frontiers | Research Topics

Public health policy and health communication challenges in the COVID-19 pandemic and infodemic

Edited by
Zhiwen Hu, Chuhan Wu and Pier Luigi Sacco

Published in
Frontiers in Public Health
Frontiers in Medicine
Frontiers in Education

ISSN 1664-8714
ISBN 978-2-8325-3272-0
DOI 10.3389/978-2-8325-3272-0

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Public health policy and health communication challenges in the COVID-19 pandemic and infodemic

Topic editors

Zhiwen Hu — Zhejiang Gongshang University, China

Chuhan Wu — Tsinghua University, China

Pier Luigi Sacco — University of Studies G. d'Annunzio Chieti and Pescara, Italy

Citation

Hu, Z., Wu, C., Sacco, P. L., eds. (2023). *Public health policy and health communication challenges in the COVID-19 pandemic and infodemic*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-3272-0

Table of contents

frontiers | Frontiers in Public Health

TYPE Editorial
PUBLISHED 04 August 2023
DOI 10.3389/fpubh.2023.1251503

OPEN ACCESS

EDITED AND REVIEWED BY
Marc Jean Struelens,
Université libre de Bruxelles, Belgium

*CORRESPONDENCE
Zhiwen Hu
✉ huzhiwen@zjgsu.edu.cn

RECEIVED 01 July 2023
ACCEPTED 14 July 2023
PUBLISHED 04 August 2023

CITATION
Hu Z, Wu C and Sacco PL (2023) Editorial: Public health policy and health communication challenges in the COVID-19 pandemic and infodemic. *Front. Public Health* 11:1251503. doi: 10.3389/fpubh.2023.1251503

Editorial: Public health policy and health communication challenges in the COVID-19 pandemic and infodemic

Zhiwen Hu[1,2]*, Chuhan Wu[3] and Pier Luigi Sacco[4,5,6]

[1]School of Computer Science and Technology, Zhejiang Gongshang University, Hangzhou, China, [2]Collaborative Innovation Center of Computational Social Science, Zhejiang Gongshang University, Hangzhou, China, [3]Department of Electronic Engineering, Tsinghua University, Beijing, China, [4]Department of Philosophical, Pedagogical and Economic-Quantitative Sciences, G. d'Annunzio University of Chieti-Pescara, Pescara, Italy, [5]metaLAB (at) Harvard, Cambridge, MA, United States, [6]Institute for the Sciences of Cultural Heritage, National Research Council, Naples, Italy

KEYWORDS

public health policy, health communication, COVID-19 pandemic, COVID-19 infodemic, large generative models

Editorial on the Research Topic
Public health policy and health communication challenges in the COVID-19 pandemic and infodemic

Introduction

On 2 February 2020, the World Health Organization (WHO) characterized the COVID-19 infodemic as an overabundance of information, "some accurate and some not—that makes it hard for people to find trustworthy sources and reliable guidance when they need it." Indeed, this assessment sheds light on the fact that we have struggled with both the COVID-19 pandemic and co-evolving infodemics (e.g., disinformation, misinformation, fake news, rumors, and lies) in the aftermath of the COVID-19 pandemic, as well as the need to foster interdisciplinary collaborations to fill crucial niches in public health policy and health communication (1–7).

The COVID-19 pandemic is fueling digital health transformation, accelerating innovations of digital health services, surveillance, and interventions, while further amplifying the social impact of deliberate COVID-19-related disinformation and misinformation activities. However, there is a relatively limited amount of research worldwide that has focused on the advancements in digital health innovations and surveillance strategies in the crux of both the COVID-19 pandemic and the COVID-19 infodemic from multidisciplinary perspectives, including proven innovations in public policy evaluation (PPE) (8).

The Research Topic "*Public health policy and health communication challenges in the COVID-19 pandemic and infodemic*" includes 14 articles reporting on research findings regarding public policy evaluation (PPE) with five overarching themes, including nine original research studies, two brief researcher reports, two reviews, and one perspective. The foci of these articles, published in the Frontiers journals *Frontiers in Public Health*, *Frontiers in Medicine*, and *Frontiers in Education*, are diverse, broadly including:

- Innovative approaches to public policy evaluation (Liu and Jiang; Carr et al.; Li et al.; Mejia et al.; Xu et al.).
- Public perception and collective behaviors (Wibowo et al.; Xue et al.; Carr et al.; Nagarajan et al.; Lee et al.; Gerretsen et al.).
- Innovative communication strategies against the COVID-19 infodemic (Adhikari et al.; Lee et al.; Hu et al.).
- SARS-CoV-2 vaccine inequity and vaccine hesitancy (Chen et al.; Shobako; Hu et al.).
- The challenges of science-based policymaking (Li et al.; Lee et al.; Wibowo et al.).

Think globally, act locally

The burdens of the COVID-19 crisis span both the direct health and societal impacts of the virus as well as the indirect impacts from the accompanying information environment. An infodemic response that promotes an accurate and consistent science-based narrative, while also supporting public mental health and wellbeing, is needed alongside measures to curb the actual spread of the virus. The crux of the issue is that we must control both the COVID-19 pandemic and the COVID-19 infodemic to overcome this global crisis. Failure in either domain will undermine the progress made in the other. An effective response requires international cooperation on both fronts.

Controlling the pandemic and infodemic requires global cooperation using place-based, tailored strategies because standard policies and messaging will not suit all social context and needs. Public health depends on addressing both the disease spread and the spread of accurate information that resonates with diverse experiences. In this Research Topic, researchers offer simple but compelling recommendations that encourage people to start making a difference in their community on issues that matter globally.

Evidence shows compliance with recommended measures depends on more than rules alone. It relies on a mix of factors like beliefs, traits, needs, and mental health that differ by groups. Alternative interventions may be needed to motivate change when experiences do not. Studies also found disproportionate impacts, needs, and information use in diverse populations based on gender, culture, vulnerability, and more. For example, Gerretsen et al. found adherence to social distancing during the COVID-19 pandemic depended on a mix of demographic factors, beliefs about the virus, personality traits, psychological needs, and more in the U.S. and Canada. While adherence was generally good, influencing the factors within our control, like risk perceptions and social support, can help strengthen public resolve, especially in the long term.

Research from across India, Latin America, Indonesia, and elsewhere shows success where policies and information were adapted to local contexts, barriers, and groups, and failure where not. Messaging must reach the vulnerable. Policies and technology improve responses, but depend on equity, inclusion, and understanding differences. In a cross-sectional study, Adhikari et al. examined the factors associated with holding stigmatizing views toward infected people and experiencing stigma as a recovered patient during India's first COVID-19 wave. Significant levels of stigma were found in communities and reported by recovered participants. Several sociodemographic factors were linked to higher stigma. Nagarajan et al. found adults in Chennai, India, generally knew masks reduce COVID-19 transmission, but many remained opposed to mask mandates. However, mask wearing when outside was still common. Knowledge was lower and attitudes less favorable in slum populations. Mejia et al. found education level and country of residence were associated with basic COVID-19 knowledge in Latin America. Most had knowledge of symptoms and transmission, but gaps remained in some areas. Peru's low knowledge and high case rates suggested limited health literacy may worsen outbreaks. Wibowo et al. found belief in health consequences motivated uptake of COVID-19 prevention behaviors during Ramadan in Indonesia, but psychological, social, and resource barriers also undermined adherence for some. Promoting new behaviors depends on recognizing their impacts in context.

Policies in the UK, Japan, and Australia aimed to curb infection but may have negatively and disproportionately impacted children and women. Balanced, evidence-based policies also consider wellbeing, development, and mental health. Information use depends on more than just access to facts. Anxiety and care duties shape experiences. In a brief research report, Carr et al. examined whether the COVID-19 pandemic impacted people's disgust sensitivity in UK adults, especially toward pathogens and COVID-19. The results found that both overall disgust sensitivity and COVID-19-related disgust sensitivity remained unchanged, despite the significant life disruptions and health crisis experiences during the pandemic. This suggests disgust sensitivity is stable and current experiences alone may not be enough to motivate behavioral changes during infection prevention and control (IPC) measures. The implications are that alternative interventions, possibly leveraging disgust, could still be useful for promoting compliance with recommended COVID-19 measures. Hu et al. argued that the disproportionate impacts of COVID-19 on South Asians in Britain reflected systemic racism that must be addressed for an equitable, just society. While vaccine hesitancy and health inequities were symptoms, the root causes ran much deeper. Tackling racism requires education, and decolonizing the secondary curriculum to teach cultural awareness, promote inclusion, and build understanding is key. In a perspective paper, Shobako et al. argued that Japan's health policies for COVID-19, while aiming to protect public health, may disproportionately and negatively impact children. The policies disrupt school, diet, physical activity, and development. They are also often promoted more by public opinion than by evidence. The article calls for policies that are balanced, evidence-based, protective of children's wellbeing, and informed by diverse experts and feedback. Health and development must be considered alongside just infection control. Lee et al. found Australians used authoritative sources for urgent COVID-19 information to enable decision making and daily activities. Some changes occurred in favor of better accuracy and timeliness. But anxiety and disproportionate mental burdens, especially for women managing care duties, require consideration

in strategic response. Their experiences highlight that information use depends on more than access or proximity to facts alone.

In China, Liu and Jiang examined factors influencing individuals' compliance with the Chinese government's COVID-19 preventive measures during regular prevention and control. The results showed that greater media exposure significantly predicts higher perceived severity, maladaptive rewards, self-efficacy, response efficacy, and response cost. Perceived severity, self-efficacy, and response efficacy positively predict protection motivation, which predicts compliance. Protection motivation also positively affects compliance through implementation intention. Perceived cultural tightness–looseness moderates the effect of protection motivation on implementation intentions, such that the effect is stronger with higher perceived tightness. Xue et al. found most people in China reported following recommended COVID-19 preventive behaviors, but information sources influencing behaviors differed in various groups. While internet resources had the largest impact overall, more tailored guidance through family doctors and community health centers was important for more vulnerable populations. In a critical review by Chen et al., the modeling study compared how COVID-19 and influenza might spread in a hypothetical city under different scenarios in China. They found that vaccination has greater potential than non-pharmaceutical interventions (NPIs) alone for curbing influenza, while a combination of emerging COVID-19 vaccines and NPIs will likely be needed to control surges. But vaccination can transition societies to less restrictive, sustainable measures if caseloads are reduced sufficiently over time. Xu et al. analyzed the Omicron subvariant BA.5 outbreak and response in Macau and found that while highly transmissible, the subvariant could be effectively contained through a multi-pronged strategy. Coordinating vaccination, social measures, testing, tracing, and treatment helped curb the spread. Despite its high population density, Macau achieved a lower infection rate than other regions facing BA.5. An integrated policy including the innovative "relatively static" plan was key.

Furthermore, AI and modeling require diverse, updated data to improve performance and match changes. In an AI-powered assessment, Li et al. introduced a multistage multimodal deep learning (MMDL) model that uses consecutive rounds of symptoms, test results, and other data to determine COVID-19 severity and predict worsening conditions in Chinese patients. The proposed approach outperformed single-point or single-modal models. However, more diverse, larger datasets—especially for severe patients—are needed to improve performance. The model must be re-tested and retrained to keep up with viral changes. If validated, this approach could help identify high-risk patients early for treatment.

Peril and promise

In this Research Topic, the research makes a persuasive case for coordinated but locally-adapted strategies to address multifaceted global crises like the COVID-19 pandemic and infodemic. A one-size-fits-all approach will fail; progress depends on addressing diverse populations based on understanding differences in experiences, needs, and obstacles. Studies worldwide show why equity, inclusion, and place-based interventions matter. Public health success requires integrated, tailored strategies fitting local contexts. Outcomes depend on tailored solutions for populations, not policies serving assumptions. They rely on grasping various realities and motivating change by building knowledge and enabling action from within. Broad policies risk overlooking marginalized groups; targeted support and education are required to overcome barriers, curb disease, and combat informational threats straining social cohesion. Culturally-sensitive, anti-racist strategies can promote inclusion when crises test communities.

Though the WHO canceled the PHEIC (Public Health Emergency of International Concern) statuses for COVID-19 and Mpox in May, the threat remains. The rising concern now is that emerging large generative models (LGMs) like chatbots may proliferate future infodemics by generating false guidance or impersonating people online at a speed and scale overwhelming official information and responses (9–11). Without mechanisms ensuring transparency, oversight, and precision, chatbots like ChatGPT could spread infodemics quickly, fueling confusion and hampering crisis response (12). With planning and prudent policies, these technologies can support response; without them, they imperil it.

While such issues seem overwhelming in scale and scope, progress starts small, through raising awareness, personal action, community involvement, and advocating local policy changes (13). Together, these steps drive real change. But it begins with a global mindset and local solutions.

Author contributions

ZH reviewed the literature and wrote the editorial. CW and PS reviewed the literature and edited the editorial. All authors read and approved the final editorial.

Funding

This study was partially supported by the Zhejiang Provincial Natural Science Foundation of China (LZ21F020004) and the Major Project of Digital and Cutting-edge Disciplines Construction, Zhejiang Gongshang University (SZJ2022B007).

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.

Publisher's note

References

1. Editorial. Coronavirus misinformation needs researchers to respond. *Nature.* (2020) 581:355–6. doi: 10.1038/d41586-020-01550-y

2. Editorial. COVID-19: fighting panic with information. *Lancet.* (2020) 395:537. doi: 10.1016/S0140-6736(20)30379-2

3. Briand SC, Cinelli M, Nguyen T, Lewis R, Prybylski D, Valensise CM, et al. Infodemics: a new challenge for public health. *Cell.* (2021) 184:6010–4. doi: 10.1016/j.cell.2021.10.031

4. Ball P, Maxmen A. The epic battle against coronavirus misinformation and conspiracy theories. *Nature.* (2020) 581:371–4. doi: 10.1038/d41586-020-01452-z

5. Buckee C, Noor A, Sattenspiel L. Thinking clearly about social aspects of infectious disease transmission. *Nature.* (2021) 595:205–13. doi: 10.1038/s41586-021-03694-x

6. Larson HJ. A call to arms: helping family, friends and communities navigate the COVID-19 infodemic. *Nat Rev Immunol.* (2020) 20:449–50. doi: 10.1038/s41577-020-0380-8

7. Scales D, Gorman J, Jamieson KH. The COVID-19 infodemic—Applying the epidemiologic model to counter misinformation. *N Engl J Med.* (2021) 385:678–81. doi: 10.1056/NEJMp2103798

8. Brusselaers N, Steadson D, Bjorklund K, Breland S, Stilhoff Sörensen J, Ewing A, et al. Evaluation of science advice during the COVID-19 pandemic in Sweden. *Humanit Soc Sci Commun.* (2022) 9:91. doi: 10.1057/s41599-022-01097-5

9. Wu C, Wu F, Qi T, Zhang W-Q, Xie X, Huang Y. Removing AI's sentiment manipulation of personalized news delivery. *Humanit Soc Sci Commun.* (2022) 9:459. doi: 10.1057/s41599-022-01473-1

10. Awad E, Levine S, Anderson M, Anderson SL, Conitzer V, Crockett MJ, et al. Computational ethics. *Trends Cogn Sci.* (2022) 26:388–405. doi: 10.1016/j.tics.2022.02.009

11. Porsdam Mann S, Earp BD, Nyholm S, Danaher J, Møller N, Bowman-Smart H, et al. Generative AI entails a credit–blame asymmetry. *Nat Mach Intell.* (2023) 5:472–5. doi: 10.1038/s42256-023-00653-1

12. Lazer DMJ, Baum MA, Benkler Y, Berinsky AJ, Greenhill KM, Menczer F, et al. The science of fake news. *Science.* (2018) 359:1094–6. doi: 10.1126/science.aao2998

13. Epstein Z, Sirlin N, Arechar A, Pennycook G, Rand D. The social media context interferes with truth discernment. *Sci Adv.* (2023) 9:eabo6169. doi: 10.1126/sciadv.abo6169

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 28 July 2022
DOI 10.3389/fpubh.2022.938642

OPEN ACCESS

EDITED BY
Chuhan Wu,
Tsinghua University, China

REVIEWED BY
Ritika Kaur,
Independent Researcher, Delhi, India
Tao Qi,
Tsinghua University, China

*CORRESPONDENCE
Prabhdeep Kaur
kprabhdeep@nieicmr.org.in

SPECIALTY SECTION
This article was submitted to Infectious Diseases – Surveillance, Prevention and Treatment, a section of the journal Frontiers in Public Health

RECEIVED 07 May 2022
ACCEPTED 06 July 2022
PUBLISHED 28 July 2022

CITATION
Nagarajan R, Rubeshkumar P, Jagadeesan M, Raju M, Sakthivel M, Murali S, Sendhilkumar M, Ilangovan K, Harikrishnan D, Venkatasamy V, Ganeshkumar P and Kaur P (2022) Knowledge, attitude, and practice towards face mask use among residents of Greater Chennai Corporation, India, March 2021. *Front. Public Health* 10:938642. doi: 10.3389/fpubh.2022.938642

Knowledge, attitude, and practice towards face mask use among residents of Greater Chennai Corporation, India, March 2021

Ramya Nagarajan[1], Polani Rubeshkumar[2], Murugesan Jagadeesan[3], Mohankumar Raju[2], Manikandanesan Sakthivel[1], Sharan Murali[1], Muthappan Sendhilkumar[1], Kumaravel Ilangovan[1], Dineshkumar Harikrishnan[1], Vettrichelvan Venkatasamy[1], Parasuraman Ganeshkumar[2] and Prabhdeep Kaur[1]*

[1]Department of Noncommunicable Diseases, ICMR-National Institute of Epidemiology, Chennai, India, [2]Department of Epidemiology, ICMR-National Institute of Epidemiology, Chennai, India, [3]Greater Chennai Corporation, Chennai, India

Background: Wearing a mask is one of the simplest ways to reduce the spread of COVID-19. Studies reported poor mask compliance in Greater Chennai Corporation, India. Hence, we described the knowledge, attitude, and practice regarding mask use among adults (≥18 years) in Greater Chennai Corporation, Tamil Nadu, India.

Methods: We conducted a cross-sectional survey among residents of Greater Chennai Corporation in March 2021. We estimated the sample size to be 203 per strata (slum and non-slum). We used a simple random sampling technique to select 20 locations using a digital map in the slum and non-slum areas. After reaching the location chosen, we selected 10 consecutive households and one adult (≥18 years of age) from each household. We used a validated, semi-structured questionnaire for collecting data regarding knowledge, attitudes, and practices for mask use. We estimated proportions and 95% CI for key variables and compared the variables between slums and non-slums.

Results: Of 430 participants included in the study, 51.4% were males. The mean (S.D.) age of the participants is 41.1 (14.6) years. The majority (86.7%) of the participants felt that wearing a mask helped in reducing the spread of coronavirus and the knowledge differed (p-value < 0.05) between the slum (81.4%) and non-slum (92.3%). Nearly half (46.5%) of the participants did not like being forced to wear the mask. About 63.9% of the participants reported the practice of mask use while going out which was similar across slums and non-slums.

Conclusion: Although the knowledge regarding mask use was good among the public, the attitude was unfavorable. We suggest continuous reinforcement by spreading awareness and educating the community on the appropriate use of the mask.

KEYWORDS

masks, COVID-19, compliance, public place, knowledge

Introduction

Mask usage is considered one of the vital non-pharmacological interventions to control the spread of COVID-19 (1). It has been scientifically proven and recommended by global public health organizations to reduce the transmissibility and risk of infection due to SARS-CoV-2 (2–8). The World Health Organization (WHO), the U.S. Centers for Disease Control and Prevention (CDC), the Government of India, and numerous other government and public health agencies have recommended that people use masks in public settings when SARS-CoV-2, the virus that causes COVID-19, is being transmitted in the community (9–11). Early in the pandemic, before accumulating evidence that mask-wearing can reduce the spread of COVID-19, some countries with no history of the practice resisted adopting mask-wearing recommendations (12). In settings, mainly in Asia, where mask-wearing is common for people with even a minor cold, people were likelier to wear masks in public spaces, even without mandates.

As scientific understanding of COVID-19 has evolved, the importance of widespread use of masks has become clear, in part because of the transmission dynamics of the virus (13). People with COVID-19 are most infectious early in the disease, including before symptoms develop, and many people infected with COVID-19 never develop symptoms (14). The higher prevalence of asymptomatic infection makes wearing masks crucial, even among people who feel healthy (15). Promotion of mask-wearing should be part of a package of measures that includes handwashing, physical distancing, and interventions to reduce indoor exposures, find infected people and their contacts quickly, and provide rapid and supportive isolation and quarantine services (16).

Even with the increased necessity of face mask use, there is a wide variation in the knowledge, attitude and practice of mask use across the globe. While Tajvar et al. has documented poor knowledge with good attitude and practice toward mask use in Iran (17), Pramana et al. has documented satisfactory results in Indonesia (18). However, according to Azlan et al., Malaysia majority had a positive attitude toward mask use, but only half of the study participants were using face masks regularly (19). But a study by Tan et al. in China showed good compliance to mask use (20).

Although transmission risk is higher in indoor settings, the mask mandate was monitored, and authorized officials-imposed fines on non-compliant individuals, predominantly in public places such as traffic signals and streets (21). Our team previously conducted three surveys to monitor mask compliance in Chennai. We conducted the surveys in October 2020, December 2020, and March 2021. We selected outdoor public places for the first survey and added indoor settings in the second and third surveys. The compliance to appropriate mask use in three rounds was 28, 29, and 21% in the slums. The compliance was 36%, 35%, and 27% in non-slums after observing 3,600 individuals from 64 selected city streets (22). Additionally, indoor compliance was 11% in slums and 10% in the non-slums, while malls in the city showed the highest compliance for appropriate use of masks (57%) during the second round (22).

Although we documented poor compliance, there was limited understanding regarding attitudes and awareness in the population, which could influence their behaviors. Understanding the knowledge, attitude and practices (KAP) of the population will help the program managers and policy makers in strategizing the Information, Education and Communication (IEC) activities related to mask use. Based on our literature search there are no other studies on mask use from Greater Chennai Corporation or Tamil Nadu in community setting to determine KAP regarding mask use in India. Hence, we carried out this study to bridge this gap by estimating the knowledge and practices regarding the appropriate mask use and attitude toward wearing masks among adults in Greater Chennai Corporation, Tamil Nadu, India.

Methods

Study design and population

We conducted a cross-sectional survey among residents of Greater Chennai Corporation in March 2021. Chennai is a city in southern India governed by Greater Chennai Corporation. It is administratively divided into 15 zones covering 200 wards. This study was conducted in all the zones of Greater Chennai Corporation, covering both the slum and non-slum populations equally. The study population was adults $\geq$18 years of age residing within Greater Chennai Corporation.

Sample size and sampling strategy

The sample size was estimated separately for the slum and non-slum populations. As per our previous survey (22), 70% of the population followed inappropriate mask use. With that we assumed that 70% of the study participants did not have the knowledge of appropriate mask use and estimated the sample size as 203 with 10% absolute precision, 95% confidence level, 20% non-response rate, and a design effect of 2. We included two strata, namely slum and non-slums. Hence sample size is 406 with 203 per strata.

All the zones under Greater Chennai Corporation limits were included in the study. We created a linelist of street separately for slums and non-slums. We randomly selected 20 sreets each from slums and non-slums. In each street

we randomly selected a starting point using digital map. After selecting the starting point, we surveyed 10 consecutive households in the same street. We surveyed one adult (≥18 years of age) from each household available at home for the interview. If more than one eligible individual was available at home during the visit, we randomly selected one individual.

Data collection

We reviewed the sample questionnaire on mask use from other studies and adapted it to the local setting (23). It was a validated, semi-structured questionnaire. We collected details on the sociodemographic profile, information on exposure to COVID-19, knowledge regarding masks used in different settings such as public places, public transport, attitude related to the mandatory mask use, and mask disposal practices. Most knowledge, attitude, and practice questions were asked on a Likert scale. However, the scales varied across the questions depending upon the nature of the question (Supplementary File 1). The data collection tool was translated into the vernacular language, pre-tested, and revised before the survey. We trained the field-level data collection team members and conducted simulation sessions to minimize the inter-observer variation. The data collection teams then interviewed the selected members face-to-face using the Open Data Kit (ODK) tool. COVID-19 appropriate behaviors were followed during the interview process.

Operational definition

We defined "mask" as any cloth mask, medical mask, or N95 respirator worn over the face. "Public places" included both indoor and outdoor settings open to the public and did not have any entry restrictions (e.g., streets, bus stops, railway stations, grocery shops, vegetable shops, pharmacies, religious places, and apparel stores). Indoor Public places included places such as gyms, convention centers, and marriage halls. Outdoor places included places such as shops, bus stops, railway station, and religious places. "Workplace" included occupational settings open only to employees with limited access to the general public.

Data analysis

We estimated the proportions with a 95% confidence interval (CI) using Stata version 16. We estimated the proportion of individuals who felt adopting appropriate mask use while in public places and at public transportation is needed. We also estimated the proportion of individuals who thought they shouldn't be forced to use masks and those who adopted appropriate

TABLE 1 Sociodemographic profile of the study participants, Greater Chennai Corporation, India, March 2021 ($N = 430$).

Characteristics	Slums ($N = 221$)		Non-slums ($N = 209$)		Total ($N = 430$)		p-Value* (X^2 test)
	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	
Gender							
Male	114	51.5 (41.9–61.1)	107	51.2 (41.9–60.3)	221	51.4 (44.6–58.0)	0.953
Female	107	48.4 (38.8–58.0)	102	48.8 (39.6–58.0)	209	48.6 (41.9–55.3)	
Education							
Graduate and above	48	21.7 (13.9–32.2)	86	41.1 (31.1–51.9)	134	31.1 (24.1–39.1)	**0.008**†
Secondary school	76	34.3 (26.5–43.2)	61	29.1 (22.6–36.7)	137	31.8 (26.5–37.6)	
Primary school	58	26.2 (18.8–35.2)	45	21.5 (15.5–28.9)	103	23.9 (18.9–29.7)	
No education	39	17.6 (11.5–26.0)	17	08.1 (05.5–11.8)	56	13.0 (09.3–17.9)	
Occupation							
Government employee	26	11.7 (06.9–19.1)	44	21.0 (14.3–29.8)	70	16.2 (12.0–21.6)	0.236
Daily wages	22	09.9 (06.2–15.4)	16	07.6 (04.3–13.1)	38	08.8 (06.1–12.5)	
Home maker	62	28.0 (18.8–39.6)	64	30.6 (22.4–40.2)	126	29.3 (22.8–36.7)	
Others‡	111	50.2 (40.7–59.7)	85	40.6 (28.7–53.7)	196	45.5 (37.8–53.5)	

*P-Value < 0.05 was considered statistical significant.
†Significant value.
‡Self-employed, non-government employees, non-paid workers, students, retired personnel, and unemployed. The bold values indicate the significant values.

mask disposal methods. We also used the chi-square test to compare the variables between the slum and non-slum populations. A p-value <0.05 was considered statistically significant.

Human subject protection

The approval for the study was obtained from the Institutional Ethics Committee, ICMR–NIE Chennai. Informed verbal consent was obtained from the study participants before collecting the data.

Results

Sociodemographic profile

Of 430 participants in our study, 221 were from slum areas and 209 from non-slum areas. Nearly half of the study participants (51.4%) were males (Table 1). The mean (S.D.) age of the participants was 41.1 (14.6) years (Slum: 42.4 (14.8) years; non-slum: 39.8 (14.3) years). Most of the study participants from the slums had secondary school education (34.3%), while those from the non-slums had graduate-level education (41.1%). Nearly 29.3% of the study participants were homemakers, followed by government employees (16.2%), and daily wage workers (8.8%), while rest of the population were self-employed, non-government employees, non-paid workers, students, retired personnel, and unemployed. Although the distribution of occupation did not vary between slums and non-slums (Table 1).

Knowledge on mask use

A large proportion (86.7%) of respondents reported that mask-wearing reduces Coronavirus spread (Table 2). The knowledge was higher among respondents in non-slums compared to slums (92.3 vs. 81.4%, $p < 0.05$). The majority (87.6%) of the participants knew that masks should be worn while going to a public place, while 85.1% knew that masks should be worn while traveling in public transport. Nearly 80.9 and 83.9% of the participants knew that masks should be

TABLE 2 Knowledge of mask use among the slum and non-slum population, Greater Chennai Corporation, India, March 2021 ($N = 430$).

Characteristics	Slums ($N = 221$)		Non-slums ($N = 209$)		Total ($N = 430$)		p-Value* (X^2 test)
	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	
Does wearing a mask help to reduce the spread of the Coronavirus?							
Yes	180	81.4 (73.2–87.5)	193	92.3 (87.1–95.5)	373	86.7 (81.5–90.6)	**0.0054**†
No	24	10.8 (07.0–16.3)	13	06.2 (03.2–11.5)	37	08.6 (05.9–12.3)	
Don't know/refused	17	07.6 (04.3–13.3)	3	01.4 (00.4–04.2)	20	04.6 (02.6–08.0)	
Masks should be worn while going out of the home							
Compulsory	190	85.9 (77.4–91.6)	187	89.4 (79.7–94.8)	377	87.6 (81.6–91.9)	0.7608
Optional	22	09.9 (04.8–19.3)	17	08.1 (03.4–18.0)	39	09.0 (05.2–15.2)	
Don't know	9	04.0 (02.0–07.9)	3	02.3 (00.4–11.4)	14	03.2 (01.5–06.6)	
Masks should be worn while traveling in Public transport such as a bus etc.,							
Compulsory	186	84.1 (75.6–90.1)	180	86.1 (75.7–92.5)	366	85.1 (78.8–89.7)	0.9326
Optional	26	11.7 (06.8–19.4)	21	10.5 (04.7–20.1)	47	10.9 (06.9–16.7)	
Don't know	9	04.0 (01.9–08.5)	8	03.8 (01.0–13.6)	17	03.9 (01.8–08.1)	
Masks should be worn in indoor public spaces such as gyms, functions, marriage halls, etc.,							
Compulsory	183	82.8 (72.6–89.7)	165	78.9 (68.2–86.7)	348	80.9 (73.8–86.4)	0.8147
Optional	28	12.6 (06.9–22.0)	33	15.7 (08.6–27.0)	61	14.1 (09.0–21.0)	
Don't know	10	04.5 (02.2–08.8)	11	05.2 (01.6–15.4)	21	04.8 (02.4–09.4)	
Masks should be worn in all outdoor public spaces, such as shops, bus stops, etc.,							
Compulsory	185	83.7 (74.4–90.0)	176	84.2 (72.7–91.4)	361	83.9 (77.0–89.0)	0.9775
Optional	25	11.3 (06.0–20.2)	24	11.4 (05.1–23.7)	49	11.4 (06.8–18.3)	
Don't know	11	04.9 (02.6–09.1)	9	04.3 (01.2–13.3)	20	04.6 (02.4–08.6)	

*P-Value < 0.05 was considered statistical significant.
†Significant value. The bold values indicate the significant values.

worn indoors and in public places. The indicators assessing the knowledge related to mask use in a public place and public transportation were similar among slums and non-slums (Table 2).

Attitude toward mask use

Nearly half (46.5%) of the participants felt they should not be forced to wear masks (Table 3). One-quarter (23.4%) of the participants reported that if they wear a mask in public, others will think they are affected by COVID-19. Nearly half of the subjects said masks disrupted breathing, caused overheating, and disturbed conversations. The proportion for attitude-related questions was similar among slums and non-slums. Out of 430 participants, 285 (66.2%) felt masks were not expensive.

Mask use practices

About 63.9% of the participants reported consistent mask use while going out (Table 4), while 58.8% used masks at

TABLE 3 Attitude toward mask use among the slum and non-slum population, Greater Chennai Corporation, India, March 2021 ($N = 430$).

Characteristics	Slums ($N = 221$)		Non-slums ($N = 209$)		Total ($N = 430$)		p-value* (X^2 test)
	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	
I shouldn't be forced to wear a mask							
Agree	107	48.4 (37.9–59.0)	93	44.5 (33.7–55.8)	200	46.5 (38.9–54.2)	0.7591
Neither agree nor disagree	12	05.4 (03.4–08.4)	14	06.6 (03.4–12.4)	26	06.0 (04.0–08.9)	
Disagree	102	46.1 (34.8–57.8)	102	48.8 (37.0–60.6)	204	47.4 (39.2–55.8)	
Everyone, including symptoms, should wear a cloth face covering if they leave their home to prevent possible transmission of the Coronavirus							
Agree	141	63.8 (51.9–74.1)	162	77.5 (66.9–85.4)	303	70.4 (62.2–77.5)	0.1023
Neither agree nor disagree	32	14.4 (08.4–23.6)	26	12.4 (06.8–21.6)	58	13.4 (09.0–19.6)	
Disagree	48	21.7 (13.5–32.8)	21	10.0 (04.9–19.2)	69	16.0 (10.7–23.3)	
I worry that if I wear a cloth face-covering out in public, other people will think I am infected with the Coronavirus							
Agree	59	26.7 (18.3–37.1)	42	20.1 (12.6–30.5)	101	23.4 (17.5–30.7)	0.0944
Neither agree nor disagree	38	17.1 (11.5–24.8)	19	09.0 (05.3–14.9)	57	13.2 (09.5–18.1)	
Disagree	124	56.1 (44.7–66.8)	148	70.8 (57.8–81.0)	272	63.2 (54.4–71.2)	
Face masks disrupt my breathing							
Agree	127	57.4 (48.3–66.0)	108	51.6 (39.2–63.8)	235	54.6 (46.8–62.1)	0.1285
Neither agree nor disagree	2	00.9 (00.2–03.5)	12	05.7 (03.0–10.4)	14	03.2 (01.7–05.9)	
Disagree	92	41.6 (32.9–50.8)	89	42.5 (29.7–56.5)	181	42.0 (34.2–50.3)	
Face masks cause me to overheat							
Agree	106	47.9 (36.6–59.5)	99	47.3 (35.9–59.0)	205	47.6 (39.5–55.9)	0.8260
Neither agree nor disagree	14	06.3 (02.7–13.7)	18	08.6 (05.3–13.5)	32	07.4 (04.7–11.4)	
Disagree	101	45.7 (35.0–56.7)	92	44.0 (32.7–55.8)	193	44.8 (37.0–52.9)	
Face mask disturbs my conversation with others							
Agree	113	51.1 (41.7–60.4)	98	46.8 (35.9–58.1)	211	49.0 (41.8–56.3)	0.7416
Neither agree nor disagree	9	04.0 (01.8–08.5)	11	05.2 (02.6–10.0)	20	04.6 (02.8–07.6)	
Disagree	99	44.8 (34.3–55.7)	100	47.8 (36.0–59.8)	199	46.2 (38.3–54.4)	
Face masks are unsafe because they force you to touch your face							
Agree	76	34.3 (27.2–42.3)	46	22.0 (15.9–29.5)	122	28.3 (23.2–34.1)	0.1190
Neither agree nor disagree	35	15.8 (10.7–22.7)	40	19.1 (12.2–28.6)	75	17.4 (12.9–23.0)	
Disagree	110	49.7 (39.7–59.8)	123	58.8 (47.3–69.4)	233	54.1 (46.4–61.7)	
Face masks are too expensive							
Agree	66	29.8 (19.7–42.3)	52	24.8 (16.8–35.1)	118	27.4 (20.6–35.4)	0.6831
Neither agree nor disagree	12	05.4 (03.0–09.4)	15	07.1 (03.0–15.9)	27	06.2 (03.6–10.5)	
Disagree	143	64.7 (52.0–75.6)	142	67.9 (55.3–78.3)	285	66.2 (57.4–74.1)	

*P-Value < 0.05 was considered statistical significant.

TABLE 4 Practice of Mask use in Public Places among the slum and non-slum population, Greater Chennai Corporation, India, March 2021 ($N = 430$).

Characteristics	Slums ($N = 221$)		Non-slums ($N = 209$)		Total ($N = 430$)		
	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	*p*-Value* (X^2 test)
How often do you wear a mask when you go out?							
Always	132	59.7 (48.0–70.4)	143	68.4 (57.0–77.9)	275	63.9 (55.7–71.4)	0.4742
Most of the times	61	27.6 (18.4–39.1)	49	23.4 (16.0–32.9)	110	25.5 (19.3–32.9)	
Sometimes	15	06.7 (03.6–12.2)	11	05.2 (02.5–00.5)	26	06.0 (03.7–09.5)	
Rarely	13	05.8 (02.8–11.7)	6	02.8 (01.0–07.5)	19	04.4 (02.4–07.9)	
What type of mask do you wear most of the time?							
Cloth mask	157	71.0 (65.1–76.3)	136	65.1 (55.5–73.5)	293	68.1 (62.5–73.2)	0.3941
Medical mask	55	24.9 (19.7–30.8)	58	27.8 (21.1–35.5)	113	26.3 (21.9–31.0)	
N-95 masks/respirators	4	01.8 (00.5–05.6)	10	04.8 (02.5–08.8)	14	03.3 (01.8–05.7)	
Kerchief/ cloth fabric	5	02.2 (00.8–05.9)	5	02.3 (00.7–07.3)	10	02.3 (01.0–04.9)	
How do you wear your mask most of the time?							
Covering chin	3	01.4 (00.4–03.9)	6	02.9 (01.4–05.7)	9	02.1 (01.1–03.8)	**0.0120**†
Covering chin and mouth	31	14.0 (07.2–25.5)	7	03.3 (01.4–07.6)	38	08.8 (04.9–15.4)	
Covering chin, mouth and nose	180	81.4 (68.8–89.7)	193	92.3 (87.1–95.5)	373	86.7 (79.5–91.6)	
Below chin	7	03.1 (01.2–08.0)	3	01.4 (00.3–06.0)	10	02.3 (01.0–05.1)	
Do you wash your hands before wearing the mask?							
Daily/wash daily	72	32.6 (23.3–43.4)	85	41.0 (31.6–50.3)	157	36.5 (29.7–43.8)	0.1686
Once in 3 days	59	26.7 (17.8–37.8)	64	30.9 (22.1–40.6)	123	28.6 (22.2–35.9)	
Once in a week	52	23.9 (17.2–31.2)	42	20.2 (14.9–26.4)	94	22.1 (17.6–26.7)	
More than a week	38	17.1 (10.7–26.4)	18	08.6 (05.6–12.9)	56	13.0 (09.0–18.3)	
How often do you touch the front side of your mask after wearing it?							
Always	21	09.5 (05.3–16.3)	29	13.9 (09.6–19.5)	50	11.6 (08.4–15.8)	0.6064
Most of the times	63	28.5 (19.2–39.9)	64	30.6 (22.7–39.8)	127	29.5 (23.2–36.7)	
Sometimes	71	32.1 (24.8–40.4)	65	31.1 (23.8–39.4)	136	31.6 (26.3–37.4)	
Rarely	66	29.8 (21.2–40.1)	51	24.4 (17.7–32.5)	117	27.2 (21.5–33.7)	
Do you wash your hands after removing the mask?							
Always	58	26.2 (17.8–36.8)	99	47.4 (36.4–58.5)	157	36.5 (28.9–44.8)	**0.0137**†
Most of the times	55	24.9 (17.7–33.6)	43	20.6 (14.3–28.5)	98	22.8 (17.8–28.6)	
Sometimes	55	24.9 (19.1–31.6)	38	18.2 (12.2–26.1)	93	21.6 (17.2–26.7)	
Rarely	53	23.9 (15.4–35.3)	29	13.8 (09.0–20.7)	82	19.0 (13.7–25.9)	
How frequently do you change/wash your mask?							
Daily/wash daily	167	75.6 (65.4–83.5)	174	83.3 (75.1–89.0)	341	79.3 (72.7–84.6)	0.1597
Once in 3 days	24	10.9 (05.9–18.9)	23	11.0 (07.1–16.6)	47	10.9 (07.5–15.5)	
Once in a week	12	05.4 (02.9–99.4)	3	01.4 (00.3–06.0)	15	03.5 (01.9–06.3)	
More than a week	18	08.1 (03.9–15.9)	9	04.3 (02.3–07.8)	27	06.2 (03.7–10.4)	
How do you dispose of the mask?							
Into a public bin	63	28.5 (18.6–41.0)	71	34.0 (23.2–46.6)	134	31.2 (23.5–39.9)	0.1973
Collect in a bin	129	58.3 (46.7–69.1)	129	61.7 (49.8–72.3)	258	60.0 (52.1–67.4)	
Throw it in road	3	01.4 (00.4–03.9)	0	0.00 (00.0–00.0)	3	00.7 (00.2–02.1)	
Never dispose	26	11.7 (06.4–20.5)	9	04.3 (01.2–13.3)	35	08.1 (04.6–13.8)	

*P-Value < 0.05 was considered statistical significant.
†Statically significant.

TABLE 5 Practice of Mask use at Workplaces among the slum and non-slum population, Greater Chennai Corporation, India, March 2021 ($N = 238$).

Characteristics	Slums ($N = 132$)		Non-slums ($N = 106$)		Total ($N = 238$)		p-value* (X^2 test)
	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	
How often do you go to your workplace?							
Daily	121	91.6 (82.4–96.2)	95	89.6 (80.6–94.7)	216	90.7 (84.8–94.5)	0.8315
Once in two-three days	7	05.3 (02.0–13.1)	7	06.6 (02.7–15.0)	14	05.8 (03.0–10.9)	
Once in a week	2	01.5 (00.3–05.9)	3	02.8 (00.9–08.4)	5	02.1 (00.8–05.0)	
More than a week	2	01.5 (00.3–06.1)	1	00.9 (00.1–06.5)	3	01.2 (00.3–03.9)	
Do you wear a face mask in your workplace?							
Always	70	53.0 (41.6–64.1)	70	66.0 (47.4–80.7)	140	58.8 (48.6–68.2)	0.1402
Most of the times	26	19.7(11.8–30.8)	23	21.7 (10.4–39.7)	49	20.5 (13.3–30.3)	
Sometimes	36	27.2 (19.5–36.6)	13	12.2 (06.9–20.7)	49	20.5 (14.9–27.6)	
Do you share your food while eating at the workplace?							
Always	18	13.6 (07.6–23.1)	2	01.8 (00.4–07.2)	20	08.4 (04.6–14.7)	0.0581
Most of the times	13	09.8 (03.8–22.7)	15	14.1 (06.8–27.1)	28	11.7 (06.5–20.3)	
Sometimes	101	76.5 (63.1–86.0)	89	83.9 (72.1–91.3)	190	79.8 (71.1–86.4)	
Is your temperature checked daily at your workplace?							
Always	28	21.2 (13.0–32.5)	38	35.8 (23.7–50.1)	66	27.7 (20.2–36.6)	0.2128
Most of the times	15	11.3 (05.2–23.0)	15	14.1 (05.1–33.5)	30	12.6 (06.6–22.5)	
Sometimes	89	67.4 (55.3–77.5)	53	50.0 (35.6–64.3)	142	59.6 (49.9–68.6)	
Is hand sanitizer available at your workplace?							
Always	51	38.6 (27.3–51.2)	61	57.5 (42.0–71.6)	112	47.0 (37.4–56.9)	0.1693
Most of the times	19	14.3 (08.0–24.3)	12	11.3 (05.1–23.2)	31	13.0 (08.1–20.0)	
Sometimes	62	46.9 (36.4–57.7)	33	31.1 (20.1–44.7)	95	39.9 (31.7–48.6)	
Does your workplace encourage self-reporting of symptoms?							
Yes	49	37.1 (25.7–50.1)	47	44.3(30.9–58.6)	96	40.3 (31.6–49.7)	0.5111
No	52	39.3 (27.0–53.2)	31	29.2 (18.4–43.1)	83	34.8 (26.1–44.6)	
Not sure	31	23.4 (13.4–37.7)	28	26.4 (12.6–47.0)	59	24.7 (15.8–36.6)	

*P-Value < 0.05 was considered statistical significant.

their workplaces (Table 5). Most participants (86.7%) reported covering their chin, mouth, and nose while wearing the mask (Table 4). Handwashing after mask use was higher among non-slum respondents than among slum (47.4 vs. 26.2%, $p < 0.05$). Most participants disposed of their masks in a closed or public bin (91.2%).

Only one-third (34.6%) reported that physical distancing is strictly followed at their workplace (Table 6). A large proportion (59.4%) felt that maintaining physical distancing was difficult in the local context.

Discussion

Most of the study participants knew that wearing a mask reduced the spread of COVID-19. The knowledge of mask use was higher in the non-slum population (92.3%) compared to the slum (81.4%). However, there was also a negative attitude toward wearing the mask (46.5%). Two-thirds (63.9%; slum: 59.7%; non-slum: 68.4%) of the participants reported consistent use of masks while going out, which was incompatible with our previous three surveys (slum: 28, 29, and 21%; non-slum: 36, 35, and 27%) based on observations in public places (22).

Our findings were consistent with studies from other low and middle-income countries, which reported high awareness about mask use (24, 25). A survey of 1,114 participants in Uganda reported knowledge of protection against COVID-19 by face masks among 86.4%. Another study conducted in Nepal among 381 individuals reported adequate knowledge of face mask use among 95.5% of the participants (24, 25). The knowledge was high in all the study settings, possibly due to frequent mentions of masks used in social media and mass media (26).

The attitude toward mask use was not encouraging, consistent with our previous surveys in the city that reported poor compliance (22). One in two study participants felt that they should not be forced to wear masks because masks interfered with breathing and speaking and caused

TABLE 6 Physical distancing practices among the slum and non-slum population, Greater Chennai Corporation, India, March 2021 ($N = 430$).

Characteristics	Slums ($N = 221$)		Non-slums ($N = 209$)		Total ($N = 430$)		p-value* (X^2 test)
	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	Frequency	Proportion (95% CI)	
Is physical distancing being a follower strictly in your workplace?							
Always	79	35.7 (26.9–45.6)	70	33.4 (24.7–43.5)	149	34.6 (28.2–41.6)	0.0743
Most of the times	24	10.8 (06.1–18.3)	33	15.7 (10.4–23.2)	57	13.2 (09.4–18.3)	
Sometimes	14	06.3 (03.7–10.4)	8	03.8 (01.6–08.6)	22	05.1 (03.2–07.9)	
Rarely	16	07.2 (03.2–15.2)	1	00.4 (13.5–27.5)	17	03.9 (01.7–08.6)	
Never	15	06.7 (04.0–11.1)	13	06.2 (03.3–11.1)	28	06.5 (04.4–09.5)	
Missing	73	33.0 (22.5–45.5)	84	40.1 (30.5–50.7)	157	36.5 (29.0–44.7)	
Is physical distancing being implemented in the places you visit like markets, malls, and departmental stores?							
Always	78	35.2 (24.1–48.3)	94	44.9 (33.5–56.9)	172	40.0 (31.6–48.9)	0.0820
Most of the times	52	23.5 (15.4–34.0)	51	24.4 (17.2–33.2)	103	23.9 (18.3–30.6)	
Sometimes	36	16.2 (09.3–26.9)	24	11.4 (06.6–19.0)	60	13.9 (09.3–20.2)	
Rarely	37	16.7 (09.7–27.2)	11	05.2 (02.6–10.1)	48	11.4 (06.9–17.4)	
Never	18	08.1 (04.5–14.2)	29	13.8 (06.6–26.5)	47	10.9 (06.1–17.5)	
Do you think maintaining physical distancing is difficult in our setting?							
Strongly agree	72	32.5 (24.7–41.5)	44	21.0 (15.8–27.4)	116	26.9 (02.5–08.4)	0.2562
Somewhat agree	71	32.1 (21.8–44.4)	69	33.0 (24.5–42.7)	140	32.5 (03.6–11.4)	
Neither agree nor disagree	10	04.5 (02.4–08.2)	15	07.1 (04.2–11.9)	25	05.8 (36.3–52.3)	
Somewhat disagree	20	09.0 (04.9–16.1)	15	07.1 (03.7–13.2)	35	08.1 (36.4–53.2)	
Strongly disagree	40	18.1 (10.8–28.7)	48	22.9 (14.9–33.6)	88	20.4 (14.7–27.7)	
Don't know/refused	8	03.6 (01.2–10.0)	18	08.6 (04.2–16.8)	26	06.0 (03.3–10.8)	

*P-Value < 0.05 was considered statistical significant.

overheating—a study conducted by Taylor et al. (27). Canada reported a negative attitude toward mask use. The respondents felt wearing a facemask was a hassle, looked ugly and silly, made other people uncomfortable and untrustworthy, and caused breathing difficulty and overheating (27).

We observed a disconnect between knowledge and attitude regarding mask use among the general public. Our study reported two-thirds of the study participants self-reported mask use while going to a public place, but this was not consistent with earlier surveys, which showed only 32% were using masks properly (22). Safe disposal was an important issue of concern with the increasing use of a mask during the pandemic (28). Disposal of the mask using a closed bin or a public bin was followed by more than two-thirds of the participants, according to WHO guidelines (29, 30). Whereas, previous study by Islam et al. in Bangladesh stated that only half of the study participants followed a safe disposal of the used mask (31). Mask use has also been an essential strategy in reducing the spread of infection in the workplace. Though WHO recommends using a mask by everyone at the workplace, only half of our study participants comply with it (32). We recommend strictly enforcing rules on mask use in public and workplaces.

Apart from mask use, physical distancing is an effective way of reducing the spread of infection in the community (1). WHO has recommended maintaining physical distancing in public and workplaces (33). The same is also adapted in India to prevent SARS-CoV-2 infection (34–36). Even from the previous influenza pandemic, several studies supported the social distanceing at workplace to prevent spread of infection (37). However, only one-third of the study participants followed physical distancing at the workplace. This could be possibly due to practical challenges in distancing at markets, workplaces, and slums in our setting. Therefore, masks will be more important in crowded cities, especially where many people come together in closed spaces.

This major strength of our study was that we surveyed a representative sample of respondents from the slum and non-slum population in a large metropolitan city in India. Hence, the results can be generalized to the slum and non-slum of a meteropolitan city in India. One of the limitations was we could not observe the study participants for mask use. Hence, the reported practice of mask use could be overestimated as it was based on self-reporting by the respondents. Hence, we recommend combining methods, including questionnaire-based surveys and observation-based studies, to understand the

mask use. The second limitation was inter-observer variation during the data collection as multiple teams collected data simultaneously. However, we tried to minimize this error through training all the data collectors simultaneously and simulation of the interviews.

