 30 points, which was very surprising.

Secondly, professionalism is necessary for pediatric cardiovascular specialists and has attracted more and more attention. Courses that focus only on diseases are no longer suitable for medical education. The American Association of Medical Colleges has established a team of experts to

TABLE 4B | Evaluation of the teacher's performance (simulation running).

Indicators	Control group ($n = 21$) (n, %)					Experimental group ($n = 23$) (n, %)					p	Z
	1	2	3	4	5	1	2	3	4	5		
Identify needs	0 (0.0)	0 (0.0)	0 (0.0)	5 (23.8)	16 (76.2)	0 (0.0)	0 (0.0)	0 (0.0)	7 (30.4)	16 (69.6)	0.626	-0.487
Provide support	0 (0.0)	0 (0.0)	0 (0.0)	5 (23.8)	16 (76.2)	0 (0.0)	0 (0.0)	0 (0.0)	5 (21.7)	18 (78.3)	0.871	-0.162
Enhance capabilities	0 (0.0)	0 (0.0)	0 (0.0)	4 (19.0)	17 (81.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (21.7)	18 (78.3)	0.827	-0.219
Explore methods	0 (0.0)	0 (0.0)	1 (4.8)	5 (23.8)	15 (71.4)	0 (0.0)	0 (0.0)	0 (0.0)	5 (21.7)	18 (78.3)	0.553	-0.593
Provide opportunities	0 (0.0)	0 (0.0)	0 (0.0)	4 (19.0)	17 (81.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (21.7)	18 (78.3)	0.827	-0.219

1, 2, 3, 4, and 5 represent very dissatisfied, dissatisfied, average, satisfied, and very satisfied, respectively.

TABLE 4C | Evaluation of the teacher's performance (simulation debriefing).

Indicators	Control group ($n = 21$) (n, %)					Experimental group ($n = 23$) (n, %)					p	Z
	1	2	3	4	5	1	2	3	4	5		
Organization	0 (0.0)	0 (0.0)	0 (0.0)	5 (23.8)	16 (76.2)	0 (0.0)	0 (0.0)	0 (0.0)	3 (13.0)	20 (87.0)	0.361	-0.914
Timeliness	0 (0.0)	0 (0.0)	0 (0.0)	4 (19.0)	17 (81.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (13.0)	20 (87.0)	0.591	-0.538
Inspiration	0 (0.0)	0 (0.0)	0 (0.0)	5 (23.8)	16 (76.2)	0 (0.0)	0 (0.0)	0 (0.0)	4 (17.4)	19 (82.6)	0.602	-0.521
Authenticity	0 (0.0)	0 (0.0)	1 (4.8)	6 (28.6)	14 (66.7)	0 (0.0)	0 (0.0)	0 (0.0)	6 (26.1)	17 (73.9)	0.544	-0.607

1, 2, 3, 4, and 5 represent very dissatisfied, dissatisfied, average, satisfied, and very satisfied, respectively.

address the challenges in medical education as part of the ongoing Medical School Objectives Project (17). The American Academy of Pediatrics has also recently issued professional quality standards for pediatricians (18). Pediatric cardiovascular patients have unique characteristics, such as poor self-expression, low emotional control, intolerance to disease, non-compliance with examination and treatment, and strong dependency on their parents. The family members of the affected children are prone to be anxious and doubt the medical staff. Many studies have shown the effectiveness of health communication interventions in improving doctor-patient/parent relationships and reducing non-compliance. The benefits of doctor-patient communication may exceed these short-term outcomes, as demonstrated by the cases of other adult chronic diseases (19). In addition, the condition of pediatric cardiovascular patients can change rapidly, so the demand for doctor professionalism, including responsibility, teamwork, and crisis resource management, is also very prominent. However, for a long time, courses on professionalism have been rather empty and boring. Recently, SBME has been reported to have been applied to improve professionalism, but the effect has not been confirmed (20). Our study found that the segmented simulation model was helpful for the professionalism training of pediatricians. In the teaching objectives of each segment, we added professionalism training (including teamwork, communication, and so on). Based on the importance of repeated stimulation (cycles of running and debriefing) for the retention of residents' memory and the cultivation of professionalism awareness, the residents' professionalism significantly improved after multiple segments of training. We found that compared with the control group, residents in the experimental group significantly improved in terms of respecting their patients, protecting patient privacy, and communication.

Residents about to enter clinical work have anxiety related to it. In the beginning, residents often lack sufficient abilities in history recording, physical examination, and diagnostic skills, resulting in a lack of confidence in their performers. They often suffer from psychological problems (stress and anxiety) due to the responsibility they have for patients. Significant stress, high anxiety, and low self-confidence increase the possibility of errors and, thus, harm the success of clinical practice (21). It is necessary to improve the ability of those engaging in patient care through various clinical experiences in a safe environment. Residents with rich medical experience showed confidence in patient care, while residents with high confidence also showed improvement in their clinical skills. In other words, confidence increases as they gain experiences (22). For residents who have limited opportunities to face real patients, it is necessary to provide an environment similar to the real clinical situation to help them better prepare themselves for clinical practice (22). This situation is particularly prominent among young pediatric cardiovascular residents because the severity of the cardiovascular disease is always higher than other diseases. SBME provides an environment very similar to the clinical setting so that students can experience the actual clinical management. The human patient simulators in our study are new and effective teaching models, which have been widely used in medical education (3). Human patient simulators allow residents to experience low-frequency or high-risk scenarios safely and improve their knowledge, skills, and professionalism

(23). In particular, with the spread of Corona Virus Disease 2019, the number of hospitalized children has decreased rapidly, and the opportunity for medical residents has decreased as well. In this case, human patient simulators can be actively used as an alternative method to improve the confidence of residents. In addition, anxiety occurring under specific circumstances or stimuli can be reduced through repeated contact (24). Some studies have found that high-fidelity simulation experience, especially repeated contact simulation, can decrease the anxiety and self-confidence of medical students (22, 25). In this study, we found that the residents' self-confidence in mastering knowledge in the experimental group was better than that in the control group. Residents received feedback, repeated similar but more difficult tasks, and saw their progress, which further improved feelings of competence and made learners more welcoming to feedback (5).

Our study proved the feasibility and effectiveness of a simulation curriculum with the segmented model for the first time. The knowledge, skill, and professionalism performance of the residents were significantly improved by applying the novel model. In addition, it also increased the residents' self-confidence. In the analysis of the satisfaction with the teachers, the two groups were comparable in simulation design, the running, and the debriefings. This indicated that the enhanced effectiveness of the experimental group came from the multiple-segmented model of simulation itself rather than from the teacher's skills. The design of the case went deeper step-by-step, which not only aroused residents' interest and self-confidence but also made full use of the two SBME metrics, thereby achieving greater teaching effectiveness.

Our study has some limitations. First, our research lacks the comparison of the patients' improvement after the training of residents through the traditional and novel models, respectively. We will follow up in the future with further studies focused on this area, which will provide more information about the teaching effectiveness of the novel model. Second, the follow-up period is short and does not fully reflect the effect of the long-term retention of knowledge and skills through the novel simulation teaching model. We will extend the follow-up period in our future work to further analyze it. In addition, although the novel simulation curriculum received positive feedback, the findings were only based on one teaching practice. We will, thus, conduct more teaching practices with more participants in future studies to support the findings reported in this study. Finally, although it appeared that the professionalism performance of residents improved based on the qualitative results, there was a lack of quantitative assessment. We will try to develop a more scientific evaluation system in the future.

In conclusion, the simulation curriculum with the novel segmented model could improve the knowledge, skills, and professionalism performance of pediatric cardiovascular residents and enhance their self-confidence. The course received positive feedback, which is worthy of further promotion and application. In future research, we plan to apply this novel simulation model to other pediatric curricula and develop a series of coherent curriculum systems. We will promote it among more pediatric teachers and students, hoping to improve the service quality of pediatric medical workers. Second, after the training, we will regularly follow up on the clinical performance of residents, the improvement and satisfaction of patients, and give feedback to residents and teachers in a timely manner. In addition, we will optimize the assessment system, including a multidimensional evaluation of resident performance, hoping to reflect the teaching effect of curricula and the learning effect of residents through a more reliable method.

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 Ethics Committee of the Children's Hospital, School of Medicine, Zhejiang University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

YY collected the data, guided the simulation course practice, and wrote the draft. L-FT, C-ZH, and J-HM performed the statistical analysis and revised the manuscript. Y-XH designed the study and critically reviewed the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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REFERENCES

1. Smith SE, Tallentire VR, Cameron HS, Wood SM. The effects of contributing to patient care on medical students' workplace learning. *Med Educ.* (2013) 47:1184–96. doi: 10.1111/medu.12217
2. Chuan W, Jie X, Cheng W, Xiao-Chuan W, Ding-An M, Sheng C. Simbaby plus standardized patient teaching model in the teaching of cases of acute and severe bronchopneumonia in infancy. *Pediatr Emerg Care.* (2017) 33:630–4. doi: 10.1097/PEC.0000000000000555
3. Lopreiato JO, Sawyer T. Simulation-based medical education in pediatrics. *Acad Pediatr.* (2015) 15:134–42. doi: 10.1016/j.acap.2014.10.010
4. Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a beme systematic review. *Med Teach.* (2005) 27:10–28. doi: 10.1080/01421590500046924
5. Hatala R, Cook DA, Zendejas B, Hamstra SJ, Brydges R. Feedback for simulation-based procedural skills training: a meta-analysis and critical narrative synthesis. *Adv Health Sci Educ Theory Pract.* (2014) 19:251–72. doi: 10.1007/s10459-013-9462-8
6. Van Heukelom JN, Begaz T, Treat R. Comparison of postsimulation debriefing versus in-simulation debriefing in medical simulation. *Simul Healthc.* (2010) 5:91–7. doi: 10.1097/SIH.0b013e3181be0d17
7. McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. *Acad Med.* (2011) 86:706–11. doi: 10.1097/ACM.0b013e318217e119
8. Kim J, Cho MJ. Acute myocarditis in children: a 10-year nationwide study (2007-2016) based on the health insurance review and assessment service database in Korea. *Korean Circ J.* (2020) 50:1013–22. doi: 10.4070/kcj.2020.0108
9. Ohki S, Hosokawa K, Tomioka S, Matsuoka M, Fushimi K, Matsuda S, et al. Pediatric fulminant myocarditis in Japan: a retrospective nationwide database study of hospital volume, management practices, and mortality. *Pediatr Crit Care Med.* (2021) 22:e391–401. doi: 10.1097/PCC.0000000000002692
10. Zhang X, Wang S, Jia J, Li W, Li J. The use of extracorporeal membrane oxygenation in the treatment of fulminant myocarditis: current progress and clinical outcomes. *Microvasc Res.* (2021) 137:104190. doi: 10.1016/j.mvr.2021.104190
11. Lv J, Han B, Wang C, Wang J, Jiang D, Zhao L, et al. The clinical features of children with acute fulminant myocarditis and the diagnostic and follow-up value of cardiovascular magnetic resonance. *Front Pediatr.* (2019) 7:388. doi: 10.3389/fped.2019.00388
12. Freedman SB, Haladyn JK, Floh A, Kirsh JA, Taylor G, Thull-Freedman J. Pediatric myocarditis: emergency department clinical findings and diagnostic evaluation. *Pediatrics.* (2007) 120:1278–85. doi: 10.1542/peds.2007-1073
13. Barbaro RP, Paden ML, Guner YS, Raman L, Ryerson LM, Alexander P, et al. Pediatric extracorporeal life support organization registry international report 2016. *ASAIO J.* (2017) 63:456–63. doi: 10.1097/MAT.0000000000000603
14. Alexandraki I, Mooradian AD. Redesigning medical education to improve health care delivery and outcomes. *Health Care Manag.* (2013) 32:37–42. doi: 10.1097/HCM.0b013e31827ed8fa
15. Sandeva MG, Tufkova S, Ketev K, Paskaleva D. Evaluating the effectiveness of simulation training in obstetrics and gynecology, pediatrics and emergency medicine. *Folia Med.* (2019) 61:605–11. doi: 10.3897/folmed.61.e47961
16. Amick AE, Feinsmith SE, Davis EM, Sell J, Macdonald V, Trinquero P, et al. Simulation-based mastery learning improves ultrasound-guided peripheral intravenous catheter insertion skills of practicing nurses. *Simul Healthcare.* (2021) 17:7–14. doi: 10.1097/SIH.0000000000000545
17. Varkey P. Educating to improve patient care: integrating quality improvement into a medical school curriculum. *Am J Med Qual.* (2007) 22:112–6. doi: 10.1177/1062860606298338
18. Fallat ME, Glover J. Professionalism in pediatrics. *Pediatrics.* (2007) 120:e1123–33. doi: 10.1542/peds.2007-2230
19. Cappuccio A, Bugliaro F, Caimmi SME, Caldarelli V, Caminiti L, D'Auria E, et al. Consensus communication strategies to improve doctor-patient relationship in paediatric severe asthma. *Ital J Pediatr.* (2019) 45:31. doi: 10.1186/s13052-019-0623-0
20. Wali E, Pinto JM, Cappaert M, Lambrix M, Blood AD, Blair EA, et al. Teaching professionalism in graduate medical education: what is the role of simulation? *Surgery.* (2016) 160:552–64. doi: 10.1016/j.surg.2016.03.026
21. Leblanc VR, Regehr C, Tavares W, Scott AK, Macdonald R, King K. The impact of stress on paramedic performance during simulated critical events. *Prehosp Disaster Med.* (2012) 27:369–74. doi: 10.1017/S1049023X12001021
22. Yu JH, Chang HJ, Kim SS, Park JE, Chung WY, Lee SK, et al. Effects of high-fidelity simulation education on medical students' anxiety and confidence. *PLoS ONE.* (2021) 16:e0251078. doi: 10.1371/journal.pone.0251078
23. Ziv A, Wolpe PR, Small SD, Glick S. Simulation-based medical education: an ethical imperative. *Acad Med.* (2003) 78:783–8. doi: 10.1097/00001888-200308000-00006
24. Benito KG, Walther M. Therapeutic process during exposure: habituation model. *J Obsessive Compuls Relat Disord.* (2015) 6:147–57. doi: 10.1016/j.jocrd.2015.01.006
25. Auerbach M, Kessler D, Foltin JC. Repetitive pediatric simulation resuscitation training. *Pediatr Emerg Care.* (2011) 27:29–31. doi: 10.1097/PEC.0b013e3182043f3b