We conclude that the community knew the benefits of masks used in a large metropolitan city in India. However, the attitudes and practice were not satisfactory. We suggest continuous reinforcement by spreading awareness and educating on the appropriate use of the mask in the community using mass media. We also suggest addressing the misconceptions related to mask use such as difficulty in breathing, conversation, and overheating. We also recommend strict enforcement of regulations in public places and workplaces to contain the spread of COVID-19 in the community.

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 Indian Council of Medical Research–National Institute of Epidemiology. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

RN: conceptualization, methodology, data collection, analysis, manuscript writing, and preparation of first draft. PK, PG, and MJ: conceptualization, methodology, and critical review and revision of the manuscript. VV and DH: data management and critical review and revision of the manuscript. KI and MSe: data collection, management of field activities,data analysis, and critical review and revision of the manuscript. SM and MSa: data collection, data analysis, and critical review and revision of the manuscript. MR: methodology, data collection, data analysis, and critical review and revision of the manuscript. PR: conceptualization, data collection, analysis, and preparation of first draft. All authors contributed to the article and approved the submitted version.

Funding

This study was funded by the Intra-Mural Fund of ICMR–National Institute of Epidemiology, Chennai, India. The funders had no role in study design, data collection, analysis, publishing decisions, or manuscript preparation.

Acknowledgments

We acknowledge the field data collectors for dedicating their time to the study's purpose. We also acknowledge the participants in our study for dedicating their time to providing valuable data.

Conflict of interest

Author MJ was employed by Greater Chennai Corporation.

The remaining 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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.938642/full#supplementary-material

References

1. Talic S, Shah S, Wild H, Gasevic D, Maharaj A, Ademi Z, et al. Effectiveness of public health measures in reducing the incidence of covid-19, SARS-CoV-2 transmission, and covid-19 mortality: Systematic review and meta-analysis. *BMJ.* (2021) 375:1–15. doi: 10.1136/bmj-2021-068302

2. Abaluck J, Kwong LH, Styczynski A, Haque A, Kabir MA, Bates-Jefferys E, et al. Impact of community masking on COVID-19: a cluster-randomized trial in Bangladesh. *Science.* (2022) 80:375. doi: 10.1126/science.abi9069

3. Payne DC, Smith-Jeffcoat SE, Nowak G, Chukwuma U, Geibe JR, Hawkins RJ, et al. SARS-CoV-2 infections and serologic responses from a sample of U.S. Navy Service Members — USS Theodore Roosevelt, April 2020. *MMWR Morb Mortal Wkly Rep*. (2020) 69:714–21. doi: 10.15585/mmwr.mm6923e4

4. Wang Y, Tian H, Zhang L, Zhang M, Guo D, Wu W, et al. Reduction of secondary transmission of SARS-CoV-2 in households by face mask use, disinfection and social distancing: a cohort study in Beijing, China. *BMJ Glob Heal.* (2020) 5:e002794. doi: 10.1136/bmjgh-2020-002794

5. Nelson SB, Dugdale CM, Bilinski A, Cosar D, Pollock NR, Ciaranello A. Prevalence and risk factors for in-school transmission of SARS-CoV-2 in Massachusetts K-12 public schools, 2020-2021. *medRxiv*. (2021) 21263900. doi: 10.1101/2021.09.22.21263900

6. Doung-ngern P, Suphanchaimat R, Panjangampatthana A, Janekrongtham C, Ruampoom D, Daochaeng N, et al. Case-control study of use of personal protective measures and risk for SARS-CoV 2 infection, Thailand. *Emerg Infect Dis*. (2020) 26:2607–16. doi: 10.3201/eid2611.203003

7. Jehn M, McCullough J Mac, Dale AP, Gue M, Eller B, Cullen T, et al. Association between K—12 school mask policies and school-associated COVID-19 outbreaks — maricopa and pima counties, Arizona, July–August 2021. *MMWR Morb Mortal Wkly Rep*. (2021) 70:1372–3. doi: 10.15585/mmwr.mm7039e1

8. Freedman DO, Wilder-Smith A. In-flight transmission of SARS-CoV-2: a review of the attack rates and available data on the efficacy of face masks. *J Travel Med*. (2020) 27:taaa178. doi: 10.1093/jtm/taaa178

9. World Health Organization. *Advice on the Use of Masks in the Context of COVID-19: Interim Guidance*. Geneva: World Health Organization (2020).

10. Center for Diseases Prevention and control. *Coronavirus Disease 2019 (COVID-19)*. Atlanta, GA: Center for Diseases Prevention and Control (2020).

11. Governmnet of India. Ministry of Health and Family Welfare. *Novel Coronavirus Disease COVID-19: Guidelines on Use of Masks by Public*. New Delhi: Ministry of Health and Family Welfare (2020).

12. Martinelli L, Kopilaš V, Vidmar M, Heavin C, Machado H, Todorović Z, et al. Face masks during the COVID-19 pandemic: a simple protection tool with many meanings. *Front Public Heal.* (2021) 13:8. doi: 10.3389/fpubh.2020.606635

13. Howard J, Huang A, Li Z, Tufekci Z, Zdimal V, van der Westhuizen H-M, et al. An evidence review of face masks against COVID-19. *Proc Natl Acad Sci*. (2021) 118:e2014564118. doi: 10.1073/pnas.2014564118

14. Johansson MA, Quandelacy TM, Kada S, Prasad PV, Steele M, Brooks JT, et al. SARS-CoV-2 transmission from people without COVID-19 symptoms. *JAMA Netw Open*. (2021) 4:e2035057. doi: 10.1001/jamanetworkopen.2020.35057

15. Feng S, Shen C, Xia N, Song W, Fan M, Cowling BJ. Rational use of face masks in the COVID-19 pandemic. *Lancet Respir Med.* (2020) 8:434–6. doi: 10.1016/S2213-2600(20)30134-X

16. Chiu N-C, Chi H, Tai Y-L, Peng C-C, Tseng C-Y, Chen C-C, et al. Impact of wearing masks, hand hygiene, and social distancing on influenza, enterovirus, and all-cause pneumonia during the coronavirus pandemic: retrospective national epidemiological surveillance study. *J Med Internet Res.* (2020) 22:e21257. doi: 10.2196/21257

17. Tajvar A, Aghamolaei T, Mohseni S, Fakherpour A, Damiri Z, Jahangiri M, et al. Knowledge, performance, and attitude towards mask use to prevent and control COVID-19 outbreak among a group of iranian people: a cross-sectional study. *Shiraz E Med J*. (2021) 22:e111491. doi: 10.5812/semj.111491

18. Pramana C, Kurniasari L, Santoso B, Afrianty I, Syahputra A. Knowledge, attitudes, and practices of using masks by the community during the Covid-19 pandemic in Indonesia. *PalArch"s J Archael Egypt/Egyptol.* (2020) 17:4800–8. Available online at: https://archives.palarch.nl/index.php/jae/article/view/4673

19. Azlan AA, Hamzah MR, Sern TJ, Ayub SH, Mohamad E. Public knowledge, attitudes and practices towards COVID-19: a cross-sectional study in Malaysia. *PLoS ONE.* (2020) 15:1–15. doi: 10.1101/2020.04.29.20085563

20. Tan M, Wang Y, Luo L, Hu J. How the public used face masks in China during the coronavirus disease pandemic: a survey study. *Int J Nurs Stud.* (2021) 115:103853. doi: 10.1016/j.ijnurstu.2020.103853

21. Jones NR, Qureshi ZU, Temple RJ, Larwood JPJ, Greenhalgh T BL. Two metres or one: what is the evidence for physical distancing in covid-19? *BMJ*. (2020) 370:m3223. doi: 10.1136/bmj.m3223

22. Jagadeesan M, Rubeshkumar P, Raju M, Sakthivel M, Murali S, Nagarajan R, et al. Surveillance for face mask compliance, Chennai, Tamil Nadu, India, October-December, 2020. *PLoS ONE.* (2021) 16:1–10. doi: 10.1371/journal.pone.0257739

23. *Resolve To Save Lives. Promoting Mask-Wearing During the COVID-19 Pandemic: A POLICYMAKER'S GUIDE 2020*. Available online at: https://preventepidemics.org/wp-content/uploads/2020/08/Promoting-Mask-Wearing-During-COVID-19.pdf (accessed June 10, 2022).

24. Sikakulya FK, Ssebuufu R, Mambo SB, Pius T, Kabanyoro A, Kamahoro E, et al. Use of face masks to limit the spread of the COVID-19 among western Ugandans: Knowledge, attitude and practices. *PLoS ONE.* (2021) 16:1–13. doi: 10.1371/journal.pone.0248706

25. Alam K, Palaian S, Shankar PR, Jha N. General public's knowledge and practices on face mask use during the COVID-19 pandemic: a cross-sectional exploratory survey from Dharan, Nepal. *F1000Res.* (2021) 10:376. doi: 10.12688/f1000research.52661.1

26. Ahmed W, Vidal-Alaball J, Lopez Segui F, Moreno-Sánchez PA. A social network analysis of tweets related to masks during the COVID-19 pandemic. *Int J Environ Res Public Health*. (2020) 17:8235. doi: 10.3390/ijerph17218235

27. Taylor S, Asmundson GJG. Negative attitudes about facemasks during the COVID-19 pandemic: the dual importance of perceived ineffectiveness and psychological reactance. *PLoS ONE.* (2021) 16:1–15. doi: 10.1371/journal.pone.0246317

28. Sangkham S. Face mask and medical waste disposal during the novel COVID-19 pandemic in Asia. *Case Stud Chem Environ Eng.* (2020) 2:100052. doi: 10.1016/j.cscee.2020.100052

29. Shiferie F. Improper disposal of face masks during COVID-19: unheeded public health threat. *Pan Afr Med J*. (2021) 38:366. doi: 10.11604/pamj.2021.38.366.29063

30. World Health Organization. *How to Put on, Use, Take Off and Dispose of a Mask*. Geneva: World Health Organization (2020).

31. Islam SMD-U, Safiq MB, Bodrud-Doza M, Mamun MA. Perception and attitudes toward PPE-related waste disposal Amid COVID-19 in Bangladesh: an exploratory study. *Front Public Heal.* (2020) 13:8. doi: 10.3389/fpubh.2020.592345

32. World Health Organization. *Mask Use in the Context of COVID-19*. Geneva: World Health Organization (2020).

33. World Health Organization. *COVID-19: Physical Distancing*. Geneva: World Health Organization (2022).

34. Government of India. Ministry of Health and Family Welfare. *SOP on Preventive Measures to Contain Spread of COVID-19 in Offices*. New Delhi: Ministry of Health and Family Welfare (2021).

35. Government of India. Ministry of Health and Family Welfare. *SOP on Preventive Measures to be Followed in Entertainment Parks and Similar Places to Contain Spread of COVID-19*. New Delhi: Government of India. Ministry of Health and Family Welfare (2021).

36. Government of India. Ministry of Health and Family Welfare. *An Illustrated Guide on COVID Appropriate Behaviour*. New Delhi: Ministry of Health and Family Welfare (2020).

37. Ahmed F, Zviedrite N, Uzicanin A. Effectiveness of workplace social distancing measures in reducing influenza transmission: a systematic review. *BMC Public Health.* (2018) 18:518. doi: 10.1186/s12889-018-5446-1

frontiers | Frontiers in Public Health

TYPE Review
PUBLISHED 27 September 2022
DOI 10.3389/fpubh.2022.973088

OPEN ACCESS

EDITED BY
Zhiwen Hu,
Zhejiang Gongshang University, China

REVIEWED BY
Oana Sandulescu,
Carol Davila University of Medicine and Pharmacy, Romania
Gang Sun,
Bloomberg School of Public Health, Johns Hopkins University, United States

*CORRESPONDENCE
Ting Zhang
zt0416@126.com

†These authors have contributed equally to this work and share first authorship

SPECIALTY SECTION
This article was submitted to Infectious Diseases – Surveillance, Prevention and Treatment, a section of the journal Frontiers in Public Health

RECEIVED 19 June 2022
ACCEPTED 31 August 2022
PUBLISHED 27 September 2022

CITATION
Chen Y, Wang Z, Li F, Ma J, Zhang J, Chen Y and Zhang T (2022) Comparison of COVID-19 and seasonal influenza under different intensities of non-pharmaceutical interventions and vaccine effectiveness.
Front. Public Health 10:973088.
doi: 10.3389/fpubh.2022.973088

Comparison of COVID-19 and seasonal influenza under different intensities of non-pharmaceutical interventions and vaccine effectiveness

Yinchang Chen[1†], Zhende Wang[2†], Feng Li[3†], Jingyu Ma[4], Jie Zhang[5], Yunpeng Chen[6] and Ting Zhang[7*]

[1]Department of Journalism and Communication, School of Media and Law, NingboTech University, Ningbo, China, [2]School of Public Health, Weifang Medical University, Weifang, China, [3]Department of General Office, China Health Education Center, Beijing, China, [4]School of Public Health, Qilu Medical College, Shandong University, Jinan, China, [5]Department of Immunoprophylaxis, Zhangdian Center for Disease Control and Prevention, Zibo, China, [6]Bartlett School of Sustainable Construction, University College London, London, United Kingdom, [7]School of Population Medicine and Public Health, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China

Background: The COVID-19 pandemic has lasted more than 2 years, and the global epidemic prevention and control situation remains challenging. Scientific decision-making is of great significance to people's production and life as well as the effectiveness of epidemic prevention and control. Therefore, it is all the more important to explore its patterns and put forward countermeasures for the pandemic of respiratory infections.

Methods: Modeling of epidemiological characteristics was conducted based on COVID-19 and influenza characteristics using improved transmission dynamics models to simulate the number of COVID-19 and influenza infections in different scenarios in a hypothetical city of 100,000 people. By comparing the infections of COVID-19 and influenza in different scenarios, the impact of the effectiveness of vaccination and non-pharmaceutical interventions (NPIs) on disease trends can be calculated. We have divided the NPIs into three levels according to the degree of restriction on social activities (including entertainment venues, conventions, offices, restaurants, public transport, etc.), with social controls becoming progressively stricter from level 1 to level 3.

Results: In the simulated scenario where susceptible individuals were vaccinated with three doses of COVID-19 coronaVac vaccine, the peak number of severe cases was 26.57% lower than that in the unvaccinated scenario, and the peak number of infection cases was reduced by 10.16%. In the scenario with level three NPIs, the peak number of severe cases was reduced by 7.79% and 15.43%, and the peak number of infection cases was reduced by 12.67% and 28.28%, respectively, compared with the scenarios with NPIs intensity of level 2 and level 1. For the influenza, the peak number of severe cases in the scenario where the entire population were vaccinated was

89.85%, lower than that in the unvaccinated scenario, and the peak number of infections dropped by 79.89%.

Conclusion: The effectiveness of COVID-19 coronaVac vaccine for preventing severe outcomes is better than preventing infection; for the prevention and control of influenza, we recommend influenza vaccination as a priority over strict NPIs in the long term.

KEYWORDS

COVID-19 pandemic, seasonal influenza, non-pharmaceutical interventions, vaccine, transmission dynamics model

Introduction

The COVID-19 pandemic has lasted more than 2 years since its outbreak in 2019. According to the World Health Organization (WHO), as of 3 August 2022, there have been 577,018,226 confirmed cases of COVID-19, including 6,401,046 deaths (1). Despite multiple epidemic waves, the pandemic does not appear to have been effectively controlled. As more and more countries gradually relax their COVID-19 prevention and control policies and opt for a governance model of co-existence with the virus, the development trend of the COVID-19 and its future impact will be more and more worthy of attention. The reason COVID-19 has had such a widespread and dramatic impact is because the SARS-CoV-2 is highly contagious and spread rapidly. There are a large number of asymptomatic infections, which poses challenges to case detection. Fortunately, viral virulence and transmission characteristics can be estimated from existing and previous outbreaks, making it possible to model disease transmission using mathematical methods.

The transmission dynamic model is widely used in the analysis of epidemic trends of infectious diseases. Based on the simulation at different time, we can formulate targeted prevention and control strategies, allocate medical resources scientifically, and maintain the proper operation of the public health system.

Currently, COVID-19 is still a significant public health emergency in China. Therefore, the Chinese government has adopted a "dynamic zero-COVID" policy strategy to minimize the epidemic's peak and delay the time to peak. Today, this strategy still plays an important role in the rapid control of the outbreaks and the prevention of the spread of COVID-19 in China. If the "dynamic zero-COVID" policy is abandoned, it can be predicted that a large number of new cases will emerge in the short term (2). However, we cannot ignore the economic and psychological burdens on Chinese society. Therefore, in the context of the omicron variant being the dominant variant strain, it is necessary to fully understand and explore the new epidemic characteristics of the omicron variant and adopt a better strategy against COVID-19. At the same time, the vaccination against COVID-19 worldwide is continuing, and we expect to use the model to make a preliminary quantitative assessment of the vaccination effectiveness.

In the past century, there have been five pandemics of respiratory infectious diseases, each of which has caused serious infection and mortality in humankind. Among them, the 1918 influenza pandemic infected about a third of the world's population and caused about 50 million deaths worldwide (3). The death toll due to the influenza pandemic of 1957–1958 is estimated at over 1 million (4); the death toll due to the influenza pandemic of 1968–1969 is estimated at 1–4 million (5).

A study showed that NPIs applied to COVID-19 also reduced influenza activity intensity in southern and northern China and the United States by 79.2%, 79.4%, and 67.2%, respectively (6). The prevention and control of COVID-19 pandemic provide an opportunity to study the epidemic patterns and prevention and control strategies of the influenza pandemic. The influenza pandemic is uncertain and inevitable. It is difficult to predict what new subtype will cause the next influenza pandemic, when and where it will occur, and there is even the possibility of the coexistence of influenza and COVID-19 pandemic. Therefore, the exploration of NPIs and the protective effectiveness of vaccines also play a positive role in preventing and controlling the influenza pandemic. This study compares the infection process and scale of COVID-19 and influenza under different scenarios to provide quantitative evidence for countries to optimize prevention and control strategies appropriately.

Methods

Formulation of mathematical model

Modeling of etiological and epidemiological characteristics was conducted based on COVID-19 and influenza pandemics using transmission dynamics models to assess the vaccine protection against infection and its disease severity and the impact of non-pharmaceutical interventions (NPIs) on the prevalence intensity of COVID-19 and influenza pandemics.

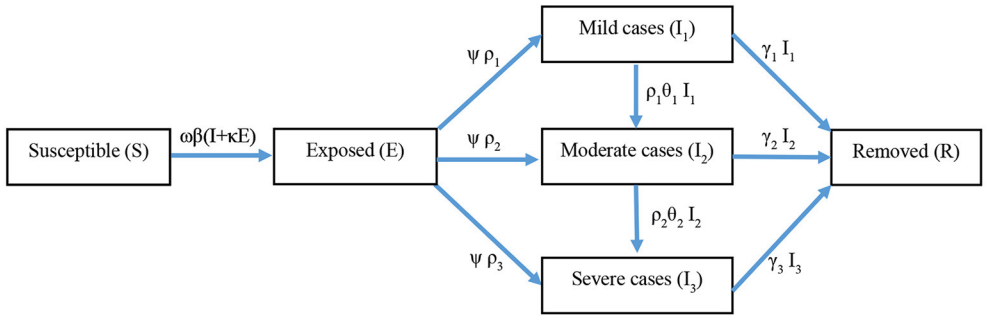


FIGURE 1
The transmission chain of transmission dynamics model is constructed according to epidemic characteristics of diseases. The SEIR model includes six compartments, i.e., Susceptible (*S*), Exposed (*E*), Mild cases (I_1), Moderate cases (I_2), Severe cases (I_3), and Removed (*R*).

We designed an improved SEIR model to show individuals' transition between compartments based on disease status. Figure 1 shows the primary infectious disease transmission structure of the model. Different NPIs levels, vaccination effectiveness, and transmission patterns, all these factors have been considered in this model. Non-pharmaceutical intervention can prevent the infected rate per contact and can prevent contact rate per unit of time. Based on concepts developed for vaccine efficacy, the immune efficacy generated by infection or vaccination can reduce susceptibility to infection, reduce infectiousness, and reduce pathology. All these factors could change the value of parameters in the model.

The system of differential equations is shown below,

$$\begin{aligned}
\frac{dS}{dt} &= -\omega\beta S(I+\kappa E)/N \\
\frac{dE}{dt} &= \omega\beta S(I+\kappa E)/N - \Psi E \\
\frac{dI_1}{dt} &= \psi\rho_1 E - \rho_1\theta_1 I_1 - \gamma_1 I_1 \\
\frac{dI_2}{dt} &= \psi\rho_2 E + \rho_1\theta_1 I_1 - \gamma_2 I_2 - \rho_2\theta_2 I_2 \\
\frac{dI_3}{dt} &= \psi\rho_3 E + \rho_2\theta_2 I_2 - \gamma_3 I_3 \\
\frac{dR}{dt} &= \gamma_1 I_1 + \gamma_2 I_2 + \gamma_3 I_3 \\
N(t) &= S(t) + E(t) + I_1(t) + I_2(t) + I_3(t) + R(t) \\
I(t) &= I_1(t) + I_2(t) + I_3(t) \\
1 &= \rho_1 + \rho_2 + \rho_3.
\end{aligned}$$

Description of variables and parameters

As we mentioned above, the SEIR model includes six main variables, i.e., Susceptible (*S*), Exposed (*E*), Mild cases (I_1), Moderate cases (I_2), Severe cases (I_3), and Removed (*R*). The relationships between them are linked by specific parameters. The variables and specific parameters in the model are set according to the relevant information, including references and expert suggestions. Details of the variables and parameters are shown in Table 1.

Scenarios setting

Based on the epidemiological and virological characteristics of the epidemic, 10 different scenarios were constructed to simulate the epidemic curve in a city with a population of 100,000. There were three levels of NPIs included in this study. We assumed that levels 1, 2, and 3 NPIs reduced the effective reproduction number (Rt) by 47%, 55%, and 69%, respectively (7). The vaccination effectiveness in preventing infection of COVID-19 and influenza were set to 33% (after three doses of CoronaVac (0.5 ml given intramuscularly) vaccination) (8) and 50% (9), respectively. Scenarios 1–5 were simulations of COVID-19, and scenarios 6–10 were simulations of influenza, with different parameter combinations for each scenario. The effects of NPIs were not considered in scenarios 1, 2, and 6, 7, which represented the natural epidemic scenario and were used to exclude the difference between NPIs. Scenario 2 was compared with scenario 1 to analyze the epidemic pattern of COVID-19 under different effectiveness of vaccination; scenario 2 was compared with scenario 7 to analyze the epidemic pattern of COVID-19 and influenza after vaccination. In scenarios 3–5/8–10, the effect of NPIs intensity on the epidemic trend was evaluated by simulating the effects of different NPIs intensities on COVID-19 and influenza based on the description and analysis of the time to reach the peak of cases and the maximum number of cases. Finally, scenarios 1–5 were compared with scenarios 6–10 to analyze the effect of NPIs with the same intensity on the epidemic trend of COVID-19 and influenza in the same initial state. See Tables 2 and 3 for more details of all scenarios.

TABLE 1 SEIR model variables and parameters.

Parameters	Description
S	Susceptible population
E	Exposed (contagious but not showing symptoms)
I_1	Mild cases (patients with asymptomatic or mild flu-like symptoms such as fever, fatigue, cough, anorexia, malaise, muscle pain, sore throat, dyspnea, nasal congestion, headache)
I_2	Moderate cases (mild or moderate clinical features. Chest imaging showed mild pneumonia manifestation)
I_3	Severe cases (patients who showed severe respiratory failure, required respiratory support, or must be admitted to the ICU)
r	Recovered[a]
ω	Control intensity index, indicating the percentage of infected cases reduced by control measures
β	Transmission coefficient, indicating the average number of susceptible people who are infected by one infectious case (including those who are ill and those in the incubation period) in unit time
κ	Infectivity discount coefficient of infected persons in incubation period compared with infected persons with onset
$\gamma_1, \gamma_2, \gamma_3$	The recovery rate of mild, moderate, and severe/critical cases, respectively, that is, the reciprocal of the recovery period
ρ_1, ρ_2, ρ_3	The composition ratio of mild, moderate, and severe/critical cases, respectively
θ_1, θ_2	The rate at which mild cases convert to moderate cases, and moderate cases convert to severe/critical cases
ψ	The rate from infection to onset, namely the reciprocal of the incubation period

[a]In the SEIR model, the compartment "removed" included recovered and death cases. In this study, we focused more on trends of maximum infections scale, which is closely linked with the health care burden, so that no death cases were involved.

TABLE 2 Scenarios setting.

Scenarios	Disease	NPI levels	Effectiveness of vaccination
Scenario 1	COVID-19	No	No
Scenario 2	COVID-19	No	33% for preventing infection (8)
Scenario 3	COVID-19	Level 3	No
Scenario 4	COVID-19	Level 2	No
Scenario 5	COVID-19	Level 1	No
Scenario 6	Influenza	No	No
Scenario 7	Influenza	No	50% for preventing infection (9)
Scenario 8	Influenza	Level 3	No
Scenario 9	Influenza	Level 2	No
Scenario 10	Influenza	Level 1	No

Level 1: NPIs announced or implemented before civil servants work from home (WFH), which usually include tightened social distancing measures in restaurants and indoor leisure facilities, and closure of kindergartens and primary schools. Level 2: NPIs announced or implemented together with civil servants WFH, which often include the closure of most indoor leisure facilities, closure of all schools, no dine-in in restaurants after 9 pm. Level 3: NPIs announced or implemented after civil servants WFH, which include more stringent control measures of restaurants, such as no dine-in after 6 pm or all day (7).

Statistical analysis

R software version 4.0.5 (the R Foundation for computing) software and deSolve software package were used for modeling and analysis, and Microsoft Office 2013 was used for data cleansing and description.

Results

Effects of COVID-19 vaccine—Scenario 1 vs. scenario 2

Simulation of the model shows that compared with scenario 1 (no NPIs or vaccination), the time for the number of mild, moderate and severe cases to reach the peak in scenario 2 (COVID-19 vaccination has 33% effectiveness for reducing the transmission coefficient of COVID-19) was shortened, and the peak number of mild and severe cases decreased. The number of severe cases in scenario 1 peaked at 17,019 on day 23, and the infections peaked at 51,294 on day 19. Compared with scenario 1, the peak number of severe cases in scenario 2 decreased by 26.57%, the day to reach the peak was delayed by 9 days, and the peak number of infections decreased by 10.16%; the day to reach the peak of infections was delayed by 6 days (Figures 2, 4A).

Effects of NPIs on COVID-19—Scenario 3 vs. scenario 4 vs. scenario 5

With the strengthening of NPIs, the peak number of mild, moderate, severe, and infections decreased. The peak of severe cases in scenario 3 (14,402) was 7.79% and 15.43% lower than that in scenario 4 (15,620) and scenario 5 (17,031), respectively, and the number of days to reach the peak decreased by 8 and 21 days, respectively. The peak number of infections in scenario 3 (36,695) was 12.67% and 28.28% lower than that in scenario 4 (42,020) and scenario 5 (51,170), respectively. The time to

TABLE 3 Parameter combinations of five scenarios of COVID-19.

Parameters	Scenario					Setting basis
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	
S	1×10^5	1×10^5	1×10^5	1×10^5	1×10^5	Hypothesis
E	24	24	63	63	63	I time the incubation period
I_1	5	5	10	10	10	Hypothesis
I_2	1	1	6	6	6	Hypothesis
I_3	1	1	2	2	2	Hypothesis
I	7	7	18	18	18	$I_1 + I_2 + I_3$
R	0	0	0	0	0	Hypothesis
Ω	–	–	0.31	0.45	0.53	Reference (7)
β	1.3	1.3×0.67	1.3	1.3	1.3	Calculation by experts (8, 10) Reference (8)
κ	0.35	0.35	0.35	0.35	0.35	Reference (2)
γ_1	1/7	1/7	1/7	1/7	1/7	Reference (11)
γ_2	1/10	1/10	1/10	1/10	1/10	References (11, 12)
γ_3	1/19	1/19	1/19	1/19	1/19	Reference (11)
ρ_1	0.51	0.57	0.51	0.51	0.51	References (13, 14) and calculated according to ρ_2, ρ_3
ρ_2	0.30	0.34	0.30	0.30	0.30	Calculated according to ρ_3
ρ_3	0.19	0.09	0.19	0.19	0.19	References (15–17)
θ_1	1/5.9	1/5.9	1/5.9	1/5.9	1/5.9	Reference (11)
θ_2	1/8.3	1/8.3	1/8.3	1/8.3	1/8.3	Reference (11)
ψ	1/3.5	1/3.5	1/3.5	1/3.5	1/3.5	Reference (18)

In this study, ρ_1 : ρ_2 approximate equal to 5:3, according to the reference (13), the proportion of mild cases is about equal to that of moderate cases, but we take asymptomatic infections [20% (14)] as mild cases, so the proportion of ρ_1 and ρ_2 confirmed.

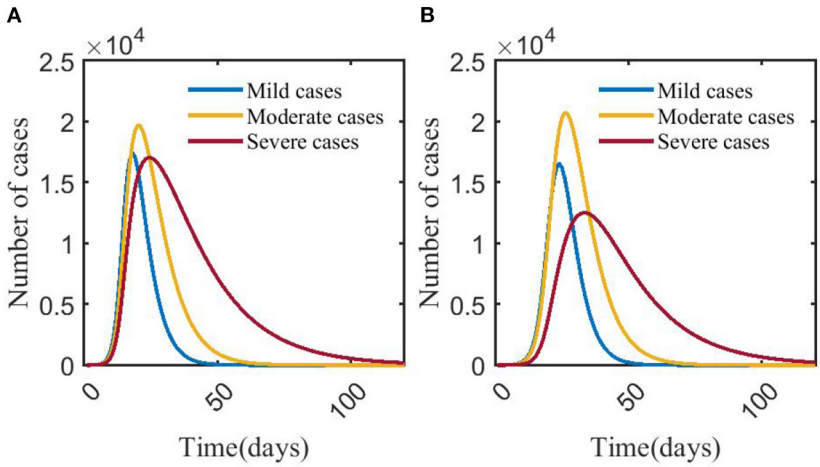


FIGURE 2
Changes in numbers of mild, moderate, and severe cases in scenarios 1 **(A)** and 2 **(B)**. In scenario 1, we assumed no NPIs or vaccination against COVID-19. In scenario 2, we assumed no NPIs and 33% effectiveness of vaccination to prevent infection of COVID-19. The blue, yellow, and red curves represent the number of mild, moderate, and severe cases, respectively. Scenarios setting are shown in Table 2. Parameter values used are given in Table 3.

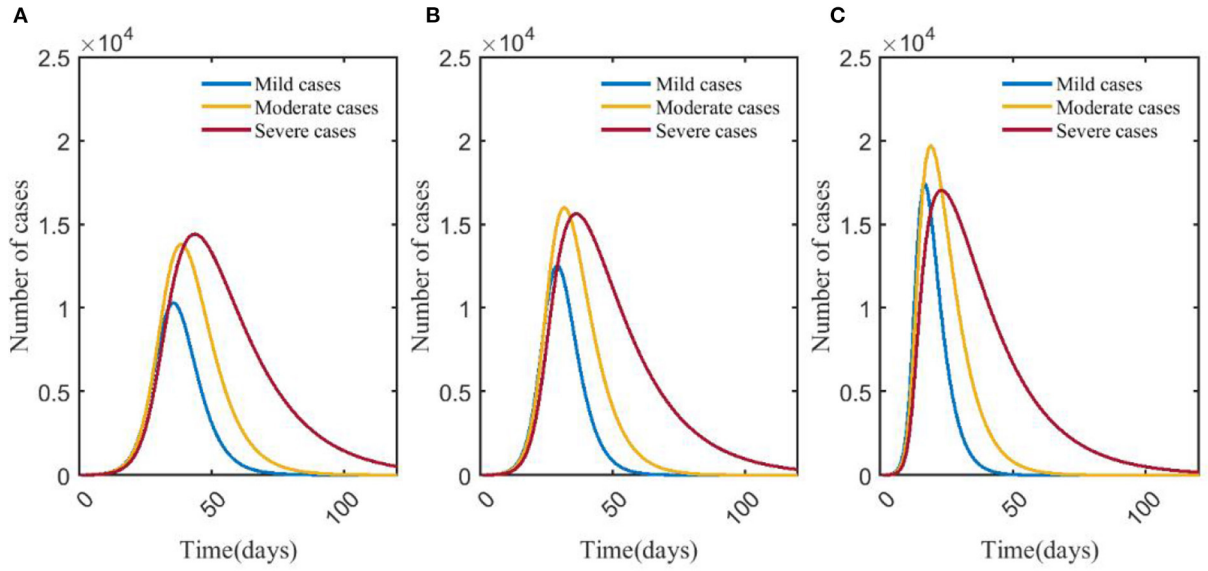


FIGURE 3
Changes in numbers of mild, moderate, severe cases in scenarios 3 **(A)**, 4 **(B)**, and 5 **(C)**. The blue, yellow, and red curves represent mild, moderate, and severe cases, respectively. Scenarios setting are shown in Table 2. Parameter values used are given in Table 3.

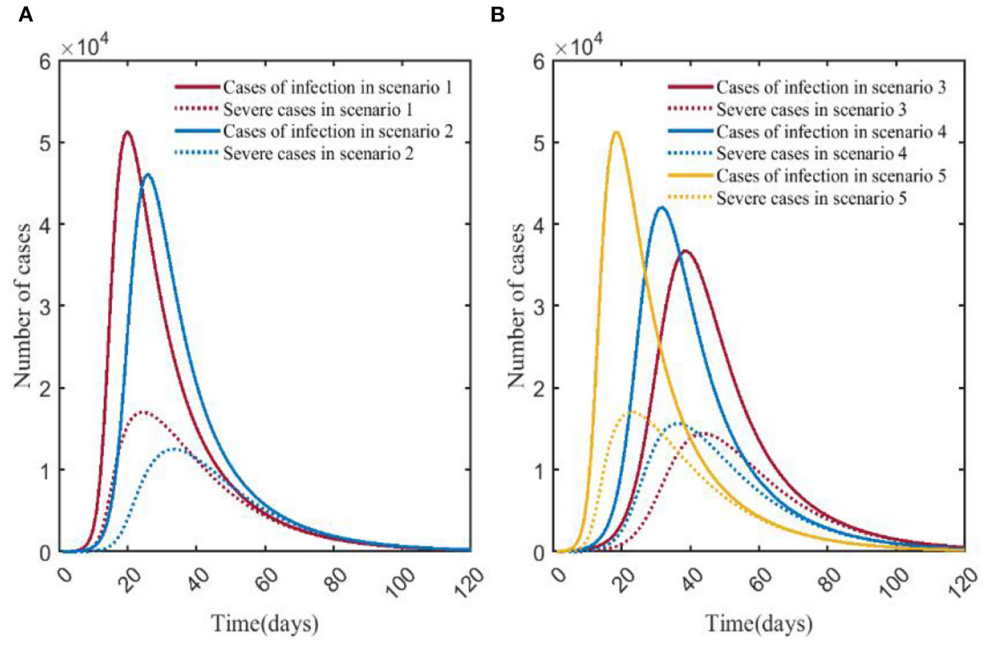


FIGURE 4
Changes in numbers of severe cases and infections in scenarios 1, 2 **(A)** and scenarios 3, 4, 5 **(B)**. In **(A)**, the red and blue solid curves represent the number of infections in scenarios 1 and 2, respectively. The red and blue dotted curves represent the number of severe cases in scenario 1 and scenario 2, respectively. In **(B)**, the red, blue, and yellow solid curves represent the number of infections in scenario 3, scenario 4, and scenario 5, respectively. The red, blue, and yellow dotted curves represent the number of severe cases in scenario 3, scenario 4, and scenario 5, respectively. Scenarios setting are shown in Table 2. Parameter values used are given in Table 3.

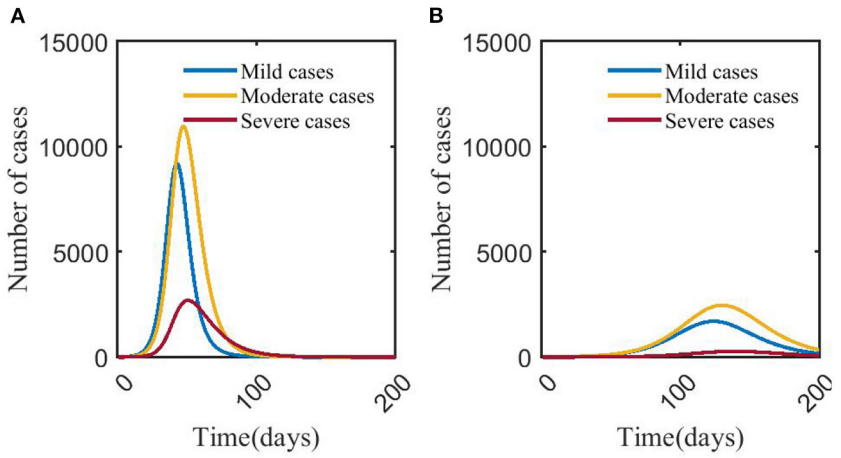


FIGURE 5
Changes in numbers of mild, moderate, and severe cases in scenarios 6 **(A)** and 7 **(B)**. The blue, yellow, and red solid curves represent the number of mild, moderate, and severe cases, respectively. Scenarios setting are shown in Table 2. Parameter values used are given in Table 4.

reach the peak number of infections was delayed by 7 and 21 days, respectively (Figures 3, 4B).

Effects of influenza vaccine—Scenario 6 vs. scenario 7

It showed that the peak number of severe cases was less than that of mild and moderate cases in scenarios 6 and 7. In scenario 7, the peak number of severe cases was 273, which was 89.85% less than that in scenario 6, and the day to the peak was 88 days later than that in scenario 6. The number of infections in scenario 7 peaked at 4,389, which was 80.01% less than that in scenario 6, and the time to peak was delayed by 83 days (Figures 5, 7A).

Effects of NPIs on influenza—Scenario 8 vs. scenario 9 vs. scenario 10

Figure 6 showed that after taking different levels of NPIs, the number of severe cases decreased significantly compared with mild and moderate cases. In scenario 8, the number of mild, moderate, and severe cases was <50, and the peak number of severe cases was 7, which was 99.27% lower than that in scenario 9. The time to peak was delayed by more than 3 months. The number of infections (46 cases) peaked on day 9, which was 93.23% lower than scenario 9, and the time to peak was delayed by 124 days. The differences in numbers of severe cases and infections between scenario 8 and scenario 10 could be negligible. The number of severe cases in scenario 10 peaked on day 45, which was about 2,693, and increased by 80.24% compared with scenario 9, and the time to peak was 96 days earlier. The number of infections in scenario 10 peaked on day 40, 93 days earlier than in scenario 9, and the number at its peak increased by 84.77% (Figure 7).

COVID-19 vs. influenza

Scenario 1 and scenario 6 simulated the natural epidemic characteristics of COVID-19 and influenza without taking any measures. The results indicated that the total number of COVID-19 infections peaked on around day 23 (51,294), while influenza peaked on day 50 (21,827). The peak number of COVID-19 infections was more than twice that of influenza. The peak number of severe cases was about 6.32 times than that of the influenza (17,019/2,692), and the time to peak was 27 days earlier (Figure 8A). By comparing scenarios 2 and 7, it showed that the peak of severe cases in scenario 2 appeared on day 32, with 12,497 cases, which was about 45.77 times that in scenario 7 (12,497/273), the number of infections in scenario 2 peaked on day 32, and the peak number was about 10.50 times (46,081/4,389) than that in scenario 7 (Figure 8B). Scenario 3 and scenario 8 were the epidemiological trends of COVID-19 and influenza, assuming that the NPI level was level 3. The results showed that in scenario 8, the peak number of severe cases and infections were both at low levels, with 7 and 46 cases, respectively. In scenario 3, severe cases and infections peaked at 14,402 and 36,695, respectively (Figure 8C). Scenario 4 and scenario 9 simulated the trends of COVID-19 and influenza when the intensity of NPI was level 2. The results showed that the peak number of severe cases of COVID-19 was about 29.39

TABLE 4 Parameter combinations of five scenarios of influenza.

Parameters	Scenario					Setting basis
	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	
S	1×10^5	1×10^5	1×10^5	1×10^5	1×10^5	Hypothesis
E	20	20	51	51	51	I time the incubation period
I_1	5	5	10	10	10	Hypothesis
I_2	1	1	6	6	6	Hypothesis
I_3	1	1	2	2	2	Hypothesis
I	7	7	18	18	18	$I_1 + I_2 + I_3$
r	0	0	0	0	0	Hypothesis
ω	–	–	0.31	0.45	0.53	Reference (7)
β	0.4	0.4×0.5	0.4	0.4	0.4	References (9, 19–21)
κ	0.5	0.5	0.5	0.5	0.5	Hypothesis
γ_1	1/4.67	1/4.67	1/4.67	1/4.67	1/4.67	Reference (22)
γ_2	1/7	1/7	1/7	1/7	1/7	References (22, 23)
γ_3	1/14	1/14	1/14	1/14	1/14	Reference (22, 23)
ρ_1	0.89	0.95	0.89	0.89	0.89	Calculated according to ρ_3
ρ_2	0.06	0.04	0.06	0.06	0.06	Calculated according to ρ_3
ρ_3	0.05	0.01	0.05	0.05	0.05	Reference (24)
θ_1	1/4.67	1/4.67	1/4.67	1/4.67	1/4.67	Reference (22)
θ_2	1/7	1/7	1/7	1/7	1/7	Reference (22)
Ψ	1/2.83	1/2.83	1/2.83	1/2.83	1/2.83	Reference (22)

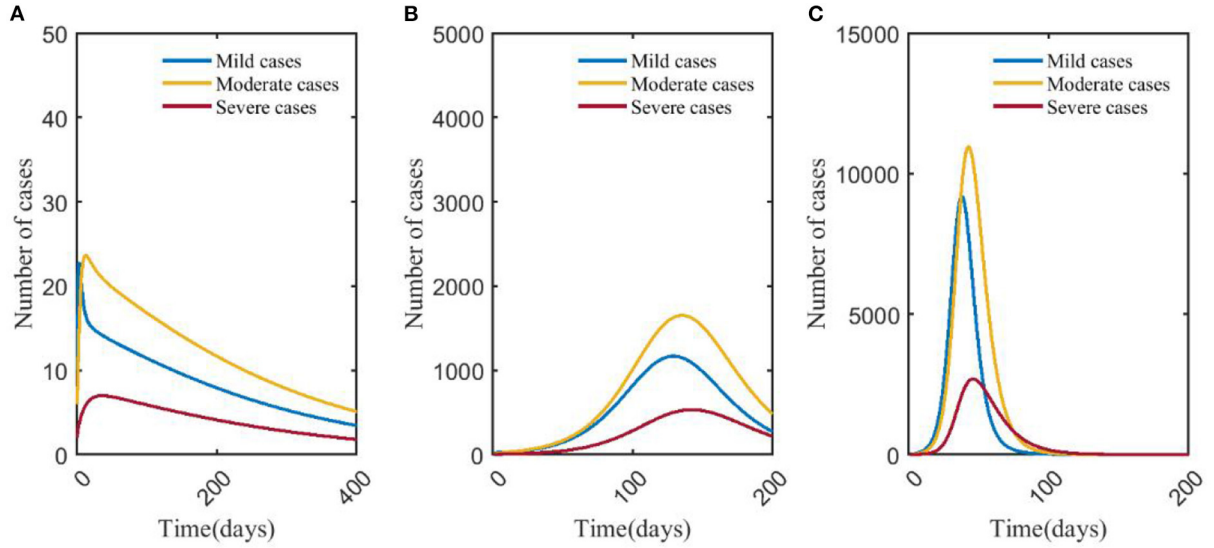


FIGURE 6
Changes in numbers of cases of different types in scenarios 8 **(A)**, 9 **(B)**, and 10 **(C)**. The blue, yellow, and red curves represent mild, moderate, and severe cases, respectively. Scenarios setting are shown in Table 2. Parameter values used are given in Table 4.

times than that of influenza (15,620/532), and the time to peak was 106 days earlier; the peak number of COVID-19 infections was about 12.62 times than that of influenza (42,020/3,327), and the time to peak was shortened by 95 days (Figure 8D). Scenarios 5 and 10 assumed that NPI level was level 1. In Figure 8E, it showed that the peak of severe COVID-19 cases was about 6.32 times than that of influenza (17,031/2,693), and the time to peak was 23 days earlier. The peak number of COVID-19 infections

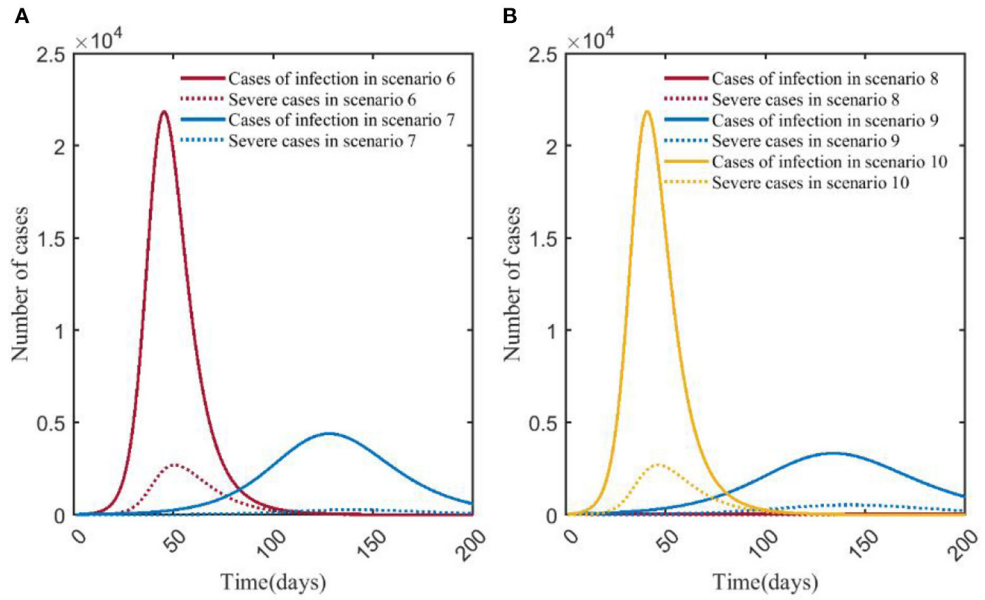


FIGURE 7
Changes in numbers of severe cases and infections in scenarios 6, 7 **(A)** and 8, 9, 10 **(B)**. In **(A)**, the red and blue solid curves represent the number of infections in scenarios 6 and 7, respectively. The red and blue dotted curves represent the number of severe cases in scenario 6, scenario 7, respectively. In **(B)**, the red, blue, and yellow solid curves represent the number of infections in scenario 8, scenario 9, scenario 10, respectively. The red, blue, and yellow dotted curves represent the number of severe cases in scenario 8, scenario 9, scenario 10, respectively. Scenarios setting are shown in Table 2. Parameter values used are given in Table 4.

was about 2.34 times than that of influenza (51,170/21,859), and the time to peak was 23 days earlier.

A horizontal comparison of scenarios 1–10 indicated that the peak numbers of infections and severe cases of COVID-19 were far more than those of influenza pandemic. For COVID-19 (scenarios 1–5), the reduction in the peaks of infections was most significant with the adoption of strict NPIs, and the time to peak could be delayed significantly. We can see that vaccination was the best way to prevent severe COVID-19 cases for the decrease of severe cases in scenario 2. As for influenza (scenarios 6–10), strict NPIs could minimize the peak numbers of both infections and severe cases, and influenza vaccination could significantly delay the time to peak (Figure 9).

Discussion

In the process of a global response to COVID-19, the prevention and control of influenza still need to be paid enough attention. Fortunately, in the process of responding to COVID-19, more and more people have developed good hygiene habits such as wearing masks and keeping their hands clean, which undoubtedly have positive significance for the prevention and control of influenza. Since severe cases have the greatest demand for medical resources, we focused more on the analysis of the scale of the severe/critically ill population. In order to compare the infections scale of COVID-19 and influenza in the same scenario, we conducted a model analysis on the infections scale and trend of influenza according to the epidemic characteristics of influenza and COVID-19.

Effectiveness of vaccination on COVID-19 and influenza

Due to differences in national policies, vaccine types, and study samples, the global study results on the effectiveness of COVID-19 vaccines are not uniform. What is certain, however, is that the vaccination effectiveness of coronaVac in preventing infection, morbidity, and hospitalization decreases over time, but by vaccinating a booster dose of coronaVac will increase the neutralizing antibodies and elicit stronger specific immunity than the second dose, today the pandemic is not yet over, and vaccination campaigns are still ongoing, so we chose to set the parameter of vaccine effectiveness to be after three doses of coronaVac. In fact, vaccine effectiveness preventing severe outcomes declines less rapidly than against infection and transmission (25). This is consistent with our findings, but the reduction in the peak number of infections is not as large as in severe cases. Many studies have proven that vaccines are more than 90% effective in preventing severe cases (26–28). At present, as the pandemic continues, many countries have

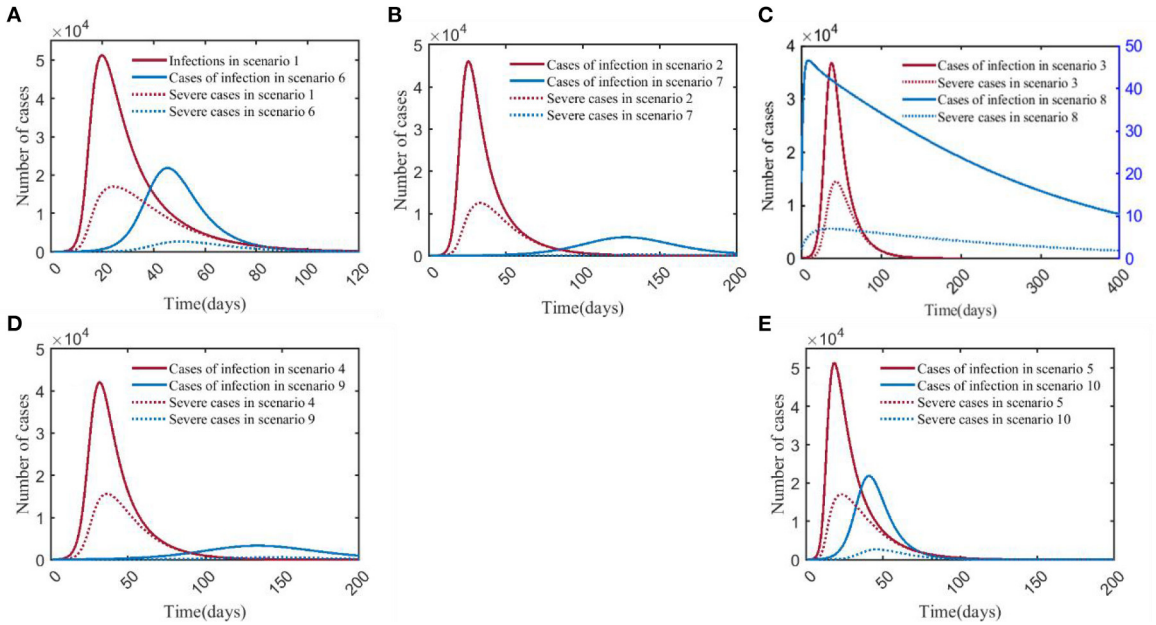


FIGURE 8
Comparison of numbers of infections and severe cases in scenarios 1–5 and scenarios 6–10. **(A)** is the result of comparison of scenario 1 and scenario 6. **(B)** is the result of comparison of scenario 2 and scenario 7. **(C)** is the result of comparison of scenario 3 and scenario 8 (Applies to the Y-axis on the right side). **(D)** is the result of comparison of scenario 4 and scenario 9. **(E)** is the result of comparison of scenario 5 and scenario 10. The red and blue solid curves represent the number of infections in scenarios 1–10, respectively. The red and blue dotted curves represent the number of severe cases in scenarios 1–10, respectively. Scenarios setting are shown in Table 2. Parameter values used are given in Tables 3, 4.

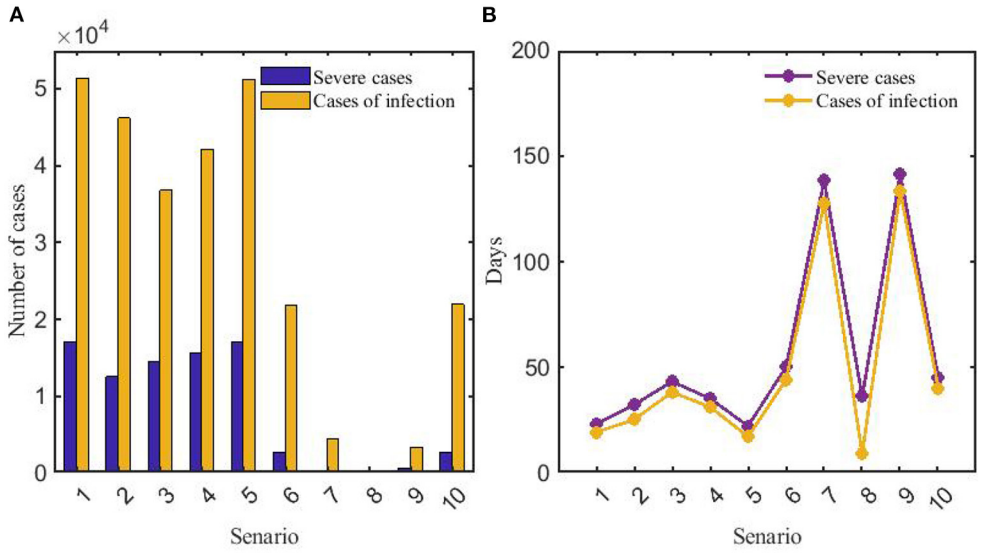


FIGURE 9
Comparison of peaks **(A)** and time to peak **(B)** of numbers of infections and severe cases in scenarios 1–10. In panel **(A)**, the orange and indigo bars represent the number of infections and severe cases in scenarios 1–10, respectively. In panel **(B)**, the orange and indigo lines represent the time to peak of numbers of infections and severe cases in scenarios 1–10, respectively. Scenarios setting are shown in Table 2. Parameter values used are given in Tables 3, 4.

move away from tough prevention and control measures to restrict the movement of people and instead have chosen a more moderate approach to epidemic prevention, that is, coexisting with the virus, thus making the importance of vaccines all the more self-evident. According to the data from WHO, as of 25 July 2022, a total of 12,248,795,623 COVID-19 vaccine doses have been administered (1). In China, as of 20 July, 2022, 92% of the population has been vaccinated with at least one dose of COVID-19 vaccine, 89% of the population has been fully vaccinated, and more than 56% of the population has been vaccinated with at least one booster dose (29). The high vaccination rate and strict NPIs controlled the COVID-19 epidemic at a low level in China. Coronavac is one of the WHO-approved vaccines and over two billion doses have been administered in more than 40 countries. One study showed that SARS-CoV-2 vaccination failed to stop the disease occurrence, but it inhibited the disease severity from mild or moderate to severe or critical (13, 14, 30).

Effectiveness of NPIs on COVID-19 and influenza

The results indicated that the final scale of both COVID-19 and influenza outbreaks declined significantly as containment efforts intensified. The results of this study showed that vaccination could greatly reduce the peak number of severe COVID-19 cases, and strict NPIs could effectively reduce the peak number of COVID-19 infections. Therefore, we recommend that at the beginning of one pandemic, strict NPIs can be taken to suppress the outbreak quickly, but the economic cost, mental health burden, and excess deaths due to not being able to seek healthcare given strict NPIs should be taken into consideration as well when the government decides to take strict NPIs. We find that influenza vaccination could effectively prevent infectiousness and clinical severity and delay the time to peak of the influenza epidemic. Under the assumption that the effectiveness of NPIs is level 3, the scale of influenza is almost negligible. However, we do not believe that strict NPIs are the most cost-effective method for influenza control in the long time. It is because the model shows that even without NPIs and with only influenza vaccination, the final scale of the influenza epidemic will eventually be within the healthcare system's capacity for most countries and regions.

Limitations

There are still some limitations to this study. First, scientific decision-making requires reliable evidence support, and the epidemic patterns of diseases should be fully understood. However, due to the complexity of the epidemic in the real world, it is challenging to accurately discover all indicators that impact the epidemic and incorporate them into the model. When evaluating the effect of NPIs, we did not subdivide NPIs and analyze the independent effect of each NPI (such as wearing masks, and maintaining social distancing). Second, the political, economic, cultural, and epidemic situations differ greatly from country to country and region to region, the above influencing factors were not considered in this model, so the real-world situation was not simulated and predicted. Third, we only referred to the effectiveness data of three doses of coronaVac COVID-19 vaccine, regarded the vaccine effectiveness as a constant and did not adjust the model according to the attenuation of vaccine effectiveness. Furthermore, the WHO Strategic Advisory Group of Experts on Immunization (SAGE) recommends that a third, additional dose of the Sinovac vaccine be offered to persons aged 60 and above as part of an extension of the primary series. Current data does not indicate the need for an additional dose in persons under 60 years of age (31), so the study has made overly optimistic vaccination estimates. Finally, the construction of model scenarios is a theoretical analysis. In fact, the effect of epidemic prevention and control is related to the prevention and control capabilities of different regions, and the disease trends may not be the same as predicted in the model.

Conclusion

The effectiveness of COVID-19 coronaVac vaccine for preventing severe outcomes is better than preventing infection; for the prevention and control of influenza, we recommend influenza vaccination as a priority over strict NPIs in the long term.

Author contributions

TZ and FL supervised the study. TZ and ZW designed the study. ZW and YC collected data. TZ, ZW, and YC performed analysis. YC, ZW, FL, JM, JZ, YC, and TZ interpreted the findings. YC, ZW, and FL wrote the manuscript. JM, ZW, JZ, YC, and TZ commented on and revised the manuscript accordingly.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher,

the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. World Health Organization. *Coronavirus (COVID-19) Dashboard*. (2022). Available online at: https://covid19.who.int/ (accessed August 4, 2022).

2. Cai J, Deng X, Yang J, Sun K, Liu H, Chen Z, et al. Modeling transmission of SARS-CoV-2 omicron in China. *Nat Med.* (2022) 28:1468–75. doi: 10.1038/s41591-022-01855-7

3. Taubenberger JK, Morens DM. 1918 Influenza: the mother of all pandemics. *Emerg Infect Dis*. (2006) 12:15–22. doi: 10.3201/eid1209.05-0979

4. Viboud C, Simonsen L, Fuentes R, Flores J, Miller MA, Chowell G. Global mortality impact of the 1957–1959 influenza pandemic. *J Infect Dis.* (2016) 213:738–45. doi: 10.1093/infdis/jiv534

5. Honigsbaum M. Revisiting the 1957 and 1968 influenza pandemics. *Lancet.* (2020) 395:1824–6. doi: 10.1016/S0140-6736(20)31201-0

6. Feng L, Zhang T, Wang Q, Xie Y, Peng Z, Zheng J, et al. Impact of COVID-19 outbreaks and interventions on influenza in China and the United States. *Nat Commun.* (2021) 12:3249. doi: 10.1038/s41467-021-23440-1

7. *Modelling the Fifth Wave of COVID-19 in Hong Kong*. (2022). Available online at: http://www.med.hku.hk/en/news/press/20220322-updates-on-modelling-the-omicron-fifth-wave (accessed August 4, 2022).

8. Suah JL, Tng BH, Keng Tok PS, Husin M, Thevananthan T, Peariasamy KM, et al. Real-world effectiveness of homologous and heterologous BNT162b2, CoronaVac, and AZD1222 booster vaccination against Delta and Omicron SARS-CoV-2 infection. *Emerg Microbes Infect.* (2022) 11:1343–5. doi: 10.1080/22221751.2022.2072773

9. World Health Organization. *Evaluation of Influenza Vaccine Effectiveness – A Guide to the Design and Interpretation of Observational Studies*. (2022). Available online at: https://www.who.int/publications/i/item/9789241512121 (accessed September 15, 2022).

10. Research Institute of Public Health, Nankai University. *Identification of Omicron Variants of COVID-19*. (2021). Available online at: https://riph.nankai.edu.cn/2021/1129/c23093a417650/pagem.htm (accessed April 13, 2022).

11. Et A, Js C, Amda B, Mppa B. Global impact of coronavirus disease 2019 infection requiring admission to the ICU: a systematic review and meta-analysis. *Chest.* (2021) 159:524–36. doi: 10.1016/j.chest.2020.10.014

12. National Institute of Infection Disease of Japan. *Active Epidemiological Investigation on SARS-CoV-2 Infection Caused by Omicron Variant (Pango lineage B.1.1.529) in Japan: Preliminary Report on Infectious Period*. (2022). Available online at: https://www.niid.go.jp/niid/en/2019-ncov-e/10884-covid19-66-en.html (accessed April 10, 2022).

13. Ma C, Sun W, Tang T, Jia M, Liu Y, Wan Y, et al. effectiveness of adenovirus type 5 vectored and inactivated COVID-19 vaccines against symptomatic COVID-19, COVID-19 pneumonia, and severe COVID-19 caused by the B.1.617.2 (Delta) variant: evidence from an outbreak in Yunnan, China, 2021. *Vaccine.* (2022) 40:2869–74. doi: 10.1016/j.vaccine.2022.03.067

14. Buitrago-Garcia D, Egli-Gany D, Counotte MJ, Hossmann S, Imeri H, Ipekci AM, et al. Occurrence and transmission potential of asymptomatic and presymptomatic SARS-CoV-2 infections: a living systematic review and meta-analysis. *PLoS Med.* (2020) 17:e1003346. doi: 10.1371/journal.pmed.1003346

15. Maslo C, Friedland R, Toubkin M, Laubscher A, Kama B. Characteristics and outcomes of hospitalized patients in south Africa during the COVID-19 omicron wave compared with previous waves. *JAMA*. (2022) 327:583–4. doi: 10.1001/jama.2021.24868

16. Jara A, Undurraga EA, González C, Paredes F, Fontecilla T, Jara G, et al. Effectiveness of an Inactivated SARS-CoV-2 vaccine in Chile. *N Engl J Med.* (2021) 385:875–84. doi: 10.1056/NEJMoa2107715

17. McMenamin ME, Nealon J, Lin Y, Wong JY, Cheung JK, Lau EH, et al. Vaccine effectiveness of one, two, and three doses of BNT162b2 and CoronaVac against COVID-19 in Hong Kong: a population-based observational study. *Lancet Infect Dis.* (2022) S1473-3099(22)00345-0. doi: 10.1016/S1473-3099(22)00345-0

18. Zhang M, Xiao J, Deng A, Zhang Y, Zhuang Y, et al. Transmission dynamics of an outbreak of the COVID-19 delta variant B.1.617.2 — Guangdong Province, China, May–June 2021. *China CDC Weekly*. (2021) 3:584–6. doi: 10.46234/ccdcw2021.151

19. Hirve S, Lambach P, Paget J, Vandemaele K, Fitzner J, Zhang W. Seasonal influenza vaccine policy, use and effectiveness in the tropics and subtropics–a systematic literature review. *Influenza Other Respir Viruses.* (2016) 10:254–67. doi: 10.1111/irv.12374

20. Nypaver C, Dehlinger C, Carter C. Influenza and influenza vaccine: a review. *J Midwifery Womens Health.* (2021) 66:45–53. doi: 10.1111/jmwh.13203

21. Rondy M, El Omeiri N, Thompson MG, Levêque A, Moren A, Sullivan SG. Effectiveness of influenza vaccines in preventing severe influenza illness among adults: a systematic review and meta-analysis of test-negative design case-control studies. *J Infect.* (2017) 75:381–94. doi: 10.1016/j.jinf.2017.09.010

22. Fu X. *Epidemiological and Clinical Characteristics of Influenza in China from 2011 to 2018*. (2020). Available online at: https://d.wanfangdata.com.cn/thesis/D02235339 (accessed April 12, 2022).

23. World Health Organization. *Overview of Influenza Seasonal*. (2022). Available online at: https://www.who.int/health-topics/influenza-seasonal#tab=tab_1 (accessed April 10, 2022).

24. Thompson MG, Pierse N, Sue Huang Q, Prasad N, Duque J, Claire Newbern E, et al. Influenza vaccine effectiveness in preventing influenza-associated intensive care admissions and attenuating severe disease among adults in New Zealand 2012–2015. *Vaccine.* (2018) 36:5916–25. doi: 10.1016/j.vaccine.2018.07.028

25. Antia R, Halloran ME. Transition to endemicity: understanding COVID-19. *Immunity.* (2021) 54:2172–6. doi: 10.1016/j.immuni.2021.09.019

26. Lutrick K, Rivers P, Yoo YM, Grant L, Hollister J, Jovel K, et al. Interim Estimate of Vaccine Effectiveness of BNT162b2 (Pfizer-BioNTech) Vaccine in Preventing SARS-CoV-2 Infection Among Adolescents Aged 12–17 Years—Arizona, July–December 2021. *MMWR Morb Mortal Wkly Rep.* (2021) 70:1761–5. doi: 10.15585/mmwr.mm705152a2

27. Haas EJ, Angulo FJ, Mclaughlin JM, Emilia A, Singer SR, Farid K, et al. Impact and effectiveness of mRNA BNT162b2 vaccine against SARS-CoV-2 infections and COVID-19 cases, hospitalisations, and deaths following a nationwide vaccination campaign in Israel: an observational study using national surveillance data. *Lancet.* (2021) 397:1819–29. doi: 10.1016/S0140-6736(21)00947-8

28. Naleway AL, Groom HC, Crawford PM, Salas SB, Henninger ML, Donald JL, et al. Incidence of SARS-CoV-2 Infection, Emergency Department Visits, and Hospitalizations Because of COVID-19 Among Persons Aged≥ 12 Years, by COVID-19 Vaccination Status—Oregon and Washington, 4 July−25 September, 2021. *MMWR Morb Mortal Wkly Rep.* (2021) 70:1608–12. doi: 10.15585/mmwr.mm7046a4

29. National Health Commission of the People's Republic of China. *Transcript of the Press Conference of the Joint Prevention and Control Mechanism of the State Council*. (2022). Available online at: http://www.nhc.gov.cn/xcs/fkdt/202207/10b358da7913436aabd12fc1cf6a8f5b.shtml (accessed August 13, 2022).

30. Smith DJ, Hakim AJ, Leung GM, Xu W, Schluter WW, Novak RT, et al. COVID-19 mortality and vaccine coverage—Hong Kong special administrative region, China, 6 January, 2022–21 March, 2022. *MMWR Morb Mortal Wkly Rep.* (2022) 71:545–8. doi: 10.15585/mmwr.mm7115e1

31. World Health Organization. *The Sinovac-CoronaVac COVID-19 Vaccine: What you Need to Know*. (2022). Available online at: https://www.who.int/news-room/feature-stories/detail/the-sinovac-covid-19-vaccine-what-you-need-to-know (accessed August 31, 2022).

frontiers | Frontiers in Medicine

TYPE Original Research
PUBLISHED 29 September 2022
DOI 10.3389/fmed.2022.978795

OPEN ACCESS

EDITED BY
Pier Luigi Sacco,
University of Studies G. d'Annunzio Chieti and Pescara, Italy

REVIEWED BY
Bernardo Vega,
University of Cuenca, Ecuador
Alejandro Piscoya,
Hospital Guillermo Kaelin de la Fuente, Peru

*CORRESPONDENCE
Telmo Raul Aveiro-Robalo
raul.aveiro45@gmail.com

SPECIALTY SECTION
This article was submitted to Infectious Diseases - Surveillance, Prevention and Treatment, a section of the journal Frontiers in Medicine

RECEIVED 26 June 2022
ACCEPTED 24 August 2022
PUBLISHED 29 September 2022

CITATION
Mejia CR, Aveiro-Robalo TR, Garlisi Torales LD, Fernández MF, Bonilla-Rodríguez FE, Estigarribia E, Coronel-Ocampos JM, Caballero-Arzamendia CJ, Torres RR, Conde-Escobar A, Canaviri-Murillo Y, Castro-Pacoricona D, Serna-Alarcón V and Arias-Chávez D (2022) Basic COVID-19 knowledge according to education level and country of residence: Analysis of twelve countries in Latin America. *Front. Med.* 9:978795. doi: 10.3389/fmed.2022.978795

Basic COVID-19 knowledge according to education level and country of residence: Analysis of twelve countries in Latin America

Christian R. Mejia[1], Telmo Raul Aveiro-Robalo[2]*, Luciana Daniela Garlisi Torales[2], Maria Fernanda Fernández[3,4], Francisco E. Bonilla-Rodríguez[5], Enrique Estigarribia[6], Johanna Magali Coronel-Ocampos[2], Cecilia J. Caballero-Arzamendia[7], Renato R. Torres[3,4], Aram Conde-Escobar[3,4], Yuliana Canaviri-Murillo[3,4], Diana Castro-Pacoricona[3,4], Victor Serna-Alarcón[8,9] and Dennis Arias-Chávez[10]

[1]Translational Medicine Research Centre. Universidad Norbert Wiener, Lima, Peru, [2]Universidad del Pacífico, Asunción, Paraguay, [3]Universidad Privada de Tacna, Centro de Investigación de Estudiantes de Medicina (CIESMED), Tacna, Peru, [4]Asociación Médica de Investigación y Servicios en Salud, Lima, Peru, [5]José Matías Delgado University, La Libertad, El Salvador, [6]National University of Caaguazú, Coronel Oviedo, Paraguay, [7]Universidad Católica Nuestra Señora de la Asunción, Guairá, Villarrica, Paraguay, [8]Antenor Orrego Private University, Trujillo, Peru, [9]Hospital José Cayetano Heredia, Piura, Peru, [10]Universidad Continental, Arequipa, Peru

Introduction: Knowing a disease is crucial for being able to fight it, especially in a region in which COVID-19 caused so many deaths, such as Latin America.

Objective: To determine the association between basic knowledge of COVID-19 and education level according to country of residence in Latin America.

Methodology: This is an analytical cross-sectional study. Basic level of knowledge was measured through nine close-ended questions (scale validated in Peru). The score obtained was analyzed through performing a crosstab vs. gender, age, education level, and country of residence.

Results: Of a total of 9,222 respondents, almost all of them knew the common symptoms (99%), modes of transmission (93%), and knew how to recognize which was not a specific symptom (93%). Through the multivariate model, we found that there was no association with gender ($p = 0.716$) or age ($p = 0.059$), in comparison with those who had primary or a lower education level. All the other higher education levels had statistically significant scores (all p-values $p < 0.001$). When comparing knowledge according to countries, and using Peru as reference for comparison, Chile, Paraguay, Mexico, Bolivia, Panama, Ecuador, Costa Rica, and Colombia had a better level of knowledge (all p-values < 0.001); however, only El Salvador had a lower level ($p < 0.001$).

Discussion: There was lack of knowledge of some topics, difference according to academic degree and country. As Peru was one of countries that obtained the lowest level of knowledge, it could have influenced the fact that it was the most affected country in the world.

KEYWORDS

coronavirus, knowledge, pandemic, COVID-19, Latin America

Introduction

COVID-19 is a disease caused by SARS-CoV-2, discovered in the city of Wuhan, China, at the end of 2019 (1). This new disease was declared a pandemic by the World Health Organization (WHO) at the beginning of 2020, and it became one of the most important in recent times (2). Nobody can deny the great impact that COVID-19 had worldwide. It caused several repercussions which affected quality of life, health of populations, the economy of families and countries, among many others (2, 3).

The information and knowledge that we currently have about COVID-19 has arisen based on the research carried out, and different topics, such as pathophysiology, clinical manifestations, and evolution have become better known (4, 5). However, despite the fact that this disease has been present in our environment for more than 2 years, it is necessary to see retrospectively what could have influenced some countries to be more affected than others. Moreover, it is important to know that mortality can also vary according to the stage of the disease, the territory or country, the population group, as well as pre-existing comorbidities (6, 7).

In other pathologies there was minimal knowledge to fight them, such as MERS and SARS (8). Therefore, effectively dealing with this disease would have meant, at least, having general knowledge, such as the modes of transmission, the main symptoms, the population at risk, among other information, which can be measured with rapid and effective tests (9, 10). Therefore, it is necessary to know how Latin America faced the disease according to its level of knowledge, as it was one of the most affected regions in the world (11). We can add also that there was a large amount of low quality information that was shared in the media in this region (12). For this reason, the objective of this research was to determine the association between basic knowledge of COVID-19 and education level according to country of residence in Latin America.

Methods

Research type and design

During June, July, and August 2020, we undertook an analytical and multicenter study with a cross-sectional observational design. We used a virtual survey, since in those months, the population was experiencing mandatory quarantine in most of the countries; hence, we had to use virtual resources in order to administer the survey.

Population and sample

We included population living in any of the countries during the pandemic and who could fill in the survey. Those who did not answer completely the questions about knowledge level and secondary variables were excluded (1,274 eliminated surveys). It should be remarked that duplicate surveys, those with incoherent responses, and those with repetitive patterns were detected through a review process by 3 different authors independently and were not taken into account at the time of debugging.

A sample size calculation was performed to find a hypothetical minimum difference of 1.5% (49% vs. 50.5%), for which a minimum of 8,719 respondents was required, with a power of 80%, a confidence level of 95% and for a single sample (due to the analytical cross-sectional design). The final sample had 9,222 respondents; this number was reached through non-random sampling.

Instruments and procedures

In order to assess the level of knowledge of the 12 Latin American countries, the COVID−19 knowledge scale was used (10). It measures knowledge about basic aspects of coronavirus, such as mortality, vulnerable populations according to mortality, and modes of transmission. This was assessed through nine multiple-choice questions. The scale was validated in Peru during the first months of the pandemic and showed good values of comprehensibility, validity, and reliability.

This survey was composed of other questions that would serve to characterize the population, as well as other adjustment variables for the analytical section. These variables were gender (dichotomous variable with the following possible answers: male or female), age (quantitative variable in years), the highest level of education they had (primary or lower, secondary, bachelor's degree, technical, college/university, and postgraduate), as well as each of the 12 countries where the respondents said they lived

TABLE 1 Percentage of correct answers by each one of the nine questions of basic knowledge of COVID-19 in 12 countries in Latin America.

Question	Correct *n*(%)
1. How is the coronavirus transmitted or what is the mechanism of transmission? Answer: Airborne transmission	8,569 (92.9 %)
2. How long is the incubation period or how soon can symptoms of coronavirus manifest? Answer: Up to 14 days.	7,122 (77.2 %)
3. Which are the common symptoms that a person infected with coronavirus could have? Answer: The same symptoms as the flu/a cold's.	9,091 (98.6 %)
4. Which of the following is not one of the most common symptoms of coronavirus infection? Answer: Diarrhea	8,529 (92.5 %)
5. What is the probability of dying (mortality rate) from coronavirus in the general population? Answer: Lower than 5%	3,686 (40.0 %)
6. Who are at a highest risk because of the coronavirus mortality rate? Answer: Older adults	8,113 (88.0 %)
7. What treatment should be given to a person who has initial (non-severe) coronavirus infection? Answer: Treatment should calm respiratory symptoms.	5,192 (56.3 %)
8. What is the diagnostic method used to confirm a coronavirus infection? Answer: Nasal and/or buccal swabbing	7,990 (86.6 %)
9. What would you do if you have symptoms of a cold and suspect you are infected with coronavirus? Answer: I would stay at home until I can recover.	4,939 (53.6 %)

TABLE 2 Percentage of correct answers by each one of the nine questions of basic knowledge of COVID-19 in 12 countries in Latin America.

Country	Percentage of correct answers of the questions									
	1	2	3	4	5	6	7	8	9	Mean (SD)
Peru	91%	72%	98%	91%	34%	83%	48%	84%	58%	6.6 (1.4)
Chile	98%	83%	99%	97%	48%	97%	73%	90%	56%	7.4 (1.2)
Paraguay	95%	81%	99%	96%	53%	92%	81%	96%	55%	7.5 (1.2)
Mexico	96%	85%	99%	93%	26%	96%	55%	85%	59%	6.9 (1.3)
Bolivia	94%	87%	99%	92%	44%	96%	60%	79%	41%	6.9 (1.3)
Panama	96%	90%	100%	96%	67%	97%	69%	98%	36%	7.5 (1.0)
Ecuador	97%	85%	99%	93%	47%	93%	63%	81%	59%	7.2 (1.3)
Costa Rica	94%	77%	97%	93%	54%	81%	68%	94%	27%	6.9 (1.3)
El Salvador	84%	65%	99%	84%	35%	83%	46%	92%	31%	6.2 (1.5)
Honduras	95%	87%	97%	94%	40%	93%	47%	93%	31%	6.8 (1.2)
Colombia	98%	86%	99%	91%	58%	95%	78%	90%	60%	7.6 (1.3)
Guatemala	97%	70%	96%	90%	41%	85%	53%	98%	39%	6.7 (1.5)
P-value	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	6.9 (1.4)*

P-values were obtained with the chi-squared test. Mean and standard deviation (SD) are of the average score for each country. *This is the global average.

(Peru, Chile, Mexico, Paraguay, Colombia, Bolivia, Panama, Ecuador, Costa Rica, El Salvador, Honduras and Guatemala).

All these questions were uploaded to a survey on the Google Forms platform. It could be distributed to all Latin American countries, through each of the authors and the FELSOCEM-ASOMEDISS COVID-19 Latam network, which generated a research group based on their contacts in each of the countries associated with this scientific collaboration network.

Statistical analysis

For the statistical analysis, first we had to obtain the frequencies and percentages of each one of the test's answers. Then, we calculated the percentage of correct answers by each country; here we could obtain *p*-values (we determined if there was a difference among the percentages of answers by each country, for which the chi-squared test was used). A box-and-whisker plot was also generated to compare the scores obtained in the test according to each level of education evaluated (a *p*-value was also obtained here, with the Kruskal Wallis statistical test).

Finally, the crude and adjusted model was obtained (a model adjusted for sex and age was obtained, and another without these variables, since, although they were not statistically significant, we wanted to see their influence on the other variables). To this end, linear regression was used, taking the score that each respondent obtained as the dependent variable. This score was based on the test of basic level of knowledge of COVID-19. For each of the statistical crosses, a p-value < 0.05 was considered statistically significant.

Ethical aspects

The ethical precepts of the research were respected at all times. After the project was set up, it was submitted to an institutional ethics committee, which evaluated and approved the protocol (resolution of the bioethics committee N°0233-2020-UPAO). It is important to mention that it was approved only by one institution, since the project was generated in April, when almost all the countries' educational institutions were not in operation or everything was paralyzed; therefore, each site agreed to participate with the current ethics committee of the main site of the research.

A consent form was sent with each virtual survey which was signed before filling out the survey. In addition, it was indicated that they were free to participate in the research, to answer the questions they wished, and that their participation was completely anonymous.

Results

Out of the 9,222 respondents in Latin America, 59.2% (5,455) were women, with a median of 22 years old (interquartile range: 20–30 years old). Regarding education level, 101 (1.1%) had primary or a lower level of education; 1,268 (13.68%), secondary education; 750 (8.1%), a bachelor's degree; 804 (8.7%), technical studies; 5,668 (61.5%), higher education; and 631 (6.8%), postgraduate studies. Almost the total of the respondents knew the common symptoms (98.6%), the modes of transmission (92.9%), and knew how to recognize which was not a specific symptom (92.5%). However, the lowest level of knowledge was about the percentage of mortality of this disease (40.0%), how to manage the symptoms (53.6%), and the treatment of a non-severe presentation of the disease (56.3%) (Table 1).

When the percentages of correct answers were broken down by country, it was observed that the Central American countries had the lowest percentages of correct answers. Among them, El Salvador had the lowest percentages in four of the questions, and Costa Rica had the lowest percentages in two of the questions. Other countries with low answers were Bolivia, Mexico and Guatemala (each with a low percentage) (Table 2).

The median of the correct answers was lower among those who had primary or a lower level of education. In the other education levels, we could obtain the same median and similar interquartile ranges (p-value < 0,001 with Kruskal Wallis test) (Figure 1).

When performing multivariate model for the test score, we found that there was no association of gender ($p = 0.716$) or age ($p = 0.059$), in comparison with those who had primary or lower education. All the other education levels had statistically significant scores (all p-values were < 0.001. When comparing the knowledge according to country, and using Peru as reference for comparison, Chile, Paraguay, Mexico, Bolivia, Panama, Ecuador, Costa Rica and Colombia had a better level of knowledge (all p-values were < 0.001); however, only El Salvador had a lower level $p < 0.001$) (Table 3).

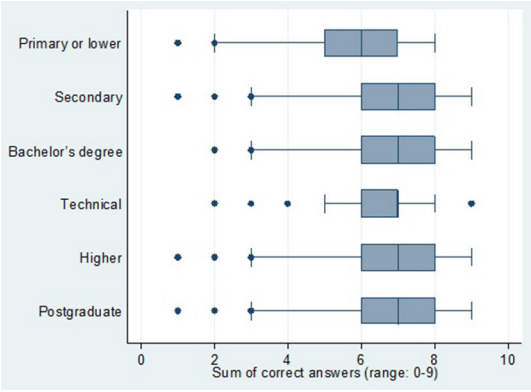


FIGURE 1

Discussion

The good implementation of sanitary measures was fundamental to control the spread of COVID-19. However, success depended largely on the mutual efforts of the population and their governments. In addition, a good level of knowledge of the population (13), as well as a good management of resources to possess the essential tools that help us face the disease was also imperative (14). In this study it was found that, although the surveyed population had good percentages of knowledge about the symptoms and route of transmission of COVID-19, the percentages of knowledge about how to act in case of suspicion of this disease, or of a non-severe presentation, were still not adequate. Thus, people considered that they should go to hospitals or health care centers, even if they had no symptoms or if these were mild. This could have led to the collapse of the health system in many countries, due to an excessive increased demand (15). It also led to self-medication with drugs that did not have sufficient scientific evidence (16), or that, in certain populations, could cause the disease to worsen (17).

On the other hand, in some countries such as El Salvador and Costa Rica, there was a lower number of correct answers, and although these results cannot be extrapolated in a conclusive way, this shows that each country should evaluate the knowledge that their population groups have at the moment of a serious event. This difference between Central American countries and the other Latin American countries may be due to the different information disseminated by the authorities of each country, as well as how they understand it (18–20). Therefore,

TABLE 3 Bivariate and multivariate models of the basic socio-educational factors associated with the score of basic knowledge of COVID-19 in 12 countries in Latin America.

Variables	Models (knowledge score as a dependent variable)		
	Bivariate	Multivariate 1	Multivariate 2
Gender	−0.04(−0.10/ 0.01) 0.128	Not included in the model	−0.01(−0.06/ 0.04) 0.716
Age (years)	<-0.01(<-0.01/ < 0.01) 0.118	Not included in the model	<-0.01(<-0.01/ < 0.01) 0.059
Education			
Primary or lower	Reference category	Reference category	Reference category
Secondary	0.82(0.54/ 1.10) < 0.001	0.88(0.61/ 1.15) < 0.001	0.85(0.58/ 1.12) < 0.001
Bachelor's degree	1.01(0.73/ 1.29) < 0.001	0.90(0.63/ 1.18) < 0.001	0.87(0.59/ 1.15) < 0.001
Technical	0.74(0.46/ 1.02) < 0.001	0.77(0.49/ 1.04) < 0.001	0.75(0.48/ 1.03) < 0.001
Higher	1.16(0.89/ 1.42) < 0.001	1.07(0.81/ 1.33) < 0.001	1.04(0.78/ 1.30) < 0.001
Postgraduate	1.40(1.11/ 1.68) < 0.001	1.32(1.04/ 1.60) < 0.001	1.33(1.05/ 1.60) < 0.001
Country of residence			
Peru	Reference category	Reference category	Reference category
Chile	0.81(0.71/ 0.90) < 0.001	0.78(0.69/ 0.88) < 0.001	0.79(0.70/ 0.89) < 0.001
Paraguay	0.89(0.79/ 0.99) < 0.001	0.84(0.73/ 0.94) < 0.001	0.83(0.73/ 0.94) < 0.001
Mexico	0.34(0.23/ 0.46) < 0.001	0.31(0.19/ 0.43) < 0.001	0.30(0.18/ 0.42) < 0.001
Bolivia	0.33(0.21/ 0.46) < 0.001	0.28(0.16/ 0.41) < 0.001	0.28(0.15/ 0.40) < 0.001
Panama	0.88(0.75/ 1.01) < 0.001	0.82(0.68/ 0.95) < 0.001	0.81(0.68/ 0.94) < 0.001
Ecuador	0.56(0.41/ 0.71) < 0.001	0.56(0.40/ 0.71) < 0.001	0.55(0.40/ 0.70) < 0.001
Costa Rica	0.25(0.08/ 0.43) 0.005	0.32(0.14/ 0.49) < 0.001	0.33(0.15/ 0.50) < 0.001
El Salvador	−0.41(−0.58/ −0.24) < 0.001	−0.43(−0.59/ −0.26) < 0.001	−0.42(−0.59/ −0.25) < 0.001
Honduras	0.16(−0.02/ 0.35) 0.086	0.12(−0.07/ 0.30) 0.211	0.11(−0.07/ 0.30) 0.240
Colombia	0.97(0.76/ 1.20) < 0.001	0.92(0.69/ 1.15) < 0.001	0.92(0.69/ 1.15) < 0.001
Guatemala	0.09(−0.16/ 0.35) 0.477	0.06(−0.20/ 0.31) 0.668	0.06(−0.20/ 0.31) 0.649

The models were obtained with linear regression. The score of each respondent obtained with the test for the level of basic knowledge of COVID-19 was taken as a dependent variable. Left of parentheses: Regression coefficient. Inside the parentheses: Confidence interval at 95% (CI 95%). Right of parentheses: p-value.

it is important for governments and authorities to disseminate accurate information during a health crisis, such as the one produced by this pandemic, in print, social and electronic media. This information should be in the local languages of the population, because a better knowledge of the disease will allow people to take appropriate measures and remain calm (21).

In regard to educational level, it was found that those with a higher or postgraduate level of education had a better level of knowledge compared to those with only a primary or a lower level. This result is similar to what was reported by multiple studies, in which a better education level was associated with having correct ideas about COVID-19 (22–24). Therefore, governments and authorities should intensify information dissemination campaigns in the population with primary or lower educational levels, as well as implement measures to reduce the dissemination of false information. Thus, we could prevent this from hindering decision making and influencing negatively, generating excessive fear, or on the contrary, denying the existence of the disease or demanding the non-use of biosecurity measures, which favors the spread of the virus (25). This is especially true in Latin America, where there was an increase in false news as the pandemic progressed (26).

In several countries there was a better knowledge of this new disease, compared to Peru. This reality could have influenced the situation that took place in this country in July and August 2020, when it was considered the most affected country by the pandemic worldwide, according to mortality rates (27). This situation occurred despite the prevention measures adopted by the Peruvian government, such as social distancing and quarantine, and it was reported that these measures were not fully complied with by the population (28). Similarly, this study found that, in Peru, there was a lack of knowledge of COVID-19 mortality rate. This could be explained by the lack of transparency in reporting deaths from this disease, as when the number of deaths from COVID-19 was revealed, it turned out to be almost three times the number reported in the official count (29).

Regarding the low percentage of knowledge of the actions that should be taken in the event of suspected infection, these results could be explained by the deficient information provided by the Peruvian authorities regarding the management of this new disease (30). In addition, we can mention the population's fear of becoming infected, and the misinformation spread by some physicians when encouraging the use of drugs, such as

Ivermectin or Warfarin, to prevent COVID-19 (31). All this was reflected in the saturation of health services in the country (32). Therefore, this evidence should be taken into account to improve the management of a health crisis, or any other type of crisis. These results could explain, partially, what was experienced. It is always necessary to inform the population adequately, since ignorance and uncertainty will always be the worst enemy in times of chaos.

The main limitation of the research was selection bias, since, due to the non-random sampling, it cannot be said that what was shown represents the knowledge of each of the countries surveyed or of the whole Latin America. However, this was already foreseen from the conception of the research, since the objective was to find specific associations (it was never to generate a research that could extrapolate the results to the territories mentioned, due to the aforementioned technical difficulties arisen during quarantine). Despite this limitation, we have a very large sample of respondents in a dozen Latin American countries, where the vast majority belong to the most affected country in the world (with the highest mortality per hundred thousand inhabitants in July and August) (27). Hence, it is considered that these results should be taken with the reservation, to show the knowledge that the surveyed populations had in the hardest months of the pandemic.

Based on the results, it is concluded that the best knowledge of the disease was about common symptoms, mode of transmission, and recognition of which was not a specific symptom. There was no association between the knowledge score with gender or age, but there was an association with education level and country of residence.

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 Universidad Privada Antenor Orrego bioethics committee. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CM, TA-R, and LG contributed to conception and design of the study. LG and TA-R organized the database. CM performed the statistical analysis. TA-R wrote the first draft of the manuscript. MF, FB-R, EE, JC-O, CC-A, RT, AC-E, YC-M, DC-P, VS-A, and DA-C wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

Conflict of interest

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

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Palacios Cruz M, Santos E, Velázquez Cervantes MA, León Juárez M. COVID-19, una emergencia de salud pública mundial. *Rev Clínica Esp.* (2021) 221:55–61. doi: 10.1016/j.rce.2020.03.001

2. Patterson GE, McIntyre KM, Clough HE, Rushton J. Societal impacts of pandemics: comparing COVID-19 with history to focus our response. *Front Public Health.* (2021) 9:206. doi: 10.3389/fpubh.2021.630449

3. Nicola M, Alsafi Z, Sohrabi C, Kerwan A, Al-Jabir A, Iosifidis C, et al. The socio-economic implications of the coronavirus pandemic (COVID-19): a review. *Int J Surg.* (2020) 78:185–93. doi: 10.1016/j.ijsu.2020.04.018

4. Díaz-Castrillón FJ, Toro-Montoya AI. SARS-CoV-2/COVID-19: the virus, the disease and the pandemic. *Med Lab.* (2021) 24:183–205. doi: 10.36384/01232576.268

5. Pérez Abreu MR, Gómez Tejeda JJ, Dieguez Guach RA. Características clínico-epidemiológicas de la COVID-19. *Rev Habanera Cienc Médicas.* (2020) 19:1–15.

6. Medeiros de Figueiredo A, Daponte A, Moreira Marculino de Figueiredo DC, Gil-García E, Kalache A. Letalidad de la COVID-19: ausencia de patrón epidemiológico. *Gac Sanit.* (2021) 35:355–7. doi: 10.1016/j.gaceta.2020.04.001

7. Ioannidis JPA. Infection fatality rate of COVID-19 inferred from seroprevalence data. *Bull World Health Organ.* (2021) 99:19–33. doi: 10.2471/BLT.20.265892

8. Park M, Thwaites RS, Openshaw PJM. COVID-19: lessons from SARS and MERS. *Eur J Immunol.* (2020) 50:308–11. doi: 10.1002/eji.202070035

9. Abounoori M, Maddah MM, Sharif Nia H, Rahmatpour P, Khosravifar S, SamadiKouchaksaraei M, et al. Development and validation of the knowledge and attitude scale toward COVID-19 pandemic breaking transmission chain (KA-C) among iranian population. *Front Public Health.* (2021) 9:61. doi: 10.3389/fpubh.2021.627013

10. Mejia CR, Rodriguez-Alarcon JF, Carbajal M, Sifuentes-Rosales J, Campos-Urbina AM, Charri JC, et al. Validación de una escala breve para la medición del nivel de conocimientos básicos acerca del Coronavirus, Perú (KNOW-P-COVID-19). *Kasmera.* (2020) 48:1–10. doi: 10.5281/zenodo.3827988

11. The Lancet. COVID-19 in Latin America—emergency and opportunity. *Lancet.* (2021) 398:93. doi: 10.1016/S0140-6736(21)01551-8

12. Nieves-Cuervo GM, Manrique-Hernández EF, Robledo-Colonia AF, Grillo AEK. Infodemia: noticias falsas y tendencias de mortalidad por COVID-19 en seis países de América Latina. *Rev Panam Salud Pública.* (2021) 45:e44. doi: 10.26633/RPSP.2021.44

13. Zhong B-L, Luo W, Li H-M, Zhang Q-Q, Liu X-G, Li W-T, et al. Knowledge, attitudes, and practices towards COVID-19 among Chinese residents during the rapid rise period of the COVID-19 outbreak: a quick online cross-sectional survey. *Int J Biol Sci.* (2020) 16:1745–52. doi: 10.7150/ijbs.45221

14. Vadlamannati KC, Cooray A, de Soysa I. Health-system equity, egalitarian democracy and COVID-19 outcomes: an empirical analysis. *Scand J Public Health.* (2021) 49:104–13. doi: 10.1177/1403494820982106

15. Sánchez-Duque JA, Arce-Villalobos LR, Rodríguez-Morales AJ. Enfermedad por coronavirus 2019 (COVID-19) en América Latina: papel de la atención primaria en la preparación y respuesta. *Aten Primaria.* (2020) 52:369–72. doi: 10.1016/j.aprim.2020.04.001

16. Quispe-Cañari JF, Fidel-Rosales E, Manrique D, Mascaró-Zan J, Huamán-Castillón KM. Chamorro–Espinoza SE, et al. Self-medication practices during the COVID-19 pandemic among the adult population in Peru: a cross-sectional survey. *Saudi Pharm J.* (2021) 29:1–11. doi: 10.1016/j.jsps.2020.12.001

17. Alessi J, de Oliveira GB, Schaan BD, Telo GH. Dexamethasone in the era of COVID-19: friend or foe? An essay on the effects of dexamethasone and the potential risks of its inadvertent use in patients with diabetes. *Diabetol Metab Syndr.* (2020) 12:80. doi: 10.1186/s13098-020-00583-7

18. Pagliaro S, Sacchi S, Pacilli MG, Brambilla M, Lionetti F, Bettache K, et al. Trust predicts COVID-19 prescribed and discretionary behavioral intentions in 23 countries. *PLoS ONE.* (2021) 16:e0248334. doi: 10.1371/journal.pone.0248334

19. Martinez-Valle A. Public health matters: why is Latin America struggling in addressing the pandemic? *J Public Health Policy.* (2021) 42:27–40. doi: 10.1057/s41271-020-00269-4

20. Min C, Shen F, Yu W, Chu Y. The relationship between government trust and preventive behaviors during the COVID-19 pandemic in China: exploring the roles of knowledge and negative emotion. *Prev Med.* (2020) 141:106288. doi: 10.1016/j.ypmed.2020.106288

21. Raza A, Ali Q, Hussain T. Role of knowledge, behavior, norms, and e-guidelines in controlling the spread of COVID-19: evidence from Pakistan. *Environ Sci Pollut Res.* (2021) 28:40329–45. doi: 10.1007/s11356-020-10931-9

22. Bonilla-Carrión R, Evans-Meza R, Salvatierra-Durán R. Ideas erróneas sobre el COVID-19: una encuesta transversal en línea, Costa Rica, 2020. *Rev Hispanoam Cienc Salud.* (2020) 6:186–92. doi: 10.56239/rhcs.2020.64.448

23. Reyes LM, Ortiz L, Abedi M, Luciano Y, Ramos W, Reyes PJ de J. Misinformation on COVID-19 origin and its relationship with perception and knowledge about social distancing: a cross-sectional study. *PLoS ONE.* (2021) 16:e0248160. doi: 10.1371/journal.pone.0248160

24. Yoseph A, Tamiso A, Ejeso A. Knowledge, attitudes, and practices related to COVID-19 pandemic among adult population in Sidama Regional State, Southern Ethiopia: a community based cross-sectional study. *PLoS ONE.* (2021) 16:e0246283. doi: 10.1371/journal.pone.0246283

25. Lee JJ, Kang K-A, Wang MP, Zhao SZ, Wong JYH, O'Connor S, et al. Associations between COVID-19 misinformation exposure and belief with COVID-19 knowledge and preventive behaviors: cross-sectional online study. *J Med Internet Res.* (2020) 22:e22205. doi: 10.2196/22205

26. López-Pujalte C, Nuño-Moral MV. La "infodemia" en la crisis del coronavirus: Análisis de desinformaciones en España y Latinoamérica. *Rev Esp Doc Científica.* (2020) 43:e274. doi: 10.3989/redc.2020.3.1807

27. Gestión. *Perú Pasa a Ser El País Con La Mayor Mortalidad Del Mundo Por el COVID-19.* (2020). Available online at: https://gestion.pe/peru/peru-pasa-a-ser-el-pais-con-la-mayor-mortalidad-del-mundo-por-la-covid-19-noticia/ (accessed November 16, 2021).

28. TVPerú. *Pacientes Positivos de COVID-19 no Cumplen Con Cuarentena, Advierte DIRIS Lima Norte.* (2020). Available online at: https://www.tvperu.gob.pe/noticias/locales/pacientes-positivos-de-covid-19-no-cumplen-con-cuarentena-advierte-diris-lima-norte (accessed November 16, 2021).

29. Martínez AR. *Perú y su verdadera cifra de fallecimientos por COVID.* (2021). Available online at: https://www.nytimes.com/es/2021/05/31/espanol/peru-covid-mortalidad.html (accessed November 16, 2021).

30. Taype-Rondan A, Herrera-Añazco P, Málaga G. Sobre la escasa transparencia en los documentos técnicos para el tratamiento de pacientes con COVID-19 en Perú. *Acta Médica Peru.* (2020) 37:215–22. doi: 10.35663/amp.2020.372.982

31. Gestión. *Ciro Maguiña Supera el COVID: "Tomé Ivermectina, Vitamina D, Zinc y Parecetamol".* (2021). Available online at: https://gestion.pe/peru/ciro-maguina-supera-el-covid-tome-ivermectina-vitamina-d-zinc-y-parecetamol-nndc-noticia/ (accessed November 16, 2021).

32. Taype-Huamaní W, Miranda-Soler D, Castro-Coronado L, Amado-Tineo J. Saturación y hacinamiento del servicio de emergencia de un hospital urbano. *Rev Fac Med Humana.* (2020) 20:216–21. doi: 10.25176/RFMH.v20i2.2709

frontiers | Frontiers in Public Health

TYPE Perspective
PUBLISHED 06 October 2022
DOI 10.3389/fpubh.2022.1015955

OPEN ACCESS

EDITED BY
Pier Luigi Sacco,
University of Studies G. D'Annunzio Chieti and Pescara, Italy

REVIEWED BY
Tatsui Otsuka,
Tohoku University, Japan
Tetsuhiro Kidokoro,
Nippon Sport Science University, Japan

*CORRESPONDENCE
Naohisa Shobako
shobako.naohisa.2x@kyoto-u.ac.jp

SPECIALTY SECTION
This article was submitted to Infectious Diseases - Surveillance, Prevention and Treatment, a section of the journal Frontiers in Public Health

RECEIVED 10 August 2022
ACCEPTED 21 September 2022
PUBLISHED 06 October 2022

CITATION
Shobako N (2022) Lessons from the health policies for children during the pandemic in Japan.
Front. Public Health 10:1015955.
doi: 10.3389/fpubh.2022.1015955

Lessons from the health policies for children during the pandemic in Japan

Naohisa Shobako*

Division of Food Science and Biotechnology, Graduate School of Agriculture, Kyoto University, Uji, Japan

It is everyone's desire to seek the sound growth of children through food education and there is a critical need for fostering an environment for this purpose. Health policies are important for this support. To the present, the Japanese society has been greatly disrupted by COVID-19 pandemic. "Stay at home", "mokusyoku (silent eating)", and mask wearing were encouraged in nationwide campaigns as public health measures to combat COVID-19. There are some papers reporting negative effects of "stay at home" and lockdowns such as weight gain, decrease in physical activities and change in eating habits. In Japan, while benefits and advantages of food education during mealtime were previously well studied, the "mokusyoku" rule may directly run counter to this food education. Moreover, there are several reports showing that nutrients might contribute to prevention of infectious diseases. Japanese children were also encouraged to wear masks all day long. The results of the clinical research, especially randomized control trials, show limited protective effect of masks. On the other hand, negative outcomes of the masks were reported in various scenes. This review focuses on these topics and arousing reconsideration for a better environment for children.