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Evaluation of clinical knowledge and perceptions about the development of thyroid cancer—An observational study of healthcare undergraduates in Saudi Arabia

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Background and objective: In the healthcare context, healthcare personnel are available to help patients according to their requirements. However, having sufficient knowledge of many elements of diseases before graduation may have a good impact on clinical practices later in one's career. As a result, the purpose of this study was to assess the clinical knowledge and perceptions of healthcare students in Saudi Arabia about thyroid cancer (TC).

Methods: A cross-sectional study was conducted in King Saud University from August 2021 to November 2021, using a validated self-reporting online survey. The data collection was carried out among senior healthcare students, including pharmacy, nursing, and medical students of both genders, who were Arabic speakers. The data were analyzed using the Statistical Package for the Social Sciences version 26 for Windows (SPSS).

Results: There were 141 healthcare students who responded, with 46.8% (n = 66) being pharmacy students, 28.4% (n = 40) being nursing students, and 24.8% (n = 35) being medical students. Male participants made up the majority of them (52.5%). Lump or swelling in the neck was described as the most common early indicator of TC by 54.6% (n = 77), followed by difficulty in swallowing by 34.04% (n = 48), and pain in the neck by 24.8% (n = 35). Female participants accounted for 44.7% (n = 63) of those with thyroid dysfunction, according to the study. About 55.3% of the participants (n = 78), reported that they had sufficient knowledge about TC. The knowledge score differed significantly by gender; female participants (60.3%) (n = 47) were more knowledgeable than male participants (30.7%) (n = 31) (p = 0.049).

Conclusion: This study depicts that half of the healthcare students thatwere knowledgeable about TC had positive perceptions about the causes of diseases. Furthermore, we also recommend arranging awareness programs for the students by the university officials to overcome the knowledge gap.

KEYWORDS

thyroid disease, hypothyroid, signs, genetics, smoking, healthcare

Introduction

Endocrine diseases, particularly thyroid diseases, have become more common over time. The thyroid gland is a small butterfly-shaped gland that sits beneath the neck and regulates metabolism, growth, and development in the human body by the continuous secretion of thyroid hormones (1, 2). Thyroid disease is more common during adolescence or during pregnancy, especially in women between the ages of 20 and 45, therefore its risk factors have gotten a lot more attention (3–5). According to recent estimates, undiagnosed subclinical hypothyroidism was 4.11% in Europe, while the prevalence of overt hypothyroidism was 0.65%, for a total prevalence of 4.70% (6). In the United States, the American Thyroid Association estimated that at least 20 million US adults have some form of thyroid disease; interestingly, the majority of the thyroids were unaware of their disease status (7). In Saudi Arabia, the overall prevalence was 49.76%, among which subclinical hypothyroidism was the most prevalent type (3922/9992), followed by primary hypothyroidism (530/9992) (8). However, studies found that the prevalence of thyroid dysfunction varies by age, gender, race/ethnicity, geographical distribution, and the amount of dietary iodine intake (8, 9).

Hypothyroidism is a type of thyroid disorder in which the thyroid gland does not generate adequate hormones. Hypothyroidism is more common in women than in men, according to the US Department of Health and Human Services; hyperthyroidism, on the other hand, happens when your thyroid overworks and produces more hormones than it should. Hyperthyroidism is more frequent in women than in hypothyroidism (10). On the other hand, a previous study among Americans reported the prevalence of TC mostly at a median age of 47 years in women and 53 years in men. (11). However, TC is the most frequent and widespread of all endocrine cancers. (12–14) Despite its prevalence, it only accounts for roughly 2% of all malignant tumors in the United States (15).

According to a study conducted by Alyahya and colleagues among citizens of Saudi Arabia's eastern province, half of the participants, 44.7% (394), had insufficient information regarding thyroid condition (16). Furthermore, previous data revealed that approximately half of the people in the study were unaware of thyroid symptoms and risk factors (17, 18). Thyroid abnormalities are more common in women than men in the Arabic population, with a peak age of more than 30 years, and are connected to an increased risk of anemia. (8). Another recent study by Iqbal et al. among university students reported knowledge deficiency with respect to many aspects of thyroid disease (17). Another recent study among medical students concluded insufficient knowledge and awareness of predisposing variables and TC screening (18).

Students, primarily pharmacists, nurses, and medical professionals, are on the 'front lines' in the healthcare setting, ready to assist patients as needed. Prior to graduation, having a sufficient understanding of many elements of diseases may have a good impact on clinical practices later in work. In Saudi Arabia, there is a scarcity of studies on TC's knowledge, risk factors, awareness, and prevention practices among senior healthcare students. A study of the literature revealed that no research on senior pharmacy, nursing, or medical students' understanding of various aspects of thyroid disease had been conducted in Saudi Arabia. Therefore, this study aimed to evaluate the healthcare students' clinical knowledge and perceptions of developing TC in Saudi Arabia.

Methods

Study design, settings, population

A cross-sectional study was conducted at King Saud University over 4 months, from August 2021 to November 2021. It is a self-reporting questionnaire-based study including both genders of senior healthcare students who were currently pursuing their graduation and were from the branches like pharmacy, nursing, and medical students, who were Arabic speakers. Prior to data collection, the study protocol was reviewed and approved by the Institutional Review Board (IRB) at King Saud University Medical City (KSUMC), Riyadh, Saudi Arabia. At the beginning of the study and following the questionnaire, a disclosing statement followed by complying and an agreement to use filled information for publication purposes were highlighted. Healthcare students who have recently joined

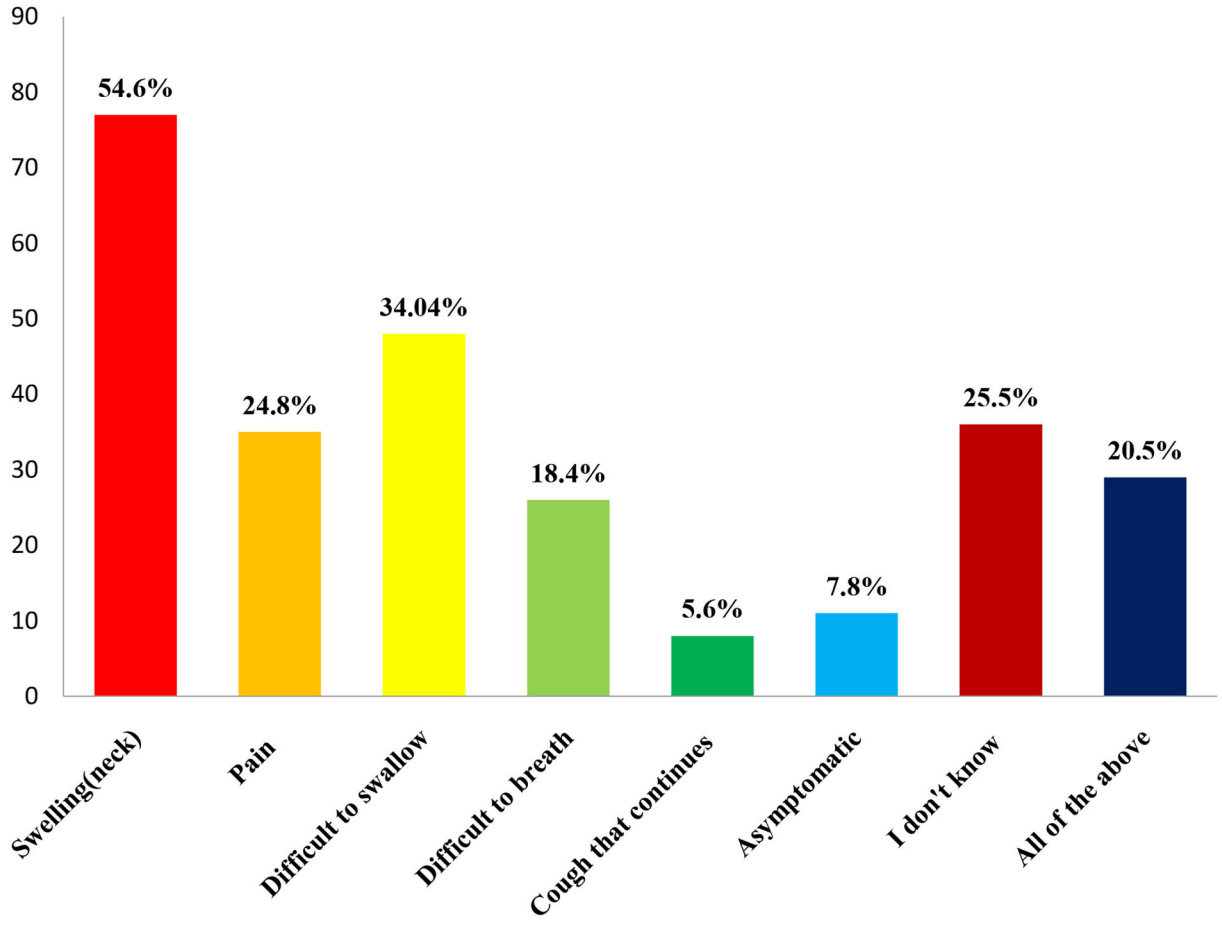

FIGURE 1
Knowledge regarding early signs of thyroid cancer.

the courses and students from other disciplines were excluded from the study.

The required sample size for this study was obtained using the Rao soft sample size calculator (http://www.raosoft.com/samplesize.html.) with a 95% confidence level and a pre-determined margin of error of 5% from approximately 200 senior residential students (pharmacy, nursing, and medicine) on the KSU campus. Because we were unsure of the potential results for each question, we assumed that the response distribution for each question would be 50%. We calculated a sample size of 132 students, but we decided to survey 200 students to ensure greater reliability.