KEYWORDS

food education, stay at home, masks, COVID-19, pandemic, health policy

Introduction

Eating, learning, and playful behaviors are essential for healthy development of children. Societies around the world, including Japan, have been severely affected by the COVID-19 pandemic. It was well announced that Japan had controlled the infection successfully without draconian lockdowns or other harsh restrictions which unduly limit private rights of citizens.

However, the environment in which children eat, learn and play has greatly been affected by health policies in Japan. While no proven effect of school closures against spread of COVID-19 has been reported (1), a few schools are still taking temporary closure measures (2). Though most schools were opened, children were strongly encouraged to follow the "mokusyoku" rule of eating lunch silently during the lunch time (3). Although the Ministry of Education, Culture, Sports, Science and Technology (MECSST) has modified the guideline of mask wearing in schools to

clarify that mask wearing is not necessary in physical education classes as long as the social distance (1–2 m) is maintained, the ministry still recommended to continue the mask wearing rule in schools (4). Typical events related to COVID-19 and children are summarized in Table 1. As shown, novel Coronavirus Response Headquarters present the basic policies for COVID-19 prevention, and each ministry announces relevant basic policies (5). MECSST presents guidelines describing the basic policy of countermeasures that the schools should take. Since most of them are only written recommendations, each municipality's board of education and school finally decide what kind of countermeasures to request for children. So, children were forced to comply with many kinds of measures. Examples of such measures are shown in Figure 1. As shown in the figure, children were forced to follow "The New Lifestyle (New Normal Lifestyle)" in the name of public health.

An object of this paper is to summarize the findings about the result of health policies taken in Japan and looking back the challenges of science-based policy making.

"Stay at home" campaign

Draconian lockdowns were enforced in many regions in the world such as China and Europe to prevent the wide-spread of COVID-19. "Stay at home" campaign was also strongly promoted in Japan even though Japan did not adopt any lockdown with severe restrictions. During the campaign, while adults were not subject to commuting restrictions, children were forced to stay at home due to the long-term school closures. Some negative effects of the lockdowns and "Stay at home" campaign were previously reported. In Japan, during the state of emergency, schools were closed and a "stay-at home order" was issued. As a consequence, it was reported that children had higher body fat percentage, shorter single leg standing time, and a larger number of falls per month compared with children before the pandemic (6). Abe also reported that fundamental movement skills, especially for object control skills were impeded during this pandemic (7). In low-income households, children's consumption of sweets, soft drinks, and ready-to-eat foods was increased (8). Horikawa et al. also reported children eating a balanced diet of meat or fish and vegetables at least twice a day decreased during the period (9). Horikawa's research also revealed the importance for the support of low-income households. Changes in eating habit was also observed in Kosaka's study and interfaced with feeling enervation and mental stress (10). Longer periods for video games were also reported in this study. Ueda et al. reported about half of children, participated in the research, experienced sleep pattern change during the period and its change was predicted by a high level of depression (11). In Nakachi et al. study, change tendency in sleep pattern was also observed in junior and high school students (12). Psychological problems were observed in lower grade of elementary school; they easily cried and complained, were unable to keep calm, and were dependent on parents and family members.

Similar results were reported outside Japan, where stronger behavioral restrictions have been imposed. For example, in China, significant increase in total food intake, especially snacks and drinks, and decrease in physical activities were reported (13). Negative effects of weight gain were also reported in research in U.S. (14, 15). Changes in eating habits and lifestyle during lockdowns were also reported (16, 17). Increased risk in type 2 diabetes was also reported (18). The restrictive lifestyle and weight gain due to the lockdown are considered be the causes of the increased risk in type 2 diabetes. The survey conducted on children also showed a significant increase in the consumption of potato chips, red meat, and sugary drinks, and a significant decrease in time spent in sports (19). The studies presented in this section are summarized in Table 2A.

"Mokusyoku rule" and food education

The "Mokusyoku rule" is prohibition of conversation during meals in schools, working spaces, and restaurants (3, 20). The novel Coronavirus Response Headquarters announced "mokusyoku" as a basic policy for COVID-19 prevention (5), and the Japanese government and industry groups are promoting this health policy by spreading awareness (21). As described in Section Introduction, the final decision relies on each municipality; some local governments relaxed the "mokusyoku rule" in schools, while others continue to instruct children to follow. In order to ensure the rule implementation, each school is trying to search for the best way, such as using partition or TV animation even in 2022 (Figures 1C,D). In the early stage of the pandemic, droplet infection was thought highly threatening, and measures aimed at an assumed droplet pathogen were over-emphasized (22). The mokusyoku rule was thought to be a remnant of that time, the same as surrounding individuals with panels (Figures 1C,E). There are no reports on the benefits of the "mokusyoku rule," and several Japanese articles have expressed worry about or negatively commented on its impact on children (20).

The importance of conversations during meals for children has been well studied in Japan. Kishida and Kamimura reported conversation positive group (group with frequent conversation) gained higher scores for good appetite, not feeling fatigue, sleeping well, and not readily catching cold (23). There are also reports of positive effects on eating habits and reducing soft drink consumption. Esaki reported frequent conversation during meals has positive relation with meal-related quality of life (QOL) (24). Previous studies also showed that Japanese children who had conversations during meals had better dietary attitudes, eating behavior and mental QOLs (25–27). Surveys outside Japan have also reported that conversations

TABLE 1 Typical events about history of COVID-19 pandemic in Japan.

Year	Month	Typical event	Topics with stay at home, mokusyoku, and masks
2020	January–March	- A man who stayed in Wuhan tested positive for COVID-19 (first case in Japan). - COVID-19 cases were confirmed among passengers aboard the Diamond Princess, which called at the port of Yokohama. - School reopening guidelines in response to COVID-19 (school reopening guidelines) was announced.	- Prime Minister Shinzo Abe requested the simultaneous closure of all elementary and junior high schools nationwide. - The Governor of Tokyo requested voluntary abstinence from going out.
	April–June	- State of emergency declaration (~25th May). - New Normal Lifestyle was presented by MHLW. - Hygiene Management Manual at Schools (hygiene manual) ver.1 was announced. - Simple school lunch was described as thoughtful for areas where infection is judged to be spreading.	- School reopening guidelines was updated. "In school education activities, please wear a mask regularly." was added. It was also stated that masks must be worn in situations where close-range conversations or vocalizations are required. - The Governor of Tokyo announced "Stay home week."
	July–September	- The "Go to travel campaign" started.	- The Governor of Tokyo required voluntary abstinence from home coming visit during summer vacation.
	October–December	- Interruption of the "Go to travel campaign." - The hygiene manual was updated to ver.5. Especially for elementary and junior high schools, it is clearly stated that temporary closures for the entire region should basically be avoided.	- For junior and senior high school students, it was stated that, depending on the infection situation, activities that pose a high risk of infection without wearing a mask should be avoided in the hygiene manual (ver.5). - The Governor of Tokyo called for "Stay at home" during the New Year holidays. - Subcommittee on Novel Coronavirus Disease Control, proposed "mask dinner*". Several local government are still requesting this practice.
2021	January–March	- State of emergency declaration (8th January—21th March). - COVID-19 vaccination was started.	- The Governor of Tokyo announced "Stay home thoroughly."
	April–June	- Pre-emergency measures (5th March—30th September). - State of emergency declaration (25th April—20th June).	- About 7,000 children were reported to be voluntarily missing school due to fear of infection. - A child died after an endurance run in school with a mask was placed on the chin. - The Governor of Tokyo announced "Stay home week".
	July–September	- The 2020 Summer Olympics was held in Tokyo.	- The Governor of Tokyo called for "stay home" during summer vacation. - There were requests for the extension of summer vacation due to fear of infection, and some schools responded.
	October–December	- COVID-19 vaccine booster shots were started.	- School closures, class closures were undertaken in Sapporo. - Novel Coronavirus response headquarter (belongs to Japanese government) announced basic policy against for COVID-19 (basic policy) and "Mokusyoku" was set as the basis.
2022	January–March	- Pre-emergency measures (7th January—21th March). - Vaccination for children (aged 5–11 years) started.	- The Governor of Tokyo called for "stay at home" hence the chairman of subcommittee on Novel Coronavirus Disease Control commented that it is not always necessary.
	April–June	- Latest guidelines for the school hygiene manual were updated (ver.8), a description about excessive sterilization was added. - Fourth shot started.	

(Continued)

TABLE 1 (Continued)

Year	Month	Typical event	Topics with stay at home, mokusyoku, and masks
	July–September	- Expanded the fourth vaccination target (e.g., healthcare workers). - Japan recorded the world's highest number of new COVID-19 infections.	- The MHLW homepage was updated about COVID-19 prevention. "Mokusyoku" is still the basis of the prevention response. In response to this, some boards of education and schools are encouraged to follow "mokusyoku" rule. On the other hand, some school boards have declared that they do not strongly recommend that.

Topics were taken from the homepage of the Japanese public broadcaster (https://www3.nhk.or.jp/news/special/coronavirus/chronology/), Tokyo metropolitan government (https://www.metro.tokyo.lg.jp/tosei/governor/governor/), the ministry of education, culture, sports, science and technology (https://www.mext.go.jp/a_menu/coronavirus/index_00012.html), the ministry of Health, Labor and Welfare (https://corona.go.jp/emergency/).

*A series of manners in which mask is removed with strings over the ears only when food is placed in the mouth and replaced immediately while chewing. This is sometimes seen in Japanese TV programs. However, it is now generally understood, as recommended by Kanagawa prefecture, that following the "mokusyoku" rule is more suitable during eating and wearing masks only when conversing (https://www.pref.kanagawa.jp/docs/r5k/mask_nisho.html).

FIGURE 1
Example of "Infectious disease counter measures" for children taken for Japanese Children. **(A)** Children watching "somen (Japanese traditional noodle) flow" with their mask on in silence in summer. Under ordinary circumstances, children eat somen noodles flowing in front of them. **(B)** Special care is taken to keep "Physical distance" in a relay race of a school sport festival. The length of the baton was 2 meters. **(C)** Children are taking lunch following "mokusyoku rule". **(D)** Children are watching TV program during lunch time to follow mokusyoku rule. **(E)** "The New way of lifestyle" adopted in a school excursion. Children must follow "mokusyoku rule". **(F)** Example of "Simple school lunch". These pictures were taken from the following websites: **(A)** "Watch over them without eating. Somen flow in Tsuwano city preventing COVID-19 infection. 8/9/2020" Japan Broadcasting Corporation https://www3.nhk.or.jp/news/html/20200809/k10012560081000.html. **(B)** "2 meter baton, shouts on paper, broadcast on TV sports festival under COVID-19 pandemic. 9/27/2020" Mainichi Shimbun https://mainichi.jp/articles/20200927/k00/00m/040/122000c. **(C)** "Infection for children is increasing in COVID-19 seventh wave. What are the characteristics of the symptoms? What measures are needed for the new semester? 8/26/2022" Tokyo shimbun https://sukusuku.tokyo-np.co.jp/education/59471/. **(D)** "A strategy to follow mokusyoku rule by showing animated films during lunch time. In the second semester of the COVID-19 epidemic at an elementary school, the educational scene is undergoing a trial-and-error process for infection prevention measures. Nagano city. 9/1/2022" Shin-etsu broadcasting https://newsdig.tbs.co.jp/articles/sbc/140832?display=1. **(E)** "Dinner with mokusyoku rule and infection control measures 11/25/2021" Official Blog of Onohara east primary school http://www.kamisu.ed.jp/onoharanishi/19314.html. **(F)** Fuji News Network "Zero side dishes painful choice "simple school lunch" to prevent COVID-19 infection, 1.2 times the amount of hot dog buns, and concerns about nutritional deficiencies. 9/8/2021" https://www.fnn.jp/articles/-/235832. For privacy, part of the face is hidden. All sites were accessed at September 19th, 2022.

during meals in pre-kindergarten are effective for vocabulary acquisition because out-of-context conversations occur uniquely (28, 29). Although some papers suggest that people have indeed contracted COVID while eating in restaurants, such risk can be minimized by ventilation which is an important factor in preventing COVID (30, 31). As described above, conversations during meals are important for children to foster healthy minds and eating habits. Thus, it will be necessary to reconsider the "Mokusyoku rule" that would adversely affect physical and mental development and abolish the rule by taking measures

such as sufficient ventilation. Articles describing mokusyoku and food education are summarized in Table 2B.

Some schools introduced "simple school lunch" with insufficient nutrition for fear of contact infection at the time of serving the meal (Figure 1F). This has been described as thoughtful for areas where the infection is judged to be spreading, as per the first version of hygiene management manual at schools to the latest version, established by MECSST (4, 32). Tanaka et al.'s survey showed simple school lunch was served in a certain number (55/205 schools for 10–40

TABLE 2 The typical studies about stay at home (A), mokusyoku and food education (B), and RCTs about mask-wearing (C).

(A) Studies about "stay at home"

References	Country	Participants (year old)	Overview of the results and notable points
Ito et al. (6)	Japan	6–7	Children after the state of emergency had significantly higher body fat percentages, shorter single-leg standing times, and a larger number of falls per month than before.
Abe et al. (7)	Japan	3–5	Consumption of snacks, juice, instant foods, and canned food during the state of emergency, was higher in the low income group than in the high income group.
Sakamoto et al. (8)	Japan	3–5	Consumption of snacks, juice, instant foods and canned food during the state of emergency, was higher in low income group rather than high income group.
Horikawa et al. (9)	Japan	10–14	"Well-balanced dietary intake" was lower in all households during the state of emergency compared with before. The authors discussed that schoolchildren's meal quality worsened during the state of emergency, especially in low-income households, because school lunches were not provided.
Kosaka (10)	Japan	First–fifth grade (6–11)	There were significant differences in "irregular sleep," "disordered eating habits," and "increased use of games and smartphones", during school closure.
Ueda et al. (11)	Japan	8–17	During the COVID-19 stay-at-home period, 46.5% of participants experienced changes in sleep patterns. These changes were associated with decreased QOL as well as internalized symptoms. The decreased QOL of children with altered sleep patterns was predicted by a high level of depression.
Nakachi et al. (12)	Japan	6–18	Children in the lower grade elementary school group easily cried and complained during quarantine (12.4%) and it was more difficult to keep calm compared to those in the other groups. Changes in sleep patterns were more prevalent in junior and senior high school students.
Zhu et al. (13)	China	16–70	There was a significant increase in total food intake especially in snacks and soft drinks under "stay at home regulation". A significant decrease in physical activity was also observed. The rate of weight gain in the total population was 30.6%. The main factors contributing to weight gain were increased food intake and reduced physical activity.
Zachary et al. (15)	U.S.	Over 18	22% of adults report having gained weight during the COVID-19 pandemic. Lack of sleep, decreased physical activity, snacking after dinner, eating in response to stress, and eating because of the appearance and smell of food are reported as behaviors linked to weight gain.
di Renzo et al. (16)	Italy	Over 12	The perception of weight gain was observed in 48.6% of the population during lockdown. Consumption of homemade sweets and pizza was increased notably. But some good trends were also observed; 15% of respondents turned to farmers or organic purchasing groups for fruit and vegetables, especially in the North and Center of Italy, where BMI values were lower. Younger people (aged 18–30) tended to consume a more Mediterranean diet.
Ghosal et al. (18)	India	Not clearly described	There was a trend toward weight gain (0.1–5.0 kg) seen in 40% of the cohort, with 16% of the population experiencing a 2.1–5.0 kg weight increase.
Pietrobeli et al. (19)	Italy	6–18 (with obesity)	Consumption of potato chips, red meat, and sugary drinks increased significantly during the lockdown. Time spent on sports activities was significantly decreased and sleep time was significantly increased. Screen time was also significantly increased.

(Continued)

TABLE 2 (Continued)

(B) Papers reporting "mokusyoku"/studies about "food education"

References	Topic	Participants (years old)	Overview of the results and notable points/how is described about "mokusyoku"
Noi et al. (3)	Mokusyoku		Students are forced to live in cramped and suffocating conditions, wear masks, and follow "mokusyoku rules," and school events are canceled or curtailed. The author expressed concern about the effect on childrens' minds and bodies.
Okuyama and Seto (20)	Mokusyoku	Adults wit/without children	The survey revealed that parents with children in elementary school are concerned about the negative impact of "mokusyoku".
Kishida and Kamimura (23)	Food education	Fifth–sixth grade (10–12)	The conversation-positive group gained higher scores in numerous items; good appetite, awakening feeling well, not feeling fatigue, sleeping well at night, not readily catching cold. Positive effects, including improved eating habits and reducing soft drink consumption were also observed.
Esaki (24)	Food education	Junior high school student (12–15)	The author reported that number of menus and people sharing meals, and helpful behavior are involved in improving quality of life (QOL).
Tominaga et al. (25)	Food education	Junior, high, university school student	Eating with having fun is associated with university personality inventory score, representing mental health.
Eto et al. (26)	Food education	5th and 8th grade student	Attitudes toward eating (communication) was associated with QOL especially in 8th grade (junior high school) students.
Nakamura et al. (27)	Food education	30–59	Higher household income and education levels were significantly associated with higher rates of eating vegetables, using the information on nutrition labels, and conversing with family or friends during meals. Higher household incomes were also significantly associated with lower frequencies of family breakfasts in men and a lower frequency of family dinners.
Barnes et al. (28) and Gest et al. (29)	Food education	3–4	Children more prone to decontextualized talk, positing a key role for language learning during mealtime rather than free play and reading time.

(C) Overview of typical RCT trials about masks

References	Participants	Group (n)			Intervention period	Overview of the results and notable points
		1	2	3		
Cowling et al. (55)	Households	Control ($n = 74$ index cases, 213 contacts)	Mask ($n = 22$ index cases, 65 contacts)	Hand hygiene ($n =$ 32 index cases, 92 contacts)	9 days	The secondary attack ratios did not significantly differ across the intervention arms.
Cowling et al. (57)	Households	Control ($n = 91$ index cases, 279 contacts)	Hand hygiene ($n =$ 85 index cases, 257 contacts)	Mask + hand hygiene ($n = 83$ index cases, 258 contacts)	1 week	The differences from the control group were not significant.
Maclntyre et al. (59)	Households	Control (100)	Surgical mask (94)	P2 mask (92)	1 week	No significant difference in ILI was observed in each group, even in the control vs. all types of masks.
Jacobs et al. (62)	Healthcare workers	Control (17)	Surgical mask (15)		11 weeks	Benefits in the prevention for cold symptoms were not observed. Days with headache was significantly longer in the mask group.

(Continued)

TABLE 2 (Continued)

References	Participants	Group (*n*)			Intervention period	Overview of the results and notable points
		1	2	3		
Aiello et al. (52)	Students living in university residence halls	Control (552)	Mask (378)	Mask + hand hygiene (367)	6 weeks	No significant difference was observed in group 2. Group 3 showed significant suppression of ILI at week 4–6. The Cochrane review excluded from the meta-analysis because of insufficient randomization. This review also pointed out unclearness of the adjustments and exclusions at the baseline.
Larson et al. (53)	Households	Control ($n = 148$ households, total 904)	Hand hygiene ($n = 148$ house holds, total 946)	Mask + hand hygiene ($n = 147$ households, total 938)	19 month	There were no significant differences in rates of infection by intervention group in the multivariate analyses. The Cochrane view pointed out that randomization and reasons for dropout were not clearly described. It was also suggested that differentials in cluster characteristics across arms point to randomization not having worked.
Canini et al. (54)	Households	Control ($n = 53$ index cases, 158 contacts)	Mask ($n = 52$ index cases, 148 contacts)		1 week	No trend suggesting effectiveness of masks was confirmed. Pain was reported significantly more in children than adults in the mask group.
Simmerman et al. (56)	Households	Control ($n = 119$ index cases, with 302 members)	Hand hygiene ($n = 119$ index cases, with 292 members)	Mask + hand hygiene ($n = 110$ index cases, with 291 members)	3 weeks	Influenza transmission was not reduced by interventions. ILI in treatment group 3 was significantly higher than the control group (OR = 2.15; 95% CI: 1.27–3.26).
Aiello et al. (51)	Students living in university residence halls	Control (370)	Mask (392)	Mask + hand hygiene (349)	6 weeks	Both intervention groups compared to the control showed cumulative reductions in influenza rates over the study period, although the results did not reach statistical significance. A significant reduction in ILI was not observed in group 2 while group 3 showed in week 3–6.
Suess et al. (50)	Households	Control (82)	Mask (69)	Mask + hand hygiene (67)	8 days	There was no statistically significant effect of the interventions on secondary infections.
Barasheed et al. (63)	Hajj pilgrimage	Control (89)	Mask (75)		5 days	There was no significant difference in laboratory-confirmed illnesses, while ILI was significantly lower in the mask group ($p = 0.04$).
Maclntyre et al. (60)	Healthcare workers	Control (458)	Cloth mask (569)	Surgical mask (580)	4 weeks	The risk rate of the medical mask group was not significantly different from control group, but higher in cloth mask group (ILI).

(Continued)

TABLE 2 (Continued)

References	Participants	Group (*n*)			Intervention period	Overview of the results and notable points
		1	2	3		
Maclntyre et al. (59)	Households	Control ($n = 122$ index cases, 295 contacts)	Mask ($n = 123$ index cases, 302 contacts)		1 week	No statistically significant difference was observed.
Alfelali et al. (58)	Hajj pilgrimage	Control (3139)	Mask (3199)		4 days	No significant difference was observed in laboratory- and clinically-confirmed infections.
Abaluck et al. (71)	Villagers	Control ($n =$ 163,861)	Mask (surgical and cloth; $n = 178,322$)		8 weeks	COVID symptoms were significantly decreased in the treatment group. The significant effectiveness of surgical mask was observed only in the ≧50 years-old subgroup. A commentary pointing out unignorable biases was provided by Chikina et al.
Bundgaard et al. (49)	Community	Control ($n = 2,740$)	Mask ($n = 2,392$)		4 weeks	There was no significant difference in COVID-19 infection between two groups. A total of 52 participants in mask group and 39 control participants reported COVID-19 in their household.

ILI, Influenza like illness.

days) of schools (33). The relationship between nutrients and infectious disease has been well studied (34). Vitamin D (VD) is probably the most well studied nutrient which has been reported to have a protective effect against COVID-19 infection (35). It is reported that serum 25-hydroxyvitamin D [25(OH)D] of <20 ng/mL is one of the risk factors of deficiency and according to a survey in South Korea, serum 25-hydroxyvitamin D [25(OH)D] of about the half of the 6–12 years old children was 20 ng/mL or less (36, 37). Not only from the diet, but also exposure to sunlight is important for vitamin D synthesis. During the pandemic, children's serum 25(OD)D concentration was significantly decreased. It was discussed that school closures and lockdowns were associated with this decrease (38). In the Turkey observational study for children under 18 years old, VD deficiency was significantly high in the COVID-19 patient group compared with the control group (39). Vitamin C (VC) and omega-3 fatty acids were also considered to prevent or reduce COVID-19 infection by cytokine modulation such as IL6, TNFα, and IL1β reduction and IL10 upregulation (40). Although some sufficient clinical observations have been reported, there are few data supporting active intervention especially for children (41). The situation of Vitamin E, considered as a natural killer cell and a T cell activator, was similar to VC (42). For children, there are a few RCTs showing positive effects of Vitamin A for preventing respiratory infections. However, the results of meta-analyses did not support active intervention (43). Zinc is well known for its important role for the development and maintenance of immune and other cells (44). Previous studies revealed that low zinc status is a risk factor of pneumonia infection for children (45). RCT studies for children also support the importance of Zinc (46). It was also reported that low selenium status is associated with COVID infection (47). Simple school lunch might be leading to opportunity loss of taking these nutrients.

Horikawa et al. discussed that school lunches play an important role in continuing well-balanced eating habits (9). Detailed research about the nutrition of simple school lunches and their effect has not been performed, but Kojima reported that it might not provide necessary nutrients compared to regular school lunch, while there was an apparent effort in the areas where a state of emergency was declared for a long time (48).

Mask rules (mandate): Review of its effectiveness

Wearing surgical masks was strongly recommended in Japan even for children in school, on the way to and from school, and even in the house (so called "family

mask" in Japanese; Yamanashi Center for Infectious Disease Control and Prevention). Randomized control trials (RCTs) with appropriate sample sizes have reported the limited effectiveness of surgical masks for infectious diseases, COVID-19 and influenza (49–63). Especially, RCT demonstrated by Simmerman et al. showed significantly opposite effect in Influenza like illness (56) and demonstrated by Jacobs showed only significantly prolonged the duration of the headache (62) (Table 2C).

Significant effectiveness of masks for COVID-19 prevention was reported in numerous observational studies (64–70) and "Bangladesh study" (71). Regarding the "Bangladesh study", there are some points to be noted in the interpretation of the results. First, the total sample size was too large to conduct proper evaluation ($N = 342{,}183$), and subgroup analysis revealed that no significant prevalence intervention ratio was observed in the age 50 subgroup for surgical mask. Second, increase of the physical distance was observed in mask group but not in the control group. Third, monetary reward was provided for participants. Chikina et al. recently reported the re-analysis results and pointed out potential biases that cannot be ignored (72). In support of this view, based on the results of meta-analysis of RCTs, the universal mask policy especially in community settings is not strongly recommended (73–75). While many observational studies reported on the effectiveness of face mask, Davies et al. pointed out that most of them were based on self-reporting, and <0.2% of studies studied the behavior in question objectively (76). Particularly, the frequency of hand washing tends to vary greatly between the actual and self-reported values, which might be the reason for overestimating mask-wearing effectiveness. Frequency of self-report mask use was also reported to differ from actual. Thus, we should carefully consider this when determining the effectiveness of personal protective equipment by observational studies. Given the sample size and results of RCTs, it may be necessary to reconsider overestimation of mask effectiveness for scientific integrity.

Effectiveness of the mask mandate should have been reconsidered as well. The survey in Europe and Texas state revealed that the mas mandate has no effect against COVID-19 infection, hospitalization, and mortality (77, 78). In Kansas, counties with mask mandate had significantly higher case fatality rates than counties without mask mandate, with a risk ratio of 1.85 for COVID-19-related deaths. The mechanism of this adverse effect is propounded as "Foegen effect" (79). This effect was supported by *in vitro* examinations. In the manikin model, favorable results of viral titer or viral RNA detection were observed when the receiver was not wearing a mask (80). It will be necessary to consider what happens if the simulation is continued for more than 20 min, extended from the experimented time. This paper also points out an important issue. The droplets captured by the mask might be transformed into aerosols and were floated in a chamber. Penetration and secondary atomization of droplets impacted on the surgical masks were also well studied (81, 82). People wear masks for a long period of time and, it is considered that, due to the deposition of respiratory droplets released through multiple respiratory events, mask matrix becomes wet and secondary atomization of the droplets was promoted to produce aerosol. Contamination of the mask due to wearing for the prolonged period should also be considered. Park reported the result of culturing bacteria and fungi from outer and inner layers of the masks wore by 109 Japanese people, and it was found that the mean colony counts were 13.4-times higher on the face-side of masks (83). To sum up, the effectiveness of masks, especially universal masking, seems to be limited based on the evidence described above. Regarding this point, the effectiveness of mask rules in schools has not been proven as well. For example, upon comparison of two cities, it was found that recommendation of face mask use in schools for pupils aged 10–12 didn't lower the number of COVID-19 infections (84). Similar results were also reported in school settings in various countries such as Norway (85), U.K (86), and Spain (87).

Mask rules (mandate): Review of side effects

Further, we should more deeply consider side effects of universal masking for children. Watanabe previously alerted mask addiction (88). Although wearing of masks makes it more difficult to read emotions and provides a temporary sense of security, the continued wearing of masks may diminish this sense of security, leading to a risk of worsening social anxiety.

Not only mental but also physical side effects of masks were well studied. Prolonged mask use is reported to cause headache and impaired cognition (89). Koseoglu et al. also reported increases in dyspnea, itching, ear pain, and headache induction (90). Ou et al. reported negative impact on the ventilation function of exercise with mask on in young healthy subjects (91). It is also important point that the weight of the surgical mask increased during the exercise (92). This means that masks were wet by evaporation of sweat. As described in the previous section, we should consider the accumulation of contaminated droplets for long periods and their release as aerosols. Children's modified Borgi score, an indicator of breath shortness, was significantly increased by the simple exercise with surgical mask compared to not wearing a mask (93).

Difficultly in recognition of emotion is also an important issue when considering universal masking for children. Ruba and Pollak reported aged 7–13 children have significant difficultly in reading emotion (94). In particular, mask inhibited

accurate reading of fear emotion < 25% (median value). Gori et al. also reported that masks inhibited reading of emotion of toddlers and children (95). Studies reported by Grahlow et al. was like this, and face masks inhibited all kinds of emotion from the face (96). When does emotional development reach adult levels? There are several scientific reports on this issue. Cohen et al. showed that cognitive abilities in emotional situations may be developing even in teenagers and young adults (97). Research on emotional understanding and prosocial behavior have been actively conducted in Japan, and some Japanese papers have been published. For example, Toda reported a significant correlation between emotional cognition and prosocial behavior in young children (98).

Discussion

Health policies during the COVID pandemic has changed our daily life especially in children in Japan. Children were encouraged to comply with "new way of life" which requires "stay at home", "mokusyoku", and wearing a mask all day long. This review summarized the scientific research related to these health policies.

First, I reviewed lockdown and "Stay at home" campaign. The relationship between COVID-19 and obesity in childhood was well reviewed (99). We should have to critically reflect on this health policy has caused changes in eating and exercise habits that increased obesity. The importance of nutritional education to prevent obesity is well studied (100). Dietary intervention programs to prevent body weight gain have also been developed (101). It will be important in the future to use these programs to develop health policies to prevent obesity during pandemic.

Second, I reviewed "mokusyoku rule" and food education and simple school lunch. Close contact is exactly risk factor of COVID infection (102) but for example, hand hygiene could reduce infection (103). In Japan, in-depth research has revealed the beneficial effects of food education and conversation during meals. Nutrients which are effective in preventing infectious diseases are also well studied. Health policies should be developed so that children can take enough these nutrients.

Third, I reviewed the mask rule. There was no mask obligation with penalties in Japan. However, mask wearing was strongly demanded. Over estimation of the effectiveness of mask might be impeding science-based health policy making and infection control. Psychological and physical adverse effect of prolonged mask wearing was also reviewed. As Thomson pointed out, any negative impact on mental or emotional wellbeing experienced by children who are required to wear masks may vary according to age and ability factors and which may yet be established, may be inconsistent with the WHO constitution (104). In the future, it will be necessary to proactively take less burdensome and less legally complex measures, such as adequate hand washing and ventilation.

Vaccination might have one of the key roles of the public health. The efficacy and safety of vaccination for children have been also well studied (105). However, the amount of spike protein synthesized in the body after vaccination has only been measured in adults and there is a discrepancy between the report of Ogata et al. which is in the pico-order (106), and the Cognetti and Miller in the micro-order (107). We should carefully consider the risk and benefits of vaccination and ensure that everyone's judgment is respected. In a recent survey, some parents (8.2%) answered that they intended to vaccinate their children because pediatricians might think less of them if they do not do so (108). This result might suggest that more thorough informed consent is needed. It is a matter of course that misleading media coverage focused only on the benefits or harms of vaccination should be refrained from, as such coverage only contributes to vaccine hesitancy.

As described in Section Introduction, Japan is a unique country that confronts the pandemic without measures with legal binding force, and administrative organs stayed with "recommendation" and avoided orders in most cases. It is reported that most Japanese people think "everyone should be responsible for their health" (109, 110) and should refrain from outside recreation during the pandemic (111). They wear masks (112) and wash their hands (113) voluntarily because they value peer pressure and are afraid of being left out of the community. Television broadcasts, which repeatedly report excessively about facemasks, might also play a part in the formation of the public opinion that it is acceptable to condemn not wearing a mask. Before the pandemic, immoral post for social network service (SNS) by healthcare workers were sometimes came to an issue (114). In the pandemic period, there were not a few posts on SNS by healthcare workers denigrating those who do not want to wear masks and such opinion also might have an influence. Public opinion formed by the accumulation of these factors might influence, sometimes excessively, societal pandemic measures, including in schools.

Health policy should be developed based on multifaced scientific evidence and respect for individual values. Even if the measures have no legal binding force, sometimes measures with greater disadvantages, like those reviewed in this paper, are enforced, especially for children. It is important to regularly receive feedback from schools and review measures from multiple perspectives, including not only the opinion of public health experts but also experts in nutrition science, food education, psychology, and of course, children's opinion and rights.

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

NS reviewed the literature and drafted the perspective.

Acknowledgments

The author would like to thanks all journalists, scientists, lawyers, translators, and all people, who have continued to examine excessive health policies, despite criticism from the general public in Japan. Their continued activities were a great encouragement for the author to write this manuscript.

Conflict of interest

Author NS is also employed by the company Nissin Foods Holdings. The company was not involved in the study design, collection, analysis, interpretation of data, the writing of this article or the decision to submit it for publication.

Publisher's note

References

1. Fukumoto K, McClean CT, Nakagawa K. No causal effect of school closures in Japan on the spread of COVID-19 in spring 2020. *Nat Med.* (2021) 27:2111–9. doi: 10.1038/s41591-021-01571-8

2. Ministry of Education Culture Sports Science and Technology. *Results of the Survey on Temporary Closure of Public School Due to New Coronavirus Infection*. Available online at: https://www.mext.go.jp/content/20220913-mxt_kouhou01-000004520_01.pdf (accessed September 17, 2022).

3. Noi S, Shikano A, Nakajima R, Shimosato S, Matsumoto R. The concern of childcare and education site about the "abnormalities in physical function" among children based on the results of 'The questionnaire about physical function of children in 2020.' *Ann Report Jpn Soc School Health Educ.* (2022) 29:3–17. doi: 10.32314/educationalhealth.29.0_3

4. Ministry of Education Culture Sports Science and Technology. *Hygiene Management Manual at Schools (ver.8)*. Available online at: https://www.mext.go.jp/content/20220404-mxt_kouhou01-000004520_01.pdf (accessed September 19, 2022).

5. Novel Coronavirus Response Headquarters. *Basic Policy on Countermeasures against New Coronavirus Infections*. Available online at: https://www.kantei.go.jp/jp/singi/novel_coronavirus/th_siryou/kihon_r2_040908.pdf (accessed September 17, 2022).

6. Ito T, Sugiura H, Ito Y, Noritake K, Ochi N. Effect of the COVID-19 emergency on physical function among school-aged children. *Int J Environ Res Public Health.* (2021) 18:9620. doi: 10.3390/ijerph18189620

7. Abe T, Kitayuguchi J, Fukushima N, Kamada M, Okada S, Ueta K, et al. Fundamental movement skills in preschoolers before and during the COVID-19 pandemic in Japan: a serial cross-sectional study. *Environ Health Prev Med.* (2022) 27:26. doi: 10.1265/ehpm.22-00049

8. Sakamoto T, Nozue M, Okabe T, Yoshioka Y, Saito S, Takahashi T, et al. Association between household income and dietary changes in young children during the COVID-19 state of emergency in Japan from April to May 2020. *J Jpn Soc Health Educ Promot.* (2022) 1:14–25. doi: 10.11260/kenkokyoiku.30.14

9. Horikawa C, Murayama N, Kojima Y, Tanaka H, Morisaki N. Changes in selected food groups consumption and quality of meals in Japanese school children during the covid-19 pandemic. *Nutrients.* (2021) 13:2743. doi: 10.3390/nu13082743

10. Kosaka Y. Parental perception of the relationship between stress responses and the changes in lifestyle habits of elementary school students during a temporary leave of absence for COVID-19. *Shinrigaku Kenkyu.* (2021) 92:408–16. doi: 10.4992/jjpsy.92.20040

11. Ueda R, Okada T, Kita Y, Ozawa Y, Inoue H, Shioda M, et al. Psychological status associated with low quality of life in school-age children with neurodevelopmental disorders during COVID-19 stay-at-home period. *Front Psychiatry.* (2021) 12:676493. doi: 10.3389/fpsyt.2021.676493

12. Nakachi K, Kawabe K, Hosokawa R, Yoshino A, Horiuchi F, Ueno-ichi S. Differences in psychological and behavioral changes between children following school closure due to COVID-19. *Psychiatry J.* (2021) 2021:5567732. doi: 10.1155/2021/5567732

13. Zhu Q, Li M, Ji Y, Shi Y, Zhou J, Li Q, et al. "Stay-at-home" lifestyle effect on weight gain during the COVID-19 outbreak confinement in China. *Int J Environ Res Public Health.* (2021) 18:1–13. doi: 10.3390/ijerph18041813

14. Seal A, Schaffner A, Phelan S, Brunner-Gaydos H, Tseng M, Keadle S, et al. COVID-19 pandemic and stay-at-home mandates promote weight gain in US adults. *Obesity.* (2022) 30:240–8. doi: 10.1002/oby.23293

15. Zachary Z, Brianna F, Brianna L, Garrett P, Jade W, Alyssa D, et al. Self-quarantine and weight gain related risk factors during the COVID-19 pandemic. *Obes Res Clin Pract.* (2020) 14:210–6. doi: 10.1016/j.orcp.2020.05.004

16. di Renzo L, Gualtieri P, Pivari F, Soldati L, Attinà A, Cinelli G, et al. Eating habits and lifestyle changes during COVID-19 lockdown: an Italian survey. *J Transl Med.* (2020) 18:229. doi: 10.1186/s12967-020-02399-5

17. Sidor A, Rzymski P. Dietary choices and habits during COVID-19 lockdown: experience from Poland. *Nutrients.* (2020) 12:1657. doi: 10.3390/nu12061657

18. Ghosal S, Arora B, Dutta K, Ghosh A, Sinha B, Misra A. Increase in the risk of type 2 diabetes during lockdown for the COVID19 pandemic in India: a cohort analysis. *Diabetes Metabolic Synd Clin Res Rev.* (2020) 14:949–52. doi: 10.1016/j.dsx.2020.06.020

19. Pietrobelli A, Pecoraro L, Ferruzzi A, Heo M, Faith M, Zoller T, et al. Effects of COVID-19 lockdown on lifestyle behaviors in children with obesity living in Verona, Italy: a longitudinal study. *Obesity.* (2020) 28:1382–5. doi: 10.1002/oby.22861

20. Okuyama J, Seto S. Physical activity and mental health of children and adolescents in prolonged COVID-19 pandemic. *Stress Sci Res.* (2021) 36:3–11. doi: 10.5058/stresskagakukenkyu.2021002

21. Ministry of Health Labor and Welfare. *Announcement for Cooperation in Preventing the Spread of Infection Disease*. Available online at: https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kansentaisaku.html (accessed September 17, 2022).

22. Greenhalgh T, Ozbilgin M, Tomlinson D. How COVID-19 spreads: narratives, counter narratives, and social dramas. *BMJ.* (2022) 378:e069940. doi: 10.1136/bmj-2022-069940

23. Kishida N, Kamimura Y. Relationship of conversation during meal and health and dietary life of school children. In the case of 5th and 6th graders in Urban District, Hiroshima. *Jpn J Nutr Dietetics.* (1993) 51:23–30. doi: 10.5264/eiyogakuzashi.51.23

24. Esaki Y. Predictors of meal-related quality of life. *Jpn J Educ Psychol.* (2017) 65:239–47. doi: 10.5926/jjep.65.239

25. Tominaga M, Kodama MK, Sato TK. Relationship between life style focusing on eating habits and mental health of junior and high school students, and university students. *J Home Econ Jpn.* (1997) 52:499–510.

26. Eto K, Nakanishi A, Takemi Y. Associations between family dinner frequency and voluntary mealtime communication with dietary attitudes, dietary behaviors, and quality of life: a cross-sectional and longitudinal study of 5th and 8th grade students. *Jpn J Nutr Dietetics.* (2014) 72:113–25. doi: 10.5264/eiyogakuzashi.72.113

27. Nakamura S, Inayama T, Hata K, Matsushita M, Takahashi M, Harada K, et al. Association of household income and education with eating behaviors in Japanese adults: a cross-sectional study. *BMC Public Health.* (2016) 16:1–14. doi: 10.1186/s12889-016-2748-z

28. Barnes EM, Grifenhagen JF, Dickinson DK. Mealtimes in head start pre-k classrooms: examining language-promoting opportunities in a hybrid space. *J Child Lang.* (2020) 47:337–57. doi: 10.1017/S0305000919000199

29. Gest SD, Holland-Coviello R, Welsh JA, Eicher-Catt DL, Gill S. Language development subcontexts in head start classrooms: Distinctive patterns of teacher talk during free play, mealtime, and book reading. *Early Educ Dev.* (2006) 17:293–315. doi: 10.1207/s15566935eed1702_5

30. Lu J, Gu J, Li K, Xu C, Su W, Lai Z, et al. COVID-19 outbreak associated with air conditioning in restaurant, Guangzhou, China, 2020. *Emerg Infect Dis.* (2020) 26:1628–31. doi: 10.3201/eid2611.203774

31. Zhang N, Chen X, Jia W, Jin T, Xiao S, Chen W, et al. Evidence for lack of transmission by close contact and surface touch in a restaurant outbreak of COVID-19. *J Infect.* (2021) 83:207–16. doi: 10.1016/j.jinf.2021.05.030

32. Ministry of Education Culture Sports Science and Technology. *Hygiene Management Manual at Schools (ver.1)*. Available online at: https://www.pref.shiga.lg.jp/file/attachment/5178754.pdf (accessed September 19, 2022).

33. Tanaka H, Kojima Y, Horikawa C, Murayama N, Morisaki N. A nationwide survey on school lunch provision during the COVID-19 pandemic. *J Natl Inst Public Health.* (2021) 70:579–86. doi: 10.20683/jniph.70.5_579

34. Iddir M, Brito A, Dingeo G, del Campo SSF, Samouda H, la Frano MR, et al. Strengthening the immune system and reducing inflammation and oxidative stress through diet and nutrition: considerations during the covid-19 crisis. *Nutrients.* (2020) 12:1562. doi: 10.3390/nu12061562

35. Mercola J, Grant WB, Wagner CL. Evidence regarding vitamin d and risk of covid-19 and its severity. *Nutrients.* (2020) 12:3361. doi: 10.3390/nu12113361

36. Roh YE, Kim BR, Choi WB, Kim YM, Cho MJ, Kim HY, et al. Vitamin D deficiency in children aged 6 to 12 years: single center's experience in busan. *Ann Pediatr Endocrinol Metab.* (2016) 21:149–54. doi: 10.6065/apem.2016.21.3.149

37. Tamaki J, Iki M, Sato Y, Kajita E, Nishino H, Akiba T, et al. Total 25-hydroxyvitamin D levels predict fracture risk: results from the 15-year follow-up of the Japanese Population-based Osteoporosis (JPOS) Cohort Study. *Osteoporosis Int.* (2017) 28:1903–13. doi: 10.1007/s00198-017-3967-6

38. Beyazgül G, Bag Ö, Yurtseven I, Coşkunol F, Başer S, Çiçek D, et al. How vitamin D levels of children changed during COVID-19 pandemic: a comparison of pre-pandemic and pandemic periods. *J Clin Res Pediatr Endocrinol.* (2022) 14:188–95. doi: 10.4274/jcrpe.galenos.2022.2021-10-6

39. Alpcan A, Tursun S, Kandur Y. Vitamin D levels in children with COVID-19: a report from Turkey. *Epidemiol Infect.* (2021) 149:e180. doi: 10.1017/S0950268821001825

40. Shakoor H, Feehan J, al Dhaheri AS, Ali HI, Platat C, Ismail LC, et al. Immune-boosting role of vitamins D, C, E, zinc, selenium and omega-3 fatty acids: could they help against COVID-19? *Maturitas.* (2021) 143:1–9. doi: 10.1016/j.maturitas.2020.08.003

41. Milani GP, Macchi M, Guz-Mark A. Vitamin C in the treatment of COVID-19. *Nutrients.* (2021) 13:1172. doi: 10.3390/nu13041172

42. Saeed H, Osama H, Abdelrahman MA, Madney YM, Harb HS, Abdelrahim MEA, et al. Vitamins and other immune-supportive elements as cofactors for passing the COVID-19 pandemic. *Beni Suef Univ J Basic Appl Sci.* (2021) 10:1–8. doi: 10.1186/s43088-021-00163-2

43. Chen H, Zhuo Q, Yuan W, Wang J, Wu T. Vitamin A for preventing acute lower respiratory tract infections in children up to seven years of age. *Cochrane Database Syst Rev.* (2008). doi: 10.1002/14651858.CD006090.pub2

44. Alexander J, Tinkov A, Strand TA, Alehagen U, Skalny A, Aaseth J. Early nutritional interventions with zinc, selenium and vitamin D for raising anti-viral resistance against progressive COVID-19. *Nutrients.* (2020) 12:1–12. doi: 10.3390/nu12082358

45. Saleh NY, Abo El Fotoh WMM. Low serum zinc level: the relationship with severe pneumonia and survival in critically ill children. *Int J Clin Pract.* (2018) 72:e13211. doi: 10.1111/ijcp.13211

46. Bhatnagar S, Aneja S, Dutta AK, Chandra J, Rath B, Sharma M, et al. Zinc as adjunct treatment in infants aged between 7 and 120 days with probable serious bacterial infection: a randomised, double-blind, placebo-controlled trial. *Lancet.* (2012) 379:2072–8. doi: 10.1016/S0140-6736(12)60477-2

47. Moghaddam A, Heller RA, Sun Q, Seelig J, Cherkezov A, Seibert L, et al. Selenium deficiency is associated with mortality risk from COVID-19. *Nutrients.* (2020) 12:1–13. doi: 10.3390/nu12072098

48. Kojima Y, Murayama N, Horikawa C, Tanaka H, Morisaki N. Impact of declaration of a state of emergency due to the COVID-19 pandemic on school lunches: a nationwide survey. *Jpn J Nutr Dietetics.* (2022) 80:116–25. doi: 10.5264/eiyogakuzashi.80.116

49. Bundgaard H, Bundgaard JS, Raaschou-Pedersen DET, von Buchwald C, Todsen T, Norsk JB, et al. Effectiveness of adding a mask recommendation to other public health measures to prevent SARS-CoV-2 infection in Danish mask wearers a randomized controlled trial. *Ann Intern Med.* (2021) 174:335–43. doi: 10.7326/M20-6817

50. Suess T, Remschmidt C, Schink SB, Schweiger B, Nitsche A, Schroeder K, et al. The role of facemasks and hand hygiene in the prevention of influenza transmission in households: results from a cluster randomised trial; Berlin, Germany, 2009-2011. *BMC Infect Dis.* (2012) 12:26. doi: 10.1186/1471-2334-12-26

51. Aiello AE, Perez V, Coulborn RM, Davis BM, Uddin M, Monto AS. Facemasks, hand hygiene, and influenza among young adults: a randomized intervention trial. *PLoS ONE.* (2012) 7:e29744. doi: 10.1371/journal.pone.0029744

52. Aiello AE, Murray GF, Perez V, Coulborn RM, Davis BM, Uddin M, et al. Mask use, hand hygiene, and seasonal influenza-like illness among young adults: a randomized intervention trial. *J Infect Dis.* (2010) 201:491–8. doi: 10.1086/650396

53. Larson EL, Ferng YH, Wong-McLoughlin J, Wang S, Haber M, Morse SS. Impact of non-pharmaceutical interventions on URIs and influenza in crowded, urban households. *Public Health Rep.* (2010) 125:178–91. doi: 10.1177/003335491012500206

54. Canini L, Andréoletti L, Ferrari P, Angelo DR, Blanchon T, Lemaitre M, et al. Surgical mask to prevent influenza transmission in households: a cluster randomized trial. *PLoS ONE.* (2010) 5:e13998. doi: 10.1371/journal.pone.0013998

55. Cowling BJ, Fung ROP, Cheng CKY, Fang VJ, Chan KH, Seto WH, et al. Preliminary findings of a randomized trial of non-pharmaceutical interventions to prevent influenza transmission in households. *PLoS ONE.* (2008) 3:e2101. doi: 10.1371/journal.pone.0002101

56. Simmerman JM, Suntarattiwong P, Levy J, Jarman RG, Kaewchana S, Gibbons R v., et al. Findings from a household randomized controlled trial of hand washing and face masks to reduce influenza transmission in Bangkok, Thailand. *Influenza Other Respir Viruses.* (2011) 5:256–67. doi: 10.1111/j.1750-2659.2011.00205.x

57. Cowling BJ, Chan KH, Fang VJ, Cheng CKY, Fung ROP, Wai W, et al. Facemasks and hand hygiene to prevent influenza transmission in households. *Ann Intern Med.* (2009) 151:437–46. doi: 10.7326/0003-4819-151-7-200910060-00142

58. Alfelali M, Haworth EA, Barasheed O, Badahdah AM, Bokhary H, Tashani M, et al. Facemask against viral respiratory infections among Hajj pilgrims: a challenging cluster-randomized trial. *PLoS ONE.* (2020) 15:e0240287. doi: 10.1371/journal.pone.0240287

59. MacIntyre CR, Zhang Y, Chughtai AA, Seale H, Zhang D, Chu Y, et al. Cluster randomised controlled trial to examine medical mask use as source control for people with respiratory illness. *BMJ Open.* (2016) 6:e012330. doi: 10.1136/bmjopen-2016-012330

60. MacIntyre CR, Seale H, Dung TC, Hien NT, Nga PT, Chughtai AA, et al. A cluster randomised trial of cloth masks compared with medical masks in healthcare workers. *BMJ Open.* (2015) 5:e006577. doi: 10.1136/bmjopen-2014-006577

61. MacIntyre CR, Cauchemez S, Dwyer DE, Seale H, Cheung P, Browne G, et al. Face mask use and control of respiratory virus transmission in households. *Emerg Infect Dis.* (2009) 15:233–41. doi: 10.3201/eid1502.081166

62. Jacobs JL, Ohde S, Takahashi O, Tokuda Y, Omata F, Fukui T. Use of surgical face masks to reduce the incidence of the common cold among health care workers in Japan: a randomized controlled trial. *Am J Infect Control.* (2009) 37:417–9. doi: 10.1016/j.ajic.2008.11.002

63. Barasheed O, Heron L, Haworth E, Almasri N, Badahdah AM, Taylor J, et al. Pilot randomised controlled trial to test effectiveness of facemasks in preventing influenza-like illness transmission among Australian Hajj Pilgrims in

2011 on behalf of the Hajj Research Team. *Infect Disord Drug Targets.* (2014) 14:110–6. doi: 10.2174/1871526514666141021112855

64. Guo X, Wang J, Hu D, Wu L, Gu L, Wang Y, et al. Survey of COVID-19 disease among orthopaedic surgeons in Wuhan, People's Republic of China. *J Bone Joint Surg Am.* (2020) 102:847–54. doi: 10.2106/JBJS.20.00417

65. Kumar S, Kumar A, Kirtana J, Singh A, Shankar S, Khan M, et al. Risk factors and outcome among COVID-19 exposed and quarantined healthcare workers: a study on the status of existing practices of standard precautions. *J Family Med Prim Care.* (2020) 9:5355. doi: 10.4103/jfmpc.jfmpc_1579_20

66. Lio CF, Cheong HH, Lei CI, Lo IL, Yao L, Lam C, et al. Effectiveness of personal protective health behaviour against COVID-19. *BMC Public Health.* (2021) 21:1. doi: 10.1186/s12889-021-10680-5

67. Xu H, Gan Y, Zheng D, Wu B, Zhu X, Xu C, et al. Relationship between COVID-19 infection and risk perception, knowledge, attitude, and four nonpharmaceutical interventions during the late period of the COVID-19 epidemic in China: online cross-sectional survey of 8158 adults. *J Med Internet Res.* (2020) 22:e21372. doi: 10.2196/21372

68. Hendrix MJ, Walde C, Findley K, Trotman R. Absence of apparent transmission of SARS-CoV-2 from two stylists after exposure at a hair salon with a universal face covering policy – springfield, missouri, May 2020. *MMWR Morb Mortal Wkly Rep.* (2020) 69:930–32. doi: 10.15585/mmwr.mm6928e2

69. Doung-Ngern P, Suphanchaimat R, Panjangampatthana A, Janekrongtham C, Ruampoom D, Daochaeng N, et al. Case-control study of use of personal protective measures and risk for SARS-CoV 2 infection, Thailand. *Emerg Infect Dis.* (2020) 26:2607–16. doi: 10.3201/eid2611.203003

70. Khalil MdM, Alam MM, Arefin MK, Chowdhury MR, Huq MR, Chowdhury JA, et al. Role of personal protective measures in prevention of COVID-19 spread among physicians in Bangladesh: a multicenter cross-sectional comparative study. *SN Compr Clin Med.* (2020) 2:1733–9. doi: 10.1007/s42399-020-00471-1

71. Abaluck J, Kwong LH, Styczynski A, Haque A, Kabir MA, Bates-Jeffery E, et al. Impact of community masking on COVID-19: a cluster-randomized trial in Bangladesh. *Science.* (2021) 375:6577. doi: 10.1126/science.abi9069

72. Chikina M, Pegden W, Recht B. Re-analysis on the statistical sampling biases of a mask promotion trial in Bangladesh: a statistical replication. *Trials.* (2022) 23:786. doi: 10.1186/s13063-022-06704-z

73. Kim MS, Seong D, Li H, Chung SK, Park Y, Lee M, et al. Comparative effectiveness of N95, surgical or medical, and non-medical facemasks in protection against respiratory virus infection: a systematic review and network meta-analysis. *Rev Med Virol.* (2022) 32:e2336 doi: 10.1002/rmv.2336

74. Nanda A, Hung I, Kwong A, Man VCM, Roy P, Davies L, et al. Efficacy of surgical masks or cloth masks in the prevention of viral transmission: systematic review, meta-analysis, and proposal for future trial. *J Evid Based Med.* (2021) 14:97–111. doi: 10.1111/jebm.12424

75. Jefferson T, del Mar CB, Dooley L, Ferroni E, Al-Ansary LA, Bawazeer GA, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses. *Cochrane Database Syst Rev.* (2020) 2011:CD006207. doi: 10.1002/14651858.CD006207.pub4

76. Davies R, Mowbray F, Martin AF, Smith LE, Rubin GJ. A systematic review of observational methods used to quantify personal protective behaviours among members of the public during the COVID-19 pandemic, and the concordance between observational and self-report measures in infectious disease health protection. *BMC Public Health.* (2022) 22:1436. doi: 10.1186/s12889-022-13819-0

77. Spira B. Correlation between mask compliance and COVID-19 outcomes in Europe. *Cureus.* (2022) 14:e24268. doi: 10.7759/cureus.24268

78. April MD, Naylor JF, Long B. Analysis of the effects of a texas state-wide mask mandate (Executive Order GA-29) on case load, hospitalizations, and mortality. *South Med J.* (2022) 115:175–80. doi: 10.14423/SMJ.0000000000001368

79. Fögen Z. The Foegen effect: a mechanism by which facemasks contribute to the COVID-19 case fatality rate. *Medicine.* (2022) 101:E28924. doi: 10.1097/MD.0000000000028924

80. Ueki H, Furusawa Y, Iwatsuki-Horimoto K, Imai M, Kabata H, Nishimura H, et al. Effectiveness of face masks in preventing airborne transmission of SARS-CoV-2. *mSphere.* (2020) 5:e00637–20. doi: 10.1128/mSphere.00637-20

81. Sharma S, Pinto R, Saha A, Chaudhuri S, Basu S. On secondary atomization and blockage of surrogate cough droplets in single-and multilayer face masks. *Sci Adv.* (2021) 7:eabf0452. doi: 10.1126/sciadv.abf0452

82. Bagchi S, Basu S, Chaudhuri S, Saha A. Penetration and secondary atomization of droplets impacted on wet facemasks. *Phys Rev Fluids.* (2021) 6:110510. doi: 10.1103/PhysRevFluids.6.110510

83. Park AM, Khadka S, Sato F, Omura S, Fujita M, Hashiwaki K, et al. Bacterial and fungal isolation from face masks under the COVID-19 pandemic. *Sci Rep.* (2022) 12:11361. doi: 10.1038/s41598-022-15409-x

84. Juutinen A, Sarvikivi E, Laukkanen-Nevala P, Helve O. Use of face masks did not impact COVID-19 incidence among 10–12-year-olds in Finland. *medRxiv [Preprint].* (2022). doi: 10.1101/2022.04.04.22272833

85. Rotevatn TA, Larsen VB, Bjordal Johansen TK, Astrup E, Surén P, Greve-Isdahl M, et al. Transmission of SARS-CoV-2 in Norwegian schools: A population-wide register-based cohort study on characteristics of the index case and secondary attack rates. *medRxiv [Preprint].* (2021). doi: 10.1101/2021.10.04.21264496

86. Marchant E, Griffiths L, Crick T, Fry R, Hollinghurst J, James M, et al. COVID-19 mitigation measures in primary schools and association with infection and school staff wellbeing: an observational survey linked with routine data in Wales, UK. *PLoS ONE.* (2022) 17:e0264023. doi: 10.1371/journal.pone.0264023

87. Coma E, Català M, Méndez-Boo L, Alonso S, Hermosilla E, Alvarez-Lacalle E, et al. Unravelling the role of the mandatory use of face covering masks for the control of SARS-CoV-2 in schools: A quasi-experimental study nested in a population-based cohort in Catalonia (Spain). *SSRN Elec J.* (2022). Available online at: https://www.ssrn.com/abstract=4046809 (accessed September 19, 2022).