Study questionnaire, data collection, and source

The questionnaires were prepared after an extensive literature review using similar studies published elsewhere (16, 17). The designed questionnaire was validated in two steps. First, the initial draft was evaluated by a research expert in the related field; second, a pilot study was conducted among a randomly selected sample of 10 students to give their opinions. Amendments from the pilot study were made, and the final draft of the questionnaires was sent to the targeted participants. The reliability test was done by calculating Cronbach's alpha using SPSS v.26, and the value of 0.76 indicated questionnaires suitable to carry out the study. The data of the pilot study were not included in the final analysis.

The questionnaire was divided into 3 sections. Section one includes the participant's demographics, including age, gender, profession, presence of diseases, and specific clinical information with a total of 9-items. The second section contains questions about the knowledge of signs and symptoms of thyroid disease with a total of 10 items. The last part of the study asks about participants' perceptions regarding a person's chance of developing TC with a total of 10 items. The responses to the last section of the questionnaires were recorded on a 5-point

TABLE 1 Shows description of the study sample.

Characteristics	Description	Frequency (*n*)	Percentage (%)
Gender	Male	74	52.5
	Female	67	47.5
Age (years)	20–22	108	76.6
	23–25	22	15.6
	26–30	11	7.8
Nationality	Saudi	137	97.2
	Non-Saudi	4	2.8
Profession	Medical student	35	24.8
	Pharmacy student	66	46.8
	Nursing student	40	28.4
Presence of disease	Yes	13	9.2
	No	128	90.8
Diagnostic methods of thyroid cancer	Neck palpation/ ultrasonography	57	40.42
	Hormonal level testing	51	36.17
	Blood smear,	20	14.18
	Biopsy	54	38.29
	I Don't know	42	29.78
Most affected Gender	Male	15	10.6
	Female	63	44.7
	Both	26	18.4
	I Don't know	37	26.2
Thyroid function impact on the menstrual cycle	Yes	64	45.4
	No	5	3.5
	I Don't know	72	51.1
Iodine required for the synthesis of thyroid hormones	Yes	57	40.4
	No	7	4.96
	I Don't know	77	54.6

Likert scale. A score of 5 indicates disagree strongly, 4 indicates disagree, 3 indicates neutral, 2 indicates agree, and 1 indicates strongly agree. The knowledge score of thyroid disease was calculated for each item by allocating 'one' to the correct answer and 'zero' to the wrong answer.

We chose a convenience sampling procedure to collect the data from the targeted population. Convenience sampling is a non-probability sampling technique in which study participants are chosen based on a set of metrics, like as accessibility at a specific time, willingness to participate, ease of access, and proximity to the investigators.

The data were collected primarily from senior students at KSU's College of Pharmacy, nursing and medicine, who were pursuing their degrees. The participants were approached for data collection by a researcher from the College of Pharmacy's Clinical Pharmacy Department. The purpose of the study was presented at the beginning of the study questionnaire, additionally, prior to approaching the questionnaire, there was a statement about the consent. The information was gathered by paying visits to the group leaders of each course, and reminders were sent to fill out the questionnaires.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26 for Windows (SPSS Inc., Chicago, Illinois). Descriptive statistics was used to summarize the demographic characteristics. All statistical tests (Chi-square/Fisher exact test) were performed at a significance level of $\alpha = 0.05$ and a 95% confidence interval (CI) for statistically significant differences between the variables.

Results

Demographic information of the participants

In this study, a total of 200 healthcare students were approached, with 59 responses being discarded due to missing responses or incompleteness. The questionnaire was completed by 141 students, resulting in a response rate of 70.5%. The majority of the responders (46.8%, or $n = 66$) were pharmacists, while 28.4% ($n = 40$) were nurses, and 24.8% ($n = 35$) were medical students. Most of the students (52.5%) were male participants between the ages of 20 and 22, with the clear majority being Saudis ($n = 108$, 76.6%). However, a large proportion (90.8%) had free from chronic diseases when asked students the most common early signs of TC more than half of them cited lump or swelling in the neck 54.6% ($n = 77$), followed by difficulty in swallowing 34.04% ($n = 48$), pain in the neck, and sometimes in ears 24.8% ($n = 35$) (Figure1).

The most common diagnostic methods for screening of TC are neck palpation and thyroid ultra-sonography (manual examination and ultrasound technique) (40.42%, $n = 57$), followed by biopsy (38.29%, $n = 54$), and hormonal level testing (36.17%, $n = 51$). Women (44.7%, $n = 63$) are the most affected gender by thyroid dysfunction. Around 40.4% ($n = 57$) of the participants believed that iodine is required to synthesize thyroid hormones, and 45.4% of them believed that thyroid function impacts the menstrual cycle. The summary of the demographic information is presented in Table 1.

Unexplained lump or swelling was identified by more than two-thirds of the students as a warning sign of cancer, followed by persistent trouble swallowing (54%), unexplainable weight loss (52.5%), chronic unexplained discomfort (50.35%), and a persistent cough or hoarseness (43.97%). Table 2 lists other cancer warning indicators.

The student's perception of a person's likelihood of having cancer is depicted in Table 3. In this study, the majority of

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TABLE 2 Knowledge regarding warning signs for cancer.

Characteristics	Description	Frequency (*n*)	Percentage (%)
Unexplained lump or swelling could be a sign of cancer	Yes	92	65.24
	No	25	17.73
	I Don't know	24	17.02
Persistent unexplained pain could be a sign of cancer	Yes	71	50.35
	No	32	22.69
	I Don't know	38	26.95
Unexplained bleeding could be a sign of cancer	Yes	57	40.42
	No	29	20.56
	I Don't know	55	39.00
A persistent cough or hoarseness could be a sign of cancer	Yes	62	43.97
	No	34	24.11
	I Don't know	45	31.91
A persistent change in bowel or bladder habits could be a sign of cancer	Yes	41	29.07
	No	31	21.98
	I Don't know	68	48.22
Persistent difficulty swallowing could be a sign of cancer	Yes	77	54.60
	No	19	13.47
	I Don't know	45	31.91
A change in the appearance of a mole could be a sign of cancer	Yes	61	43.26
	No	33	23.40
	I Don't know	47	33.33
A sore that does not heal could be a sign of cancer	Yes	54	38.3
	No	29	20.6
	I Don't know	58	41.1
Unexplained weight loss could be a sign of cancer	Yes	74	52.5
	No	23	16.3
	I Don't know	44	31.2

the students believed that smoking can cause cancer (87.9%). Similarly, 83% of the students agreed that exposure to smoking can cause cancer. Likewise, more than two-thirds of the students agreed that eating red or processed meat and junk food once a day or more increases the risk of cancer, and more than half (56%) agreed that being overweight (BMI over 25) increases the risk of cancer, while 59.6% agreed that being over 70 years increases the risk of cancer. A total of 51.1% of the 141 students agreed that eating < five servings of fruits and vegetables per day increases the risk of acquiring cancer. Furthermore, 48.2% agreed that having a close relative with cancer is the chance of developing cancer. However, 54.6% of the students agreed that doing < 30 min of moderate physical activity five times a week could develop cancer.

In this study, 55.3% ($n = 78$) of the participants reported good knowledge of TC. The knowledge score is significantly different with respect to gender; 60.3% of the female participants ($n = 47$) and 39.7% of the male participants ($n = 31$) ($p = 0.049$) were knowledgeable. Although the knowledge score on the thyroid is not significantly associated with the student's age, the professional class had previous knowledge of thyroid disease and the presence of chronic disease ($p > 0.005$). The association between the knowledge score and participants' demographics is given in Table 4.

Discussion

One of the most prevalent forms of disease these days is endocrine-related and most commonly known as TC, a cancerous tumor that is more common among people with a risk factor. However, in most cases, the specific cause is unknown. Globally, the rates of TC have risen dramatically. This cross-sectional study summarizes the knowledge and perceptions of TC among healthcare students in Saudi Arabia. In this context, the present study offers insight into the existing state of awareness among the healthcare students of King Saud University, Riyadh, Saudi Arabia. This study

TABLE 3 Perception regarding a person's chance of developing cancer.

Variables	Mean ± Std	Strongly agree *n* (%)	Agree *n* (%)	Neutral *n* (%)	Strongly Disagree *n* (%)	Disagree *n* (%)
Smoking any cigarettes at all	4.15 ± 1.53	97 (68.8)	27 (19.1)	12 (8.5)	2 (1.4)	3 (2.1)
Exposure to another person's cigarette smoke	3.36 ± 1.81	63 (44.7)	56 (38.3)	19 (13.5)	2 (1.4)	3 (2.1)
Eating less than five portions of fruit and vegetables a day	4.18 ± 1.98	17 (12.1)	30 (39.0)	45 (31.9)	19 (13.5)	5 (3.5)
Eating red or proceed meat and junk food once a day or more	3.95 ± 2.08	29 (20.6)	58 (41.1)	41 (29.1)	10 (7.1)	3 (2.1)
Being overweight (BMI over 25)	4.08 ± 2.00	26 (18.4)	53 (37.6)	46 (32.6)	11 (7.8)	5 (3.5)
Getting sun burnt more than once as a child	4.53 ± 1.99	30 (21.3)	28 (28.4)	48 (34.0)	20 (14.2)	3 (2.1)
Being over 70-year old	4.06 ± 2.09	29 (20.6)	55 (39.0)	43 (30.5)	12 (8.5)	2 (1.4)
Having a close relative with cancer	3.97 ± 1.52	43 (30.5)	25 (17.7)	37 (26.2)	19 (13.5)	17 (21.1)
Infection with HPV (Human Papilloma virus)	5.63 ± 2.01	31 (22.0)	25 (17.7)	61 (43.3)	16 (11.3)	8 (5.7)
Doing < 30 min of moderate physical activity five times a week	4.18 ± 2.03	23 (16.3)	54 (38.3)	40 (28.4)	18 (12.8)	6 (4.3)

shows that more than half of the healthcare students have a good knowledge level of TC. These results were higher than a similar study by Iqbal et al. that revealed that almost all participants had poor knowledge about early signs, predisposing factors, and preventive practices of TC (17). On the contrary, a similar study conducted in Riyadh showed a similar result to our study, and it showed that the participants had a good level of knowledge (18). Another study conducted among women in India showed that most participants had inadequate knowledge about thyroid disorders (19). Our study reported that the knowledge score is significantly different concerning gender, 60.3% of the females ($n = 47$) and 39.7% of the males ($n = 31$) ($p = 0.049$) were knowledgeable. Another similar study was found to be having a knowledge ratio of 1:2.2 male to female (20).

The early sign of TC among this participant provides an exciting result. For instance, the current study population answered that 77% of the participants knew that lumps or swelling in the neck were early signs of TC. In contrast, a study in Saudi Arabia concluded that 70.6% of neck lumps could be a sign of TC (16). In this survey, more than half of the healthcare students agreed that persistent difficulty swallowing, unexplained weight loss, and persistent unexplained pain as the warning sign of cancer. Conversely, a previous study by Iqbal A et al. reported unexplained bleeding (45.9%), persistent difficulty in swallowing (42.5%), and unexplained weight loss (41.3%) as the early sign of TC (17).

Consistent with the present findings, it has been reported that exposure to smoking is the associated factor in the development of TC. On the other hand, a study conducted among residents of the Eastern Province, Saudi Arabia, showed that 40.5% agreed that smoking is a risk factor for thyroid diseases (16). Another recent study conducted among university students showed that 55.4% agreed that smoking causes the chances to develop TC (17, 21). One-third of the students believed that having a close relative with cancer is the cause of TC. A study conducted in Saudi Arabia among females showed that 68.5% of the participants reported that TC is often genetic (22).

Furthermore, the American Cancer Society and EndocrineWeb reported that family history, radiation exposure, sex, and age were the vital factors that can cause TC (23, 24). Increased public awareness about early signs of TC can improve overall disease diagnosis and treatment, morbidity, and death rates.

Iodine plays a crucial role in synthesizing thyroid hormones in the thyroid gland. At the same time, most of the participants in our study did not think that iodine was crucial for thyroid hormone synthesis. Nevertheless, many studies have shown that

TABLE 4 Association between the participants' knowledge score levels and demographics.

	Number of Respondents	Not Knowledgeable ($n = 62$; 44%)	Knowledgeable ($n = 78$; 55.3%)	p- value
Age				
20–22 years	Respondents	51	57	
	% within age	47.2%	52.8%	
23–25 years	Respondents	05	16	0.110
	% within age	23.8%	76.2%	
26–30 years	Respondents	06	05	
	% within age	54.5	45.5	
Gender				
Male	Respondents	35	31	0.049
	% within gender	53.0%	47.0%	
Female	Respondents	27	47	
	% within gender	36.5%	63.5%	
Profession				
Pharmacy	Respondents	29	36	
	% within professional class	44.6%	55.4%	
Nursing	Respondents	18	22	0.980
	% within professional class	45.0%	55.0%	
Medical	Respondents	15	20	
	% within professional class	42.9	57.1	
Presence of disease				
Yes	Respondents	06	07	
	% within presence of disease	46.2%	53.8%	
No	Respondents	56	71	0.887
	% within presence of disease	44.1%	55.9%	
Heard about thyroid				
Yes	Respondents	57	63	
	% within heard about thyroid	47.5%	52.5%	0.061
No	Respondents	05	15	
	% within heard about thyroid	25.0%	75.0%	

iodine deficiency is a risk factor for many thyroid gland diseases (25). This is mainly due to the lack of awareness of the disease among healthcare students. The majority of the students in our study opined that females are the most affected gender. Previous research on TC has shown that females are affected more frequently than males, consistent with our findings (17, 26, 27). The study participants in our study remained neutral on the statement that thyroid function impact the menstrual cycle; in contrast, university students in Pakistan (47.8%) reported that thyroid function impacts the menstrual cycle (17). This can be attributed to the efforts for creating awareness on TC among the different levels of healthcare students.

In this current research, we emphasize the importance of further studies that can evaluate the perceptions of healthcare students. This study provides a good platform for others to conduct research within the domains. However, the current study has some limitations. First, the results were based on a self-completed questionnaire, which may have increased the possibility of biases such as social desirability bias or recall bias. Second, the results were derived from a single institute in Saudi Arabia, thus making them not representative of others and not generalizable globally. Third, the study did not involve junior students as it was conducted among senior healthcare students of the university, given the more accessible access to students found while spreading the questionnaire. Despite these limitations, our study lays more emphasis on increasing the awareness of health in college students, especially toward the knowledge of thyroid and its complications to make them more competent in raising public health.

Conclusion

This study depicts that half of the healthcare students who were knowledgeable about TC had positive perceptions of TC. The knowledge with respect to predisposing factors and early signs was inadequate and appropriate steps should be implemented to increase awareness to prevent the incidence of thyroid cancer. Thus, health education programs might help the participants understand and prevent the complications of TC and good adherence to treatment.

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 King Saud University College of Medicine E-21-6371. The patients/participants provided their written informed consent to participate in this study.

Author contributions

WS, OS, AA, MH, and MA-R conceived of this study and its design, conducted the data collection, reviewed and edited, performed the screening process, performed the content analysis and coding, and involved in interpreting the results. All authors have read and agreed to the published version of 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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References

1. Taylor PN, Albrecht D, Scholz A, Gutierrez-Buey G, Lazarus JH, Dayan CM, et al. Global epidemiology of hyperthyroidism and hypothyroidism. *Nat Rev Endocrinol.* (2018) 14:301–16. doi: 10.1038/nrendo.2018.18

2. Garmendia Madariaga A, Santos Palacios S, Guillén-Grima F, Galofré JC. The incidence and prevalence of thyroid dysfunction in Europe: a meta-analysis. *J Clin Endocrinol Metab.* (2014) 99:923–31. doi: 10.1210/jc.2013-2409

3. Vanderpump MP. The epidemiology of thyroid disease. *Br Med Bull.* (2011) 99:39–51. doi: 10.1093/bmb/ldr030

4. Canaris GJ, Manowitz NR, Mayor G, Ridgway EC. The Colorado thyroid disease prevalence study. *Arch Intern Med.* (2000) 160:526–34. doi: 10.1001/archinte.160.4.526

5. Wilson GR, Curry RWJ. Subclinical thyroid disease. *Am Fam Phys.* (2005) 72:1517–24.

6. Mendes D, Alves C, Silverio N, Marques FB. Prevalence of undiagnosed hypothyroidism in Europe: a systematic review and meta-analysis. *Eur Thyroid J.* (2019) 8:130–43. doi: 10.1159/000499751

7. American Thyroid Association (ATA). *Optimal thyroid health for all. General Information/Press Room*. Available online at https://www.thyroid.org/media-main/press-room/ (accessed November 2, 2021).

8. Alqahtani SA. Prevalence and characteristics of thyroid abnormalities and its association with anemia in ASIR region of Saudi Arabia: a cross-sectional study. *Clin Pract.* (2021) 11:494–504. doi: 10.3390/clinpract11030065

9. Ittermann T, Khattak RM, Nauck M, Cordova CM, Volzke H. Shift of the TSH reference range with improved iodine supply in Northeast Germany. *Eur J Endocrinol.* (2015) 172:261–7. doi: 10.1530/EJE-14-0898

10. Meisinger C. et al. Geographic variations in the frequency of thyroid disorders and thyroid peroxidase antibodies in persons without former thyroid disease within Germany. *Eur J Endocrinol.* (2012) 167:363–71. doi: 10.1530/EJE-12-0111

11. BannerHealth.com. *Do I have a Thyroid Condition? What Should I Do*?. Available online at https://www.bannerhealth.com/healthcareblog/teach-me/types-and-symptoms-of-thyroid-conditions (accessed November 3, 2021).

12. Parkin DM, Bray F, Ferlay J, et al. Global cancer statistics 2002. *CA Cancer J Clin.* (2005) 55:74–108. doi: 10.3322/canjclin.55.2.74

13. Brown RL, de Souza JA, Cohen EE. Thyroid cancer: burden of illness and management of disease. *J Cancer.* (2011) 2:193–9. doi: 10.7150/jca.2.193

14. Nguyen QT, Lee EJ, Huang MG, et al. Diagnosis and treatment of patients with thyroid cancer. *Am Health Drug Benefits.* (2015) 8:30–40.

15. Sipos J, Mazzaferri E. Thyroid cancer epidemiology and prognostic variables. *Clin Oncol.* (2010) 22:395–404. doi: 10.1016/j.clon.2010.05.004

16. Alyahya A, AlNaim A, AlBahr AW, Almansour F, Elshebiny A. Knowledge of thyroid disease manifestations and risk factors among residents of the eastern province, Saudi Arabia. *Cureus.* (2021) 13:e13035. doi: 10.7759/cureus.13035

17. Iqbal A, Azhar S, Ibrahim NA, Kharaba ZJ, Iqbal MM, Khan SA, et al. Thyroid cancer risk factors and Pakistani University students' awareness towards its preventive practice. *J Oncol Pharm Prac.* (2021) 27:570–8. doi: 10.1177/1078155220925166

18. Issa LF, Alzahrani OA, Alsharif MH, Albogami TF, Alharthi MH, Abdullah AM. Awareness of screening thyroid tumors among medical students in Saudi Arabia. *IJMDC.* (2021) 5:1411–6. doi: 10.24911/IJMDC.51-1621845922

19. Rai S, Sirohi S, Khatri AK, Dixit S, Saroshe S. Assessment of knowledge and awareness regarding thyroid disorders among women of a cosmopolitan city of central India. *Natl J Community Med.* (2016) 7:219–2.

20. Almuzaini A, Alshareef B, Alghamdi S, Munshy AA, Aljarallah AK, Salman SA, et al. Assessment of knowledge and awareness regarding thyroid disorders among Saudi people. *IJDMC.* (2019) 3:1070–6. doi: 10.24911/IJMDC.51-1568037206

21. Zuberi LM, Yawar A, Islam N, Jabbar A. Clinical presentation of thyroid cancer patients in Pakistan–AKUH experience. *J Pak Med Assoc.* (2004) 54:526–8.

22. Al Fayi MS. Thyroid cancer awareness among women in the asir region of Saudi Arabia. *King Khalid Univ J Health Sci.* (2021) 6:27. doi: 10.4103/KKUJHS.KKUJHS_6_21

23. *Eendocrineweb*. Available online at https://www.endocrineweb.com/conditions/thyroid-cancer/thyroid-cancer (accessed January 11, 2022).

24. American cancer society. *Thyroid Cancer Risk Factors*. Available online at https://www.cancer.org/cancer/thyroid-cancer/causes-risks-prevention/risk-factors.html (accessed January 11, 2022).

25. Zimmermann MB. and Galetti V. Iodine intake as a risk factor for thyroid cancer: a comprehensive review of animal and human studies. *Thyroid Res.* (2015) 8:8. doi: 10.1186/s13044-015-0020-8

26. Pambinezhuth F, Al Busaidi N, Al Musalhi H. Epidemiology of thyroid cancer in Oman. *Ann Endocrinol Metab.* (2017) 1:11–7. doi: 10.36959/433/561

27. Kilfoy BA, Devesa SS, Ward MH, Zhang Y, Rosenberg PS, Holford TR, et al. Gender is an age-specific effect modifier for papillary cancers of the thyroid gland. *Cancer Epidemiol Biomark Prev.* (2009) 18:1092–100. doi: 10.1158/1055-9965.EPI-08-0976

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An overview of public health education in South Asia: Challenges and opportunities

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Over the past two decades, there has been an increased demand for Public Health Education (PHE) in South Asia. While this region has a large number of Public Health (PH) institutions, the quality of PHE has not been aligned with the core PH competencies. In this article, we present an overview of Master of Public Health (MPH) programs across South Asian countries. An extensive systematic search on various web search engines regarding PH course offerings was conducted, including specific institute and educational websites. By 2021, more than 180 institutions in South Asia provided an MPH degree. Most of these institutions/universities were found in India, Pakistan, and Bangladesh, and a few among these institutions were established as independent Schools of Public Health (SPH), separate from medical colleges, and had a multidisciplinary faculty. But, dedicated training facilities in the specialized field of public health were not found in most of these institutions. Generally, a well-defined MPH curriculum is not currently available except in India where the University Grants Commission (UGC) guideline for a model MPH curriculum has been proposed by the Ministry of Health and Family Welfare. The entry criteria for an MPH degree in India is accepting students in multidisciplinary fields, while in other South Asian countries this is primarily restricted to medical/paramedical students with a basic understanding of preventive medicine. The aim of this review was to document the current and future PHE opportunities and challenges in South Asia.

KEYWORDS

career opportunities, challenges of public health education (PHE), higher education in PH, MPH program, South Asia

Introduction

Public health (PH), an interdisciplinary field takes into account not only physical ailments but also incorporates psychological and social well-being. PH encompasses the science and art of preventing diseases, prolonging life, and improving quality of life through organized efforts and informed choices of society, organizations, communities, and individuals (1). In 1978, the Alma Ata Conference restated the critical role of PH in accomplishing health for all by addressing the importance of equity, community participation, and inter-sectoral collaboration (2). The determinants of health in the population and analysis of the threats are grounded in the PH approach (3).

For the growth and prosperity of a nation, health is a key aspect to be considered (4). The field of PH encompasses various courses including epidemiology, bio-statistics, management of health services, environmental health, community health, behavioral health, health economics, public health policy, health politics, occupational safety including sub-fields such as disability, gender issues in health, mental health, and maternal and child health (5). On an international level, conflicting viewpoints on the approach to public health issues may arise, for instance, the goal of preventive vs. curative services, selective vs. comprehensive primary health care, or integrated (horizontal) vs. top down (vertical) programs (6). Intervention strategies that incorporate the PH sector's collaboration must contain the establishment of appropriate graduate and post-graduate study opportunities in PH.