88. Watanabe N. Mask addiction. *Stress Sci Res.* (2018) 33:15–20. doi: 10.5058/stresskagakukenkyu.2018006

89. Elisheva R. Adverse effects of prolonged mask use among healthcare professionals during COVID-19. *J Infect Dis Epidemiol.* (2020) 6:130. doi: 10.23937/2474-3658/1510130

90. Koseoglu S, Caklcl K, Demirtaş M, Gokdogan O, Ucuncu H. Ear nose and throat symptoms of mask-earing in the COVID era. *J Laryngol Otol.* (2022) 136:645–8. doi: 10.1017/S0022215122000676

91. Ou H, Zheng Y, Li M, Liang J, Chen H, Lang S, et al. The impacts of surgical mask in young healthy subjects on cardiopulmonary function and muscle performance: a randomized crossover trial. *Arch Public Health.* (2022) 80:1. doi: 10.1186/s13690-022-00893-4

92. Roberge RJ, Kim JH, Benson SM. Absence of consequential changes in physiological, thermal and subjective responses from wearing a surgical mask. *Respir Physiol Neurobiol.* (2012) 181:29–35. doi: 10.1016/j.resp.2012.01.010

93. Reychler G, Standaert M, Audag N, Caty G, Robert A, Poncin W. Effects of surgical facemasks on perceived exertion during submaximal exercise test in healthy children. *Eur J Pediatr.* (2022) 181:2311–7. doi: 10.1007/s00431-022-04430-x

94. Ruba AL, Pollak SD. Children's emotion inferences from masked faces: implications for social interactions during COVID-19. *PLoS ONE.* (2020) 15:e0243708. doi: 10.1371/journal.pone.0243708

95. Gori M, Schiatti L, Amadeo MB. Masking emotions: face masks impair how we read emotions. *Front Psychol.* (2021) 12:669432. doi: 10.3389/fpsyg.2021.669432

96. Grahlow M, Rupp CI, Derntl B. The impact of face masks on emotion recognition performance and perception of threat. *PLoS ONE.* (2022) 17:e0262840. doi: 10.1371/journal.pone.0262840

97. Cohen AO, Breiner K, Steinberg L, Bonnie RJ, Scott ES, Taylor-Thompson KA, et al. When is an adolescent an adult? Assessing cognitive control in emotional and nonemotional contexts. *Psychol Sci.* (2016) 27:549–62. doi: 10.1177/0956797615627625

98. Toda S. The relation between understanding of other people's emotion and prosocial behavior in preschoolers. *J Hokkaido Univ Educ Kushiro.* (2003) 35:95–105. Available online at: http://s-ir.sap.hokkyodai.ac.jp/dspace/handle/123456789/1291

99. Nogueira-de-Almeida CA, del Ciampo LA, Ferraz IS, del Ciampo IRL, Contini AA, da Ued FV. COVID-19 and obesity in childhood and adolescence: a clinical review. *J Pediatr.* (2020) 96:546–58. doi: 10.1016/j.jped.2020.07.001

100. Yu HJ, Li F, Hu YF, Li CF, Yuan S, Song Y, et al. Improving the metabolic and mental health of children with obesity: a school-based nutrition education and physical activity intervention in Wuhan, China. *Nutrients.* (2020) 12:194. doi: 10.3390/nu12010194

101. Nakazeko T, Shobako N, Hirano Y, Nakamura F, Honda K. Novel dietary intervention program "COMB meal program" approaching health and presenteeism: two pilot studies. *J Funct Foods.* (2022) 92:105050. doi: 10.1016/j.jff.2022.105050

102. Alsohime F, Temsah MH, Al-Nemri AM, Somily AM, Al-Subaie S. COVID-19 infection prevalence in pediatric population: etiology, clinical presentation, and outcome. *J Infect Public Health.* (2020) 13:1791–6. doi: 10.1016/j.jiph.2020.10.008

103. Lotfinejad N, Peters A, Tartari E, Fankhauser-Rodriguez C, Pires D, Pittet D. Hand hygiene in health care: 20 years of ongoing advances and

perspectives. *Lancet Infect. Dis.* (2021) 21:e209–21. doi: 10.1016/S1473-3099(21)00383-2

104. Thomson S. Mask mandates for children during the COVID-19 pandemic: an international human rights perspective. *Scand J Public Health.* (2022) 50:683–5. doi: 10.1177/14034948221081087

105. Olson SM, Newhams MM, Halasa NB, Price AM, Boom JA, Sahni LC, et al. Effectiveness of BNT162b2 vaccine against critical Covid-19 in adolescents. *New Engl J Med.* (2022) 386:713–23. doi: 10.1056/NEJMoa2117995

106. Ogata AF, Cheng CA, Desjardins M, Senussi Y, Sherman AC, Powell M, et al. Circulating severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) vaccine antigen detected in the plasma of mRNA-1273 vaccine recipients. *Clin Infect Dis.* (2022) 74:715–8. doi: 10.1093/cid/ciab465

107. Cognetti JS, Miller BL. Monitoring serum spike protein with disposable photonic biosensors following SARS-CoV-2 vaccination. *Sensors.* (2021) 21:5857. doi: 10.3390/s21175857

108. Ruiz JB, Bell RA. Parental COVID-19 vaccine hesitancy in the United States. *Public Health Rep.* (2022). doi: 10.1177/00333549221114346

109. Burgess A, Horii M. Risk, ritual and health responsibilisation: Japan's "safety blanket" of surgical face mask-wearing. *Sociol Health Illn.* (2012) 34:1184–98. doi: 10.1111/j.1467-9566.2012.01466.x

110. Nakayachi K, Ozaki T, Shibata Y, Yokoi R. Why do Japanese people use masks against COVID-19, even though masks are unlikely to offer protection from infection? *Front Psychol.* (2020) 11:1918. doi: 10.3389/fpsyg.2020.01918

111. Tanaka K, Inagaki T, Iwata K, Onishi M, Kanda Y, Kii M, et al. Basic survey of attitudes and behaviors under state of emergency by COVID-19 in Japan. *J Jpn Soc Civil Engin.* (2021) 77:129–40. doi: 10.2208/jscejipm.77.2_129

112. Yoshizawa H, Yoshizawa E. Examination of motivations for college students to wear masks in COVID-19 pandemic. *J Appear Adornment Stud.* (2022) 1:20–8.

113. Nakayachi K, Ozaki T, Shibata Y, Yokoi R. Determinants of hand-washing behavior during the infectious phase of COVID-19. *Shinrigaku Kenkyu.* (2021) 92:327–31. doi: 10.4992/jjpsy.92.20314

114. Moroi Y, Kobayashi G, Sugawara A, Ishikawa K. A checklist for healthcare students and professionals on how to use social media. *Med Educ.* (2020) 51:401–4. doi: 10.11307/mededjapan.51.4_401

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 14 October 2022
DOI 10.3389/fpubh.2022.992046

OPEN ACCESS

EDITED BY
Pier Luigi Sacco,
University of Studies G. d'Annunzio Chieti and Pescara, Italy

REVIEWED BY
Ayi Kwaghe,
Federal Ministry of Agriculture and Rural Development (FMARD), Nigeria
Karandeep Singh,
Institute for Basic Science (IBS), South Korea

*CORRESPONDENCE
Saritha Nair
nairs@icmr.gov.in

†These authors have contributed equally to this work

SPECIALTY SECTION
This article was submitted to Infectious Diseases - Surveillance, Prevention and Treatment, a section of the journal Frontiers in Public Health

RECEIVED 12 July 2022
ACCEPTED 27 September 2022
PUBLISHED 14 October 2022

CITATION
Adhikari T, Aggarwal S, Nair S, Joshi A, Diwan V, Stephen A, Devi KR, Kumar Mishra B, Yadav GK, Bangar SD, Sahu D, Yadav J, Ovung S, Gulati BK, Sharma S, Singh C, Duggal C, Sharma M, Ujagare D, Padmakar Chinchore S, Rebecca PB, Rani S, Selvaraj P, Xavier GG, Peter V, Watson B, Kannan T, Asmathulla KSM, Bhattacharya D, Turuk J, Palo SK, Kanungo S, Kumar Behera A, Pandey AK, Zaman K, Misra BR, Kumar N, Behera SP, Singh R, Narain K, Kant R, Sahay S, Tiwari RR, Thomas BE and Rao MVV (2022) Factors associated with COVID-19 stigma during the onset of the global pandemic in India: A cross-sectional study. *Front. Public Health* 10:992046. doi: 10.3389/fpubh.2022.992046

Factors associated with COVID-19 stigma during the onset of the global pandemic in India: A cross-sectional study

Tulsi Adhikari[1†], Sumit Aggarwal[2†], Saritha Nair[1*†], Aparna Joshi[3†], Vishal Diwan[4†], A. Stephen[5†], K. Rekha Devi[6†], Bijaya Kumar Mishra[7†], Girijesh Kumar Yadav[8†], Sampada Dipak Bangar[9], Damodar Sahu[1], Jeetendra Yadav[1], Senthanro Ovung[1†], Bal Kishan Gulati[1], Saurabh Sharma[1], Charan Singh[1], Chetna Duggal[3], Moina Sharma[10], Dhammasagar Ujagare[11], Sneha Padmakar Chinchore[11], Pricilla B. Rebecca[5], S. Rani[5], Pradeep Selvaraj[12], Gladston G. Xavier[13], Vanessa Peter[14], Basilea Watson[15], T. Kannan[16], K. S. Md. Asmathulla[17], Debdutta Bhattacharya[18], Jyotirmayee Turuk[18], Subrata Kumar Palo[19], Srikanta Kanungo[19], Ajit Kumar Behera[20], Ashok Kumar Pandey[8], Kamran Zaman[8], Brij Ranjan Misra[8], Niraj Kumar[8], Sthita Pragnya Behera[8], Rajeev Singh[8], Kanwar Narain[21], Rajni Kant[8,22], Seema Sahay[11†], Rajnarayan R. Tiwari[23], Beena Elizabeth Thomas[5†] and M. Vishnu Vardhana Rao[1†]

[1]ICMR-National Institute of Medical Statistics, New Delhi, India, [2]Division of Epidemiology and Communicable Diseases (ECD), Indian Council of Medical Research, New Delhi, India, [3]School of Human Ecology, Tata Institute of Social Sciences, Mumbai, Maharashtra, India, [4]Division of Environmental Monitoring and Exposure Assessment (Water and Soil), ICMR-National Institute for Research in Environmental Health, Bhopal, Madhya Pradesh, India, [5]Department of Social and Behavioral Research, ICMR-National Institute for Research in Tuberculosis, Chennai, Tamil Nadu, India, [6]Enteric Disease Division, ICMR-Regional Medical Research Center, NE Region, Dibrugarh, Assam, India, [7]Medical Department, ICMR-Regional Medical Research Center, Bhubaneswar, Odisha, India, [8]ICMR-Regional Medical Research Center, Gorakhpur, Uttar Pradesh, India, [9]Division of Epidemiology and Biostatistics, ICMR-National AIDS Research Institute, Pune, Maharashtra, India, [10]Department of Environmental Health and Epidemiology, ICMR-National Institute for Research in Environmental Health, Bhopal, Madhya Pradesh, India, [11]Division of Social and Behavioral Research, ICMR-National AIDS Research Institute, Pune, Maharashtra, India, [12]Office of District Non-Communicable Disease, Directorate of Public Health and Preventive Medicine, Chennai, Tamil Nadu, India, [13]Department of Social Work, Loyola College, Chennai, Tamil Nadu, India, [14]Information and Resource Center for the Deprived Urban Communities, Chennai, Tamil Nadu, India, [15]Electronic Data Processing Unit (EDP), ICMR-National Institute for Research in Tuberculosis, Chennai, Tamil Nadu, India, [16]Epidemiology Statistics Unit, ICMR-National Institute for Research in Tuberculosis, Chennai, Tamil Nadu, India, [17]Integrated People Development Project, Krishnagiri, Tamil Nadu, India, [18]Department of Microbiology, ICMR-Regional Medical Research Center, Bhubaneswar, Odisha, India, [19]Department of Epidemiology, ICMR-Regional Medical Research Center, Bhubaneswar, Odisha, India, [20]Clinical Department, ICMR-Regional Medical Research Center, Bhubaneswar, Odisha, India, [21]ICMR-Regional Medical Research Center, NE Region, Dibrugarh, Assam, India, [22]Research Management, Policy, Planning and Coordination Cell, Indian Council of Medical Research, New Delhi, India, [23]ICMR-National Institute for Research in Environmental Health, Bhopal, Madhya Pradesh, India

10.3389/fpubh.2022.992046

Objective: To assess factors associated with COVID-19 stigmatizing attitudes in the community and stigma experiences of COVID-19 recovered individuals during first wave of COVID-19 pandemic in India.

Methods: A cross-sectional study was conducted in 18 districts located in 7 States in India during September 2020 to January 2021 among adults > 18 years of age selected through systematic random sampling. Data on socio demographic and COVID-19 knowledge were collected from 303 COVID-19 recovered and 1,976 non-COVID-19 infected individuals from community using a survey questionnaire. Stigma was assessed using COVID-19 Stigma Scale and Community COVID-19 Stigma Scale developed for the study. Informed consent was sought from the participants. Univariate and multivariate binary logistic regression analysis were conducted.

Results: Half of the participants (51.3%) from the community reported prevalence of severe stigmatizing attitudes toward COVID-19 infected while 38.6% of COVID-19 recovered participants reported experiencing severe stigma. Participants from the community were more likely to report stigmatizing attitudes toward COVID-19 infected if they were residents of high prevalent COVID-19 zone (AOR: 1.5; CI: 1.2–1.9), staying in rural areas (AOR: 1.5; CI:1.1–1.9), belonged to the age group of 18–30 years (AOR: 1.6; CI 1.2–2.0), were male (AOR: 1.6; CI: 1.3–1.9), illiterate (AOR: 2.7; CI: 1.8–4.2), or living in Maharashtra (AOR: 7.4; CI: 4.8–11.3). COVID-19 recovered participants had higher odds of experiencing stigma if they had poor knowledge about COVID-19 transmission (AOR: 2.8; CI: 1.3–6.3), were staying for 6–15 years (AOR: 3.24; CI: 1.1–9.4) in the current place of residence or belonged to Delhi (AOR: 5.3; CI: 1.04–26.7).

Conclusion: Findings indicated presence of stigmatizing attitudes in the community as well as experienced stigma among COVID-19 recovered across selected study sites in India during the first wave of COVID-19 pandemic. Study recommends timely dissemination of factual information to populations vulnerable to misinformation and psychosocial interventions for individuals affected by stigma.

KEYWORDS

COVID-19, stigma, stigmatizing attitudes, first wave, India

Introduction

The outbreak of the novel Coronavirus Disease in 2019 (COVID-19) and public health preventive measures to contain the spread of the virus led to worry, uncertainty and fear among people (1). Further, lack of reliable information about the virus transmission and prevention, and apprehension about contracting it during the initial periods of the outbreak resulted in stigma and discrimination against people infected with or vulnerable to COVID-19 (2–4). Stigma is a social dynamic characterized by negative attitudes and exclusion of those who are perceived to be potential carriers of the disease (5). Stigmatization can increase unfavorable consequences of disease in multiple ways which could pose a challenge to the path of recovery. Literature review on experiences of people with Tuberculosis (TB), Human Immunodeficiency Virus (HIV) and Severe Acute Respiratory Syndrome (SARS) reported delay in testing and diagnosis, and non-adherence to or non-completion of treatment due to stigma or fear of stigma that led to increased disease transmission and impeded disease control (6–8).

Across the globe, several instances of COVID-19 stigma were reported among patients (and their families), persons suspected of having the infection, belonging to certain religious groups or geographical areas, people returning from overseas, healthcare workers, and migrant workers (2–5). A recent systematic review estimated prevalence of COVID-19 stigma (enacted stigma and perceived public stigma) as 35% [95% CI: 26–44%] (9) among affected individuals. People from low- and

middle-income countries or with lower education were more vulnerable to stigma. In some countries, COVID-19 survivors continued to experience stigma even after the outbreak was well-contained (10).

Stigmatizing acts included social exclusion, stereotyping, insults, blame or threat, verbal abuse or gossip, physical abuse, denial of housing, and essential healthcare service including medicine, dismissal from job, and refusal from stores and restaurants during the pandemic (11–15). Being a part of a particular race, occupation, religious identity and social minority (migrants), illiteracy, poor knowledge, and lower income were reported to be some factors associated with COVID-19 stigma (5, 11).

Studies from India have documented stigma experienced by COVID-19 infected individual or those at risk; however, to our knowledge few have reported about the stigmatizing attitudes prevalent among those non-infected individuals and the factors associated with it, and about stigma experienced by those who were affected by COVID-19 or perceived to be affected by the same. Although, with greater understanding of COVID-19, its transmission pathways, treatment options, and better preventive measures including vaccination, there is a considerable decrease in stigma (16), instances of discrimination continue to exist in certain communities and groups. Hence, it is pertinent to understand the factors associated with stigma which will in turn inform strategies for mitigation. In this regard, a multi-centric study was conducted during the first wave of the COVID-19 pandemic in India to understand COVID-19 knowledge, risk perception, preventive measures and stigma so as to suggest appropriate mitigation strategies for minimizing stigma related to COVID-19. The study aimed to assess stigmatizing attitudes toward COVID-19 infected; stigma experienced by COVID-19 recovered individuals and factors associated with stigmatizing attitudes and experienced stigma.

Methodology

Study design

A cross-sectional national level study was conducted in 18 districts (administrative divisions) located in 7 States (Delhi, Uttar Pradesh, Madhya Pradesh, Odisha, Assam, Tamil Nadu, and Maharashtra) representing Central, East, North, North East, South, and West zones in India during the pandemic outbreak in the country (September 2020 to January 2021). The Ministry of Health and Family Welfare (MoHFW), India order dated 30/04/2020 number 28015/19/2020-EMR was used to select the states and districts according to the prevalence of COVID-19 epidemic (red zone indicating high prevalence and green zone indicating no cases until then). Out of the 18 districts, 12 belonged to the red zone and 6 to the green zone. For the study purpose, COVID-19 recovered individuals were defined as persons who were COVID-19 positive and had recovered and completed their isolation/hospitalization period, while, non-COVID-19 participants from the community were defined as persons who had not been infected with COVID-19 till the time of the survey.

Participants for the study included adults above the age of 18 years. Assuming prevalence of 30% stigmatizing attitudes in the community with 10% margin of error, 5% level of significance and design effect of 1.5, the sample size calculated was 1,800 for non-COVID-19 respondents. For COVID-19 recovered respondents, assuming prevalence of 70% experienced stigma, 16% margin of error, 5% level of significance and with design effect 1.5, the sample size calculated was 302. The required sample size for both non COVID-19 participants and COVID-19 recovered was equally distributed among 18 districts.

Tools

A Survey questionnaire was designed to elicit information on socio-demographic characteristics, COVID-19 related knowledge (cause, transmission mode, symptoms and preventive measures), risk perception for the family and self, place of quarantine (for COVID-19 recovered participants) and COVID-19 stigma. Given the absence of standardized scales for measuring COVID-19 related stigma, the research team referred to the existing established framework (17) and researched scales for measuring HIV related stigma (18, 19). The HIV stigma frameworks (18, 19), for example, comments on the interaction between the individual and societal level factors in triggering stigma, the power differentials between those who are infected and non-infected, and also the differing mechanisms of stigma (manifested through enacted, anticipated and internalized stigma for those who are infected and through the prejudiced attitudes, discriminatory behaviors for those who are not infected). Hence, experienced stigma among COVID-19 recovered and prevailing stigmatizing attitudes displayed by the non-infected community members were assessed using two different scales (COVID-19 Stigma Scale and Community COVID-19 Stigma Scale) in the present study. Drawing from the HIV stigma framework, the Community COVID-19 stigma scale, comprising 6 statements, assessed prejudice, labeling, and discrimination by the non-infected community members. On the other hand, drawing from the same framework and the HIV stigma scale, COVID-19 stigma scale, comprising 13 statements, measured personalized stigma (perceived negative results of others knowing about the person's disease status), disclosure concerns (hiding information or worrying about breach of information) and concerns with public attitudes toward COVID-19 disease (harmful consequences of public attitudes). Details of scale development and pilot testing are available elsewhere (20). Survey questionnaires were translated to local languages (Hindi, Oriya, Tamil, Marathi, and Assamese).

Due to restrictions imposed on conducting face-to-face data collection during COVID-19 pandemic, telephonic surveys were conducted by trained investigators across the study sites. Data collected was entered into the Census and Survey Processing System (CSPro) and later transferred to SPSS for analysis.

Participants

Community (non-COVID-19) participants: The contact tracing list of COVID-19 infected persons above 18 years of age maintained by the health department as well as beneficiary data available with community-based organizations from the respective study areas were used to prepare a heterogenous and representative frame of non-COVID-19 participants from the community. The participants were selected from this frame using systematic random sampling Information was elicited from a total of 1,976 participants who had not been infected with COVID-19 till the date of the survey administration.

COVID-19 recovered participants: The sampling frame was prepared using the list of COVID-19 recovered individuals, as provided by the district health officials or the institutes conducting COVID-19 diagnosis between May and July 2020. A systematic random sampling procedure was used separately for the selection of the female and male participants. A total of 303 participants were included in the study.

The selected participants from both the groups were informed about the study and consent was sought orally over telephone; those who consented were included in the study. Total response rate ranged from 11.5% in Tamil Nadu to 43% in Odisha with an overall response rate of 22%. The success rates of contacting participants depended on the completeness and accuracy in obtaining telephone numbers of the selected participant in the sample frame and this may have induced bias. Few of the challenges reported by the sites in conducting telephonic surveys included: wrong numbers, discontinued numbers, participants not interested in the study, phone number in the name of another family member and network coverage issues. Persons not owning a mobile such as those from low-income communities, rural areas may have got excluded and also, since the participants were selected from lists available with health departments or community-based organizations, the population dynamics may have been different than the general population. However, given the urgency of conducting the study for providing information for mitigating stigma, telephonic surveys were the only possibility.

For ensuring the quality of data across the study sites, a manual was prepared to guide the investigators in collection of accurate information and training was conducted on best practices for telephonic data collection and recording information. Supportive supervision was provided, and data collected from each site was verified. Skipping and range checks were incorporated in the data entry forms and 10% post-entry check from the hard copies of the data were carried out. Data validation using frequency distributions at the time of data analysis was conducted.

Ethical considerations

The study proposals and data collection tools were reviewed and approved by the Indian Council of Medical Research (ICMR)-National Task Force for Operations Research for COVID-19, ICMR-Central Ethics Committee for Human Research for COVID-19 (File No. NCDIR/BEU/ICMR-CECHR/75/2020, reference number: CECHR 015/2020 dated 10th June, 2020) and the Ethical Review Committees of all the institutes participating in the study. Scientific robustness and accountability were audited by the ICMR Institute's Annual Scientific Advisory Committees (SAC). Participant Information Sheet (PIS) and Informed Consent (IC), translated to local languages, were read out to the participant over the phone and shared where ever possible through email or whatsapp. Consent was sought from the participants and recorded by the investigators from the respective sites.

Data sharing

Data was available with the investigators. Necessary government approvals were sought for sharing data.

Patient and public involvement statement

Patients or public were not involved in the conduct of research.

Transparency statement

The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted, and that there are no discrepancies from the study as originally planned.

Role of the funding source

The study was funded by the ICMR and had no role in the study design, collection of data, analysis and interpretation of data, writing of the report, and in the decision to submit the article for publication. The authors also confirm the independence of all researchers from funders and that all authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study. The

authors also take responsibility for the integrity of the data and the accuracy of the data analysis.

Measurements

Independent variables were chosen as per literature review (5, 11–15) and expert advice. These included State, zone (red, green), socio demographic profile of the participant, place of quarantine (home/institution), any family member (s) with COVID-19 positive (yes, no), knowledge of cause (yes, no), transmission (yes, no), symptoms (>4, at least 4) and preventive measures (>3, at least 3), and risk perception of COVID-19 (unlikely, neutral, likely).

Dependent variables

COVID-19 stigmatizing attitudes (outcome indicator)

Community COVID-19 Stigma Scale consisting of 6 statements assessed the stigmatizing attitudes of the community participants. Each statement was rated on a 3-point scale ranging from 0 = disagree to 2 = agree with higher scores indicating higher stigma attitudes. All the 6 statements were in the same direction. In the case of Community-19 stigma Scale, total score ranged from 0–12. The reliability of the scale was 0.60 and the median score was 6 (Table 1). In the absence of valid cut off points, it is generally advisable to use tertiles or quartiles to categorize scale score (21, 22). In the study, based on the sample size, tertile distribution was considered appropriate to categorize the stigma scores. The tertile distribution stigma score for community participants were 4 and 6 and were used as cut off points. Based on the categorization of the participants as per tertile distribution stigma scores ranged from no/mild stigma (<4), moderate stigma (4–5) and severe stigma (6+), and 51.3% of participants from the community displayed severe stigmatizing attitudes toward COVID-19 patients. A separate binary stigma variable was developed recoding the tertile stigma score of <4 as 0 and else 1 for binary logic regression analysis.

Experienced COVID-19 stigma (outcome indicator)

A total of 13 statements assessed the stigma experiences of COVID-19 recovered participants. Each statement in the scale was rated on a 3-point scale ranging from 0 = disagree to 2 = agree with higher scores indicating higher experienced stigma. All 13 statements were framed in the same direction, to sustain logical interpretation and reduce the need for reversed responses. Total score ranged from 0–26. This composite stigma score was categorized based on tertiles, mild (less than 1st tertile stigma score), moderate (between 1st and 2nd tertile stigma score) and severe stigma (≥ 2nd tertile stigma scores). The tertile stigma score for COVID-19 recovered participants were 2 and 10 and were used as cut off points. The reliability of the scale was 0.85 and the median score was 6 (Table 1). Based on the categorization of the participants as per tertile distribution stigma scores no/mild stigma (<2), moderate stigma (2–9) and severe stigma (10+), 38% of the participants reported experiencing severe stigma. A separate binary stigma variable was developed recoding the tertile stigma score of <1 as 0 and else 1. This recoded variable was used for binary logic regression analysis.

TABLE 1 Community COVID-19 stigma scale and COVID-19 stigma scale.

	Community COVID-19 stigma scale ($N = 1,976$)	COVID-19 stigma scale ($N = 303$)
Reliability (Cronbach Alpha)	0.60	0.855
Mean (SD), Median	5.4 (3.09), 6	7.8 (6.9), 6
Range	0–12	0–26
Tertiles		
33	<4 (T1): 33% of the participants had score <4	<2 (T1): 33% of the participants had score <2
66	<6 (T2) 66% of the participants had score < 6	<10 (T2) 66% of the participants had score <10
Category for stigma	0–3: No stigma/ mild; 4–5: moderate and >5 severe stigmatizing attitudes	0–1: No / mild; 2–9: moderate and >9 severe stigma
No/mild	25.3%	19.5%
Moderate stigma	23.4%	41.9%
Severe	51.3%	38.6%

Statistical analysis

To study the bivariate association between the outcome variable and the background characteristics and covariates, test of significance with cross tabs, chi-square test with *p*-value were conducted. The multivariate binary logistics regression analysis was conducted between the recoded outcome variable (no or mild stigma as 0 and else 1) and the variables which were significantly associated with stigma in the bivariate analysis. The multivariate binary logistic regression gave the adjusted Odds ratio, *p*-value and Confidence Interval of the adjusted ORs, adjusting for the confounding effect of all the other covariates.

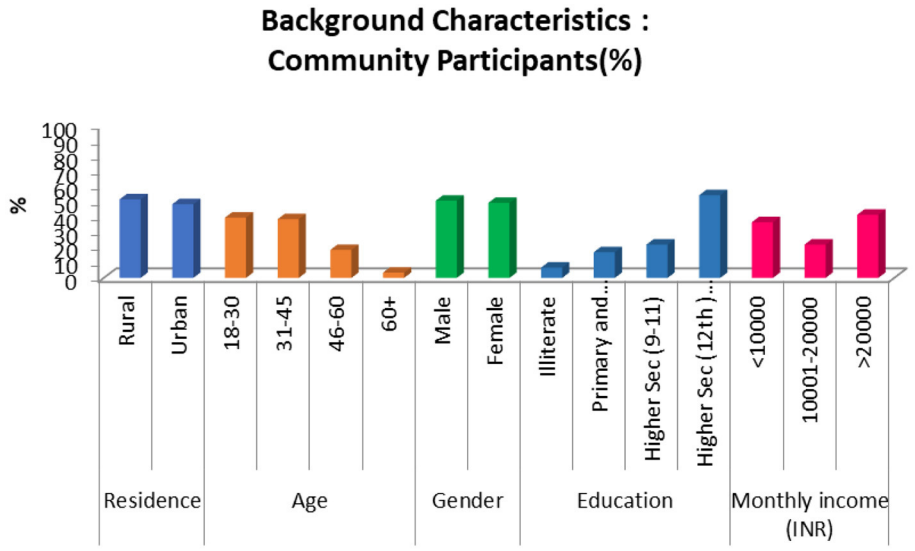


FIGURE 1
Socio-demographic characteristics of community participants.

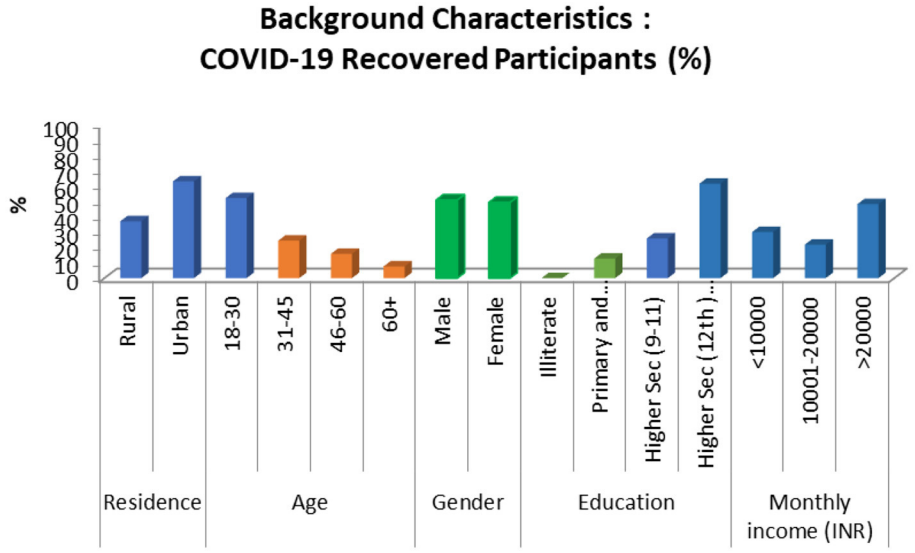


FIGURE 2
Socio-demographic characteristics of COVID-19 recovered participants.

Results

Profile of participants

The mean age of the community participants ($n = 1,976$) was 36 years, 71.8% were married, 54.3% had higher secondary and above education, and 51% of the participants resided in urban areas (Figure 1). Nearly three-fifths perceived no risk of getting infected with COVID-19.

The mean age of the COVID-19 recovered participants ($n = 303$) was 38 years, 69% were married, 61.5% had higher secondary and above education, and 63% were residing in urban areas (Figure 2). Many (83%) participants reported of institutional quarantine during the time they were COVID-19 positive.

Majority of the participants from the community reported knowledge about the cause (66.0%), modes of transmission (69.0%), symptoms (54.0%) and preventive measures of

10.3389/fpubh.2022.992046

TABLE 2 Stigmatizing attitude among non-COVID-19 community participants and stigma experienced among COVID-19 recovered participants by selected variables (socio demographic, COVID-19 knowledge and risk perception) (bivariate analysis).

	COVID-19 stigmatizing attitudes					Experienced COVID-19 stigma				
	No/Mild	Moderate	Severe	n	*p*-value	No/Mild	Moderate	Severe	*n*	*p*-value
Total	25.3	23.4	51.3	1,976		19.5	41.9	38.6	303	
Age group (years)										
18–29	22.6	21.2	56.1	782	0.008	24.1	41.7	34.3	108	0.586
30–44	27.3	26.6	46.1	763		14.9	40.4	44.7	94	
45–59	26.5	21	52.5	362		19.5	45.5	35.1	77	
≥60	27.5	24.6	47.8	69		16.7	37.5	45.8	24	
Sex										
Male	21.6	23.1	55.4	1,002	<0.001	16.2	45.5	38.3	154	0.268
Female	29.2	23.7	47.1	974		22.8	38.3	38.9	149	
Completed years of schooling										
Illiterate	23.1	18.7	58.2	134	<0.001	20	50	30	20	0.259
1–10 std	21.8	22.5	55.7	743		18.3	34.6	47.1	104	
11 and above	27.9	24.6	47.5	1,099		20.1	45.3	34.6	179	
Occupation										
Govt. employees	26.8	23.7	49.4	257	<0.001	25.5	50.9	23.6	55	0.12
Pvt. Employees	25.3	30.2	44.5	391		22.5	35.2	42.3	71	
Skilled/unskilled labor/Self employed	20.5	22.0	57.5	610		11.1	44.4	44.4	18	
Others	28.8	20.8	50.4	718		19.1	44.3	36.5	115	
Income in Indian rupees										
<10,000	24.6	21	54.4	723	0.139	19.8	38.5	41.8	91	0.462
10,001–20,000	23.6	24.5	52	433		22.7	34.8	42.4	66	
>20,000	26.8	24.9	48.3	820		17.8	47.3	34.9	146	
Marital status										
Never married	21.1	23.3	55.7	494	0.081	23.1	39.7	37.2	78	0.699
Currently married	26.6	23.7	49.7	1,420		18.7	41.6	39.7	209	
Separated	29	17.7	53.2	62		12.5	56.2	31.2	16	
Religion										
Hindu	25.5	23.3	51.2	1,729	0.844	20	39.2	40.8	255	0.152
Muslim	23.3	21.9	54.8	146		23.1	50	26.9	26	
Others	24.8	26.7	48.5	101		9.1	63.6	27.3	22	
State										
Madhya Pradesh	36.8	25.9	37.4	340	<0.001	16.1	39.3	44.6	56	<0.001
Odisha	7.7	18.1	74.2	326		25	18.8	56.2	48	
Delhi	31.8	36.4	31.8	110		9.5	42.9	47.6	21	
Uttar Pradesh	24.8	22	53.2	218		31.2	40.6	28.1	32	
Assam	47.1	24.2	28.7	327		31.2	47.9	20.8	48	
Tamil Nadu	22.4	26.6	51.1	331		8.3	58.3	33.3	48	
Maharashtra	10.2	18.5	71.3	324		14	46	40	50	
COVID-19 zone										
Red	27.6	23.4	48.9	1,259	<0.001	22.8	40.8	36.4	206	0.095
Green	21.2	26.6	55.5	717		12.4	44.3	43.3	97	
Place of residence										
Urban	25.2	26.6	48.2	956	<0.001	17.8	45.5	36.6	191	0.236
Rural	25.4	20.4	54.2	1,020		22.3	35.7	42	112	

(Continued)

10.3389/fpubh.2022.992046

TABLE 2 (Continued)

	COVID-19 stigmatizing attitudes					Experienced COVID-19 stigma				
	No/Mild	Moderate	Severe	n	*p*-value	No/Mild	Moderate	Severe	*n*	*p*-value
Duration of residence in the place										
<5 years	21.5	20.8	57.8	303	<0.001	32.7	38.2	29.1	55	0.015
6–15 Years	30.2	27.5	42.2	334		12	56	32	50	
>15 Years	24.9	22.9	52.1	1,339		17.7	39.4	42.9	198	
Place of quarantine										
Home	Not applicable					16	42	42	50	0.76
Institution						20.2	41.9	37.9	253	
Family member infected with COVID-19										
Yes	32.2	24.6	43.2	301	<0.001	15.4	40.6	44.1	143	0.104
No	24.1	23.2	52.8	1,675		23.1	43.1	33.8	160	
Knowledge of cause of COVID-19										
Yes	25.8	24.2	50	1,306	0.25	20.3	40.6	39.1	202	0.778
No	24.3	21.8	53.9	670		17.8	44.6	37.6	101	
Knowledge of COVID-19 transmission										
No	24.7	22.2	53.1	599	0.561	10.2	50	39.8	88	0.024
Yes	25.6	23.9	50.5	1,377		23.3	38.6	38.1	215	
Knowledge of symptoms (COVID-19 recovered median = 3 symptoms; community participants median = 4 symptoms) <3 symptoms	26.6	22.1	51.3	903	0.342	15.1	48.8	36	86	0.253
Atleast 3 symptoms	24.2	24.4	51.4	1,073		21.2	39.2	39.6	217	
Knowledge of preventive measures (median score = 3)										
<3 preventive measures	26.9	25.1	48	487	0.251	11.8	43.4	44.7	76	0.131
Atleast 3 preventive	24.8	22.8	52.4	1,489		22	41.4	36.6	227	
Risk perception										
Unlikely	25	21.3	53.7	1,151	0.081	Not applicable				
Neutral	25.6	26.5	47.9	426						
Likely	25.8	26.1	48.1	399						

*Significant p value < 0.05.
**Significant p value < 0.001.

COVID-19 (75.0%). Similar results were observed for the COVID-19 recovered participants.

Factors associated with COVID-19 stigmatizing attitudes in the community and stigma experiences

Table 2 illustrates the percentage distribution of COVID-19 stigmatizing attitudes by selected socio demographic and COVID-19 related variables. Majority of community participants from Odisha (92%) and Maharashtra (90%) reported of moderate and severe stigmatizing attitudes. Participants from Assam reported the lowest (53%) stigmatizing attitudes (Table 2). Fifty-four percent of participants from rural as compared to 48% from urban area reported stigmatizing attitudes. Fifty percent of males compared to 47% of females reported of severe stigmatizing attitudes. Participants in the age group of 18–30 and 45–60 years reported of severe stigmatizing (56.1 and 52.5 %, respectively) attitudes. Community participants with a COVID-19 positive family member had less stigmatizing attitudes (67.8%) than those without (76%). All the above differences were statistically significant.

The multivariate binary logistic regression analysis for factors associated with stigmatizing attitudes, revealed that the inter-state differences were statistically significant ($p < 0.001$) with least stigmatizing attitudes reported in Assam (Table 3). Stigmatizing attitudes were significantly higher among the participants from Maharashtra (AOR = 7.3), and Odisha (AOR = 6.3). People living in red (high COVID- 19 prevalence) zones and rural areas had more stigmatizing attitudes with

10.3389/fpubh.2022.992046

TABLE 3 Factors associated with stigma experience among the COVID-19 recovered participants and stigmatizing attitude among non-COVID-19 community participants (multivariate analysis).

	Non COVID-19 community participants (stigmatizing attitudes)			COVID-19 recovered participants (experienced stigma)		
	Sig.	Adj OR	95% CI	Sig.	AOR	95% CI
Age group (years)						
31–45 (Ref)	<0.001					
18–30	0.0	1.558	1.229 1.975			
46–60	0.02	1.423	1.057 1.915			
60+	0.961	1.016	0.545 1.894			
Sex						
(Ref - Female)						
Male	0	1.561	1.266 1.926			
Education						
11th and higher (Ref)						
Illiterate	0	2.734	1.761 4.246			
1–10 std	0	1.512	1.203 1.899			
Knowledge about COVID-19 transmission						
Yes (Ref)						
No				0.011	2.829	1.267 6.319
Place of residence						
Urban (ref)						
Rural	<0.001	1.45	1.13 1.86			
Duration of residence in the current place						
<6 years (Ref)				0.054		
6 to 15 years				0.03	3.24	1.117 9.397
>15 years				0.051	2.089	0.998 4.375
COVID-19 zone						
(Ref-Green)						
Red	<0.001	1.492	1.148 1.940			
State						
Assam (Ref)	<0.001			0.058		
Madhya Pradesh	0.024	1.554	1.059 2.282	0.156	2.049	0.760 5.529
Odisha	0	6.314	4.232 9.419	0.73	1.18	0.460 3.025
Delhi	0.217	1.409	0.817 2.429	0.044	5.278	1.043 26.695
Uttar Pradesh	0	2.189	1.419 3.376	0.952	0.969	0.352 2.666
Tamil Nadu	0	3.184	2.153 4.709	0.026	4.009	1.177 13.667
Maharashtra	0	7.379	4.825 11.286	0.054	2.771	0.983 7.812

*Variables significant in bivariate analysis were considered for the multivariate analysis.

adjusted odds ratio of around 1.5. The difference between red and green (zero prevalence) zones were statistically significant. Individuals in the age group of 31–45 years had less stigmatizing attitudes as compared to the younger age group, i.e., 18–30 years (AOR = 1.6) or the older age group (AOR = 1.4), i.e., 46–60 years. Men had more stigmatizing attitudes (AOR = 1.6) toward COVID-19 patients. Illiterate participants had more stigmatizing attitudes than those with education higher than secondary level (AOR = 2.7).

Significant differences were observed in stigma experiences of COVID-19 recovered participants based on the State to which they belonged. A little more than half (56%) of COVID-19 recovered participants from Odisha reported of experiencing severe stigma compared to 28% from Uttar Pradesh (Table 2). Stigma experiences were significantly different among residents who were staying at their current residential address for more than 5 years than those who were living at the current place for short duration of time. Experienced stigma was significantly

higher among participants who did not know about the mode of transmission of COVID-19 infection.

Multivariate logistic regression model for factors associated with reporting of experienced stigma by COVID-19 recovered individuals is presented in Table 3. Experiences of COVID-19 stigma were statistically significant and more likely to be reported by COVID-19 recovered individuals who belonged to the state of Delhi (AOR = 5.28) and Tamil Nadu (AOR = 4.01). COVID-19 recovered individuals who were staying at the place of residence (district) for more than 6 years experienced more stigma as compared to those who were residing at the current place for <6 years (AOR>2). Individuals who had good knowledge about modes of transmission of COVID-19 were less likely to have experienced stigma as compared to those who did not have the knowledge (AOR = 2.83).

Discussion

The widespread stigma associated with COVID-19 experienced by many and reported by media especially during the initial phases had devastating health consequences such as prompting people to hide the illness and preventing from seeking help and adopting healthy behaviors (1–3, 5). It also led to debilitating psychological and social consequences (12, 15, 23). To design targeted strategies for information dissemination, disease prevention, and stigma mitigation in India, a multi-centric study was undertaken during the onset of COVID-19 pandemic in India. The aim of the study was to understand COVID-19 stigmatizing attitudes in the community and stigma experienced by COVID-19 recovered individuals as well as factors associated with the same. Findings from this study document that nearly three-fourths of the study participants reported of stigmatizing attitudes and majority of the COVID-19 recovered participants had experienced some levels of stigma. Similar findings on stigma experiences of COVID-19 patients were reported from studies conducted in India and China (24, 25). Stigmatizing attitudes and discrimination toward COVID-19 patients were also observed among 60–80% of individuals from the general population in China and Jordan (26, 27). Higher levels in reporting of stigma, both experienced and stigmatizing attitudes, may be due to fear and paucity of knowledge on prevention or possible treatment options during the COVID-19 outbreak in India when the study was conducted. Fear of infection has been reported to be associated with heightened perceived stigma (28, 29). These results have implications for developing strategies in mitigating stigmatizing attitudes in the community and providing support to those who may experience stigma particularly during the initial phases of any infectious disease outbreak.

In this study, severity of stigma experienced by COVID-19 recovered individuals as well as prevailing stigmatizing attitudes in the community were associated with the state in which the participants resided at the time of the interview. Participants selected for the study belonged to districts located in States that had higher number of COVID-19 confirmed cases during the first wave and were declared red zones during the outbreak in the country (30). News reports had also highlighted the presence of COVID-19 stigma in these locations (31). Similar reports of increased COVID-19 stigma experiences were reported by individuals residing in highly affected countries or in hotspot zones (32–34). Also, residents living in geographical locations with the greatest number of cases reported higher levels of stigmatizing attitudes due to fear for potential infection (35, 36).

Good knowledge about COVID-19 was significantly associated with lesser stigma experiences. Having an appropriate knowledge on COVID-19 pandemic may have helped in judging misinformation and stereotypes (37) resulting in reduced stigma experiences. However, this is contrary to the study conducted by Saine and colleagues (38) that reported an increase in perceived stigma among patients who had hepatitis C virus (HCV)-related knowledge.

Stigmatizing attitudes were found more among the younger (18–30) and older (46–60) age groups of community participants. Older population had significantly higher stigmatizing attitudes toward COVID-19 infected due to higher perceived susceptibility and severity of COVID-19 (33, 39). Our study findings differ from other studies that reported lower stigmatizing attitudes among older (40) and younger adults (39, 41). Higher stigmatizing attitudes among younger population may have been due to their heightened exposure to misinformation which was widely circulated through social media groups. Male compared to female participants in the study had higher stigmatizing attitudes toward COVID-19 infected. The findings are consistent with previous studies on COVID-19 (33, 42, 43). Fear of increased risk of morbidity and mortality reported among men due to COVID-19 during the initial phases of pandemic may have resulted in higher stigmatizing attitudes among this group (44).

Our findings show that community participants with lower literacy levels were more likely to have stigmatizing attitudes toward COVID-19 infected. Education level of an individual could have a significant influence on their knowledge and thereby result in lesser stigmatizing attitudes (23, 45). Similar findings have been stated in several studies (13, 33, 40, 46–48), which reported that participants who had difficulties to find and understand information about COVID-19 were more likely to have stigmatizing attitudes toward people with the infection.

The present research not only corroborates media reports published during the onset of COVID- pandemic in India regarding stigma experienced by majority of COVID-19 infected individuals, but also provides supporting evidence for the presence of stigmatizing attitudes and factors associated with the same among non-COVID-19 infected individuals from the community Given the devastating health, social and psychological consequences of COVID-19 pandemic, our study

findings call for timely deployment of anti-stigma programmes along with public health protective measures for mitigation of discriminatory attitudes and stigma experiences that may interfere with overall health and wellbeing and come in way of pandemic containment responses. For example, responding to initial media reports of COVID-19 stigma and its impact, the Ministry of Health and Family Welfare (MoHFW) in India released guidelines on do's and don'ts for mitigation of stigma. Likewise, other initiatives undertaken by the GoI (Government of India) included psycho-social toll-free helpline and the "Break the Stigma" campaign (49). Such steps not only eased the struggle of the COVID-19 affected individuals against stigma but also dealt with the infodemic of misinformation and rumors that played a crucial role in creating stigma.

In addition to dissemination of correct information as currently undertaken by the Government and other organizations engaged in infection prevention, the study also emphasizes the need to particularly focus on populations more vulnerable to misinformation. These include less educated, those living in high prevalence States, people living in rural areas or migrant workers. Since lack of proper knowledge and poor literacy resulting in fear are major factors associated with stigma, mass media, and social media outreach could be leveraged to disseminate updated, accurate and easily understandable information, dispel myths, fears and stigmatizing attitudes, and promote empathic behaviors toward those infected. Lastly, the study recommends the need for timely psychosocial interventions to alleviate negative impacts of stigma in individuals affected by COVID-19 and to provide necessary support.

Strengths and limitations

Certain limitations may be considered while interpreting the results of the present study. Collection of sensitive information on stigma experiences and attitudes through surveys, in the absence of face to face methods of data collection may have induced biases. This also might have resulted in greater non-response rates. Since, findings are based on participants chosen from selected districts in India, the results although largely indicative of the COVID-19 stigma situation in India, may not be generalizable. A cross sectional study design may have posed challenges in assessing the factors associated with COVID-19 stigma as both stigma and its independent variables were examined at the same time. Use of robust methodology, triangulation of COVID−19 stigma from stigmatized and stigmatizers from major geographical zones affected by COVID-19 during the first wave in India are the strengths of the study.

Conclusion

Study indicates the presence of COVID-19 stigma in the study population and emphasizes the need for timely interventions to mitigate stigma by increasing awareness and knowledge on COVID-19.

Data availability statement

The datasets presented in this article are not readily available because data is available with the investigators. Necessary government approvals would have to be sought for sharing data. Requests to access the datasets should be directed to nairs@icmr.gov.in.

Ethics statement

The studies involving human participants were reviewed and approved by ICMR-Central Ethics Committee for Human Research for COVID-19 (File No. NCDIR/BEU/ICMR-CECHR/75/2020, Reference Number: CECHR 015/2020 dated 10th June, 2020). Written informed consent was not provided because Participant Information Sheet (PIS) and Informed Consent (IC), translated to local languages, were read out to the participant over the phone and shared where ever possible through email or whatsapp messenger. Consent was sought from the participants and recorded by the investigators from the respective sites.

Author contributions

SB, JY, BG, SSh, CS, CD, MS, DU, SPC, PR, SR, PS, GX, VP, BW, TK, KA, DB, JT, SKP, SK, AK, AP, KZ, BM, NK, SB, RS, KN, RK, and RT contributed by conducting critical review and editing. All authors contributed to the article and approved the submitted version.

Funding

This study was financially supported by the Indian Council of Medical Research (ICMR), New Delhi (wide letter No. HIV/COVID-19/3/5/2020/ECD-II dated July 20th 2020).

Acknowledgments

The authors acknowledge the support received from the research teams across the study sites and the study participants.

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.

Publisher's note

References

1. World Health Organization. *Pandemic Triggers 25% Increase in Prevalence of Anxiety and Depression Worldwide*. (2022). Available online at: https://www.who.int/news/item/02-03-2022-covid-19-pandemic-triggers-25-increase-in-prevalence-of-anxiety-and-depression-worldwide (accessed June 30, 2022).

2. Ransing R, Ramalho R, de Filippis R, Ojeahere MI, Karaliuniene R, Orsolini L, et al. Infectious disease outbreak related stigma and discrimination during the COVID-19 pandemic: drivers, facilitators, manifestations, and outcomes across the world. *Brain Behav Immunity*. (2020) 89:555–8. doi: 10.1016/j.bbi.2020.07.033

3. Bagcchi S. Stigma during the COVID-19 pandemic. *Lancet Infect Dis.* (2020) 20:782. doi: 10.1016/S1473-3099(20)30498-9

4. Turner-Musa J, Ajayi O, Kemp L. Examining social determinants of health, stigma, and COVID-19 disparities. *Healthcare*. (2020) 8:168. doi: 10.3390/healthcare8020168

5. Bhanot D, Singh T, Verma SK, Sharad S. Stigma and discrimination during COVID-19 pandemic. *Front Public Health*. (2021) 8:577018. doi: 10.3389/fpubh.2020.577018

6. Mukerji R, Turan JM. Exploring manifestations of TB-related stigma experienced by women in Kolkata, India. *Ann Global Health*. (2018) 84:727–35. doi: 10.29024/aogh.2383

7. Turan B, Budhwani H, Fazeli PL, Browning WR, Raper JL, Mugavero MJ, et al. How does stigma affect people living with HIV? The mediating roles of internalized and anticipated HIV stigma in the effects of perceived community stigma on health and psychosocial outcomes. *AIDS Behav*. (2017) 21:283–91. doi: 10.1007/s10461-016-1451-5

8. Siu JYM. The SARS-associated stigma of SARS victims in the post-SARS era of Hong Kong. *Qual Health Res.* (2008) 18:729–38. doi: 10.1177/1049732308318372

9. Yuan K, Huang XL, Yan W, Zhang YX, Gong YM, Su SZ, et al. A systematic review and meta-analysis on the prevalence of stigma in infectious diseases, including COVID-19: a call to action. *Mol Psychiatry*. (2022) 27:19–33. doi: 10.1038/s41380-021-01295-8

10. Bu NN. *The 80 Thousand COVID-19 Survivors Are Undergoing Discrimination (in Chinese)*. (2020). Available online at: http://k.sina.com.cn/article_1690367810_64c0f74201900py8d.html?from=mood (accessed February 2, 2022).

11. Mostafa A, Sabry W, Mostafa NS. COVID-19-related stigmatization among a sample of Egyptian healthcare workers. *PloS ONE*. (2020) 15:e0244172. doi: 10.1371/journal.pone.0244172

12. Chew NWS, Lee GK, Tan BY, Jing M, Goh Y, Ngiam NJ, et al. A multinational, multicentre study on the psychological outcomes and associated physical symptoms amongst healthcare workers during COVID-19 outbreak. *Brain Behav Immunity*. (2020) 88:559–65. doi: 10.1016/j.bbi.2020.04.049

13. Villa S, Jaramillo E, Mangioni D, Bandera A, Gori A, Raviglione MC. Stigma at the time of the COVID-19 pandemic. *Clin Microbiol Infect.* (2020) 26:1450–2. doi: 10.1016/j.cmi.2020.08.001

14. Muzzi L. *'As if We Were the Disease': Coronavirus Brings Prejudice for Italy's Chinese Workers*. (2020). Available online at: https://www.theguardian.com/global-development/2020/mar/25/as-if-we-were-the-disease-coronavirus-brings-prejudice-for-italys-chinese-workers (accessed July 1, 2022).

15. Dubey S, Biswas P, Ghosh R, Chatterjee S, Dubey MJ, Chatterjee S, et al. Psychosocial impact of COVID-19. *Diabetes Metab Syndr*. (2020) 14:779–88. doi: 10.1016/j.dsx.2020.05.035

16. CIFRC, UNICEF, WHO. *Social Stigma Associated with COVID-19: A Guide to Preventing and Addressing Social Stigma*. (2020). Available online at: https://www.who.int/docs/default-source/coronaviruse/covid19-stigma-guide.pdf?sfvrsn=226180f4_2 (accessed June 7, 2022).

17. Stangl AL, Earnshaw VA, Logie CH, van Brakel W, Simbayi LC, Barré I, et al. The health stigma and discrimination framework: a global, crosscutting framework to inform research, intervention development, and policy on health-related stigmas. *BMC Med*. (2019) 17:31. doi: 10.1186/s12916-019-1271-3

18. Berger BE, Ferrans CE, Lashley FR. Measuring stigma in people with HIV:Psychometric assessment of the HIV stigma scale. *Res Nurs Health.* (2001) 24:518–29. doi: 10.1002/nur.10011

19. Reinius M, Wettergren L, Wiklander M, Svedhem V, Ekström AM, Eriksson LE., 2017. Development of a 12-item short version of the HIV stigma scale. *Health Qual Life Outcomes.* (2017) 15:115. doi: 10.1186/s12955-017-0691-z

20. Nair S, Joshi A, Aggarwal S, Adhikar T, Mahajan N, Diwan V, et al. Development and validation of scales to assess stigma related to COVID-19 in India. *Indian J Med Res.* (2022) 155:156–164. doi: 10.4103/ijmr.ijmr_2455_21

21. Mostafa A, Mostafa NS, Ismail N. Validity and reliability of a COVID-19 stigma scale using exploratory and confirmatory factor analysis in a sample of Egyptian physicians: E16-COVID19-S. *Int J Environ Res Public Health.* (2021) 18:5451. doi: 10.3390/ijerph18105451

22. Charles B, Jeyaseelan L, Pandian AK, Sam AE, Thenmozhi M, Jayaseelan V. Association between stigma, depression and quality of life of people living with HIV/AIDS (PLHA) in South India–a community based cross sectional study. *BMC Public Health.* (2012) 12:1–11. doi: 10.1186/1471-2458-12-463

23. Nursalam N, Sukartini T, Priyantini D, Mafula D, Efendi F. Risk factors for psychological impact and social stigma among people facing COVID-19: a systematic review. *Sys Rev Pharm*. (2020) 11:1022–8.

24. Yuan Y, Zhao YJ, Zhang QE, Zhang L, Cheung T, Jackson T, et al. COVID-19-related stigma and its socio-demographic correlates: a comparative study. *Glob Health.* (2021) 17:1–9. doi: 10.1186/s12992-021-00705-4

25. Dar SA, Khurshid SQ, Wani ZA, Khanam A, Haq I, Shah NN, et al. Stigma in coronavirus disease-19 survivors in Kashmir, India: a cross-sectional exploratory study. *PLoS ONE.* (2020) 15:e0240152. doi: 10.1371/journal.pone.0240152

26. Liu R, Nicholas S, Leng A, Qian D, Maitland E, Wang J. The influencing factors of discrimination against recovered Coronavirus disease 2019 (COVID-19) patients in China: a national study. *Hum Vaccines Immunother*. (2022) 18:191396. doi: 10.1080/21645515.2021.1913966

27. Abuhammad S, Alzoubi KH, Khabour O. Fear of COVID-19 and stigmatization towards infected people among Jordanian people. *Int J Clin Pract.* (2021) 75:e13899. doi: 10.1111/ijcp.13899

28. Smith LE, Potts HW, Amlôt R, Fear NT, Michie S, Rubin GJ. Holding a stigmatizing attitude at the start of the COVID-19 outbreak: a cross-sectional survey. *Br J Health Psychol*. (2022) 27:588–604. doi: 10.1111/bjhp.12564

29. Saeed F, Mihan R, Mousavi SZ, Reniers RL, Bateni FS, Alikhani R et al. A narrative review of stigma related to infectious disease outbreaks: what can be learned in the face of the COVID-19 pandemic? *Front Psychiatry*. (2020) 11:565919. doi: 10.3389/fpsyt.2020.565919

30. The Hindu. *Coronavirus | Health Ministry Identifies 130 Districts as Red Zones*. (2020). Available online at: https://www.thehindu.com/news/national/coronavirus-india-lists-red-zones-as-it-extends-lockdown-till-may-17/article31478592.ece (accessed February 11, 2022).

31. Times of India. *COVID-19: Doctors Gone to Collect Samples Attacked in Indore*. (2020). Available online at: https://timesofindia.indiatimes.com/videos/news/covid-19-doctors-gone-to-collect-samples-attacked-in-indore/videoshow/74942153.cms (accessed February 4, 2022).

32. Dapaa E. *Stop Stigmatizing Suspected COVID-19 Patients – Eastern Regional Directorate of the Ghana Health Service*. (2020). Available online at: https://citinewsroom.coma (accessed February 11, 2022).

33. Jiang T, Zhou X, Lin L, Pan Y, Zhong Y, Wang X, et al. COVID-19-related stigma and its influencing factors: a nationwide cross-sectional study during the early stage of the pandemic in China. *BMJ Open.* (2021) 11:e048983. doi: 10.1136/bmjopen-2021-048983

34. The Kathmandu Post. 2020. *Stigma Against Health Workers, Patients and Area Locals Continues in COVID-19 Hotspots*. (2020). Available online at: https://kathmandupost.com/national/2020/05/01/stigma-against-health-

workers-patients-and-area-locals-continues-in-covid-19-hotspots (accessed February 11, 2022).

35. Lee S, Chan LY, Chau AM, Kwok KP, Kleinman A. The experience of SARS-related stigma at Amoy Gardens. *Soc Sci Med*. (2005) 61:2038–46. doi: 10.1016/j.socscimed.2005.04.010

36. Des Jarlais DC, Galea S, Tracy M, Tross S, Vlahov D. Stigmatization of newly emerging infectious diseases: AIDS and SARS. *Am J Public Health*. (2006) 96:561–7. doi: 10.2105/AJPH.2004.054742

37. Alhadidi M, Abdullah KL, Tang LY, Danaee M, Al Hadid LAR. Knowledge about schizophrenia, insight into illness, and internalized stigma and their associated factors among people diagnosed with schizophrenia in a long-term care facility. *Persp Psychiatric Care*. (2021) 57:225–34. doi: 10.1111/ppc.12553

38. Saine ME, Szymczak JE, Moore TM, Bamford LP, Barg FK, Forde KA, et al. The impact of disease-related knowledge on perceptions of stigma among patients with Hepatitis C Virus (HCV) infection. *PLoS ONE*. (2021) 16:e0258143. doi: 10.1371/journal.pone.0258143

39. Zhang TM, Fang Q, Yao H, Ran MS. Public stigma of COVID-19 and its correlates in the general population of China. *Int J Environ Res Public Health*. (2021) 18:11718. doi: 10.3390/ijerph182111718

40. Lamptey E, Serwaa D, Antwi MH, Ikome MT, Odogwu N. A comparative analysis of the knowledge and stigmatizing attitude of Ghanaians and Nigerians towards COVID-19 survivors. *J Refugee Glob Health*. (2021) 4:1. doi: 10.18297/rgh/vol4/iss1/1

41. Lau JT, Yang X, Wong E, Tsui HY. Prevalence and factors associated with social avoidance of recovered SARS patients in the Hong Kong general population. *Health Educ Res*. (2006) 21:662–73. doi: 10.1093/her/cyl064

42. Grivel MM, Lieff SA, Meltzer GY, Chang VW, Yang LH, Des Jarlais DC. Sociodemographic and behavioral factors associated with COVID-19 stigmatizing attitudes in the U.S. *Stigma Health*. (2021) 6:371–9. doi: 10.1037/sah0000345

43. Singh R, Subedi M. COVID-19 and stigma: Social discrimination towards frontline healthcare providers and COVID-19 recovered patients in Nepal. *Asian J Psychiatry*. (2020) 53:102222. doi: 10.1016/j.ajp.2020.102222

44. Jin JM, Bai P, He W, Wu F, Liu XF, Han DM, et al. Gender differences in patients with COVID-19: focus on severity and mortality. *Front Public Health*. (2020) 8:152. doi: 10.3389/fpubh.2020.00152

45. Abdelhafiz AS, Mohammed Z, Ibrahim ME, Ziady HH, Alorabi M, Ayyad M, et al. Knowledge, perceptions, and attitude of Egyptians towards the novel Coronavirus Disease (COVID-19). *J Community Health*. (2020) 45:881–90. doi: 10.1007/s10900-020-00827-7

46. Chellan R, Charles B, Nanjan G, Periyathambi R. Perceived stigma and discrimination towards people living with HIV/AIDS among young people in Tamil Nadu, India. *Int J Curr Res*. (2011) 3:186–94.

47. Sagili KD, Satyanarayana S, Chadha SS. Is knowledge regarding tuberculosis associated with stigmatising and discriminating attitudes of general population towards tuberculosis patients? Findings from a community based survey in 30 Districts of India. *PLoS ONE*. (2016) 11:e0147274. doi: 10.1371/journal.pone.0147274

48. Haddad C, Bou Malhab S, Malaeb D, Sacre H, Saadeh D, Mourtada V, et al. Stigma toward people with COVID-19 among the Lebanese population: a cross-sectional study of correlates and mediating effects. *BMC Psychol*. (2021) 9:1–15. doi: 10.1186/s40359-021-00646-y

49. Tewari S. *Govt launches #Breakthestigma campaign with Amitabh Bachchan for COVID survivors*. (2020). Available online at: https://www.livemint.com/industry/media/govt-launches-breakthestigma-campaign-with-amitabh-bachchan-for-covid-survivors-11589274819182.html (accessed November 11, 2021).

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 14 October 2022
DOI 10.3389/fpubh.2022.981649

OPEN ACCESS

EDITED BY
Pier Luigi Sacco,
University of Studies G. d'Annunzio Chieti and Pescara, Italy

REVIEWED BY
Hua You,
Nanjing Medical University, China
Xuewei Chen,
Oklahoma State University, United States

*CORRESPONDENCE
Chichen Zhang
zhangchichen@sina.com
Yuxi Liu
yuxiliu123@126.com

†These authors have contributed equally to this work

SPECIALTY SECTION
This article was submitted to Infectious Diseases - Surveillance, Prevention and Treatment, a section of the journal Frontiers in Public Health

RECEIVED 29 June 2022
ACCEPTED 23 September 2022
PUBLISHED 14 October 2022

CITATION
Xue B, Wu Y, Zheng X, Xue Y, Dong F, Xiao S, Yin M, Wang M, Liu Y and Zhang C (2022) Effects of information sources on public preventive behaviors in health emergencies: Evidence from a digital epidemiologic study during the COVID-19 pandemic. *Front. Public Health* 10:981649. doi: 10.3389/fpubh.2022.981649

Effects of information sources on public preventive behaviors in health emergencies: Evidence from a digital epidemiologic study during the COVID-19 pandemic

Benli Xue[1†], Yibo Wu[2†], Xiao Zheng[1,3†], Yaqing Xue[1,4], Fang Dong[1], Shujuan Xiao[1,4], Mei Yin[5], Mingxu Wang[6,7], Yuxi Liu[8*] and Chichen Zhang[1,3,9*]

[1]School of Health Management, Southern Medical University, Guangzhou, China, [2]School of Public Health, Peking University, Beijing, China, [3]Department of Health Management, Shunde Hospital, Southern Medical University (The First People's Hospital of Shunde, Foshan), Guangdong, China, [4]School of Public Health, Southern Medical University, Guangzhou, China, [5]School of Humanities and Social Sciences, Harbin Medical University, Harbin, China, [6]School of Public Health, Xi'an Jiaotong University Health Science Center, Xi'an, China, [7]Health Culture Research Center of Shaanxi, Xi'an, China, [8]School of Humanities and Management, Guangdong Medical University, Dongguan, China, [9]Department of Health Management, Nanfang Hospital, Southern Medical University, Guangzhou, China

Introduction: It has been approved that information sources would affect public behaviors. However, due to the outbreak of COVID-19, this influence was enhanced and showed a distinctive pattern among different populations, which has been less noticed before. We aimed to investigate the potential roles of different information sources in COVID-19 preventive behaviors of different publics.

Methods: A cross-sectional online survey with 11,190 participants from 33 province-level regions in China was conducted during the COVID-19 pandemic. Sociodemographic characteristics, COVID-19 preventive behaviors, and information sources for COVID-19-related information were assessed. A mixed linear model was used to analyze risk factors of COVID-19 preventive behaviors. The effects of different information sources on COVID-19 prevention behaviors of different publics were analyzed.

Results: Generally, the Chinese public had good COVID-19 preventive behaviors, and the top three COVID-19 preventive behaviors with the higher action rate were avoiding eat bushmeat (76.1%), a healthy diet (74.8%), and avoiding contact with people with symptoms of respiratory diseases (73.0%). About information sources, 12320 telephone (National Public Health Hotline) (−0.62, 95% CI: −0.94 to −0.31) and acquaintances consulting (−1.00, 95% CI: −1.31 to −0.69) were negatively associated with COVID-19 preventive behaviors, while internet resources, family doctors, hospitals, and community health centers

were positively associated with COVID-19 preventive behaviors (1.00 vs. 0.47 vs. 0.46 vs. 0.33, $P < 0.05$). For older adults, accessing to COVID-19-related information through family doctors and community health centers were positively associated with COVID-19 preventive behaviors. For the non-educated, family doctors and community health centers had positive effects on their COVID-19 preventive behaviors. Family doctors and internet resources were positively associated with COVID-19 preventive behaviors among those earning 5,000 yuans and above. The effects of family doctors, hospitals, and internet resources were higher for COVID-19 preventive behaviors of urban publics than for rural publics. Finally, the effect of internet resources on COVID-19 preventive behaviors of females was lower than males.

Conclusions: Obtaining COVID-19-related information through internet resources had the most significant effect on COVID-19 preventive behaviors, but was not significant among publics with old age, low education, low income, and living in rural area.

KEYWORDS

COVID-19, preventive behaviors, information sources, internet resources, public health

Introduction

COVID-19 is a new infectious disease with a strong transmission ability and has caused hundreds of millions of infections worldwide. The World Health Organization (WHO) has declared COVID-19 as a public health emergency of international concern, and WHO Information Network for Epidemics was launched to address the vast amounts of information being disseminated (1, 2). The COVID-19 pandemic requires large-scale behavior change to control virus spreading (3). The government issued COVID-19 preventive behavioral guidelines to the public, including wear masks, wash hands frequently, not agglomerate, and others (4). Despite the efforts of the government and related agencies, there are still some people who do not take protective behaviors against COVID-19.

Scientific information and knowledge are important to improve COVID-19 preventive behaviors for public. It is essential to help the public learn more about COVID-19 as soon as possible (5). During the COVID-19 pandemic, obtaining credible information from trusted information sources are helpful to reduce the public fear and stress when facing COVID-19 and stop the spread of rumors (6). Currently, there are numerous information for the public, and some of them are not scientific, misinformation about COVID-19 is a major threat to public health (7). For example, social media can be a vehicle to disseminate erroneous, alarmists, and exaggerated information (8). And the dissemination of these misinformation can affect public COVID-19 preventive behaviors, which can lead to an increased risk of infection (9).

Social media such as internet and WeChat are the main sources to obtain COVID-19-related information in China, whereas health professionals, academic institutions, and governments were trusted sources of information (10, 11). Several studies indicated that different information sources had different effects on public psychological health regarding COVID-19. People who obtained COVID-19-related information through the internet, traditional media, and friends presented a higher current worry (12), while receiving information from medical staff was positively related with psychological wellbeing (13). However, the existing studies mainly focused on the effect of information sources on public psychology and risk perception, while their effects on public COVID-19 prevention behaviors also deserves to be studied (14, 15). Meanwhile, different publics often have different primary information sources. For example, females and higher income groups are more likely to select doctors or healthcare providers as their first source of health information than males and lower-income groups (16). Younger people prefer to obtain information through the internet, while older people prefer to use traditional media (12). Therefore, there may be differences in the effects of different information sources on COVID-19 prevention behaviors of different publics.

We conducted a nationwide network survey among Chinese citizens to evaluate the influence of different information sources on COVID-19 preventive behaviors, and to identify differences between publics. We hypothesized that information sources would have the effects on COVID-19 preventive behaviors and

there would be differences across different publics. The results can help governments and related agencies to provide more scientific and accurate COVID-19-related information for different publics, which will improve public COVID-19 preventive behaviors and reduce the risk of COVID-19 infection.

Materials and methods

Study design and participants

We conducted a nationwide network survey among Chinese citizens from January 30, 2020 to February 20, 2020. We recruited university students as investigators from around the country, ensuring 1–3 investigators for each province-level region. Students from Taiwan Province were not recruited. All investigators were trained uniformly through the internet. Owing to the impact of the closed-off management, the communities where the investigators live were used as the investigation sites. The investigators randomly selected families in the community and, with the people's informed consent, sent the electronic questionnaires to these families through an online survey platform (SurveyStar: Changsha Ranxing Science and Technology). Members of the selected family who were 16 years and above, without cognitive impairment, without serious mental illness, and voluntarily participated in the survey could answer the questionnaire. For people who do not use electronic questionnaire, they could complete questionnaire with the help of other family members, or have the investigator complete the survey on them over the telephone. In order to ensure the quality of the questionnaire, investigators would check questionnaires at the end of the day's survey, and would confirm and verify unclear or incomplete answers by contacting participants. A total of 11,190 participants from 33 province-level regions (except Taiwan Province) were involved in this study. Regarding the participants, the age ranged from 16 to 67 years. 6,697 were females and 4,493 were males, 7,294 lived in urban area and 3,896 lived in rural area.

Province-level regions were categorized into different risk levels based on the number of COVID-19 confirmed cases on February 12, 2020, obtained from the National Health Commission of the People's Republic of China (17). Hubei Province was assessed as high-risk area (level-1). In addition, the number of confirmed cases in other provincial-level regions were ranked from largest to smallest, and the data were divided into 3 levels according to the method of quartile. The results showed that level-1 risk area including Hubei Province, level-2 risk area including 6 province-level regions, level-3 risk area including 17 province-level regions, and level-4 risk area including 10 province-level regions.

Measures

COVID-19 preventive behaviors

In this survey we included 10 COVID-19 preventive behaviors, including (1) Wearing protective masks; (2) Covering your mouth and nose with a tissue when coughing or sneezing; (3) Washing hands carefully; (4) Indoor ventilation; (5) A healthy diet; (6) Avoiding eat bushmeat; (7) Health surveillance; (8) Avoiding contact with people with symptoms of respiratory diseases; (9) Avoiding crowds; (10) Avoiding visit their relatives and friends. For each behavior, participants were asked "which stage is your behavior?". There were five stages can be selected, including pre-intention (I do not plan to take this behavior), interruption (I carried out this behavior, but now I stop), intention (I realized the importance of this behavior), planning (I have the plan of taking this behavior), and action (I carry out this behavior). The five stages were recorded as 0, 1, 2, 3, and 4 points, respectively. COVID-19 preventive behaviors scores ranged from 0 to 40, with higher scores indicating better COVID-19 preventive behaviors. Cronbach's α for this section was 0.958.

Information sources

The question "During the COVID-19 pandemic, when you encounter health problems or need health information, how do you get help? (You should choose any that apply)" was used to collect information sources of participants. Answers including: (1) 12320 telephone (National Public Health Hotline); (2) Acquaintances consulting; (3) Family doctors; (4) Hospitals; (5) Community health centers; (6) Internet resources (including social media, internet diagnosis and treatment platforms).

Covariates

Several sociodemographic characteristics were collected, including sex (female, male), age (25 and below, 26–40, 41–50, 51–60, 60 above), residence (rural, urban), income (no income, 1,000 below, 1,000–2,999, 3,000–4,999, 5,000 and above), education (non-educated, primary education, secondary education, higher education, and graduate education), smoke (non-smoker, current and former smoker), and drink (non-drinker, current and former drinker).

Statistical analysis

Continuous variables were described as means ± standard deviations. Categorical variables were summarized as the counts and percentages in each category. The X^2-test was used for categorical variables. A mixed linear model was used to analyze risk factors of COVID-19 preventive behaviors. Provincial units were used as clustering units to account for a within-clustering

correlation attributable to the complex sample. Candidate related factors included sex, age, residence, income, education, smoke, and drink. All analyses were weighted by the distribution of sex and age ranked on a national survey (The Sixth National Census). The effects of different information sources on COVID-19 preventive behaviors of different publics were analyzed. The mean difference along with the 95% confidence interval were reported. The significant level was set up $P < 0.05$. All analyses were conducted with SPSS 24.0.

Results

Adoption of COVID-19 preventive behaviors

For the 10 COVID-19 preventive behaviors evaluated, the top three of them with the higher action rates were avoiding eat bushmeat (76.1%), a healthy diet (74.8%), and avoiding contact with people with symptoms of respiratory diseases (73.0%) (Table 1). The publics who were female, aged 26–40, lived in urban area, earned 5,000 yuans and above, had graduate education, and were non-smokers and non-drinkers had higher action rates on COVID-19 preventive behaviors. The adoption of four COVID-19 preventive behaviors (health surveillance, avoiding contact with people with symptoms of respiratory diseases, avoiding crowds, and avoiding visit their relatives and friends) had significant differences in different COVID-19 risk areas ($P < 0.05$) (Appendix).

Risk factors for COVID-19 preventive behaviors

Figure 1 presents the COVID-19 preventive behaviors scores of different publics and the effects of different factors for COVID-19 preventive behaviors. The COVID-19 risk in different province-level regions was the random effect that varied across provincial units. The Intra-Class Correction (ICC) of the model was 0.027. The results showed that older adults had the lowest scores. Compared to those with graduate education, those with non-educated (−5.77, 95%CI: −6.63 to −4.90) presented the lowest scores. Those who had no income (−1.90, 95% CI: −2.31 to −1.48) and earned below 1,000 yuans (−0.84, 95% CI: −1.34 to −0.34) showed lower scores than others. Urban publics (1.37, 95%CI: 1.10–1.64) had higher scores than rural one. Males (−1.38, 95% CI: −1.64 to −1.12) scored lower than females. The scores of current and former smokers (−0.90, 95%CI: −1.29 to −0.51) was lower than non-smokers. The public that lived in the area with higher COVID-19 risk presented higher scores (level-1, 36.24 > level-3, 34.84 > level-2, 34.79 > level-4, 34.13).

The association between information sources and COVID-19 preventive behaviors

Among the six information sources, internet resources, family doctors, hospitals, and community health centers were positively associated with COVID-19 preventive behaviors (1.00 vs. 0.47 vs. 0.46 vs. 0.33, $P < 0.05$) (Figure 1). Table 2 presents the effects of them on COVID-19 preventive behaviors of different publics. For older adults, accessing to COVID-19-related information through family doctors (1.38, 95% CI: 0.63–2.12) and community health centers (1.22, 95% CI: 0.48–1.97) was positively associated with COVID-19 preventive behaviors. For the non-educated, family doctors (6.08, 95% CI: 4.71–7.45) and community health centers (3.69, 95% CI: 2.32–5.05) had positive effects on their COVID-19 preventive behaviors, except for internet resources and hospitals. Family doctors (0.72, 95% CI: 0.29–1.15) and internet resources (0.97, 95% CI: 0.51–1.42) were positively associated with COVID-19 preventive behaviors among those earning 5,000 yuans and above. The effects of family doctors (0.36, 95% CI: 0.07–0.65), hospitals (0.43, 95% CI: 0.13–0.73), and internet resources (0.92, 95% CI: 0.60–1.23) on COVID-19 preventive behaviors of urban publics were higher than rural publics. The effect of internet resources (0.43, 95% CI: 0.09–0.77) on female COVID-19 preventive behaviors was lower than on male. These four information sources had positive association with COVID-19 preventive behaviors in all areas, except for family doctors in level-4 risk area (−0.98, 95% CI: −1.81 to −0.14).

Discussion

This study found that the Chinese public generally had good COVID-19 preventive behaviors, mean COVID-19 preventive behaviors score was 34.82 (total score: 40). Action rates for all COVID-19 preventive behaviors were above or near 70%. The top three COVID-19 preventive behaviors with the higher action rate were avoiding eat bushmeat (76.1%), a healthy diet (74.8%), and avoiding contact with people with symptoms of respiratory diseases (73.0%). This indicated that the Chinese public had a comprehensive understanding of the infection sources, pathogenesis and virulence of the virus, transmissibility, and risk factors for infection and disease progression of COVID-19. In addition, we found that publics with old age, low education, low income, living in rural area, male, current and former smoker presented worse COVID-19 preventive behaviors. Therefore, more attention should be paid to the COVID-19 preventive behaviors of these publics to reduce their risk of COVID-19 infection. To information sources, internet resources had the most significant effect on COVID-19 preventive behaviors, while each information source presented different effect on COVID-19 preventive behaviors of different publics.

10.3389/fpubh.2022.981649

TABLE 1 COVID-19 preventive behaviors by stages.

Behaviors	Behavior stages [*N* (%)]				
	Pre-intention	Interruption	Intention	Planning	Action
1. Wearing protective masks	165 (1.5%)	351 (3.1%)	1,501 (13.4%)	1,375 (12.3%)	7,798 (69.7%)
2. Covering your mouth and nose with a tissue when coughing or sneezing	126 (1.1%)	277 (2.5%)	1,625 (14.5%)	1,355 (12.1%)	7,807 (69.8%)
3. Washing hands carefully	112 (1.0%)	323 (2.9%)	1,459 (13.0%)	1,400 (12.5%)	7,896 (70.6%)
4. Indoor ventilation	107 (1.0%)	305 (2.7%)	1,468 (3.1%)	1,357 (12.1%)	7,953 (71.1%)
5. A healthy diet	94 (0.8%)	187 (1.7%)	1,348 (12.0%)	1,192 (10.7%)	8,369 (74.8%)
6. Avoiding eat bushmeat	143 (1.3%)	161 (1.4%)	1,276 (11.4%)	1,097 (9.8%)	8,513 (76.1%)
7. Health surveillance	97 (0.9%)	238 (2.1%)	1,456 (13.0%)	1,491 (13.3%)	7,908 (70.7%)
8. Avoiding contact with people with symptoms of respiratory diseases	84 (0.8%)	216 (1.9%)	1,356 (12.1%)	1,363 (12.2%)	8,171 (73.0%)
9. Avoiding crowds	90 (0.8%)	325 (2.9%)	1,340 (12.0%)	1,339 (12.0%)	8,096 (72.3%)
10. Avoiding visit their relatives and friends	96 (0.8%)	273 (2.4%)	1,361 (12.2%)	1,362 (12.2%)	8,098 (72.4%)

We analyzed the association between information sources and COVID-19 preventive behaviors. We found that obtaining COVID-19-related information through internet resources had the most significant effect on COVID-19 preventive behaviors. The internet has advantages such as timely information release, wide coverage, and fast dissemination (18, 19). In response to public health emergencies, like the outbreak of COVID-19, the government can release related information, collect public opinion and reaction, and deal with rumors in a timely manner through internet (20). At the same time, the public could be advocated and guided to take good protective measures by releasing information through internet, for example, a variety of COVID-19-related knowledge and guidelines for public were issued by the National Health Commission of the People's Republic of China and Chinese Center for Disease Control and Prevention through their official websites, microblogs, WeChat, and other social media. This provided the possibility to take preventive behaviors for public. Due to the large number of medical personnel from across the country traveling to help Hubei Province during the COVID-19 pandemic, some areas experienced weakened medical services and public basic medical needs could not be met in a timely manner (21). At the same time, the public was inconvenient to go to hospitals for medical services due to the closed-off management. Therefore, the public turned to internet diagnosis and treatment platforms to obtain health services, such as Ali Health, Ping An Good Doctor, and other internet hospitals. Besides providing basic medical services to the public, internet diagnosis and treatment platforms also have functions such as COVID-19-related information release, symptom diagnosis, psychology health assessment, dispelling rumors, and purchase of epidemic prevention supplies during the COVID-19 pandemic (22). These internet diagnosis and treatment platforms could provide professional information for the public.

However, we did not analyze the relationship between different types and contents of information from internet resources and COVID-19 preventive behaviors in this study. Therefore, we could not understand the impact of professional and unprofessional information on COVID-19 preventive behaviors. Some misinformation may exist on the internet and the public lack sufficient ability to discern the information accuracy, leading to inappropriate COVID-19 preventive behaviors, such as panic shopping, buying medical supplies or drugs, and taking drugs without a medical prescription (23). But it is undeniable that in the face of public health emergencies, governments, medical experts, and other authoritative institutions or individuals can release COVID-19-related information to the public, disclose policy measures, and carry out health promotion and education through the internet promptly. The public can also take the initiative to obtain the needed health knowledge through a series of internet platforms to raise preventive awareness and related preventive behaviors.

While accessing COVID-19-related information through internet resources is an important way to improve public COVID-19 preventive behaviors, we further found that it is not effective for all members of the public. Accessing COVID-19-related information through family doctors and community health centers can improve COVID-19 preventive behaviors of older adults, rather than internet resources. This can be related to the fact that older adults prefer to obtain information through traditional media (12). Wang et al. also found that older adults more like to obtain health information from radio instead of internet (24). Additionally, it has also been found that older adults were skeptical for information released

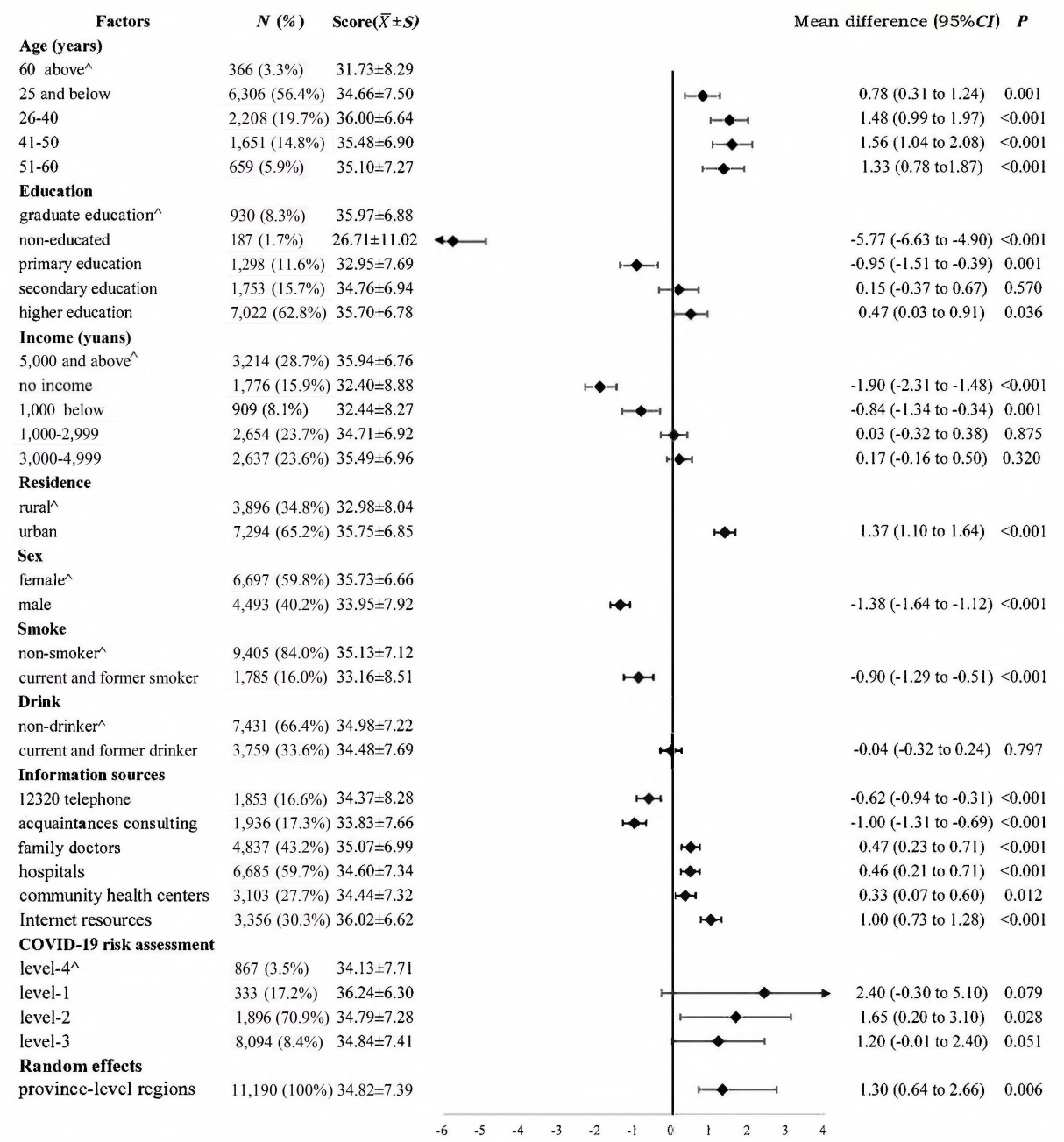


FIGURE 1
Risk factors for COVID-19 preventive behaviors.

through the internet (25), which also affected them access to COVID-19-related information through the internet resources. In this study, we found that the public with higher income and higher education had better COVID-19 preventive behaviors and obtaining COVID-19-related information through internet resources did not have positive effect on improving COVID-19 preventive behaviors in low income and low education publics. Incomes and education were associated with people's healthy behaviors (26, 27). The low income and low education public tend to have lower socioeconomic status, the low socioeconomic status group is more likely to ignore health promotion behavior (28). Guo et al. found that education and income were positively associated with seeking of web-based information on COVID-19 (29). The low income and low education public may

TABLE 2 The association between different information sources and COVID-19 preventive behaviors of different publics.

Factors	Information sources [Mean difference (95%CI)]			
	Family doctors	Hospitals	Community health centers	Internet resources
Age (years)				
25 and below	0.50 (0.15 to 0.85)[b]	0.69 (0.32 to 1.05)[b]	0.40 (0.02 to 0.78)[a]	0.82 (0.45 to 1.20)[b]
26–40	0.07 (−0.43 to 0.57)	−0.22 (−0.72 to 0.28)	−0.26 (−0.84 to 0.33)	0.96 (0.40 to 1.48)[b]
41–50	0.01 (−0.66 to 0.69)	−0.29 (−0.96 to 0.38)	−0.44 (−1.21 to 0.34)	1.34 (0.58 to 2.10)[b]
51–60	−1.16 (−2.2 to −0.71)[b]	−0.15 (−0.91 to 0.60)	0.30 (−0.52 to 1.11)	0.13 (−0.76 to 1.02)
60 above	1.38 (0.63 to 2.12)[b]	−0.50 (−1.30 to 0.30)	1.22 (0.48 to 1.97)[b]	−0.77 (−1.84 to 0.30)
Education				
Non-educated	6.08 (4.71 to 7.45)[b]	1.16 (−0.25 to 2.56)	3.69 (2.32 to 5.05)[b]	−1.90 (−4.30 to 0.50)
Primary education	0.39 (−0.25 to 1.03)	0.07 (−0.59 to 0.73)	0.73 (0.09 to 1.37)[a]	0.25 (−0.58 to 1.08)
Secondary education	−0.45 (−1.06 to 0.16)	0.08 (−0.54 to 0.70)	−0.08 (−0.73 to 0.56)	1.69 (0.98 to 2.41)[b]
Higher education	−0.06 (−0.37 to 0.24)	0.17 (−0.15 to 0.48)	0.80 (−0.26 to 0.42)	0.66 (0.34 to 0.97)[b]
Graduate education	1.32 (0.53 to 2.12)[b]	0.04 (−0.76 to 0.83)	−0.25 (−1.27 to 0.77)	1.03 (0.22 to 1.83)[b]
Income (yuans)				
No income	0.51 (−0.17 to 1.14)	1.03 (0.39 to 1.68)[b]	0.89 (0.23 to 1.56)[b]	0.74 (0.05 to 1.44)[a]
1,000 below	0.87 (0.04 to 1.70)[a]	0.02 (−0.84 to 0.87)	0.09 (−0.73 to 0.92)	0.18 (−0.81 to 1.16)
1,000–2,999	−0.57 (−1.06 to −0.09)[a]	−0.19 (−0.69 to 0.31)	−0.04 (−0.55 to 0.48)	0.69 (0.14 to 1.23)[a]
3,000–4,999	0.08 (−0.40 to 0.56)	0.41 (−0.08 to 0.90)	0.16 (−0.37 to 0.70)	0.75 (0.23 to 1.28)[b]
5,000 and above	0.72 (0.29 to 1.15)[b]	−0.14 (−0.57 to 0.29)	0.36 (−0.15 to 0.86)	0.97 (0.51 to 1.42)[b]
Residence				
Rural	0.02 (−0.38 to 0.42)	−0.37 (−0.79 to 0.04)	0.51 (0.10 to 0.92)[a]	0.45 (−0.02 to 0.91)
Urban	0.36 (0.07 to 0.65)[a]	0.43 (0.13 to 0.73)[b]	0.11 (−0.23 to 0.44)	0.92 (0.60 to 1.23)[b]
Sex				
Female	0.31 (0.00 to 0.63)	0.02 (−0.30 to 0.34)	0.08 (−0.27 to 0.43)	0.43 (0.09 to 0.77)[a]
Male	0.16 (−0.20 to 0.51)	0.34 (−0.03 to 0.70)	0.49 (0.11 to 0.88)[a]	1.25 (0.85 to 1.66)[b]
COVID-19 risk assessment				
Level-1	1.87 (0.81 to 2.93)[b]	2.54 (1.39 to 3.69)[b]	2.86 (1.63 to 4.08)[b]	3.18 (2.01 to 4.35)[b]
Level-2	0.99 (0.31 to 1.67)[b]	2.09 (1.34 to 2.83)[b]	1.67 (0.95 to 2.39)[b]	1.51 (0.79 to 2.23)[b]
Level-3	0.79 (0.22 to 1.37)[b]	2.37 (1.69 to 3.04)[b]	1.52 (0.93 to 2.09)[b]	1.92 (1.37 to 2.48)[b]
Level-4	−0.98 (−1.81 to −0.14)[a]	2.08 (1.24 to 2.92)[b]	1.24 (0.36 to 2.11)[b]	1.02 (0.11 to 1.93)[a]

Interaction terms and random coefficients. All other fixed effects remain similarly to Figure 1. The model controls for sex, age, residence, income, education, smoke, and drink.
[a] $P < 0.05$.
[b] $P < 0.01$.

lack the ability and effective way to access COVID-19-related information through internet, and have difficulty learning related knowledge and identifying misinformation on internet. Internet resources also did not improve COVID-19 preventive behaviors of rural public. There is a digital divide between urban and rural areas (30). Compared to the urban public, the rural public is less likely to access information through internet. The income and education levels of rural public are generally lower than urban public, and the network construction in rural area is relatively poor than urban area, especially in remote area. These factors are not conducive to the rural public to obtain COVID-19-related information through internet resources to improve their COVID-19 preventive behaviors. In addition, we found that females had better COVID-19 preventive behaviors than males. This may be related to the fact that females have better lifestyles and more health literacy than males (31). However, internet resources had a more significant effect on COVID-19 prevention behaviors in males. Compared with females, males could be paying more attention to health-related information during the COVID-19 pandemic than before, leading to a significant improvement in their healthy behaviors.

Limitations

Our findings should be considered with several limitations. Firstly, we performed a cross-sectional survey, which makes it impossible to build causal relationships between variables. Secondly, owing to the impact of closed-off management, data

were collected online. Although we helped people who do not use electronic questionnaires by performing a telephone survey and matched the age and the sex of our sample to the national population, the generalizability of our sample may still be a limitation. Finally, we mainly focused on whether participants obtained information through internet resources, while other variables related to internet resources, such as the type and content of the information obtained, were not be considered. The same situation existed for other information sources, so we cannot know the quality of the information provided by each information source. Future studies should incorporate more comprehensive variables to further analyze the association between information sources and COVID-19 preventive behaviors.