Significance of the review

The South Asian countries form the South Asian Association for Regional Cooperation (SAARC) including Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. The SAARC nations are home to nearly one-fifth of the world's population and have been suffering from a vast number of health-related challenges such as a double burden of infectious and non-communicable diseases (NCDs), malnutrition, unsafe pregnancies, and a rapidly escalating plethora of NCD epidemics (7). Even though PH existed for over a century, it is still an evolving field in SAARC nations. PH knowledge is necessary to help students develop community health by organizing, evaluating, and implementing effective and equity-based PH programs (8). However, the multidisciplinary field of PH needs coordinated efforts with teams of PH workforce, specialists, and professionals from diverse sectors who contribute to the broader field of PH (9). The SPH is better placed to offer comprehensive health professional education, conduct multidisciplinary research, population studies, and adopt collaborative partnerships to achieve the sustainable development goals (SDGs) (9). With an aim to examine the challenges and opportunities in professional PHE in South Asia, a brief review was undertaken.

Review of the literature

MPH programs in South Asia were explored by Google scholar, CINAHL, Pub Med, Web of Science, ELDIS using keywords-PHE, South Asia, SAARC nations, higher education, study programs, MPH/M.Sc., career opportunities for PH graduates, challenges of PHE in SAARC nations. The Masters of Public Health (MPH) program is of 2 years duration as per the University Grants Commission standards (10). Post Graduate Diploma in Health Science, which is comparable to a 1-year MPH, was not included. The University websites, and education-based websites including Collegedunia.com (11), career360 (12), Eduvision (13), Collegedekho (14) were searched. Further, information on the SAARC nation's PHE, current situation, and challenges was obtained from the World Health Organization (WHO) and the Centre for Disease Control and Prevention (CDC) country pages. Articles in other regional languages apart from English, Bachelor's degree in Public Health, and doctoral programs were excluded.

Current status of public health education in SAARC nations

India

In India, 95 institutions were identified that provide MPH programs of 2 years duration with English as the medium of instruction. The number of MPH programs has increased dramatically during the last two decades and specifically over the last couple of years with the onset of the COVID-19 pandemic (15). However, it is necessary to recognize that the curricula and criteria for admissions in these programs are diverse (16). The universities follow the Model Curriculum floated by the Ministry of Health and Family Welfare (17). A new National Education Policy (NEP 2020), replacing the National Policy on Education from 1986, addressing the importance of research and a multi-disciplinary approach has been approved by the Union Cabinet of India (18). Under the NEP 2020, Higher Education Institutes (HEIs) in India have a choice of providing a 1 year Master's degree for those who have done their Bachelors degree of 4 years that includes research component in the programme (19). A 2-year Master's program with research activities in the second year is offered for those who obtained a bachelor's degree in 3 years (18). The NEP 2020 allows students to experience research-based learning on par with the academic structure of HEIs in developed countries (18, 19).

The MPH program includes five traditional core areas proposed by the Association of Schools and Program of Public Health (ASPPH). These disciplines are Epidemiology, Bio-statistics, Environmental Health Sciences, Health Policy and Management, Social and Behavioral Sciences. Some universities offer unique non-core subjects such as global health technology in PH by Kalinga Institute of Industrial Technology, food and nutrition courses and field posting at Career Point University. Medical colleges have traditionally been the primary source of PH specialty training in India (20). Outside of medical institutions, there has been an intentional shift in the past decade toward the establishment of SPH that allow non-medical personnel to obtain academic competencies in PH (21). Incidentally, India is the largest educational hub among the SAARC nations and accepts students from neighboring and other foreign nations to enroll in HEIs offering an MPH course. The Government of India through the Indian Council

for Cultural Relations (ICCR) offers scholarships for students from SAARC nations and the MPH course has gained increased demand over the past 2 years. The private-public partnership (PPP) model too has boosted MPH programs that provide PHE to students in the region. The Public Health Foundation of India (PHFI) remains a one-of-a-kind private–public collaboration that aims to reinvigorate PH by pooling resources from the government and private philanthropy to address the most pressing public health issues (22).

Bangladesh

In Bangladesh, 32 institutions offer MPH programs as of mid-year 2022. At Jahangirnagar University, there has been a M.Sc. in PH degree program for which only B.Sc. in PH students of this department can enroll. Most of the courses are of 1-year duration and the medium of instruction is English, while some courses are 16/18 months in duration. There is only one University (First capital) that provides an MPH degree with 2-year duration for students from a non-medical background. The most reputable University for an MPH degree is the James P. Grant School of Public Health established in 2005 at BRAC University. This program offers an innovative 12-month MPH curriculum that begins with 6 months of training in basic PH skills in the context of rural health action on the Savar rural campus, followed by training on the BRAC University campus (23).

Pakistan

In Pakistan, PH programs are available in 44 institutions including the MPH and MSPH degrees. Most of the courses were regular (2 year duration) and full time. The Provincial Health Services Academy provides a 4-year program and the Institute of PH and Gandhar University offer a 1-year MPH program. The entry criteria include medical/non-medical background and few universities require work experience to enroll in the MPH program (e.g., Jinnah Sindh Medical University). Very few universities provide training to graduates in primary health care and research including Jinnah Sindh Medical University.

Nepal

Ten universities provide MPH programs of 2 years duration, except Manmohan Technical University and Tribhuvan University, which offer programs with a duration of one and half years and 1 year, respectively. Some universities ask for the TOEFL/IELTS test as a pre-requisite for admission (notably Purbanchal University in Biratnagar).

Bhutan, Maldives, Afghanistan, and Sri Lanka

In Bhutan, Bachelor's of Public Health is offered by Khesar Gyalpo University of Medical Sciences (KGUMSB). There is no MPH program offered.

The Maldives higher education system consists of four universities with a total of 40 study programs. Two universities, the Maldives National University and the Villa College University, provide MPH program with English as the medium of instruction. However, there is no core course offered in Statistics.

In Afghanistan, a total of nine provinces have 87 universities. The website of universities was not updated and meager information was available. Only two universities appeared to offer an MPH credential with the medium of instruction as English. The Minister of Higher Education in partnership with WHO formally created the MPH program at Kabul Medical University (KMU) in the year 2013. Another MPH program was developed at Kandahar University with funding from the United States of America Agency for International Development (USAID), University Support and Workforce Development Program (USWDP), and technical help from Johns Hopkins University in the United States of America (23).

In Sri Lanka, the University Grants Commission provides oversight of 17 Sri Lankan universities and other educational institutions, all of which are classified as HEIs. A joint MPH program is provided by two institutions: the University of Kelaniya and the University of Peradeniya. Thus, by 2022 nearly 183 institutions in SAARC nations provided an MPH degree (Table 1).

Core competencies of public health education

The essential minimum set of attributes, such as applied knowledge, skills, and attitudes, that enable an individual to perform a set of tasks to an appropriate standard efficiently and effectively is defined as core competencies (24). Core competencies provide a common shared language for all PH professions to define what all are expected to be able to do to work optimally (25).

The COVID-19 pandemic has underlined the necessity of core competencies in performing PH functions such as disease outbreak prevention, detection, and response (26). However, most resource-poor countries struggle to impart the necessary PH competencies to the public health personnel to conduct these and other PH duties successfully (22, 27). In order to effectively deliver the critical PH functions such as epidemiological surveillance, situation assessments, and health promotion required that the PH professional should have fundamental competencies (28, 29). The functions are

TABLE 1 List of institutions offering public health education in SAARC nations.

India

1. Achutha Menon Centre for Health Science Studies, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram, Kerala
2. Adesh University, Bathinda, Punjab
3. Akal School of Public Health, Eternal University, Sirmour, Himachal Pradesh
4. All India Institute of Hygiene and Public Health, Kolkata, West Bengal
5. All India Institute of Medical Sciences, Jodhpur, Rajasthan
6. All India Institute of Medical Sciences, Rishikesh, Uttarakhand
7. All India Institute of Medical Sciences, Raipur, Chhattisgarh
8. Amity University, Noida, Uttar Pradesh
9. Amrita Institute of Medical Sciences and Research Centre, Kochi, Kerala
10. Asian Institute of Public Health, Bhubaneswar, Odisha
11. Athar Institute of Health and Management Studies, Gautam Nagar, New Delhi
12. B. J Government Medical College, Pune, Maharashtra
13. Career Point University, Kota, Rajasthan
14. Central University of Kerala, Kasargod, Kerala
15. Central University of Tamil Nadu, Thiruvarur, Tamil Nadu
16. Centre for Emerging Areas in Science and Technology, Punjab University, Chandigarh
17. Chitkara University, Chandigarh, Punjab
18. Christian Medical College, Vellore, Tamil Nadu
19. Datta Meghe Institute of Medical Sciences, Wardha, Maharashtra
20. Delhi Pharmaceutical Sciences and Research University, Pusp Vihar, Delhi
21. Dr. Shankarrao Chavan Government Medical College, Nanded, Maharashtra
22. Dr. Rammanohar Lohia Avadh University, Ayadhya, Uttar Pradesh
23. Edward and Cynthia Institute of Public Health, Mangaluru, Karnataka
24. Eternal University, Sirmour, Himachal Pradesh
25. Ganpat University, Kherva, Gujrat
26. GD Goenka University, Gurgoan, Haryana
27. Global Institute of Healthcare Management, Najafgarh, Delhi
28. Global Institute of Public Health, Thiruvananthapuram, Kerala
29. Government Medical College, Akola, Maharashtra
30. Government Medical College, Aurangabad, Maharashtra
31. Government Medical College, Chandrapur, Maharashtra
32. Government Medical College, Gondia, Maharashtra
33. Government Medical College, Nagpur, Maharashtra
34. Grant Government Medical College, Mumbai, Maharashtra
35. Guru Gobind Singh Indraprastha University, New Delhi
36. ICMR- National Institute of Epidemiology, Chennai, Tamil Nadu
37. I K Gujral Punjab Technical University, Khapurthala, Punjab
38. Institute of Clinical Research India (ICRI), Sam Global University, Bhopal, Madhya Pradesh
39. Indian Institute of Health Management Research (IIHMR) Jaipur, Rajasthan
40. Indian Institute of Public Health - Delhi
41. Indian Institute of Public Health - Gandhinagar, Gujarat
42. Indian Institute of Public Health - Hyderabad, Telangana
43. Indian Institute of Public Health – Shillong, Meghalaya
44. Institute of Management studies, Kolkata, West Bengal
45. Institute of Public Health, Kalyani, West Bengal
46. Interdisciplinary School of Health Sciences, Savitribai Phule Pune University, Maharashtra
47. Jagadguru Sri Shivarathreeswara University, Mysuru, Kamataka
48. Jawaharlal Institute of Postgraduate Medical Education and Research, Puducherry
49. Jawaharlal Nehru University, Munirka, Delhi
50. Jodhpur School of Public Health, Jodhpur, Rajasthan
51. Karnatak Lingayat Education University, Belgaum, Karnataka
52. Karnataka State Rural Development & Panchayat Raj University, Gadag, Karnataka
53. Kalinga Institute of Industrial Technology (KIIT), Bhubaneswar, Odhisa
54. KPC Medical College, Kolkata, West Bengal
55. Krishna Institute of Medical Sciences, Karad, Maharashtra
56. Maharashtra University of Health Sciences, Nashik, Maharashtra
57. Mahatma Gandhi University, Kottayam, Kerala
58. Mahatma Jyoti Rao Phoole University, Jaipur, Rajasthan
59. MD Goenka University, Sohna, Haryana
60. MIT world peace University, Pune, Maharashtra
61. M.S. Ramaiah University of Applied Sciences (MSRUAS), Bengaluru
62. National Centre for Disease Control, Sham Nath Marg, Delhi
63. National Institute of Mental Health and Neuro Sciences, Bengaluru, Karnataka
64. NITTE University, K.S. Hegde Medical Academy (KSHMA) Mangaluru, Karnataka
65. NSHM Knowledge Campus (NSHMKC), Kolkata
66. Noida International University, Gautam Budh Nagar, Uttar Pradesh
67. Om sterling global University, Hisar, Haryana
68. Padmashree School of Public Health, Bengaluru, Karnataka
69. Punjab University, Punjab
70. Parul University, Ahmedabad, Gujarat
71. Post Graduate Institute of Medical Education and Research, Chandigarh, Punjab
72. P P Savani University, Surat, Gujarat
73. Prasanna School of Public Health, Manipal University, Manipal, Karnataka
74. Pravara Institute of Medical Sciences, Ahmednagar, Maharashtra
75. Rabindranath Tagore University (RNTU), Bhopal, Madhya Pradesh
76. Rajiv Gandhi Institute of Public Health and Centre for Disease Control, Karnataka
77. Rayat Bahra University, Mohali, Punjab
78. Shalom Institute of Health & Allied Sciences, SHUATS, Allahabad, Uttar Pradesh
79. Sri Devaraj Urs Academy of Higher Education and Research, Kolar, Karnataka
80. Sai Group of Institutions (SGI)', Dehradun, Uttarakhand
81. Sam Higginbottom Institute of Agriculture, Technology and Sciences, Uttar Pradesh