Conclusion

Internet resources had an important and positive role in improving COVID-19 preventive behaviors, and governments and related agencies should timely provide COVID-19-related information on internet. However, it is important to focus on publics with old age, low education, low income, and living in rural area who have difficulty obtaining COVID-19-related information through internet resources to improve their behaviors. Therefore, in addition to internet resources, traditional offline health promotion and education should be conducted through hospitals, community health centers, and other professional institutions and personnel. This would ensure these publics can access scientifically and valid information, and improve their COVID-19 preventive behaviors and reduce the risk of COVID-19 infection.

Data availability statement

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

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

YW and CZ conceived and designed the study. MY, MW, and YL provided valuable advice and guidance for this study. BX, XZ, YX, FD, and SX cleaned data. BX, XZ, and YX conducted a statistical analysis of the data. BX, YW, XZ, and YL drafted and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding

This work was supported by the Directive Project of Medical Scientific Research Foundation in Guangdong (Grant Number: C2020062); Special Research Project of Prevention and Control during COVID-19 Epidemic in Universities of Guangdong (Grant Number: 2020KZDZX1046); Guangdong Basic and Applied Basic Research Foundation (Grant Number: 2022A1515011591); Discipline Construction Project of Guangdong Medical University (Grant Number: 4SG22265G); and Key Laboratory Development Project for Philosophy and Social Sciences in Guangdong (Grant Number: G620369695).

Acknowledgments

The authors would like to thank the investigators and participants for supporting this study. This work would not have been possible without them.

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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.981649/full#supplementary-material

References

1. Zarocostas J. How to fight an infodemic. *Lancet*. (2020) 395:10225. doi: 10.1016/S0140-6736(20)30461-X

2. The Lancet Infectious Diseases. The COVID-19 infodemic. *Lancet Infect Dis*. (2020) 20:875. doi: 10.1016/S1473-3099(20)30565-X

3. Bavel JJV, Baicker K, Boggio PS, Capraro V, Cichocka A, Cikara M, et al. Using social and behavioural science to support COVID-19 pandemic response. *Nat Hum Behav*. (2020) 4:460–71. doi: 10.1038/s41562-020-0884-z

4. National Health Commission of the People's Republic of China. *Notice on the Issuance of Guidelines for the Protection of People at Different Risks of Novel Coronavirus Infection and Guidelines for the Use of Pneumonia Masks for the Prevention of Novel Coronavirus Infection*. (2020). Available online at: http://www.nhc.gov.cn/jkj/s7916/202001/a3a261dabfcf4c3fa365d4eb07ddab34.shtml (accessed January 12, 2021).

5. Zhao Y, Cheng S, Yu X, Xu H. Chinese public's attention to the COVID-19 epidemic on social media: observational descriptive study. *J Med Internet Res*. (2020) 22:e18825. doi: 10.2196/18825

6. Garfin DR, Silver RC, Holman EA. The novel coronavirus (COVID-2019) outbreak: amplification of public health consequences by media exposure. *Health Psychol*. (2020) 39:355–7. doi: 10.1037/hea0000875

7. Roozenbeek J, Schneider CR, Dryhurst S, Kerr J, Freeman ALJ, Recchia G, et al. Susceptibility to misinformation about COVID-19 around the world. *R Soc Open Sci*. (2020) 7:201199. doi: 10.1098/rsos.201199

8. Gonzalez-Padilla DA, Tortolero-Blanco L. Social media influence in the COVID-19 Pandemic. *Int Braz J Urol*. (2020) 46(Suppl. 1):120–4. doi: 10.1590/s1677-5538.ibju.2020.s121

9. Nsoesie EO, Cesare N, Muller M, Ozonoff A. COVID-19 misinformation spread in eight countries: exponential growth modeling study. *J Med Internet Res*. (2020) 22:e24425. doi: 10.2196/24425

10. Zhong Y, Liu W, Lee TY, Zhao H, Ji J. Risk perception, knowledge, information sources and emotional states among COVID-19 patients in Wuhan, China. *Nurs Outlook*. (2020) 69:13–21. doi: 10.1016/j.outlook.2020.08.005

11. Lu L, Liu J, Yuan YC, Burns KS, Lu E, Li D. Source trust and COVID-19 information sharing: the mediating roles of emotions and beliefs about sharing. *Health Educ Behav*. (2020) 48:132–9. doi: 10.1177/1090198120984760

12. Ho HY, Chen YL, Yen CF. Different impacts of COVID-19-related information sources on public worry: an online survey through social media. *Internet Interv*. (2020) 22:100350. doi: 10.1016/j.invent.2020.100350

13. Ko NY, Lu WH, Chen YL, Li DJ, Wang PW, Hsu ST, et al. COVID-19-related information sources and psychological well-being: an online survey study in Taiwan. *Brain Behav Immun*. (2020) 87:153–4. doi: 10.1016/j.bbi.2020.05.019

14. Campbell K, Weingart R, Ashta J, Cronin T, Gazmararian J. COVID-19 knowledge and behavior change among high school students in semi-rural Georgia. *J Sch Health*. (2021) 91:526–34. doi: 10.1111/josh.13029

15. Li X, Liu Q. Social media use, ehealth literacy, disease knowledge, and preventive behaviors in the COVID-19 pandemic: cross-sectional study on Chinese netizens. *J Med Internet Res*. (2020) 22:e19684. doi: 10.2196/19684

16. Swoboda CM, Van Hulle JM, McAlearney AS, Huerta TR. Odds of talking to healthcare providers as the initial source of healthcare information: updated cross-sectional results from the Health Information National Trends Survey (HINTS). *BMC Fam Pract*. (2018) 19:146. doi: 10.1186/s12875-018-0805-7

17. National Health Commission of the People's Republic of China. *Update on the New Coronavirus Pneumonia Outbreak as of 24:00 on February 12*. (2020). Available online at: http://www.nhc.gov.cn/xcs/yqtb/202002/26fb16805f024382bff1de80c918368f.shtml (accessed January 14, 2021).

18. Kittler AF, Hobbs J, Volk LA, Kreps GL, Bates DW. The Internet as a vehicle to communicate health information during a public health emergency: a survey analysis involving the anthrax scare of 2001. *J Med Internet Res*. (2004) 6:e8. doi: 10.2196/jmir.6.1.e8

19. Eysenbach G. Infodemiology and infoveillance: framework for an emerging set of public health informatics methods to analyze search, communication and publication behavior on the Internet. *J Med Internet Res*. (2009) 11:e11. doi: 10.2196/jmir.1157

20. Gu H, Chen B, Zhu H, Jiang T, Wang X, Chen L, et al. Importance of Internet surveillance in public health emergency control and prevention: evidence from a digital epidemiologic study during avian influenza A H7N9 outbreaks. *J Med Internet Res*. (2014) 16:e20. doi: 10.2196/jmir.2911

21. National Health Commission of the People's Republic of China. *Notice from the General Office of the National Health Commission on Strengthening the Management of Medical Services during the Epidemic to Meet the Basic Medical Needs of the Public*. (2020). Available online at: http://www.nhc.gov.cn/yzygj/s7659/202002/6d5a8556c5ce46368263711698d8237a.shtml (accessed January 20, 2021).

22. He D, Gu Y, Shi Y, Wang M, Lou Z, Jin C. COVID-19 in China: the role and activities of Internet-based healthcare platforms. *Glob Health Med*. (2020) 2:89–95. doi: 10.35772/ghm.2020.01017

23. Cuan-Baltazar JY, Munoz-Perez MJ, Robledo-Vega C, Perez-Zepeda MF, Soto-Vega E. Misinformation of COVID-19 on the internet: infodemiology study. *JMIR Public Health Surveill*. (2020) 6:e18444. doi: 10.2196/18444

24. Wang MP, Viswanath K, Lam TH, Wang X, Chan SS. Social determinants of health information seeking among Chinese adults in Hong Kong. *PLoS ONE*. (2013) 8:e73049. doi: 10.1371/journal.pone.0073049

25. Kwon JH, Kye SY, Park EY, Oh KH, Park K. What predicts the trust of online health information? *Epidemiol Health*. (2015) 37:e2015030. doi: 10.4178/epih/e2015030

26. St-Pierre M, Sinclair I, Elgbeili G, Bernard P, Dancause KN. Relationships between psychological distress and health behaviors among Canadian adults: differences based on gender, income, education, immigrant status, and ethnicity. *SSM Popul Health*. (2019) 7:100385. doi: 10.1016/j.ssmph.2019.100385

27. Cutler DM, Lleras-Muney A. Understanding differences in health behaviors by education. *J Health Econ*. (2010) 29:1–28. doi: 10.1016/j.jhealeco.2009.10.003

28. Xue Y, Lu J, Zheng X, Zhang J, Lin H, Qin Z, et al. The relationship between socioeconomic status and depression among the older adults: the mediating role of health promoting lifestyle. *J Affect Disord*. (2021) 285:22–8. doi: 10.1016/j.jad.2021.01.085

29. Guo Z, Zhao SZ, Guo N, Wu Y, Weng X, Wong JY, et al. Socioeconomic disparities in eHealth literacy and preventive behaviors during the COVID-19 pandemic in Hong Kong: cross-sectional study. *J Med Internet Res*. (2021) 23:e24577. doi: 10.2196/24577

30. Greenberg AJ, Haney D, Blake KD, Moser RP, Hesse BW. Differences in access to and use of electronic personal health information between rural and urban residents in the United States. *J Rural Health*. (2018) 34(Suppl. 1):s30–s8. doi: 10.1111/jrh.12228

31. Hiller J, Schatz K, Drexler H. Gender influence on health and risk behavior in primary prevention: a systematic review. *Z Gesundh Wiss*. (2017) 25:339–49. doi: 10.1007/s10389-017-0798-z

frontiers | Frontiers in Public Health

TYPE Brief Research Report
PUBLISHED 27 October 2022
DOI 10.3389/fpubh.2022.1020850

OPEN ACCESS

EDITED BY
Pier Luigi Sacco,
University of Studies G. d'Annunzio Chieti and Pescara, Italy

REVIEWED BY
Arista Lahiri,
Indian Institute of Technology Kharagpur, India
Supreet Saluja,
Macquarie University, Australia

*CORRESPONDENCE
Rachel McMullan
rachel.mcmullan@open.ac.uk

SPECIALTY SECTION
This article was submitted to Infectious Diseases - Surveillance, Prevention and Treatment, a section of the journal Frontiers in Public Health

RECEIVED 16 August 2022
ACCEPTED 07 October 2022
PUBLISHED 27 October 2022

CITATION
Carr P, Breese E, Heath CJ and McMullan R (2022) The effect of the COVID-19 pandemic on disgust sensitivity in a sample of UK adults. *Front. Public Health* 10:1020850. doi: 10.3389/fpubh.2022.1020850

The effect of the COVID-19 pandemic on disgust sensitivity in a sample of UK adults

Peter Carr[1,2], Emily Breese[1], Christopher J. Heath[1] and Rachel McMullan[1]*

[1]School of Life, Health and Chemical Sciences, The Open University, Milton Keynes, United Kingdom, [2]The Alan Turing Institute, London, United Kingdom

The COVID-19 pandemic led to the introduction of a range of infection prevention and control (IPC) measures that resulted in dramatic changes in people's lives however these IPC measures are not practiced consistently across the population. One predictor of an individual's responses to the pandemic is disgust sensitivity. Understanding how disgust sensitivity varies within the population could help to inform design of public health messages to promote more uniform behavioral change during future pandemics. To understand the effect of the current COVID-19 pandemic on an individual's pathogen disgust sensitivity we have compared pathogen disgust sensitivity during the current COVID-19 pandemic to baseline pathogen disgust sensitivity, determined prior to the COVID-19 pandemic, in the same sample of UK adults. We find that the COVID-19 pandemic did not alter overall pathogen disgust sensitivity suggesting that disgust sensitivity is stable despite IPC measures, public health messaging, media coverage and other factors associated with the COVID-19 pandemic.

KEYWORDS

disgust sensitivity, COVID-19, disease avoidance, behavior, pathogen disgust

Introduction

In March 2020 the World Health Organization (WHO) declared the outbreak of COVID-19 a global pandemic (1). As of 20th December 2021 there were over 250 million confirmed cases of COVID-19 worldwide and over 5 million deaths (2). In the UK the government introduced social distancing and social isolation guidelines, restrictions on public gatherings and recommended a number of preventative health behaviors, including washing hands more frequently, in late March 2020 (3). These infection prevention and control (IPC) measures prompted many people to dramatically change their everyday lives in order to avoid contracting and spreading COVID-19. However, IPC measures are not practiced consistently. In the month after the UK government introduced social distancing measures the UK police force issued more than 9,000 fixed penalty fines (4) under new public health regulations (5) aimed at enforcing the lockdown suggesting that some people did not comply with guidelines. Conversely, a survey of Britons conducted by IPSO-MORI during the lockdown at the end of April 2020 suggested that some people would feel uncomfortable returning to "normal" activities such as visiting friends and family even once the lockdown restrictions were lifted (6).

What underlies these differences in behavior? Engagement with IPC measures is likely to be multi-factorial with an individual's engagement being influenced by a number of demographic and psychological factors such as functional fear, risk perception, socioeconomic status, disgust, engagement with social media, belief in conspiracy theories and moral values regarding the importance of caring for others. A number of studies have shown that pre-pandemic disgust sensitivity and proneness are important predictors of an individual's responses to the current COVID-19 global pandemic (7–10). Disgust sensitivity and proneness correlate with anxiety related to COVID-19 and predicts levels of concern about COVID-19 and efforts to comply with official recommendations (7–10). These studies are broadly in agreement with studies during previous pandemics (11), and disease outbreaks (12) which found disgust sensitivity to be a predictor of disease-related anxiety.

The emotion of disgust is the psychological mechanism for producing disease avoidance behaviors that protect us from infection by reducing our contact with pathogens and parasites (13). This pathogen avoidance theory of disgust (PAT) (13, 14) is supported by strong correlations between disgust elicitors and pathogen sources (15, 16). Sensitivity to disgust elicitors varies considerably amongst individuals (16) and one prediction derived from the pathogen-avoidance theory is that disgust sensitivity will be higher when the threat of infection is higher.

In support of this hypothesis Skolnick and Dzkoto (17) have demonstrated an association between disgust sensitivity and differing levels of national pathogen stress in Ghana and the USA however existing data do not fully support this association. Tybur et al. (18) comparing over 30 nations with differing levels of national parasite stress failed to find a correlation between disgust sensitivity and national rates of infectious diseases while a similar pattern of disgust sensitivity was found across nine different cultural regions using photo-based disgust stimuli (14). Overall, the findings of these studies do not consistently support the hypothesis that pathogen disgust sensitivity is correlated with vulnerability to infection therefore further research is warranted.

According to PAT, it could be hypothesized that disgust sensitivity should be higher during the COVID-19 pandemic in response to the increased real and perceived threat of infection globally. Recent studies have supported this hypothesis by demonstrating an impact of the COVID-19 pandemic on disgust sensitivity (19, 20). Using the Disgust Scale (16) to assess disgust sensitivity Stevenson et al. (20) reported overall higher levels of disgust sensitivity and higher scores for core disgust in a cohort of Australian university students during the first Australian lockdown in March/April 2020 when compared to previous cohorts of university students. Consistent with this, a study by Milkowska et al. (19) found that a cohort of women living in Poland assessed photographs depicting sources of infection as more disgusting during the COVID-19 pandemic when compared to a matched, pre-pandemic cohort. However, using questions adapted from the pathogen and moral disgust domains of the Three-Domain Disgust scale (21), the same study found a reduction in moral disgust during the pandemic when compared to the pre-pandemic cohort and no significant effect of COVID-19 on the pathogen disgust domain (19).

One limitation of these studies is their between-subjects design in which data was collected from different cohorts of individuals pre- and post-pandemic which does not allow disgust sensitivity in the same group of individuals to be compared pre- and post-pandemic. Thus, despite cohorts being matched, it remains possible that the observed differences in disgust sensitivity are a result of variation between individuals in the cohorts rather than as a result of increase threat of infection during the pandemic. Here we report a comparison of pathogen disgust sensitivity during the COVID-19 pandemic to baseline pathogen disgust sensitivity, determined in the same individuals prior to the COVID-19 pandemic, in order to better understand the effect of the current COVID-19 pandemic on pathogen disgust sensitivity.

Materials and methods

Survey instrument

A pathogen disgust survey comprised of 30 disgust elicitor statements derived from infectious disease transmission routes that included a statement reflecting transmission routes, signs and symptoms associated with COVID-19 was used (Supplementary Table 1). This shortened pathogen disgust survey was based on a pathogen disgust survey previously described by Curtis and de Barra which comprised 75 disgust elicitor statements derived from infectious disease transmission routes (22). To develop our shortened pathogen disgust survey we selected the 30 items which loaded most strongly onto the six factors identified by Curtis and de Barra (22). Invariance testing and cluster analysis were used to determine whether removing the remaining items impacted on the survey structure as described below. Participants were asked to rate their disgust toward each item on a scale from 1–100 from no disgust to extreme disgust. The default position of the scale was set to 50. In addition to these disgust elicitor statements participants were also asked to indicate how often they experienced disgust. Basic demographic data including age, occupation and gender was also collected.

Exploratory factor and principal component analysis

Exploratory factor analysis was conducted by splitting the sample into a 2019 cohort ($N = 299$) and 2020 cohort ($N = 340$). Factors that had eigenvalues > 1 (23) were extracted and principal component analysis (PCA) with oblique rotation to extract factors was used, mirroring the analysis conducted by

Curtis and de Barra (22). Internal consistency for extracted factors was analyzed using Cronbach's α.

Invariance testing

Invariance testing on the pathogen disgust scale was carried out to ensure that measurement of pathogen disgust had not significantly changed before the COVID-19 pandemic (2019 cohort) and during the COVID-19 pandemic (2020 cohort) using the steps described by van de Schoot et al. (24) to test for measurement invariance. Metric invariance was tested by constraining the factor loadings (i.e., how important each question item is to the underlying factor). Finally, scalar invariance which forces both the intercepts and factor loadings to be equal across the 2019 and 2020 cohorts was tested.

Data collection

All data were collected using the online participant recruitment platform Prolific (www.prolific.co) and the Gorilla Experiment Builder (RRID: SCR_020991) to create and host all experiments. All study participants were aged between 18 and 65 and were UK nationals resident in the UK at the time of the study. The infection status of participants was not determined. Data were collected in two stages; once before the COVID-19 pandemic (09/06/19) (referred to as the 2019 cohort throughout) and once during the pandemic (between 13/03/20 and 07/04/20) (referred to as the 2020 cohort throughout). The 2020 cohort consisted of a repeated sampling of the 2019 cohort ($N = 151$) [referred to as the 2020 cohort (group 1)] and a new sample ($N = 189$) [referred to as the 2020 cohort (group 2)]. All received financial payment for taking part in the study (£1.25).

Data analysis

Regression analysis

Various regression models were conducted, primarily a linear regression and a multilevel linear regression with factor responses (level-1 units) nested within participants (level-2 units). Three models were used to demonstrate that statistically significant improvements in fit could be observed by allowing disgust to vary by participant and that additional assumptions about disgust were supported at each step. The primary aim of the second stage was to establish the effect of COVID-19 on disgust responses while controlling for covariates such as age, gender, and disgust factor.

A series of three multivariate regression analyses were conducted using the following set of predictors: disgust factor, study group, gender, age. In addition to these main effects, several two-way interactions were considered, including study group by disgust factor, gender by disgust factor, age by disgust factor, and gender by age. Finally, two three-way interactions were considered - gender by age by disgust factor and gender by study group by disgust factor. The most important predictors to the current investigation were the main effects of study group (which shows the overall effect that responding during the COVID-19 pandemic had on pathogen disgust), the interaction between study group and disgust factor (which shows the factor specific effect that responding during the COVID-19 pandemic had on pathogen disgust e.g., "Hygiene" disgust or "Animal" disgust).

The first was a linear regression and did not account for the correlation between pathogen disgust responses within each participant (i.e., did not account for the fact that the same participant responded to the six disgust factors).

The second regression analysis used the same set of predictors but accounted for the "nested" structure of our data (with each participant responding to each of the six factors of pathogen disgust) using a random intercept. This allows each participant to have a unique component of their "disgust" response, accounting for individual differences in mean disgust ratings.

The third regression analysis used the same set of predictors as the first and second analysis but introduced a random effect of disgust factor i.e., the influence that a disgust factor (such as hygiene) has on disgust response was allowed to vary between participants. For example, for the majority of participants responding to hygiene factor statements reduced disgust response by 20 points on average compared to lesion factor statements. However, this relationship may not hold for all participants e.g., some participants may find lesion factor statements less disgusting than hygiene statements. The random effects model allows for individual differences in response to each disgust factor.

All analysis was conducted in R version 1.2.5001. Packages used were sjPlot (25), GGally (26), lme4 (RRID: SCR_015654), ggplot2 (RRID: SCR_014601), and psych (RRID: SCR_021744).

Ethics approval statement

This research has received ethical approval following review by The Open University's Human Research Ethics Committee (HREC/3231/McMullan/Carr) and adheres to all BPS ethics standards. A full information sheet and debrief form were provided and each participant was required to provide written informed consent before being enrolled.

Results

Participants

Of the 499 unique participants, 21 either failed to respond correctly to an attention check question or reported an age $<$ 18 or $>$ 65 and were excluded from the analysis. Participants

TABLE 1 Participant demographic data.

	2019 cohort	2020 cohort			Whole study (unique participants)
		Group 1	Group 2	Total	
Size of cohort	299	151	189	340	488
Percentage female	50.8	49.7	47.6	48.8	50.5
Average age (years)	33.48 (s.d. 12.07)	33.76 (s.d. 12.36)	36.5 (s.d. 12.59)	34.98 (s.d. 12.52)	34.3 (s.d. 12.32)
Employment					
Professional occupation (undergraduate degree or equivalent required)	47	29	36	65	112
Student	48	18	37	55	103
Administrative and secretarial	50	31	22	53	103
Not currently in work	48	17	28	45	93
Sales and customer service	22	15	17	32	54
Manager or director	22	12	14	26	48
Skilled trade	21	9	14	23	44
Associate professional and technical occupation (high-level vocational qualification or training required)	12	11	15	26	38
Caring or leisure occupation	21	6	5	11	32
Elementary occupation	6	3	1	4	10
Process plant and machine operator	2	-	-	-	2

were not excluded on the basis of whether or not they had COVID-19. There were 299 participants in the 2019 cohort and 340 participants in the 2020 cohort. This cohort contained 151 participants who were part of the 2019 cohort (2020 cohort group 1) and 189 new participants (2020 cohort group 2). Participant demographic data is summarized in Table 1.

Factor analysis and measurement invariance shows that the measurement of pathogen disgust does not vary with COVID-19

Before investigating the effect of the COVID-19 pandemic on pathogen disgust sensitivity we established whether pathogen disgust responses were measured in a similar way before the COVID-19 pandemic and during the COVID-19 pandemic i.e., ensuring that a one point increase in response to a statement represents the same increase in "disgust" for both 2019 and 2020 groups. This stage involved conducting a factor analysis and measurement invariance testing. The first stage had two aims: (1) establish that the underlying factor structure is unchanged between the 2019 and 2020 cohorts and (2) identify whether mean factor scores are comparable between the 2019 and 2020 cohorts.

Similar factors were extracted for both the 2019 and 2020 cohorts (Supplementary Table 2). This factor structure was broadly similar to the factor structure of the 75 item pathogen disgust sensitivity instrument described by Curtis and de Barra that our survey was derived from (22). Therefore, in agreement with Curtis and de Barra (22), we labeled our factors "Hygiene," "Lesion," "Food," "Animal," "Sex," and "Atypical" disgust based on the common theme of the statements that loaded onto each of these factors. The factors had broadly the same factor structure with some key differences between the 2019 and 2020 cohorts (Supplementary Table 2). Firstly, some cross-loading was seen in the 2019 cohort. The questionnaire item "Walking in your bare feet, you step on and squash a slug" had a significant loading (>0.3) for both the Animal and Hygiene factors. The loading on Hygiene only marginally passed the definition of a significant loading, 0.304, and was excluded from the Hygiene factor. Secondly, there were some differences in the items that loaded onto the six disgust factors. The items "A hairless old cat rubs up against your leg," "Eating a sausage 2 weeks past its use by date," and "Eating onion flavored ice-cream" did not have significant loadings on their respective factors in the 2019 cohort but achieved significant loadings in the 2020 cohort. Cronbach α's for each disgust extracted factors were between 0.73 for the Food factor and 0.88 for the Lesion factor (Hygiene 0.78, Lesion 0.88, Food 0.73, Animal 0.76, Sex 0.83, Atypical 0.79) reflecting satisfactory internal consistency.

TABLE 2 Results of invariance testing.

Model	χ2	df	Comparative fit index (CFI)	Root mean square error approximation (RMSEA)	Standardized root mean square residual (SRMR)
Overall model	1,038.823	390	0.904	0.051	0.059
2019 model	668.903	390	0.906	0.049	0.064
2020 model	748.958	390	0.905	0.052	0.064
Configural	1,417.862	780	0.905	0.051	0.064
Metric	1,439.255	804	0.906	0.05	0.065
Scalar	1,474.649	828	0.904	0.049	0.065

Following the exploratory factor analysis, we carried out invariance testing on the pathogen disgust scale to ensure that measurement of pathogen disgust had not significantly changed before the COVID-19 pandemic (2019 cohort) and during the COVID-19 pandemic (2020 cohort). Firstly, to ensure that the underlying factor structure (i.e., what factor each question item relates to) was equivalent between the 2019 and 2020 cohorts we tested for configural invariance. Across a range of criteria [comparative fit index (CFI), Root mean square error approximation (RMSEA), and standardized root mean square residual (SRMR)], there was not a significant reduction in model fit when the factor structure was constrained to be equal between the two groups (Table 2) indicating that there was no difference in the underlying factor structure between the two cohorts. Secondly, we tested for metric invariance to determine how important each question item was to the underlying factor. Again, there was not a significant reduction in model fit after constraining the factor loadings to be equal across the 2019 and 2020 (Table 2) implying that there was no difference in the importance of the question between the two cohorts. Finally, we tested for scalar invariance to determine whether that the starting point of the disgust scale was equivalent for both the 2019 and 2020 cohorts i.e., the 2020 cohort might have a higher average disgust response but equivalent measurement across the factor loadings which would upwardly bias the disgust responses taken in 2020 when compared to 2019. Again, we found that there was no reduction in model fit for the model compared to the metric model (Table 2) indicating that measurement in 2019 and 2020 is equivalent allowing for comparison of factor scores.

Taken together the results of invariance testing indicate that measurement of pathogen disgust in both cohorts was comparable.

Age, gender and disgust sensitivity

Previous work has demonstrated associations between pathogen disgust sensitivity, age and gender (22). To determine whether there were any interactions between age, gender and pathogen disgust factor in our sample we used a series of multivariate regression analyses as detailed in the Materials and Methods section to consider two-way interactions between gender and pathogen disgust factor and also age and pathogen disgust factor and three-way interactions between age, gender and pathogen disgust factor (Supplementary Table 3 and Figure 1A). Three factors, animal, sex and hygiene disgust, showed a significant three-way interaction with age and gender while no significant interaction was observed between food, lesion or atypical disgust, age and gender. The effect of gender on disgust factors broadly mirrors that observed by Curtis and de Barra who found the most significant effect of gender on sex and animal disgust (22). Given that we observed effects of age and gender on disgust responses we controlled for both of these factors as covariates in our analysis of disgust sensitivity before and during the COVID-19 pandemic.

COVID-19 and disgust sensitivity

The COVID-19 pandemic did not alter overall pathogen disgust responses in this cohort

To determine whether there was an effect of the COVID-19 pandemic on pathogen disgust sensitivity we performed a series of regression analyses comparing pathogen disgust responses in the 2019 and 2020 cohorts as detailed in the Materials and Methods section. We found no significant influence of cohort on pathogen disgust responses (Figure 1B). Both the 2020 cohort (group 1), who had previously completed the survey as part of the 2019 cohort, ($\beta = 1.75$, 95% CI: −1.52, 5.02) and 2020 cohort (group 2), who had not previously completed the survey, ($\beta = 2.06$, 95% CI: −3.30, 7.42) did not have significantly different pathogen disgust responses compared to the 2019 cohort or each other (Figure 1B).

The COVID-19 pandemic did not alter pathogen disgust responses to COVID-19 transmission routes in this cohort

Since overall pathogen disgust sensitivity was not altered during the COVID-19 pandemic (2020 cohort) when compared to baseline pathogen disgust (2019 cohort) we looked at interactions between the 6 disgust factors, identified

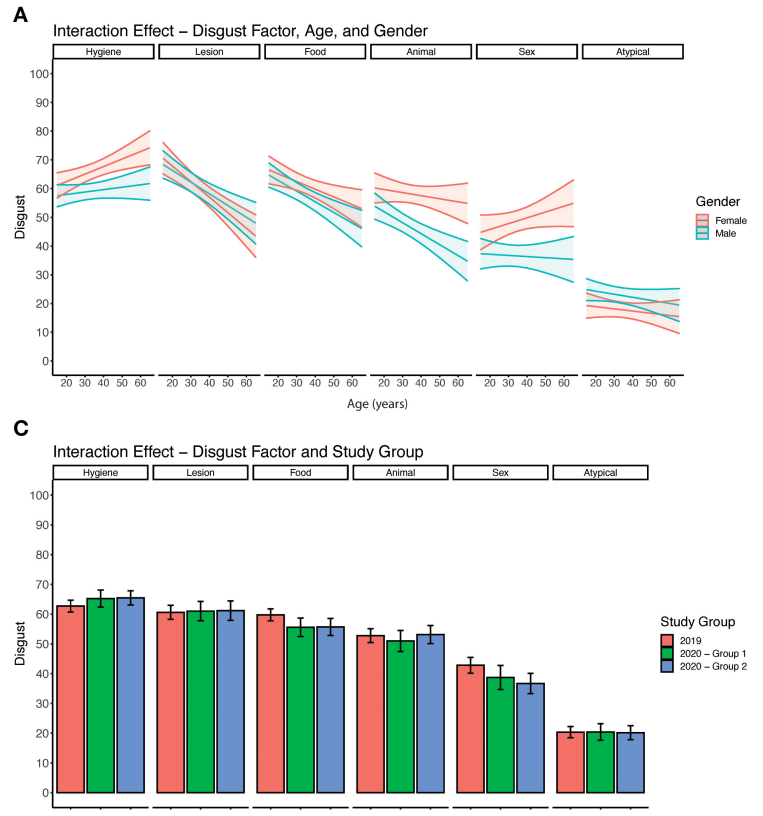


FIGURE 1
Analysis of disgust responses. **(A)** Three-way interaction between age, gender, and disgust factor. For each disgust factor, a pair of lines with a 95% confidence interval (shaded region) indicates average disgust response across age. **(B)** Average disgust response across all 30 items by study group. 2019 group which refers to the sample collected in 2019. 2020 – Group 1 refers to the subset of responses collected in 2020 that had previously completed the disgust survey. 2020 – Group 2 refers to responses collected in 2020 that had not previously completed the disgust survey. **(C)** Average disgust response across 6 disgust factors separated by study group.

by our exploratory factor analysis, and our cohorts. In particular, we hypothesized that disgust responses to a statement reflecting COVID-19 disease transmission routes (Supplementary Table 1), which loaded onto the hygiene factor, might be altered during the COVID-19 pandemic. Using regression analysis as detailed in the Materials and Methods section we found a significant interaction between the cohort and one disgust factor (Figure 1C). The 2020 cohort (group 2) had significantly lower disgust responses for the food disgust factor ($\beta = -6.48$, 95% CI: −12.36, −0.60) than the 2019 cohort (Figure 1C). No interactions were found between the cohort and other disgust factors including hygiene disgust [2020 cohort (group 2): $\beta = 0.67$, 95% CI: −4.99, 6.33; 2020 cohort (group 1): $\beta = 1.03$ 95% CI: −5.54, 3.48] (Figure 1C).

Discussion

The pathogen avoidance theory of disgust predicts that disgust sensitivity is associated with the threat of infection. In this study we tested this prediction by comparing pathogen disgust sensitivity during the COVID-19 pandemic in 2020 to baseline pathogen disgust sensitivity in the same sample of UK adults. Given the magnitude of the COVID-19 pandemic, its impact on people's lives and the scale of media coverage relating to the outbreak, we hypothesized that, if disgust sensitivity is correlated with the threat of infection, as predicted by pathogen avoidance theory, individual's disgust sensitivity will be increased during the pandemic when compared to their baseline disgust sensitivity.

Key findings

To test pathogen disgust sensitivity we utilized an online pathogen disgust survey containing 30 items reflecting signs, symptoms and transmission routes of disease. This instrument was derived from a 75 item pathogen disgust survey previously described by Curtis and de Barra (22). Analysis of our data across both cohorts shows that our shortened version of this survey has a broadly similar factor structure to that previously described by Curtis and de Barra (22), validating their six factor structure model and demonstrating the robustness of the model across

multiple cohorts. Furthermore, it demonstrates that a shortened version of the pathogen disgust survey can be used to measure pathogen disgust sensitivity.

Using this shortened pathogen disgust survey we compared overall pathogen disgust sensitivity before and during the 2020 COVID-19 pandemic in a sample of UK adults. When controlling for covariates such as age, gender and disgust factor we found that the COVID-19 pandemic did not alter overall pathogen disgust sensitivity in our sample. Therefore, we accept our null hypothesis that overall pathogen disgust responses are equal during the COVID-19 pandemic and prior to the COVID-19 pandemic.

Comparisons to existing disgust literature

Our findings are consistent with previous data which do not fully support an association between disgust sensitivity and infection susceptibility or risk of infection (18, 27–29), however they are in contrast to other studies, in different populations under different COVID-19 restrictions, which found that disgust sensitivity was increased during the early stages of the COVID-19 pandemic (19, 20). There are a number of possible explanations why our results may differ from those of past studies on COVID-19 and disgust sensitivity. Firstly, this difference may be due to the disgust sensitivity measures used across studies. In contrast to Milkowska et al. (19) and Stevenson et al. (20), who used measures using disgust elicitor statements based on self-reported lists of disgusting items (16, 21) the pathogen disgust measure in this study uses disgust elicitor statements derived from infectious disease transmission routes (22). Furthermore, the disgust scale (16) and Three Domain disgust scale (21) used by Stevenson et al. (20) and Milkowska et al. (19) are based on a Likert-scale however, in this study pathogen disgust was assessed using a scale from 1–100. These differences may have resulted in differing baseline disgust sensitivity across the measures.

Secondly, our study controlled for co-variates including age and gender therefore demographic differences between studies are unlikely to account for these different findings. However, it should be noted that the proportion of males and females differs across studies. In this study the population was equally balanced with respect to gender in contrast to Stevenson et al. (20) (75% female) and Milkowska et al. (19) (100% female). A supplementary analysis of only the female data from our study gave broadly similar results to our analysis of the whole cohort with the exception of a significant decrease in disgust for the Sex factor in the 2020 (group 2) cohort which was not observed in the analysis of the whole cohort or females in the 2020 (group 1) cohort (data not shown). This data suggests that differences in the proportion of males and females does not account for the different findings of our study.

Thirdly given that each study collected data from a sample taken from a different geographic location, one possible explanation may be that the pandemic altered disgust sensitivity in some countries but not others. Similar patterns of disgust sensitivity have been observed across all regions of the world (14) however differences in the severity of the pandemic and/or the IPC measures introduced in each country may account for the different findings of our study. Related to this point it should be noted that these studies were all conducted at a similar time point prior to the introduction of COVID-19 vaccination programmes and therefore differences in the availability of vaccines between countries do not explain the different findings between studies. Fourthly, since study participants were not asked to report their COVID-19 infection status in any of the three studies it remains possible differences in the prevalence of COVID-19 amongst the different survey cohorts may have served to alter the perceived risk of COVID-19 and therefore disgust sensitivity.

Finally, in contrast to Milkowska et al. (19) and Stevenson et al. (20) who both used matched populations to compare disgust sensitivity pre- and post-pandemic, our study included data collected from a group of individuals whose pathogen disgust sensitivity had been determined prior to the COVID-19 pandemic allowing us to compare responses from the same individuals before and during the COVID-19 pandemic and so reduce the confounding effect of inter-individual differences. Studies investigating differences in disgust sensitivity in response to infection risk in a single population are limited. Previous studies have used natural variation in vulnerability to infection across the female menstrual cycle and during pregnancy to relate disgust sensitivity to physiological changes in vulnerability to infection within individuals (28–31). However, to our knowledge, this is the first study of pathogen disgust sensitivity that collected data from the same group of participants before and during an outbreak of an infectious disease in order to investigate the effect of external changes in the threat of infection.

The relationship between COVID-19 and pathogen disgust factors

While a general pathogen avoidance response may be appropriate for all infectious disease cues, specific behavioral responses to infection are likely to be related to the nature of the pathogen threat. Therefore, we hypothesized that disgust sensitivity would be greatest toward disgust elicitors that reflect transmission routes, signs and symptoms associated with COVID-19. Our pathogen disgust survey included one statement reflecting COVID-19 transmission routes "Feeling someone cough into your face" and one statement reflecting failure to comply with IPC social distancing measures "On the

subway, you are forced to stand close to someone with body odor and greasy hair." Consistent with previous results (22) both of these statements loaded onto the hygiene disgust factor in both cohorts however when controlling for other covariates we did not find a significant difference in hygiene disgust during the COVID-19 pandemic when compared to baseline responses. Therefore, we accept our null hypothesis that disgust responses to COVID-19 related statements are not significantly altered during the pandemic with the following caveats. Firstly, scores for statements that loaded onto hygiene disgust were relatively high in the 2019 cohort raising the possibility that baseline hygiene disgust was too high to detect any increase as a result of COVID-19. Secondly, our survey was designed prior to the current COVID-19 pandemic and therefore statements were not specifically designed to reflect COVID-19 signs, symptoms, transmission routes or IPC measures. It is possible that the inclusion of further statements reflecting specific aspects of COVID-19 may have revealed effects on specific behavioral responses.

Although COVID-19 did not alter hygiene, lesion, sex, atypical or animal disgust sensitivity we did observe a small but significant decrease in food disgust during the COVID-19 pandemic when compared to baseline. Lowered food disgust does not immediately seem consistent with the hypothesis that disgust responses reflect the nature of the pathogen threat however food disgust sensitivity has been shown to affect eating and food behavior including a positive association between food disgust sensitivity and frequency of wasting food (32). Interestingly food disgust sensitivity has been identified as a predictor of shopping behavior and disease preventative behavior related to the COVID-19 pandemic with higher food disgust associated with shopping behavior aimed at reducing exposure to the virus such as purchasing pre-packed and long-life foods (33). Our study did not specifically address individual's eating and food behavior however changes in shopping and eating habits such as a more relaxed attitude to best before dates and a reduction in food waste in the early stages of lockdown (when data from cohort 2 was collected) have been reported (34, 35) raising the possibility that the lowered food disgust that we observed could be associated with changes in shopping and eating habits during the pandemic.

Although our findings do not support an association between overall disgust sensitivity or hygiene disgust and threat of infection by COVID-19, they do reveal possible associations with other disgust factors that it is tempting to speculate could be attributed to consequences of IPC measures.

Study strengths and limitations

Previous studies exploring the relationship between COVID-19 and disgust sensitivity have used a between-participant design in which data was collected from different cohorts of individuals pre- and post-pandemic which does not allow disgust sensitivity in the same group of individuals to be compared pre- and post-pandemic. Thus, despite cohorts being matched, it remains possible that the observed differences in disgust sensitivity are a result of variation between individuals in the cohorts rather than as a result of increased threat of infection during the pandemic. The main strength of this study is the use of both within- and matched-subjects approaches which find replicable results. However, while our data may provide further insight into the relationship between COVID-19 and disgust sensitivity which can be used to inform the design of public health messages to promote uniform behavior change they are not without their limitations. Firstly, our survey was designed prior to the current COVID-19 pandemic and therefore statements were not specifically designed to reflect COVID-19 signs, symptoms, transmission routes or IPC measures. It is possible that the inclusion of further statements reflecting specific aspects of COVID-19 may have revealed effects on specific behavioral responses. Related to this point our findings do not exclude the possibility that epidemic or pandemic diseases with different signs, symptoms or transmission routes could alter individual's disgust sensitivity. Further studies comparing baseline pathogen disgust sensitivity to disgust sensitivity during other disease outbreaks with varying transmission routes, signs and symptoms in the same group of individuals are needed to determine whether pathogen disgust sensitivity is associated with threat of infection in other contexts. Secondly, as previously mentioned the COVID-19 status of participants or their experience of the pandemic were not determined in our study. Factors such as recent or current infection with COVID-19, hospitalization or death of a family member, inclusion in a vulnerable/at risk group and the degree to which they were involved in employment that increased their exposure to COVID-19 may all have served to alter participants perceived risk of COVID-19 and therefore their disgust sensitivity.

Conclusion and implications

Understanding the psychological, behavioral and cultural factors that influence compliance with evidence-based IPC measures such as social distancing can help to inform the design of public health messages to promote more uniform behavioral change. Disgust sensitivity appears to be an important predictor of individual's responses to the COVID-19 pandemic (7–10) leading to suggestions that emphasizing aspects of the virus that induce feelings of disgust could be used to promote behavioral change and improve compliance with public health measures designed to tackle COVID-19. Disgust has previously been leveraged in this way to influence social behaviors

such as hand washing to prevent the spread of disease. For example, during the 2009/10 H1N1 influenza pandemic, the UK Government's information leaflet which was delivered to every house in the UK depicted the aerosol spread of a sneeze on its cover. Exposure to this material was associated with increases in hygienic behavior although disgust was not explicitly evaluated (36). Our study suggests that current IPC measures, public health messaging, media coverage and other factors associated with the 2020 COVID-19 pandemic do not alter people's overall disgust sensitivity or their disgust in relation to symptoms, signs and transmission routes for COVID-19. Indeed, evidence shows people tend to show solidarity and cooperation in times of emergency (37) and UK Government public health messaging during the COVID-19 lockdown promoted social responsibility and moral values associated with caring for others. However, our findings do not exclude the possibility that novel interventions targeting disgust could be leveraged to promote compliance with IPC related to COVID-19.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number (s) can be found at: Open Research Data Online (ORDO) repository https://doi.org/10.21954/ou.rd.13109831.v1.

Ethics statement

The studies involving human participants were reviewed and approved by the Open University Human Research Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CJH and RM designed the study. PC and EB collected the data. PC analyzed the data. All authors interpreted the data, prepared the manuscript, and approved the final version before submission.

Funding

This work was supported by funding from The Open University Health and Wellbeing Priority Research Area to RM and CJH (https://www.open.ac.uk/health-wellbeing/). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the 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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1020850/full#supplementary-material

References

1. WHO. *Virtual Press Conference on COVID-19*. (2020). Available online at: https://www.who.int/docs/default-source/coronaviruse/transcripts/who-audio-emergencies-coronavirus-press-conference-full-and-final-11mar2020.pdf?sfvrsn=cb432bb3_2 (accessed May 09, 2021).

2. WHO. *Coronavirus Disease (COVID-19) Dashboard*. (2020). Available online at: https://covid19.who.int (accessed December 20, 2021).

3. Government UK. *PM Address to the Nation on Coronavirus: 23 March 2020*. (2020). Available online at: gov.uk/government/speeches/pm-address-to-the-nation-on-coronavirus-23-march-2020 (accessed May 09, 2021).

4. National Police Chiefs Council. *Update: Latest COVID-19 FPN Data, and News About Police Recruitment Drive*. (2020). Available online at: news.npcc.police.uk/releases/police-chiefs-welcome-positive-start-to-recruitment-drive (accessed May 09, 2021).

5. UK Home Office. *Police Given New Powers and Support to Respond to Coronavirus*. (2020). Available online at: https://www.gov.uk/government/news/police-given-new-powers-and-support-to-respond-to-coronavirus (accessed May 09, 2021).

6. IPSO MORI. *Majority of Britons Uncomfortable Returning to Large Sport or Music Events, Public Transport and Bars or Restaurants Post Lockdown*. (2020). Available online at: ipsos.com/ipsos-mori/en-uk/majority-britons-uncomfortable-sport-music-bars-coronavirus (accessed May 09, 2021).

7. Shook NJ, Sevi B, Lee J, Oosterhoff B, Fitzgerald HN. Disease avoidance in the time of COVID-19: the behavioral immune system is associated with concern and preventative health behaviors. *PLoS ONE*. (2020) 15:e0238015. doi: 10.1371/journal.pone.0238015

8. Díaz R, Cova F. Reactance, morality, and disgust: the relationship between affective dispositions and compliance with official health recommendations during the COVID-19 pandemic. *Cogn Emot.* (2021) 36:120–36. doi: 10.31234/osf.io/5zrqx

9. Kempthorne JC, Terrizzi JA. The behavioral immune system and conservatism as predictors of disease-avoidant attitudes during the COVID-19 pandemic. *Pers Individ Dif.* (2021) 178:110857. doi: 10.1016/j.paid.2021.110857

10. Cox RC, Jessup SC, Luber MJ, Olatunji BO. Pre-pandemic disgust proneness predicts increased coronavirus anxiety and safety behaviors: evidence for a diathesis-stress model. *J Anxiety Disord.* (2020) 76:102315. doi: 10.1016/j.janxdis.2020.102315

11. Wheaton MG, Abramowitz JS, Berman NC, Fabricant LE, Olatunji BO. Psychological predictors of anxiety in response to the H1N1 (swine flu) pandemic *Cogn Ther Res.* (2012) 26:210–8. doi: 10.1007/s10608-011-9353-3

12. Blakey SM, Reuman L, Jacoby RJ, Abramowitz JS. Tracing "Fearbola": psychological predictors of anxious responding to the threat of Ebola. *Cogn Ther Res.* (2015) 39:816–25. doi: 10.1007/s10608-015-9701-9

13. Curtis V, de Barra M, Aunger R. Disgust as an adaptive system for disease avoidance behavior. *Philos Trans R Soc Lond B Biol Sci.* (2011) 366:389–401. doi: 10.1098/rstb.2010.0117

14. Curtis V, Aunger R, Rabie T. Evidence that disgust evolved to protect from risk of disease. *Proc Biol Sci.* (2004) 271:S131–3. doi: 10.1098/rsbl.2003.0144

15. Curtis V, Biran A. Dirt, disgust, and disease. Is hygiene in our genes? *Perspect Biol Med.* (2001) 44:17–31. doi: 10.1353/pbm.2001.0001

16. Haidt J, McCauley C, Rozin P. Individual differences in sensitivity to disgust: a scale sampling seven domains of disgust elicitors. *Pers Individ Dif.* (1994) 16:701–13. doi: 10.1016/0191-8869(94)90212-7

17. Skolnick AJ, Dzokoto VA. Disgust and contamination: a cross-national comparison of Ghana and the United States. *Front Psychol.* (2013) 4:91. doi: 10.3389/fpsyg.2013.00091

18. Tybur JM, Inbar Y, Aarøe L, Barclay P, Barlow FK, de Barra M, et al. Parasite stress and pathogen avoidance relate to distinct dimensions of political ideology across 30 nations. *Proc Natl Acad Sci U S A.* (2016) 113:12408–13. doi: 10.1073/pnas.1607398113

19. Miłkowska K, Galbarczyk A, Mijas M, Jasienska G. Disgust sensitivity among women during the COVID-19 outbreak. *Front Psychol.* (2021) 12:622634. doi: 10.3389/fpsyg.2021.622634

20. Stevenson RJ, Saluja S, Case TI. The impact of the COVID-19 pandemic on disgust sensitivity. *Front Psychol.* (2021) 11:600761. doi: 10.3389/fpsyg.2020.600761

21. Tybur JM, Lieberman D, Griskevicius V. Microbes, mating, and morality: individual differences in three functional domains of disgust. *J Pers Soc Psychol.* (2009) 97:103–22. doi: 10.1037/a0015474

22. Curtis V, de Barra M. The structure and function of pathogen disgust. *Philos Trans R Soc Lond B Biol Sci.* (2018) 373:20170208. doi: 10.1098/rstb.2017.0208

23. Kaiser HF. The application of electronic computers to factor analysis. *Educ Psychol Meas.* (1960) 20:141–51. doi: 10.1177/001316446002000116

24. van de Schoot R, Lugtig P, Hox J. A checklist for testing measurement invariance. *Eur J Dev Psychol.* (2012) 9:486–92. doi: 10.1080/17405629.2012.686740

25. Lüdecke MD. *sjPlot: Data Visualisation for Statistics in Social Sciences*. (2020). Available online at: https://rdrr.io/cran/sjPlot (accessed July 14, 2022).

26. Schloerke B. *GGally: Extension to ggplot2*. (2021). Available online at: https://cran.r-project.org/web/packages/GGally/GGally.pdf (accessed July 14, 2022).