(Continued)

TABLE 1 (Continued)

82. Sri Ramaswamy Memorial Institute of Science and Technology, Chennai, Tamil Nadu
83. SGT University- Faculty of Engineering and Technology (SGTU), Gurugram, Haryana
84. Shri Ramasamy Memorial (SRM) Institute of Science and Technology, Chennai, Tamil Nadu and Gangtok, Sikkim
85. Sri Ramachandra Medical College and Research Institute, Chennai, Tamil Nadu
86. Symbiosis Institute of Health Sciences, Pune, Maharashtra
87. Tata Institute of Social Sciences, Mumbai, Maharashtra
88. The Global Open University, Dimapur, Nagaland
89. The Tamil Nadu Dr.M.G.R Medical University, Chennai, Tamil Nadu
90. University of Hyderabad, Hyderabad, Telangana
91. University of Lucknow, Lucknow, Uttar Pradesh
92. Utkal University, Bhubaneswar, Odisha
93. University of Technology Sanganer, Jaipur, Rajasthan
94. Vinayaka Mission's Research Foundation, Salem, Tamil Nadu
95. Vinayaka Mission's Research Foundation - School of Allied Health Sciences (AVIT), Puducherry
96. Yenepoya Medical College, Mangaluru, Karnataka

Bangladesh

1 American International University-Bangladesh, Kuratoli, Dhaka
2 ASA University Bangladesh, Dhaka
3 Atish Dipankar University of Science and Technology, Dhaka
4 Bangabandhu Sheikh Mujib Medical University, Dhaka
5 Bangladesh University of Health Sciences, Dhaka
6 Bangladesh University of Professionals, Dhaka
7 BRAC University, Dhaka
8 Fareast University, Dhaka
9 First Capital University of Bangladesh, Chuadanga
10 Hamdard University Bangladesh, Gazaria, Dhaka
11 Independent University Bangladesh, Dhaka
12 Islamic University Bangladesh, Kushtia
13 Jagannath University, Dhaka
14 Jahangirnagar University, Dhaka
15 Leading University Bangladesh, Sylhet
16 National Institute of Preventive and Social Medicine (NIPSOM), Dhaka
17 North East University Bangladesh, Dhaka
18 North South University, Dhaka
19 North Western University, Khulna
20 Northern University, Bangladesh, Dhaka
21 Bangladesh Open University, Dhaka
22 Premier University, Chittagong
23 Pundra University of Science & Technology, Rangpur
24 Rajshahi University, Rajhshahi
25 Ranada Prasad Shaha University, Narayanganj, Dhaka
26 State University of Bangladesh, Dhaka
27 United International University, Dhaka
28 University of Comilla, Comilla
29 University of Creative Technology, Chittagong, (UCTC)
30 University of South Asia, Dhaka
31 Varendra University, Rajhshai
32 Z H Sikder University of Science & Technology, Shariatpur

Pakistan

1 Afro-asian Institute, Lahore
2 Al- Hamd Islamic University, Quetta
3 Allied College of Health Sciences, Khanewal
4 Allied College of Health Sciences, Multan
5 Armed Forces Postgraduate Medical Institute, Rawalpindi
6 Baqai Medical University/hospital, Karachi
7 Buraq Institute of Higher Studies, Peshawar
8 Dow University of Health Sciences, Karachi
9 Federal Institute of Health Sciences, Lahore
10 Federal Institute of Health Sciences, Multan
11 Fedral Institute of Health Sciences, Muzaffarabad
12 Frontier Institute of Medical Sciences, Abbottabad
13 Gandhara University, Peshawar
14 Gomal University, D.i. Khan
15 Institute of Computer and Management Sciences(icms), Peshawar
16 Institute of Health & Management Sciences, Islamabad
17 Institute of Health Sciences, Mardan
18 Institute of Public Health, Lahore
19 Institute of Public Health, Quetta
20 Islamabad Federal College F-10, Islamabad
21 Khyber Medical University, Peshawar
22 Liaquat University of Medical and Health Sciences, Jamshoro
23 Mardan Institute of Sciences, Mardan
24 National University f Medical Sciences, Rawalpindi
25 Pakistan Institute of Community Ophthalmology, Peshawar
26 Peoples University of Medical and Health Sciences for Women, Nawab Shah
27 Peshawar Institute of Modern Sciences, Peshawar
28 Peshawarcity Institute of Modern Sciences, Peshawar
29 Prime Institute of Public Health, Peshawar
30 Provincial Health Services Academy, Peshawar
31 Shaheed Mohtarma Benazir Bhutto Medical University, Larkana
32 The Next College, Multan
33 The University of Lahore (Main Campus), Lahore
34 Times Institute, Multan
35 Udhyana Instititue Of Medical Sciences, Abbottabad
36 University of Health Sciences, Lahore
37 Vertex College of Science and Technology, Islamabad

Nepal

1 B.P. Koirala Institute of Health Sciences, Dharan
2 Central Department of Public Health, IOM, Kathmundu
3 Chitwan Medical College, Chitwan
4 Kathmandu University School of Medical Sciences, Kathmundu
5 ManMohan Memorial Institute of Health Sciences, Nagarjun

(Continued)

TABLE 1 (Continued)

6	Nobel College, Kathmandu
7	Om Health Campus, Purbanchal University
8	Patan Academy of Health Sciences, Lalitpur
9	Pokhara University, Pokhara
10	Purbanchal University College of Medical and Allied Sciences, Biratnagar
11	Tribhuvan University, Kathmundu

Countries	Institutions
Bhutan, Maldives, Afghanistan, Sri Lanka	
Bhutan	Khesar Gyalpo University of Medical Sciences (KGUMSB), Thimpu*, *No Master degree offer in PH
Maldives	1. Maldives National University, Male 2. Villa College universities, Male
Afghanistan	1. Kabul Medical University (KMU), Kabul 2. Kandahar University, Kandahar
Sri Lanka	1. University of Kelaniya, Kelaniya 2. University of Peradeniya, Peradeniya

multidisciplinary in nature and not limited to a single program or topic, and every staff at all levels in the PH system should have these core skills established (26). Toward this goal, the core competencies of the Association of Schools and Program of Public Health (ASPPH) in the United States established by a national consensus in 2006 remain a useful resource and reference for PH educators, administrators, and students (30). The ASPPH proposed Core Competence in Public Health model includes competencies in five traditional PH core areas as well as seven interdisciplinary/cross-cutting areas (Figure 1). The MPH students graduated from a Council on Education for Public Health (CEPH)-accredited school or program of PH in the United States are equipped with these core competencies. The discipline specific competencies are Bio-statistics, Environmental Health Sciences, Epidemiology, Health Policy and Management, Social and Behavioral Sciences. The Interdisciplinary/Cross-cutting competencies include Communication and Informatics, Diversity and Culture, Leadership, Public Health Biology, Professionalism, Program Planning, Systems Thinking. The core competency assessment for MPH graduates in low and middle-income countries (LMICs) is uncommon and there exists a need for a Accreditation Council on PHE in the region (26, 30).

The WHO-ASPHER (Association of Schools of Public Health in the European Region) Competency Framework can be used as a starting point for more context-specific competencies to be developed (31). It contains three core categories: Content and context, Relations and interactions, and Performance and achievement.

Among South Asian countries, we found few studies regarding core competencies and one study emphasized the cross-cutting domain that included health communication and informatics, health management and leadership, professionalism, systems thinking, and PH biology along with the five core areas (32, 33). A study from Uttar Pradesh in India has identified core competencies for practicing PH professionals using a Delphi exercise (26). This study proposed 48 competency statements across eight domains: PH sciences, assessment and analysis, policy and program management, financial management and budgeting, partnerships and collaboration, social and cultural determinants, communication, and leadership.

Challenges and opportunities of PHE for SAARC nations

The South Asian countries have similar health profiles to their neighboring countries. India, as the biggest among the SAARC nations in the region, has encountered challenges such as a scarce PH workforce; a lack of skilled workers in accordance with the health system needs of the population, and an unequal range of types and levels of ability of health workforce (34). There are gaps in PHE requiring in-depth understanding and addressing including the quantity and quality of PH education (35). The shortages in the health workforce are not the only issues, the limited availability of jobs, and lack of opportunities to absorb the recent MPH graduates within the health system, NGOs, and the industry seems a huge concern and this scenario was affecting the enrolment in higher studies in PH (36). In the wake of the pandemic, "Health" has become a central issue in our lives; thus, to attain it, the SAARC nations need to act in an organized manner. The curricula require to evolve in such a way that all levels of students can find the opportunities to enter the PH program and acquire training on health and human ecology (37). As PH deals with the health of the population as a whole, the term "Health literacy" can be a goal of our learning system in a true sense (38). Explicitly, the spread of health challenges and duties in society creates a demand for health training in a variety of vocations that do not include the word "health" in the title (37). A small percentage of students join MPH program by choice after undergraduate studies, prompted by the desire to work in the health-care field (22). However, research capabilities, financial accessibility, and innovation are strengths of SPH in India. But there is a need to improve collaborations and synchronize training with well-defined career routes (39).

Public health allied practitioners have always been viewed as being at the bottom of the health-care hierarchy (40). When there will be appropriate course curricula with evidence-based research opportunities and training in epidemiological studies, a better workforce in health care will be added. While there has always been a mismatch between supply and demand for healthcare workers in Bangladesh's healthcare sector, the

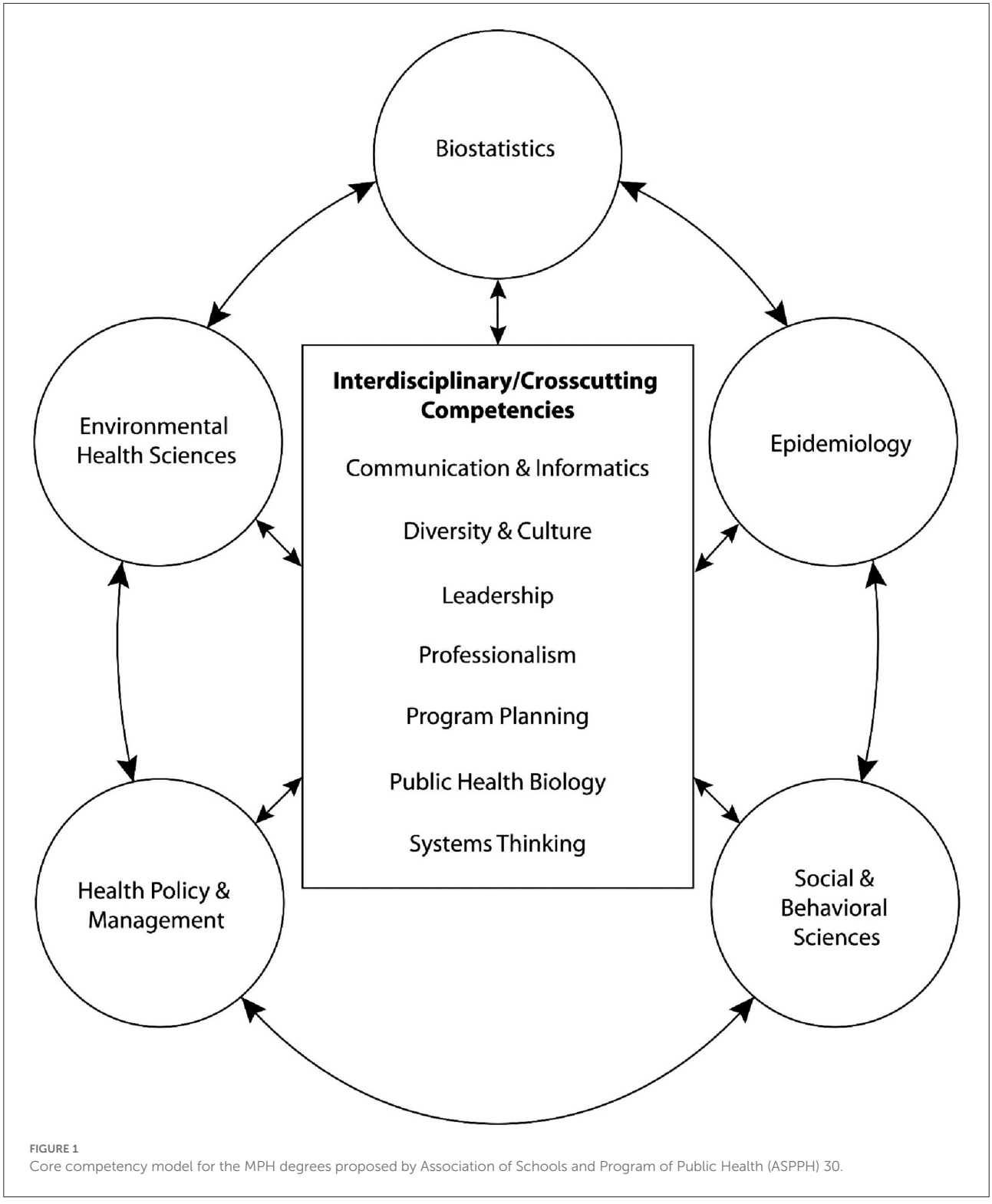

FIGURE 1
Core competency model for the MPH degrees proposed by Association of Schools and Program of Public Health (ASPPH) 30.

situation has been different for allied PH practitioners and medical professionals (40).

Competence is critical in determining a health worker's capacity and preparedness for offering high-quality care (41). According to the findings of a study, academic institutions are creating PH graduates that lack the necessary abilities to operate in a variety of PH disciplines, and also the present MPH curriculum varies greatly between institutes with different

emphasis (42, 43). A recent scoping analysis sheds light on the state of the MPH program across South Asian countries. Due to the lack of a comprehensive and consistent curriculum, the competencies acquired by these graduates may vary (44). WHO South-East Asia region (45) showed vast variation in institutes and courses offered regardless of the existence of numerous postgraduate courses and undergraduate courses in these countries. It demonstrates that there is a significant gap in our understanding of how effectively research outputs affect PH decision-making as a result of this gap between PHE and real-world PH policies and practices (46).

MPH is largely a professional practice degree in Nepal, as it is in most other SAARC nations. Despite this, MPH graduates are likely to work in research and academic settings due to the scarcity of possibilities for further education in PH (47). "Community Medicine" is an integral part of Nepalese medical school curricula. It was observed that a synergistic relationship between departments of PH and clinical sciences was not well integrated in actual practice (47). The notion that research has to be "community-based" has further discouraged interdisciplinary research within these institutions. The SPH in Nepal is located in educational institutions affiliated with specialized health centers, hospitals, and peripheral health facilities, all of which are engaged in the treatment and prevention of disease. Some of these diseases/conditions include infectious and chronic diseases, trauma, maternal and child health problems, and mental illness (47).

The literature available regarding PHE and training programs in Pakistan is scant. One study involving In-depth interviews with stakeholders revealed PH practitioners preferred to recruit someone with a medical degree (48). They further seek practical experience, skills in program coordination, resource mobilization, management, analytical skills, grant-writing abilities, strategic thinking, monitoring, and program evaluation as well as specific knowledge of Pakistan's health system. Investing in a PH training program is difficult as the government of Pakistan funds only 5% of the Health Service Academy's budget and the rest is to be raised through grants for capacity building and research (48). The literature on medical education has continued evidence of dispute on whether or not to include PH in a basic medical curriculum. Woodward, argues that the "clinical imperative of diagnosis and treatment is so firmly entrenched in the minds of students and in the cultures of medical schools that PH will always be diminished and elbowed to one side in medical curricula" (49). Usually, the dissimilarity is in the fundamental, philosophical, and practical differences between these two fields (50). The emphasis of PH is on the health of populations and stress prevention and health promotion, whereas clinical medicine focuses on the individual's health by concentrating on curative measures e.g., diagnosis and treatment (50). However, the COVID-19 pandemic highlighted the need for interdisciplinary collaboration to address the worsening pre-existing disparities and inequity that exacerbated the lack of access to health care around the world (51). The epidemic has raised awareness of the urgency for more funding for SPH and PH programs to create and execute new courses and techniques for acquiring key competencies (51, 52).

During the eighteenth and nineteenth centuries, the focus shifted to the development of personal preventive services and also the establishment of maternal and child health services including mass vaccination (53). To ensure "Health for all", preventive practice in PH in parallel with the clinical practice was emphasized. By the early twentieth century, it was clear that PH was required to combat chronic diseases. Over the recent decades, it has become obvious that PH is needed to address the social, political, and commercial determinants of health, including through actions outside of the health system, such as in the agriculture sector, rural development, urban planning, and Health in all policies (53). Some studies document the surge in enrolment of MPH education following the onset of the COVID-19 pandemic. The applications to Masters in PH programs in the USA had seen a sharp increase (20%) for the academic year 2020-21 and were nearly 40,000, according to the Association of Schools and Programs of PH (54). Likewise, the number of institutions and universities offering MPH courses has gone up in South Asia specifically in India. But, there are no studies available in current literature that estimated the number of students successfully graduating with MPH degrees annually.

For obvious reasons, the COVID-19 pandemic has had a particularly important influence on the need for online education in PH. The MOHFW, Government of India has recognized these training programs as an innovative model of education in their National innovation summits (55). The holistic education envisaged under the NEP 2020 offers students at HEIs an internship with local industries/craftspeople as well as research internships at their own/other institutions. This enables them to actively engage with practical learning and, as a result, improve their skills and employability. The credits earned at foreign universities will be allowed to be counted toward the award of a degree if suitable and in accordance with the rules of each HEI (18). In Bangladesh, the government has big plans for digital and e-learning with the goal of making it a permanent part of the educational system (56). In Pakistan, The Prime Institute of Public Health offers competency-based PH courses that are practice-oriented to individuals with at least 14 years of education and interest in PH (57).

Evaluation method of MPH program in South Asia

As discussed earlier, the content and structure of the WHO-ASPHER competency have proposed the development of a new approach to evaluating the MPH level programs, which highlighted that there is a wide range of competencies

required to perform professional duties in PH (58). The choice-based credit system (CBCS) gives students the option of three different course types: Core, Elective, and Foundation. The CBCS is followed by most South Asian universities. But few universities lack the option of fundamental courses. Regarding the evaluation, we found that the method is mostly formative (Internally by the concerned faculty member through quizzes, tutorials, lab works, home assignments, class tests, class participation, term papers, and internal exams) and summative (Externally by the Office of the Controller of Examinations of concern University through year/semester-end examinations). In Bangladesh, private universities mostly follow the semester system, while public universities offer annual system courses; especially, while for other countries, majority of the universities offered semester system courses. The total credits varied across South Asian universities for MPH programs with most universities requiring more than 50 credits except Afghanistan (46 credit). The universities offered internship opportunities and facilitated the process, but a program-based research opportunities were generally lacking. Despite the vast scope, there is a strong necessity to improve cooperation and align training and employment paths as well as effective community engagement techniques in the region. An MPH program evaluation survey revealed that MPH graduates should be able to monitor health problems and epidemics in their communities, develop indicators and instruments to monitor and evaluate community health programs, develop proposals, apply biostatistics principles in public health, conduct operations/action research, understand social and community influences on public health, and involve the community in planning, delegating, and evaluating community health programs (33). In this review, the scarcity of literature on the evaluation of MPH programs in South Asia presents a challenge. A study on the transdisciplinarity of India's master's level public health programs revealed the lack of inclusivity of non-medical disciplines (59).

Strengths and limitations of the review

This review provides an up-to-date perspective on the availability of rapidly emerging professional public health training and education programs in South Asia. The introduction of the National Education Policy, 2020 in India has large positive implications for Public Health Education nationally, regionally, and globally. This review updates the public health educational institutions that emerged in response to the pandemic in the region and generate greater awareness among the general public and PH professionals. Further, it emphasizes the need for a robust public health curriculum and core competencies for aspiring professionals who would constitute the future public health workforce in the region. However, there are some limitations, such as a lack of information pertaining to country-wise number of students' enrollment, professional accreditation, and regulatory bodies in South Asia to evaluate public health education.

Conclusion

The professional PHE is evolving rapidly in the South Asia region. Among the eight SAARC nations, India has structured and well-defined PH course curricula. Indian universities and HEIs welcome foreign nationals for higher studies in PH. The literature and information on PHE are more readily available for India than for other SAARC nations. Till now Bhutan, Maldives, Afghanistan, and Sri Lanka have not expanded the scope of PHE in independent schools or separated it from medical schools. Some countries are strict in the eligibility criteria in Master's programs to only medical students (Sri Lanka, Afghanistan). Therefore, as PH is a multidisciplinary field, students from varied backgrounds should find the chance to enroll in the program. Since PH literacy is required for the recognition and fundamental grasp of how the social and physical environment influences health, it is a legitimate and worthwhile societal aim.

The emphasis on core competencies will be meaningful if it culminates with a job or higher education opportunities. To this effect, the engagement and involvement of academia, industry, and government stakeholders are essential. However, currently, there are no clear avenues for absorbing MPH graduates within the existing government health care infrastructure, NGO, or industries. A robust PH culture can be promoted by ensuring training facilities for students from both medical and non-medical backgrounds, a necessity in the twenty-first century. As the new PH graduates enter the government or development sectors, more opportunities to enroll non-medical graduates in the PH workforce become necessary. There is a lack of literature and critical analysis regarding PHE in the South Asia region. There is a compelling need to address the gaps and the consequent scope of PHE and job opportunities in the South Asian region. Given the spread of Institutes and Schools of Public Health in South Asia in recent decades, it would be worthwhile to evaluate the PHE in the region. South Asian countries must examine their human resource needs for health and create the capacity to meet education and health service needs in the future.

Author contributions

CTA contributed to the conceptualization and project administration. CTA and KA contributed to the methodology.

KA conducted the investigation and contributed to writing original draft. CTA and KM performed supervision and acquired resources, performed validation, contributed to writing, reviewing, and editing of the manuscript. All authors read and approved the final version of the manuscript for publication and their respective contributions.

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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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References

1. Winslow C-E. The untilled fields of public health. *Science.* (1920) 51:23–33. doi: 10.1126/science.51.1306.23

2. Petrakova A, Sadana R. Problems and progress in public health education. *Bull World Health Organ.* (2007) 85:963–5. doi: 10.2471/BLT.07.046110

3. CDC. *What is Public Health.* (2022). Available online at: https://www.cdcfoundation.org/what-public-health#:\sim:text=Public%20health%20is%20the%20science,and%20responding%20to%20infectious%20diseases

4. World Health Organization. *South-East Asia public health initiative 2004-2008.* New Delhi: WHO Regional Office for South-East Asia (2004).

5. Perdiguero E. Anthropology in public health. Bridging differences in culture and society. *J Epidemiol Commun Health.* (2001) 55:528. doi: 10.1136/jech.55.7.528b

6. Jamison DT, Mosley WH. Disease control priorities in developing countries: health policy responses to epidemiological change. *Am J Public Health.* (1991) 81:15–22. doi: 10.2105/AJPH.81.1.15

7. World Health Organization. *Regional Office for South-East Asia. A Decade of Public Health Achievements in WHO's South-East Asia Region.* WHO Regional Office for South-East Asia (2013).

8. Sadana R, Mushtaque A, Chowdhury R, Petrakova A. Strengthening public health education and training to improve global health. *Bull World Health Organ.* (2007) 85:163. doi: 10.2471/BLT.06.039321

9. Rabbani F, Shipton L, White F, Nuwayhid I, London L, Ghaffar A, et al. Schools of public health in low and middle-income countries: an imperative investment for improving the health of populations? *BMC Public Health.* (2016) 16:1–12. doi: 10.1186/s12889-016-3616-6

10. UGC. *Minimum Standards of Instruction for the Grant of the Master's Degree through Formal Education Regulations.* New Delhi (2003).

11. Collegedunia. *Top Colleges, Universities & Institutes in India | Admission, Fees, Rankings of Top Management, Engineering, Medical Colleges.* (2021). Available online at: https://collegedunia.com/

12. Careers360. *Explore Exams, Colleges, Courses and Latest News about Education.* (2021). Available online at: https://www.careers360.com/

13. EduVision. *Career Planning and Educational Guidance.* (2021). Available online at: https://www.eduvision.edu.pk/

14. Collegedekho.com. *Find Top Colleges & Universities in India | Explore Courses, Exams, Admissions & Latest News.* (2022). Available online at: https://www.collegedekho.com/

15. Sawleshwarkar S, Zodpey S, Negin J. "Public health is global": examining Indian stakeholders' perspectives on Global Health education. *BMC Public Health.* (2020) 20:1–12. doi: 10.1186/s12889-020-09357-2

16. Tiwari R, Negandhi H, Zodpey Z. Current status of master of public health programmes in India: a scoping review. *WHO South-East Asia J Public Health.* (2018) 7:29–35. doi: 10.4103/2224-3151.228425

17. MOHFW. *Model Curriculum Handbook Masters In Public Health.* New Delhi: Ministry of Health and Family Welfare 2017-18 (2017).

18. India. *MoHRDGoI.* Ministry of Human Resource Development, Government of India. National Education Policy (2020).

19. Kanika Khurana. NEP 2020:4-Year Bacherlors' Degree, M.Phil to be discontinued-how UG/PG Course structure would change. *Times now News* (2020).

20. Negandhi H, Sharma K, Zodpey SP. How can departments of community medicine shape the future of Public Health Education in India? *Indian J Public Health.* (2010) 54:184. doi: 10.4103/0019-557X.77257

21. Suresh K. Public Health Schools in India need to go beyond syllabus. *J Qual Health Care Econ.* (2020) 3:000155. doi: 10.23880/jqhe-16000155

22. Frenk J, Chen L, Bhutta ZA, Cohen J, Crisp N, Evans T, et al. Health professionals for a new century: transforming education to strengthen health systems in an interdependent world. *Lancet.* (2010) 376:1923–58. doi: 10.1016/S0140-6736(10)61854-5

23. Wadsam. *Kandahar University Inaugurates New Online Resource Center.* Kandahar: Afghanistan Afghan Business (2018).

24. Moynihan S, Paakkari L, Välimaa R, Jourdan D, Mannix-McNamara P. Teacher competencies in health education: results of a Delphi study. *PLoS ONE.* (2015) 10:e0143703. doi: 10.1371/journal.pone.0143703

25. Albarqouni L, Hoffmann T, Straus S, Olsen NR, Young T, Ilic D, et al. Core competencies in evidence-based practice for health professionals: consensus statement based on a systematic review and Delphi survey. *JAMA Network Open.* (2018) 1:e180281–e. doi: 10.1001/jamanetworkopen.2018.0281

26. Bhandari S, Wahl B, Bennett S, Engineer CY, Pandey P, Peters DH. Identifying core competencies for practicing public health professionals: results from a Delphi exercise in Uttar Pradesh, India. *BMC Public Health.* (2020) 20:1737. doi: 10.1186/s12889-020-09711-4

27. Rao M, Rao KD, Kumar AS, Chatterjee M, Sundararaman T. Human resources for health in India. *Lancet.* (2011) 377:587–98. doi: 10.1016/S0140-6736(10)61888-0

28. Core Competencies Domains.aspx. *Core Competencies for Public Health Professionals: Domains.* (2021). Available online at: http://www.phf.org/programs/corecompetencies/Pages/Core_Competencies_Domains.aspx

29. World Health Organization. *Essential Public Health Functions, Health Systems and Health Security: Developing Conceptual Clarity and a WHO Roadmap for Action* (2018).

30. ASPH Education Committee. *Master's Degree in Public Health Core Competency Development Project.* Washington, DC: The Association of Schools of Public Health (ASPH) (2006).

31. World Health Organization. *WHO-ASPHER Competency Framework for the Public Health Workforce in the European Region.* Copenhegan: World Health Organization; Regional Office for Europe (2021).

32. Raghav PR, Kumar D, Bhardwaj P. Experience of Delphi technique in the process of establishing consensus on core competencies. *Int J Appl Basic Med Res.* (2016) 6:191. doi: 10.4103/2229-516X.186966

33. Sharma K, Zodpey S, Gaidhane A, Syed ZQ, Kumar R, Morgan A. Designing the framework for competency-based master of public health programs in India. *J Public Health Manag Pract.* (2013) 19:30–9. doi: 10.1097/PHH.0b013e318241da5d

34. Hazarika I. Health workforce in India: assessment of availability, production and distribution. *WHO South-East Asia J Public Health.* (2013) 2:106–12. doi: 10.4103/2224-3151.122944

35. Zodpey SP, Negandhi H, Yeravdekar R. Future directions for public health education reforms in India. *Front Public Health.* (2014) 2:68. doi: 10.3389/fpubh.2014.00068

36. Sharma K, Zodpey S. Public health education in India: Need and demand paradox. *Indian J Commun Med.* (2011) 36:178. doi: 10.4103/0970-0218.86516

37. Brownson RC, Burke TA, Colditz GA, Samet JM. Reimagining public health in the aftermath of a pandemic. *Am J Public Health.* (2020) 110:1605–10. doi: 10.2105/AJPH.2020.305861

38. St Leger L. Schools, health literacy and public health: possibilities and challenges. *Health Promot Int.* (2001) 16:197–205. doi: 10.1093/heapro/16.2.197

39. Miller E, Reddy M, Banerjee P, Brahmbhatt H, Majumdar P, Mangal D, et al. Strengthening institutions for public health education: results of an SWOT analysis from India to inform global best practices. *Hum Resour Health.* (2022) 20:1–11. doi: 10.1186/s12960-022-00714-3

40. Rahnuma Binte Rashed. *The Evolving Trend of Public Health Careers in Pandemic*. Dhaka: The Financial Express (2021).

41. Kak N, Burkhalter B, Cooper M-A. Measuring the competence of healthcare providers. *Operat Res Issue Paper*. (2001) 2:1–28.

42. Sharma K, George S, Zodpey S. Understanding the current status and exploring the potential for distance education in public health in India. *Indian J Public Health.* (2011) 55:7. doi: 10.4103/0019-557X.82533

43. Sharma K, Zodpey S, Syed Z, Gaidhane A. Career opportunities for master of public health graduates in India. *Asia Pacific J Health Manag.* (2013) 8:45–50.

44. Ambade P. *Down To Earth*. (2021). Available online at: https://www.downtoearth.org.in/blog/health/covid-19-why-indianeeds-a-robust-public-health-infrastructure-77222

45. World Health Organization. *South-East Asia Public Health Initiative 2004-2008*. New Delhi: WHO (2005).

46. Fee E, Brown TM. The past and future of public health practice. *Am J Public Health.* (2000) 90:690–1. doi: 10.2105/AJPH.90.5.690

47. Mahat A, Bezruchka SA, Gonzales V, Connell FA. Assessment of graduate public health education in Nepal and perceived needs of faculty and students. *Hum Resour Health.* (2013) 11:1–12. doi: 10.1186/1478-4491-11-16

48. Mureed S, Hamid S, Hafeez A. Transforming public health education in pakistan: matching competencies to health system needs. *Educ Res J.* (2017) 7:181–91.

49. Woodward A. For Debate: Public health has no place in undergraduate medical education. *J Public Health.* (1994) 16:389–92. doi: 10.1093/oxfordjournals.pubmed.a043018

50. Keith KC. Student perspectives on public health education in undergraduate medical education. *Diversity Equal Health Care.* (2018) 15:181. doi: 10.21767/2049-5471.1000181

51. Ghaffar A, Rashid SF, Wanyenze RK, Hyder AA. Public health education post-COVID-19: a proposal for critical revisions. *BMJ Glob Health.* (2021) 6:e005669. doi: 10.1136/bmjgh-2021-005669

52. Gummeson H, Goel SR, Elmusharaf K. Public health practicum: a scoping review of current practice in graduate public health education. *BMJ Open.* (2021) 11:e047512. doi: 10.1136/bmjopen-2020-047512

53. World Health Organization. *European Observatory on Health Systems and Policies* (2007).

54. Smith M, Young K. Public health programs see surge in students amid pandemic. *ABC News*. (2020).

55. Public Health Foundation of India. *Training Division*. Available online at: https://phfi.org/thework/research/training-division/

56. Future Learn. *Top 25 Online Courses in Bangladesh - Study for Free with FutureLearn*. (2021). Available online at: https://www.futurelearn.com/info/blog/top-25-online-courses-inbangladesh

57. Prime Institute of Public Health. *Certificate Courses*. Available online at: https://piph.prime.edu.pk/academics/certificate-courses-workshops

58. Gruzieva TS, Hrechyshkina NV, Antonyuk OY, Dufynets VA, Konovalov SE. Self-assessment of the content of the public health master's educational program for compliance with the european public health core competences programme. *Wiadomości Lekarskie*. (2021) 2021:713. doi: 10.36740/WLek202103227

59. Ilangovan K, Muthappan S, Govindarajan K, Vairamani V, Venkatasamy V, Ponnaiah M. Transdisciplinarity of India's master's level public health programmes: evidence from admission criteria of the programmes offered since 1995. *Hum Resour Health.* (2022) 20:1–11. doi: 10.1186/s12960-022-00713-4

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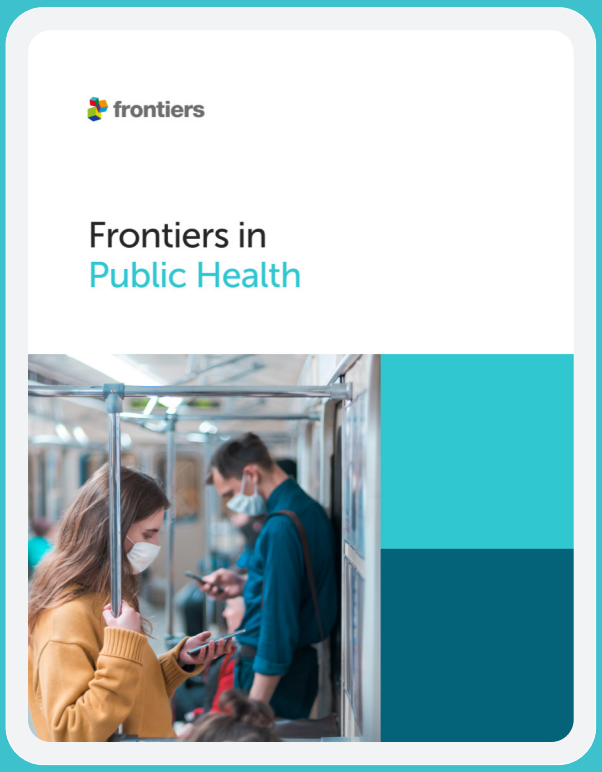

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