27. de Barra M, Islam MS, Curtis V. Disgust sensitivity is not associated with health in a rural Bangladeshi sample. *PLoS ONE.* (2014). 9:e100444. doi: 10.1371/journal.pone.0100444

28. Zelazniewicz A, Borkowska B, Nowak J, Pawłowski B. The progesterone level, leukocyte count and disgust sensitivity across the menstrual cycle. *Physiol Behav.* (2016) 161:60–5. doi: 10.1016/j.physbeh.2016.04.002

29. Jones BC, Hahn AC, Fisher CI, Wang H, Kandrik M, Lee AJ, et al. Hormonal correlates of pathogen disgust: testing the compensatory prophylaxis hypothesis. *Evol Hum Behav.* (2018) 39:166–9. doi: 10.1016/j.evolhumbehav.2017.12.004

30. Fleischman DS, Fessler DMT. Progesterone's effects on the psychology of disease avoidance: support for the compensatory behavioral prophylaxis hypothesis. *Horm Behav.* (2011) 59:271–5. doi: 10.1016/j.yhbeh.2010.11.014

31. Fessler D, Eng SJ, Navarrete CD. Elevated disgust sensitivity in the first trimester of pregnancy: evidence supporting the compensatory prophylaxis hypothesis. *Evol Hum Behav.* (2005) 26:344–51. doi: 10.1016/j.evolhumbehav.2004.12.001

32. Egolf A, Siegrist M, Hartmann C. How people's food disgust sensitivity shapes their eating and food behavior. *Appetite.* (2018) 127:28–36. doi: 10.1016/j.appet.2018.04.014

33. Ammann J, Casagrande M. Food disgust sensitivity predicts disease-preventing behavior beyond the food domain in the COVID-19 pandemic in Germany. *PLoS ONE.* (2021) 16:e0254648. doi: 10.1371/journal.pone.0254648

34. Hubbub. *How has COVID-19 Changed our Eating Habits.* (2020). Available online at: https://www.hubbub.org.uk/blog/how-has-covid-19-changed-our-eating-habits (accessed May 09, 2021).

35. BBC News. *Coronavirus: Five Ways the Outbreak is Hitting Global Food Industry*. (2020). Available online at: https://www.bbc.co.uk/news/world-52267943 (accessed May 09, 2021).

36. Rubin GJ, Amlot R, Page L, Wessely S. Public perceptions, anxiety, and behavior change in relation to the swine flu outbreak: cross sectional telephone survey. *BMJ.* (2009) 339:b2651. doi: 10.1136/bmj.b2651

37. Drury J, Reicher S, Stott C. COVID-19 in context: Why do people die in emergencies? It's probably not because of collective psychology. *Br J Soc Psychol.* (2020) 59:686–93. doi: 10.1111/bjso.12393

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 22 November 2022
DOI 10.3389/fpubh.2022.982289

OPEN ACCESS

EDITED BY
Chuhan Wu,
Tsinghua University, China

REVIEWED BY
Tao Qi,
Tsinghua University, China
Peiru Yang,
Tsinghua University, China

*CORRESPONDENCE
Zhuo Li
lizhuo@cqupt.edu.cn
Yifei Shen
sam.yifei.shen@gmail.com

SPECIALTY SECTION
This article was submitted to Infectious Diseases - Surveillance, Prevention and Treatment, a section of the journal Frontiers in Public Health

RECEIVED 30 June 2022
ACCEPTED 12 October 2022
PUBLISHED 22 November 2022

CITATION
Li Z, Xu R, Shen Y, Cao J, Wang B, Zhang Y and Li S (2022) A multistage multimodal deep learning model for disease severity assessment and early warnings of high-risk patients of COVID-19.
Front. Public Health 10:982289.
doi: 10.3389/fpubh.2022.982289

A multistage multimodal deep learning model for disease severity assessment and early warnings of high-risk patients of COVID-19

Zhuo Li[1,2]*, Ruiqing Xu[3], Yifei Shen[2]*, Jiannong Cao[2], Ben Wang[4], Ying Zhang[5] and Shikang Li[5]

[1]School of Computer Science and Technology, Chongqing University of Posts and Telecommunications, Chongqing, China, [2]Department of Computing, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR, China, [3]Department of Computer Science, The University of Sheffield, Sheffield, United Kingdom, [4]Baoding No. 2 Central Hospital, Baoding, China, [5]Chongqing Public Health Medical Center, Chongqing, China

The outbreak of coronavirus disease 2019 (COVID-19) has caused massive infections and large death tolls worldwide. Despite many studies on the clinical characteristics and the treatment plans of COVID-19, they rarely conduct in-depth prognostic research on leveraging consecutive rounds of multimodal clinical examination and laboratory test data to facilitate clinical decision-making for the treatment of COVID-19. To address this issue, we propose a multistage multimodal deep learning (MMDL) model to (1) first assess the patient's current condition (i.e., the mild and severe symptoms), then (2) give early warnings to patients with mild symptoms who are at high risk to develop severe illness. In MMDL, we build a sequential stage-wise learning architecture whose design philosophy embodies the model's predicted outcome and does not only depend on the current situation but also the history. Concretely, we meticulously combine the latest round of multimodal clinical data and the decayed past information to make assessments and predictions. In each round (stage), we design a two-layer multimodal feature extractor to extract the latent feature representation across different modalities of clinical data, including patient demographics, clinical manifestation, and 11 modalities of laboratory test results. We conduct experiments on a clinical dataset consisting of 216 COVID-19 patients that have passed the ethical review of the medical ethics committee. Experimental results validate our assumption that sequential stage-wise learning outperforms single-stage learning, but history long ago has little influence on the learning outcome. Also, comparison tests show the advantage of multimodal learning. MMDL with multimodal inputs can beat any reduced model with single-modal inputs only. In addition, we have deployed the prototype of MMDL in a hospital for clinical comparison tests and to assist doctors in clinical diagnosis.

KEYWORDS

COVID-19, disease severity assessment, disease progression prediction, sequential stage-wise learning, multimodal feature fusion

1. Introduction

Since December 2019, a novel viral pneumonia caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), also known as coronavirus disease 2019 (COVID-19) (1–3), first occurred in Wuhan, Hubei Province, China (4), then swept the globe very quickly. As of Sep 1, 2022, data from the World Health Organization (WHO) revealed more than 600 million infections confirmed worldwide with approximately 6.45 million deaths since the outbreak of COVID-19 (5). In view of its strong infectivity and high mortality, WHO declared the pandemic as a Public Health Emergency of International Concern (6).

In practice, the clinical manifestations of COVID-19 vary diversely from asymptomatic, mild infection to severe symptoms (4, 7–9). According to clinical statistics, the majority of COVID-19 cases are mild, and only approximately 5% of the total patients (a part of severe cases) require admission to ICU (10, 11). One of the serious problems we are facing is that the surge of COVID-19 infections leads to rapid depletion of the limited medical resources. The fact is that most of the mild patients can heal without supportive treatment (2, 3), and only a small proportion of them will progress toward severe illness. However, patients whose condition subsequently deteriorate are more prone to be older adults with comorbidities of diabetes, hypertension, cardiac disease, obesity etc. (9, 12), Once the illness changes for the worse, the mortality rate increases significantly, moreover, treating critical patients consumes more medical resources and takes longer treatment courses.

During COVID-19 treatment, doctors perform clinical examinations and laboratory tests on patients every few days. Hence, in every round of the tests, massive multimodal (i.e., various types or categories) clinical data are generated, including the patient demographics, clinical manifestation, laboratory outcomes, the use of drugs and medication, etc. Naturally, it is of great importance that we quickly and accurately distinguish mild and severe patients on admission, then identify those mild cases who are at high risk of turning for the worse in the future based on clinical data analysis and modeling. As a result, early intervention can be taken to prevent mild patients from deterioration.

In the past decade, AI and big data technologies have been widely applied in healthcare and medication and made remarkable achievements (13), which also play an important role in COVID-19 prevention and containment, including screening, testing, contact tracing, treatment and vaccination, and drug development (14–16). So far various forecasting models have been developed for the diagnosis and prognosis of COVID-19 (17–19), which leveraged X-ray and CT images (20–22), clinical characteristics (23, 24), blood test results (25), etc., for model development.

Most of the existing literature for the diagnosis and prognosis of COVID-19 simply makes use of one or two modalities of clinical data, which fails to explore the complementary information provided by multimodal sources. Moreover, the prognostic model is purely based on a single round of lab test results and cannot track the disease progression since onset. To address the characteristics of the consecutive rounds of multimodal clinical test data, in this paper, we propose a multistage multimodal deep learning (MMDL) model to (1) first assess the disease severity, and (2) identify those who are at an early stage of illness and are likely to grow worse. In MMDL, we conceive and implement a sequential stage-wise learning architecture, which abandons the classic structure of RNN (26, 27)/LSTM (28). It is because most patients take no more than five rounds of exams and lab tests before they recover from COVID-19 and are discharged from the hospital, so if we insist on using the RNN/LSTM (Recurrent Neural Network/Long Short-Term Memory) model, the input time step of RNN/LSTM is too few to forecast the future. The design philosophy of MMDL is motivated by the sequence-to-sequence (seq2seq) model (29, 30) in contextual sequence prediction, which extracts the latent feature of one sequence (encoder) and turns it to another sequence (decoder), then the decoded word in a sentence is based on the output from its previous contexts. Concretely, the embodiment of sequential stage-wise learning incorporates the input of the latest round of multimodal clinical data and the past information, and higher weights are given to recent inputs because it has direct influences on the final assessment and prediction results. In each round, to extract the feature of the multimodal clinical data, we design a two-layer multimodal feature extractor: in the **1st**-hierarchy, we build multiple separate fully-connected multi-layer perceptron (MLP) neural networks sharing the same network architecture, and each MLP extracts the intra-modal latent feature of an independent modality of clinical data; in the **2nd**-hierarchy, the extracted latent features of all modalities are concatenated, then input to another similar MLP for cross-modal feature fusion.

Extensive experiments are conducted on a dataset consisting of 216 patients diagnosed with COVID-19, which has passed the review of the medical ethics committee and can be used for research purposes only. These patients were admitted to the Public Health Medical Center in Chongqing, China, and received intensive medical care. The experimental results of the prognostic study show the advantage of sequential stage-wise learning of MMDL over conventional single-stage learning. In addition, the results also prove that MMDL with multimodal inputs can surpass the reduced model with any single-modal clinical data input by a large margin, particularly for the severe group in disease severity assessment and the mild-to-severe incidence group in the disease progression prediction.

2. Dataset description

2.1. Patient demographics

We retrospectively review the medical records of 216 patients with COVID-19 who were admitted to the Public Health Center in Chongqing, China from January 24, 2020,

to February 16, 2020. These patients were admitted fulfilling the following criteria: (1) tested positive with two consecutive nucleic acid tests; (2) showed distinct characteristics of pneumonia in CT images.

Figure 1 shows the demographics of these admitted patients that 103 cases (47.69%) out of the total number were male patients while female patients occupied 52.31% (113 cases). Depending upon the patient's severity of symptoms, 186 cases (86.11%) and 30 cases (13.89%) are diagnosed with mild and severe symptoms, respectively. By age, patients aged between 41 and 50 are the largest group with 50 cases (23.15%), which is followed by the group 31–40 and the group 60+ accounting for 20.83% (45 cases) each. Patients under the age of 18 and aged 19–30 only make up 5.09% (9 cases) and 11.57% (25 cases), respectively. Moreover, Figure 1d shows the average duration of onset of symptoms to hospital admission. A total of 76 and 20% of the patients were admitted in the first and the second week, respectively, since the onset of the disease. The remaining 4% of the patients developed symptoms after 2 weeks.

Figure 2 reveals the top 10 clinical manifestations of the 216 patients with COVID-19 infections. As it shows, cough [135 cases (62.50%)], fever [108 cases (50.00%)], and expectoration [68 cases (31.48%)] are reported as the most typical symptoms. It records 53 cases (24.54%) of fatigue and 38 cases (17.59%) of shortness of breath, which are another two common clinical manifestations. In addition, about 35 patients show no symptoms on admission.

2.2. Multimodal clinical data

During the COVID-19 treatment, numerous patients' clinical data are produced including patients' vital signs, laboratory test results, CT image findings, medical experts' diagnoses, and corresponding treatment plans. Among these clinical data, laboratory test results comprise 11 different categories, which is termed "multimodal" in the context of big data and machine learning. Specifically, the 11 modalities are named blood test, flow cytometry, inflammation, liver function, renal function, blood lipids, glucose, electrolyte, myocardial zymogram and heart failure indicator, coagulation, and arterial blood gas. Each modality contains many laboratory test items. For example, the blood test modality consists of white blood cell count (WBC), red blood cell count (RBC), neutrocyte count (NEUT#), monocytes count (MONO#), lymphocyte count (LYMPH#), etc., and the inflammation modality contains erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) and hypersensitive C-reactive protein (hs-CRP), and procalcitonin (PCT).

Table 1 describes the statistical results of the 11 modalities of laboratory tests of the mild group, the severe group, and the total population below:

3. Summary of notations

All the notations used in this paper are summarized below:

$\mathcal{F}_\Theta$	MMDL model for disease severity assessment with network parameters Θ;
$\mathcal{F}_\Phi$	MMDL model for disease progression prediction with network parameters Φ;
$\mathbf{X^{(n)}}$	A matrix. $\mathbf{X}^{(n)} = \left[X_1^{(n)}, ..., X_k^{(n)}, ..., X_K^{(n)}\right]$ is the input multimodal clinical data of the n-th stage;
$X_k^{(n)}$	A vector. The k-th modality clinical input data of the n-th stage;
$X_k'^{(n)}$	A vector. The extracted latent feature of k-th modality of the n-th stage;
$X_{\text{CAT}}^{(n)}$	A matrix. $X_{\text{CAT}}^{(n)} = \left[X_1'^{(n)}, ..., X_k'^{(n)}, ..., X_K'^{(n)}\right]$ is the concatenation of the extracted intra-modal latent features of all different modalities of the n-th stage;
N	A scalar. The total rounds (stages) of the performed clinical examination and lab tests;
K	A scalar. The total number of input modalities, $K = 13$, including the patient demographics, clinical manifestation and laboratory test results (e.g., blood test, inflammation, liver function, renal function, blood lipids, etc.);
$\mathbf{D}$	A vector. The extracted latent feature of patient demographics modality;
$\mathbf{Z}^{(n)}$	A vector. The extracted cross-modal feature representation of the n-th round clinical manifestation modality and other 11 laboratory test modalities;
$\mathbf{S}^{(n)}$	A vector. The intermediate learning outcome of the n-th stage;
$\mathbf{W_D}$	A matrix. The weighting matrix multiplying with $\mathbf{D}$;
$\mathbf{W}_\mathbf{Z}^{(n)}$	A matrix. The weighting matrix multiplying with $\mathbf{Z}^{(n)}$;
$\mathbf{W}_\mathbf{S}^{(n)}$	A matrix. The weighting matrix multiplying with $\mathbf{S}^{(n)}$;
$\mathbf{b}_\mathbf{S}^{(n)}$	A vector. The bias vector added to the computed results at stage n;
α	A scalar. $\alpha \in [0, 1]$ is a decay factor, by multiplying with which the learning outcome of the previous stage $\mathbf{S}^{(n)}$ is attenuated every round;
$\overline{Y}$	A vector. The output vector for computing $\bar{y}$;
$\bar{y}$	A scalar. The obtained result of either disease severity assessment ($\bar{y} \in \{mild, severe\}$) or disease progression prediction ($\bar{y} \in \{not\text{–}develop\text{–}severe, develop\text{–}severe\}$);
y	A scalar. The corresponding ground truth label;
MLP	The fully connected multilayer perceptron neural network;
$ReLU$	The rectified linear unit activation function;

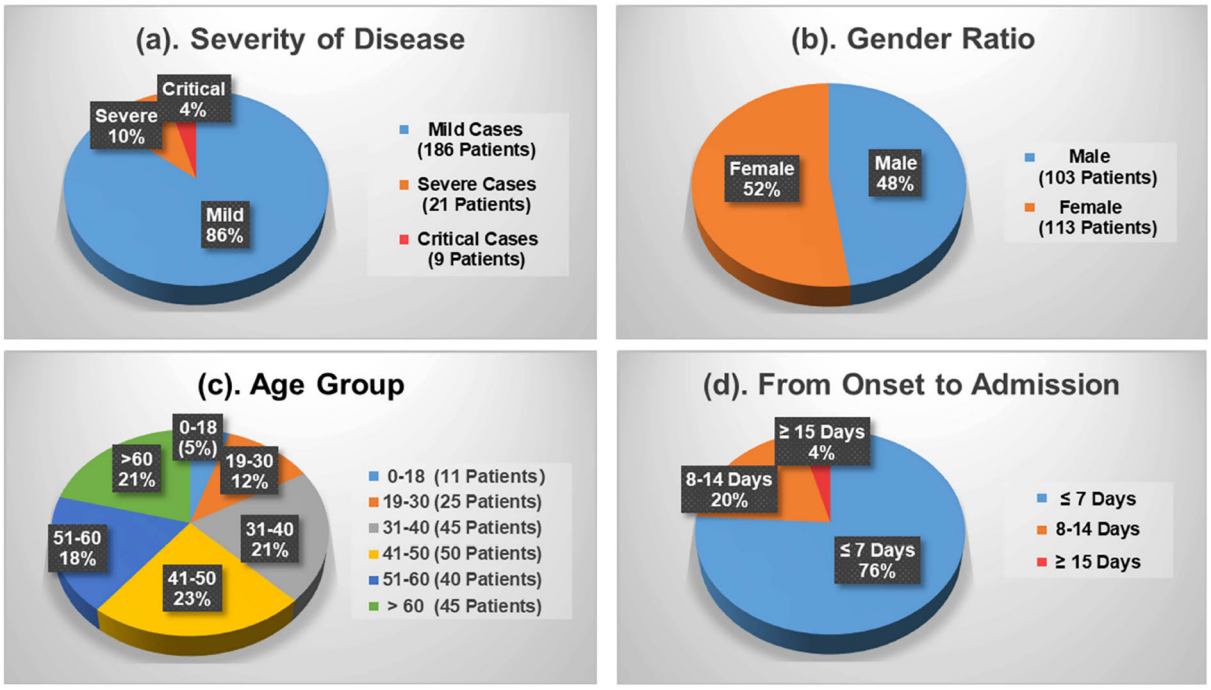


FIGURE 1
Demographics of the COVID-19 patients contained in the dataset. **(a)** Severity of disease. **(b)** Gender ratio. **(c)** Age group. **(d)** From onset to admission.

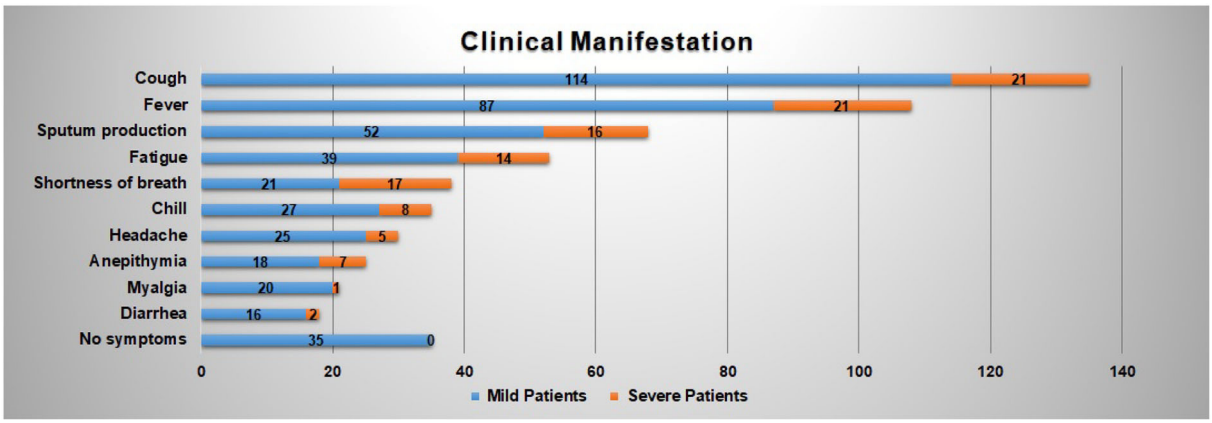


FIGURE 2
Clinical manifestation of the COVID-19 patients contained in the dataset.

Softmax	The softmax multi-class classifier;
$\mathcal{L}_{\text{cross-entropy}}$	The cross-entropy loss function.

4. Problem formulation

Given patients infected by COVID-19 take N rounds of clinical examination and laboratory tests in total during the treatment. In each round, K different modalities of clinical data (e.g., clinical manifestation, blood test, inflammation, liver function, etc.) are collected for disease assessment and prediction. Take the n-th round as an example, the notation $\mathbf{X^{(n)}}$ is used to denote the stage-wise multimodal input:

$$\mathbf{X}^{(n)} = \left[X_1^{(n)}, X_2^{(n)}, \ldots, X_k^{(n)}, \ldots, X_K^{(n)} \right], \tag{1}$$

where $1 \leq n \leq N$ and $1 \leq k \leq K$.

By leveraging the stage-wise multimodal clinical data, $\mathbf{X}^{(1)}, \mathbf{X}^{(2)}, \ldots, \mathbf{X}^{(n)}, \ldots, \mathbf{X}^{(N)}$, our goal is to develop a model $\mathcal{F}$ to: (1) assess the disease severity of patients diagnosed with COVID-19, and (2) forecast mild cases who have a high risk of progressing to critical illness. The two tasks share the same network architecture but are trained separately with two different sets of network parameters.

Mathematically, in the disease severity assessment task, it can be expressed as:

$$\bar{y}_{\bar{y}\in\{mild,\,severe\}} = \mathcal{F}_{\Theta}\left(\mathbf{X}^{(1)}, \mathbf{X}^{(2)}, \ldots, \mathbf{X}^{(n)}, \ldots, \mathbf{X}^{(N)} \mid \Theta\right), \quad (2)$$

where $\bar{y} \in \{mild, severe\}$ is used to denote the obtained result of assessment, $\mathcal{F}_{\Theta}$ represents the MMDL model with the parameter Θ that maps the multistage input to the output $\bar{y}$.

Similarly, in the disease progression prediction task, it can be written as:

$$\bar{y}_{\bar{y}\in\{not\text{–}develop\text{–}severe,\,develop\text{–}severe\}} = \mathcal{F}_{\Phi}\left(\mathbf{X}^{(1)}, \mathbf{X}^{(2)}, \ldots, \mathbf{X}^{(n)}, \ldots, \mathbf{X}^{(N)} \mid \Phi\right), \quad (3)$$

Likewise, $\bar{y}_{\bar{y}\in\{not\text{–}develop\text{–}severe,\,develop\text{–}severe\}}$ is the predicted results and $\mathcal{F}_{\Phi}$ is the corresponding prediction model with network parameters Φ.

5. Multistage multimodal deep learning model

In this section, we introduce the multistage, multimodal deep learning (MMDL) model in detail. We first illustrate the sequential stage-wise learning framework, then present the feature extraction of the multimodal clinical data at each stage, and finally come to the end-to-end training of MMDL.

5.1. Sequential stage-wise learning

Sequential stage-wise learning and sequence prediction share some common ground, although they are different in some respects. The sequence-to-sequence (seq2seq) model (29, 30) is one of the classical benchmarks in contextual sequence prediction. It transforms one sequence into another sequence, and the context of the decoded sentence is based on the output from its previous contexts.

Motivated by this, we propose the sequential stage-wise learning architecture of MMDL, which is illustrated in Figure 3. As we can see, it meticulously joins the extracted cross-modal latent feature of the previous stage and the current stage, then concatenates the result with the extracted multimodal feature of the next stage sequentially for further processing.

In the first stage, the model takes the patient demographics $\mathbf{D}$ and the initial examination and laboratory test results $\mathbf{Z}^{(1)}$ when admitted to the hospital as the model input. It should be noted that $\mathbf{D}$ is the extracted latent feature of the patient demographics modality only, and $\mathbf{Z}$ is the merged multimodal feature representation across all different modalities of lab test results. How $\mathbf{Z}$ is extracted and merged will be justified in the next subsection in detail.

$\mathbf{D}$ and $\mathbf{Z}$ first multiply with $\mathbf{W}_{\mathbf{D}}$ and $\mathbf{W}_{\mathbf{Z}}^{(1)}$ respectively, and add together, then pass through the *ReLU* activation function.

$$\mathbf{S}^{(1)} = ReLU\left(\mathbf{W}_{\mathbf{D}}\mathbf{D} + \mathbf{W}_{\mathbf{Z}}^{(1)}\mathbf{Z}^{(1)} + \mathbf{b}_{\mathbf{S}}^{(1)}\right), \quad (4)$$

where $\mathbf{S}^{(1)}$ is the output of the first stage. $\mathbf{W}_{\mathbf{D}}$ and $\mathbf{W}_{\mathbf{Z}}^{(1)}$ are the weight matrices, and $\mathbf{b}_{\mathbf{S}}^{(1)}$ is the bias term. *ReLU* is short for rectified linear units (31), which can be expressed as $ReLU(x) = max(0, x)$ and is a non-linear activation function.

Then $\mathbf{b}_{\mathbf{S}}^{(1)}$ multiplies with the weight $\mathbf{W}_{\mathbf{S}}^{(1)}$ accordingly and adds to the result of the multiplication of $\mathbf{Z}^{(2)}$ and $\mathbf{W}_{\mathbf{Z}}^{(2)}$. Similarly, we can derive the expression of the learning process of the second stage:

$$\mathbf{S}^{(2)} = ReLU\left(\mathbf{W}_{\mathbf{Z}}^{(2)}\mathbf{Z}^{(2)} + \alpha\mathbf{W}_{\mathbf{S}}^{(1)}\mathbf{S}^{(1)} + \mathbf{b}_{\mathbf{S}}^{(2)}\right), \quad (5)$$

in which $\mathbf{Z}^{(2)}$ is the extracted cross-modal latent feature of the second stage and $\mathbf{W}_{\mathbf{Z}}^{(2)}$ is the corresponding weight. It should be mentioned that $\mathbf{W}_{\mathbf{S}}^{(1)}\mathbf{S}^{(1)}$ is attenuated by multiplying with a decay factor $\alpha \in [0, 1]$ because the new round of test results has a direct impact on the predicted results while the influence of the test result obtained long ago weakens as time passes.

Note that the modality of patient demographics is incorporated into the model in the initial stage only since the patient demographics modality contains patients' basic information, like gender and age, that does not change in every round of test.

For the n-th stage ($2 \leq n \leq N$), a more general form can be written as:

$$\mathbf{S}^{(n)} = ReLU\left(\mathbf{W}_{\mathbf{Z}}^{(n)}\mathbf{Z}^{(n)} + \alpha\mathbf{W}_{\mathbf{S}}^{(n-1)}\mathbf{S}^{(n-1)} + \mathbf{b}_{\mathbf{S}}^{(n)}\right), \quad (6)$$

Finally, the learned representation of the last stage $\mathbf{W}_{\mathbf{S}}^{(N)}$ is further fused to get the output vector $\overline{Y}$:

$$\overline{Y} = \mathbf{W}_{\mathbf{S}}^{(N)}\mathbf{S}^{(N)} + \mathbf{b}_{\mathbf{S}}', \quad (7)$$

and pass it through a multi-class Softmax classifier to get the predicted outcome $\bar{y}$.

$$\bar{y} = Softmax\left(\overline{Y}\right), \quad (8)$$

$\bar{y}$ is the output scalar, which is either *mild* or *severe* in the first task and $not-develop-severe$ or $develop-severe$ in the second.

TABLE 1 Characteristics of multimodal lab test results of the COVID-19 patients contained in the dataset.

Characteristics	All patients $N = 216$	Mild patients $N = 186$ (86.11%)	Severe patients $N = 30$ (13.89%)
Blood test			
White blood cell (WBC), $\times 10^9/L$	6.03	5.32	6.47
Neutrophils (NEUT), $\times 10^9/L$	4.05	3.32	4.98
Lymphocyte (LYMPH), $\times 10^9/L$	1.34	1.43	0.86
Monocytes (MONO), $\times 10^9/L$	0.40	0.42	0.36
Eosinophils (EO), $\times 10^9/L$	0.06	0.06	0.06
Basophils (BASO), $\times 10^9/L$	0.02	0.02	0.02
Red blood cell (RBC), $\times 10^{12}/L$	4.20	4.25	4.00
Hemoglobin (HGB), g/L	128	130	124.3
Hematocrit (HCT), L/L	38.80	39.10	37.57
Mean corpuscular hemoglobin concentration (MCHC), g/L	331.6	332	331.2
Platelet (PLT), $\times 10^9/L$	229	216	244.8
Mean platelet volume (MPV), fL	9.40	9.30	9.62
Platelet hematocrit (PCT), (%)	0.21	0.20	0.23
Flow cytometry			
Absolute CD3+ T lymphocyte, $cells/\mu L$	729	829	461
Absolute CD4+ T lymphocyte, $cells/\mu L$	420	451	259
Absolute CD8+ T lymphocyte, $cells/\mu L$	281	316	145
CD4+ / CD8+ ratio	1.43	1.38	1.47
Inflammation			
Erythrocyte sedimentation rate (ESR), mm/h	46.6	38.2	71.3
C-reactive protein (CRP), mg/L	26.2	17.3	65
Hypersensitive C-reactive protein (hsCRP), mg/L	32.5	21.9	71.1
Procalcitonin (PCT), ng/L	0.096	0.040	0.331
Liver function			
Prealbumin (PA), $\mu g/dL$	221	227	200
α-L-Fucosidase (AFU), U/L	27.8	27.4	29.7
Alanine aminotransferase (ALT), U/L	34	28.1	59.3
Aspartate aminotransferase (AST), U/L	27.8	24.6	41.5
Alkaline phosphatase (ALP), IU/L	58.9	57.2	66.1
Gamma-glutamyltransferase (GGT), IU/L	43.3	32.2	90.7
Lactate dehydrogenase (LDH), IU/L	235	209	343
Total protein (TP), g/L	66.7	67.3	64.5
Albumin (ALB), g/L	40.2	41.2	35.5
Globulin (GLB), g/L	27.3	26.8	29.5
A/G Ratio	1.40	1.50	1.24
Total bilirubin (TBIL), $\mu mol/L$	15.6	15.8	15.1
Total bile acid (TBA), $\mu mol/L$	3.00	3.10	2.34
Renal function			
UREA, $mmol/L$	3.83	3.71	4.10
Creatinine (CREA), $\mu mol/L$	66.9	67.2	65.9
Uric acid (UA), $\mu mol/L$	303	320	231
Beta 2-microglobulin ($\beta 2 - M$), mg/L	2.19	2.16	2.38
Cystatin C (CysC), mg/L	0.99	0.96	1.16

(Continued)

TABLE 1 (Continued)

Characteristics	All patients $N = 216$	Mild patients $N = 186$ (86.11%)	Severe patients $N = 30$ (13.89%)
Glucose modality			
Glucose (hexokinase (HK) method), *mmol/L*	6.41	6.11	7.73
Blood lipids			
Triglyceride (TG), *mmol/L*	2.23	2.11	2.69
Total cholesterol (CHOL), *mmol/L*	4.39	4.28	4.26
High-density lipoprotein (HDL), *mmol/L*	1.02	1.03	0.97
Low-density lipoprotein (LDL), *mmol/L*	2.47	2.42	2.38
Electrolyte			
Potassium (K), *mmol/L*	4.21	4.24	4.00
Sodium (NA), *mmol/L*	138.2	138.4	137.8
Chlorine (CL), *mmol/L*	102.7	103.0	101.5
Calcium (CA), *mmol/L*	2.24	2.26	2.13
Phosphorus (P), *mmol/L*	1.08	1.11	0.98
Magnesium (MG), *mmol/L*	0.89	0.88	0.93
Coagulation function			
Prothrombin time (PT), *seconds*	11.77	11.76	11.81
International normalized ratio (INR)	1.00	1.01	0.96
Activated partial thromboplastin time (APTT), *seconds*	38.50	38.40	39.25
Thrombin time (TT), *seconds*	14.90	14.70	15.15
Fibrinogen (FIB), *g/L*	4.25	4.20	4.62
D-dimer, *mg/L*	0.68	0.44	1.64
Myocardial zymogram & Heart failure			
Adenosine deaminase (ADA), *U/L*	14.10	13.85	14.36
Creatine kinase (CK), *U/L*	100	88	151
α-Hydroxybutyrate dehydrogenase (α-HBDH), *IU/L*	179	160	262
5'-Nucleotidase (5'-NT), *U/L*	4.38	3.94	6.25
Cholinesterase (CHE), *U/L*	7960	8409	6699
Arterial blood gas			
Arterial blood pH	7.42	7.41	7.45
Partial pressure of oxygen (PaO2), *mmHg*	85	85	86
Partial pressure of carbon dioxide (PaCO2), *mmHg*	41	41	40
Bicarbonate (HCO3-), *mEq/L*	26.10	26.00	26.95
Oxygen saturation (SaO2), (%)	96.90%	97.30%	96.15%

5.2. Multimodal feature extraction

As mentioned above, the input to each stage is multimodal lab test results. To address the characteristics of the multimodal input data, we would like to introduce a two-layer multimodal feature extractor conceived by us and the architecture of which is shown in Figure 4. As we can see, the **1st**-hierarchy aims to perform intra-modal feature learning and extraction, while the **2nd**-hierarchy attempts to perform cross-modal feature fusion.

Concretely, in the **1st** hierarchy, we build up K ($K = 13$) independent multilayer perceptron (MLP) neural networks. Each MLP is responsible for extracting the latent feature of a separate input modality, including the patient demographics, clinical manifestation, and 11 other modalities of laboratory test data.

For example, the extracted feature of the k-th modality of the n-th round test can be expressed as:

$$X_k'^{(n)} = MLP\left(X_k^{(n)}\right), \tag{9}$$

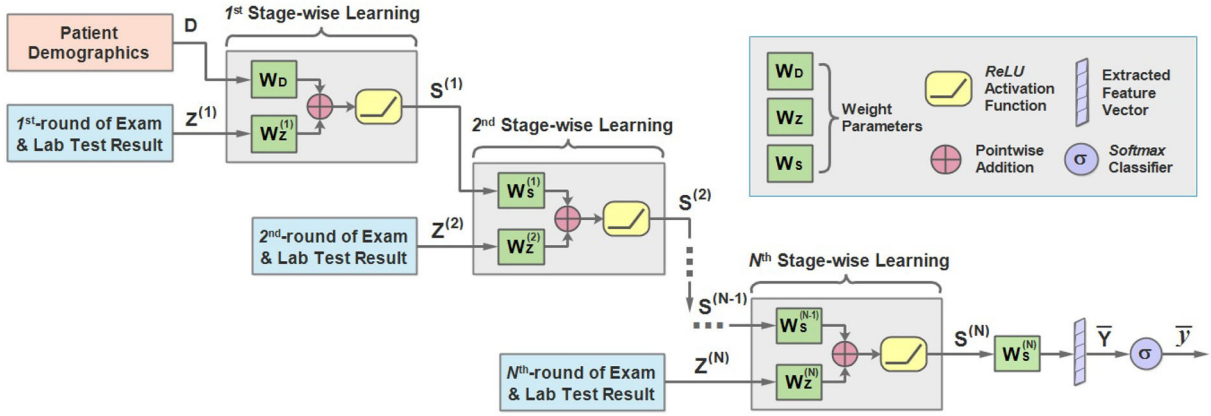


FIGURE 3
An illustration of the architecture of the sequential stage-wise learning of the MMDL model.

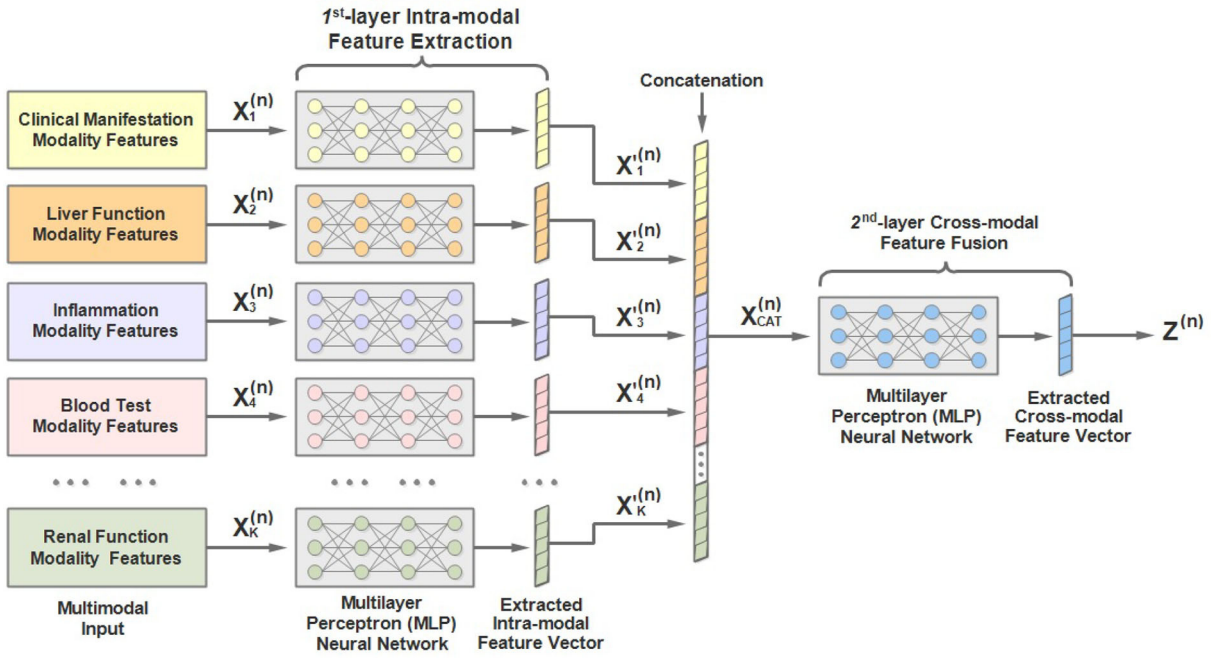


FIGURE 4
An illustration of the architecture of multimodal feature extractor of the MMDL model.

where $X_k'^{(n)}$ denotes the extracted latent feature vector of the k-th modality ($1 \leq k \leq K$), and *MLP* represents the multi-layer fully-connected neural network.

Afterwards, the extracted intra-modal feature vectors of all modalities $X_1'^{(n)}, X_2'^{(n)}, \ldots, X_k'^{(n)}, \ldots, X_K'^{(n)}$ are concatenated:

$$X_{\mathrm{CAT}}^{(n)} = \left[X_1'^{(n)}, X_2'^{(n)}, \ldots, X_k'^{(n)}, \ldots, X_K'^{(n)}\right]. \quad (10)$$

Finally, the concatenated feature vectors $X_{\mathrm{CAT}}^{(n)}$ are further processed by another *MLP* to obtain the fused cross-modal feature representation $\mathbf{Z}^{(n)}$, which is then taken as the input of the n-th stage of MMDL:

$$\mathbf{Z}^{(n)} = MLP\left(X_{\mathrm{CAT}}^{(n)}\right), \quad (11)$$

5.3. Model training

Before training the model, we have to define the loss function in the first place, which gives the learning objective

during the training process. The loss function compares the difference between the predicted results $\bar{\mathbf{y}}$ and the ground truth labels y given by medical experts, and a smaller value of $\mathcal{L}$ means the model's performance is better. Either the patient disease assessment or the disease progression prediction can be regarded as a classification problem, hence we choose cross-entropy as the loss function, which is widely used in multi-class classification problems:

$$\mathcal{L}_{\text{cross-entropy}} = -\sum_j y_j \cdot \log\left(p(\bar{y}=j)\right), \tag{12}$$

where j represents the predicted class, and $j = \{mild, severe\}$ for the disease severity assessment and $j = \{not-develop-severe, develop-severe\}$ for disease progression prediction. $p(\hat{\mathbf{y}} = j)$ is the predicted probability of the class j using *Softmax*, i.e.,

$$p(\bar{y}=j) = Softmax(Y_j) = \frac{e^{Y_j}}{\sum_{i=1}^{\#class} e^{Y_i}}. \tag{13}$$

The notation *#class* represents the number of classes, and $\#class = 2$ in our settings because there are two results for both the assessment and the prediction tasks.

During the training process, the end-to-end supervised learning is used to train MMDL. Adam optimizer is adopted to backpropagate the calculated loss to the input layer of the model, and all network parameters (weights and biases) are updated through iterative optimization. MMDL is trained two times separately to learn two different sets of network parameters, i.e., Θ and Φ, one for the disease severity assessment and the other for the disease progression prediction.

6. Experiments

In this section, we will present the experimental part of MMDL in detail. We first introduce how we set up the experiment, then the evaluation metrics, and finally present the comparison results for both tasks.

6.1. Experiment setup

In the experiment, we first assess the severity of illness of patients using different numbers of consecutive stages of multimodal inputs (*#Multistage Input*), then forecast whether patients with mild symptoms will progress to severe illness or not with different prediction steps (*Prediction Step*). To start with, we assess the severity of illness of patients using the initial exam and lab test data on admission, then identify patients diagnosed with mild symptoms who are prone to develop severe symptoms. Subsequently, we extend it to the scenario of the diesese severity assessment using multistage input, i.e., use multiple successive rounds of clinical test data to assess the disease severity.

In addition, in view of the limited samples contained in the dataset, 10-fold cross validation is adopted, that is, in each round of training, 10% of the cases are randomly selected for testing and the remaining 90% cases are used for training, while in another round, another 10% cases are selected as the test set.

6.2. Evaluation metric

We use a group of evaluation metrics to evaluate the classification performance of MMDL, including accuracy, error rate, precision, recall, and F1 score, which are computed as follows:

$$\begin{cases} Accuracy = \dfrac{TP+TN}{TP+TN+FP+FN}, \\ Error\ Rate = 1 - Accuracy, \\ Precision = \dfrac{TP}{TP+FP}, \\ Recall = \dfrac{TP}{TP+FN}, \\ F1 = \dfrac{2}{\frac{1}{Precision}+\frac{1}{Recall}} = \dfrac{2\times TP}{2\times TP+FP+FN}, \end{cases} \tag{14}$$

where TP, FP, TN, and FN represent True Positive, False Positive, True Negative, and False Negative samples, respectively. The higher the value obtained, the better performance is achieved for all evaluation metrics but the error rate.

6.3. Results

6.3.1. Disease severity assessment with different numbers of multistage input

To show the advantage of learning with multistage data, we compare the performance of MMDL using a single stage's inputs (i.e, $\#Multistage\ Input = 1$) and multiple successive stages' inputs (i.e, $\#Multistage\ Input > 1$) on disease severity assessment (i.e., $Prediction\ Step = 0$).

Table 2 shows the obtained results. Accuracy is the proportion of the correctly classified samples (i.e., TP + TN) to the total number of samples, so the mild and the severe groups have the same accuracy, which increases from 96.26% using the current stage inputs only to 98.10% using five consecutive stages' inputs. Precision is the correct predictions (i.e., TP) out of all patients predicted to be infected (i.e., TP + FP), which grows from 97.52% with $\#Multistage\ Input = 1$ to 98.69% with $\#Multistage\ Input = 5$, respectively. Recall, which represents the percentage of truly predicted infections (i.e., TP) among all infections (i.e., TP + FN), goes from 98.33 to 99.60%. F1 is the harmonic mean of precision and recall, which is a more balanced evaluation metric to reflect the overall classification results. Moreover, we plot the curve depicting the change of F1 as the increase of the numbers of used multistage input in Figure 5.

TABLE 2 Performance comparison of MMDL model with different numbers of multistage inputs.

	#Multistage Input data	Prediction Step	Accuracy	Error Rate	Precision	Recall	F1 Score
Mild group	1	0	96.26%	3.73%	97.52%	98.33%	0.9792
	2	0	96.98%	3.01%	97.74%	98.86%	0.9830
	3	0	97.74%	2.25%	98.03%	99.40%	0.9871
	4	0	98.09%	1.90%	98.60%	99.50%	0.9887
	5	0	98.10%	1.89%	98.69%	99.60%	0.9890
Severe group	1	0	96.26%	3.73%	84.12%	77.94%	0.8091
	2	0	96.98%	3.01%	90.56%	82.75%	0.8648
	3	0	97.74%	2.25%	95.52%	86.48%	0.9078
	4	0	98.09%	1.90%	95.16%	92.18%	0.9365
	5	0	98.10%	1.89%	95.71%	93.05%	0.9436

We can see that in the training phase, the obtained results are all 100% for both the mild and severe groups, which reveals that MMDL fits the training set perfectly. In the testing phase, the F1 score of the mild and the severe groups increases from 0.9792 and 0.8091 by simply taking a single stage's inputs to 0.9890 and 0.9436 by considering all five successive stages' multimodal data, respectively.

6.3.2. Prediction of disease progression with different prediction steps

In this subsection, we would like to forecast progression from mild to severe COVID-19. First, it gives a brief introduction to the labels of the dataset. Medical experts assess patients' status after every round of the exam and lab test, which is treated as the ground truth labels of the prediction task of that stage. We set *Prediction Step* $=$ 1 if we want to predict the patient's condition after the next round's test, and *Prediction Step* $=$ 4 if we predict the patient's situation four stages ahead.

Table 3 describes the predicted results as the increase of the *PredictionStep*. The accuracy, precision, and recall of the mild group are 96.26, 97.52, and 98.33%, respectively, when *Prediction Step* $=$ 0, then gradually decrease to 93.44, 95.74, and 97.12% when predicting the state of the illness of patients four stages away from now (*Prediction Step* $=$ 4). For the severe group, these figures start from 96.26, 84.12, and 77.94%, then drop rapidly and finally stop at 93.44, 48, and 36.36%, respectively. Figure 6, left, right plot the curves of the F1 score of the mild-to-mild and mild-to-severe progressions as the increase of *Prediction Step*. In the testing phase, the F1 of the mild-to-mild incidence decreases from 0.9792 (*Prediction Step* $=$ 0) to 0.9653 (*Prediction Step* $=$ 4) gradually. But the situation worsens when predicting progression from mild to severe COVID-19 that F1 begins at 0.8091 (*Prediction Step* $=$ 0), then declines dramatically to 0.5957 (*Prediction Step* $=$ 1) and 0.5098 (*Prediction Step* $=$ 2), then continues to decrease and finally stops at 0.4137 for *Prediction Step* $=$ 4.

6.3.3. The ROC and AUC of disease severity assessment and prediction of disease progression

Figure 7 shows the receiver operating characteristic (ROC) and the area under the curve (AUC) of disease severity assessment (left) with *#Multistage Input* $=$ 1 and *Prediction Step* $=$ 0 and prediction of disease progression (right) with *#Multistage Input* $=$ 1 and *Prediction Step* $=$ 4. An ROC curve is a graph showing the performance of a classification model at different classification thresholds. The x-axis is FPR (False Positive Rate) which is calculated as $FPR = \frac{FP}{FP+TN}$, and the y-axis is TRP (True Positive Rate), also known as recall, which is computed as $TRP = \frac{TP}{TP+FN}$. Lowering the classification threshold classifies more items as positive, thus increasing both False Positives (FP) and True Positives (TP).

As Figure 7 (left) illustrates, the blue and red curves represent the ROC of the mild group and the severe group, respectively, and the green curve is the arithmetical average of them. The blue curve approaches the top-left corner, which means the MMDL model is a good classifier for distinguishing mild cases out of all infections. The classification result of severe cases is worse than that of the mild cases as the red curve is not as steep as the blue one in the beginning until FPR equals around 0.3, then the red curve approaches the blue one. In the right subfigure of Figure 7, it shows the ROC and AUC of patients' progression from mild to severe infection (denoted by the light blue curve) and of the ones that deteriorate (denoted by the red curve). As the figure shows, the achieved results of the MMDL model for predicting disease progression are not as good as those for assessing the patient's status. We can observe a distinct plateau region in Figure 7, right where both the blue and red curves do not go up. It means the MMDL model has difficulty

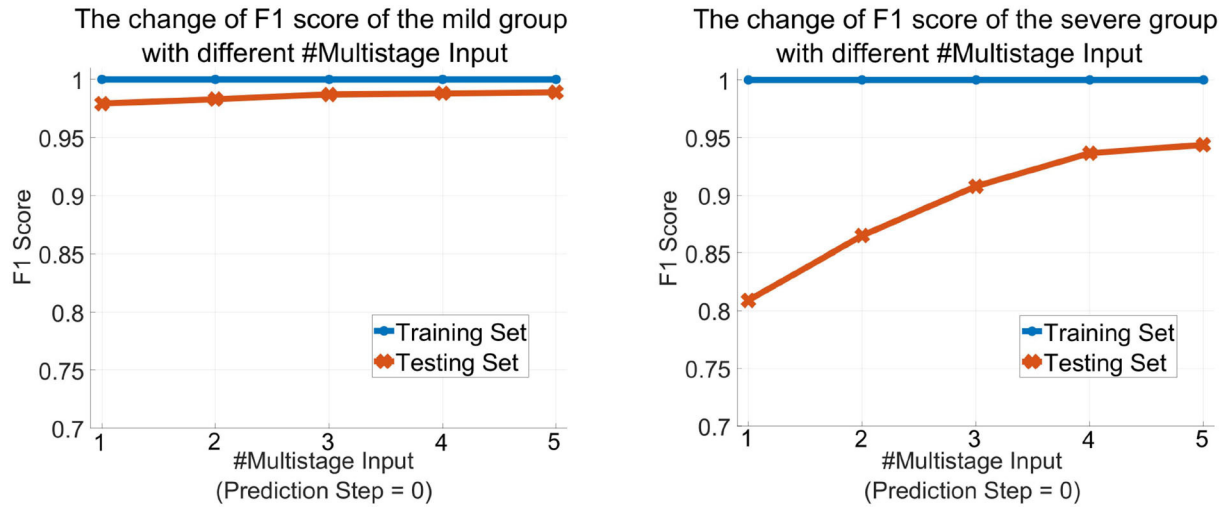


FIGURE 5
The change of the F1 score of MMDL model as the increase in the number of multistage inputs of the mild group **(left)** and the severe group **(right)**.

TABLE 3 Performance comparison of MMDL model with different prediction step.

	#Multistage Input data	Prediction Step	Accuracy	Error Rate	Precision	Recall	F1 Score
Mild group	1	0	96.26%	3.73%	97.52%	98.33%	0.9792
	1	1	95.63%	4.30%	96.86%	98.52%	0.9769
	1	2	94.43%	5.50%	96.25%	97.85%	0.9704
	1	3	93.61%	6.30%	96.00%	97.22%	0.9661
	1	4	93.44%	6.55%	95.74%	97.12%	0.9653
Severe group	1	0	96.26%	3.73%	84.12%	77.94%	0.8091
	1	1	95.63%	4.30%	70.00%	51.85%	0.5957
	1	2	94.43%	5.50%	59.09%	44.82%	0.5098
	1	3	93.61%	6.30%	50.00%	40.62%	0.4482
	1	4	93.44%	6.55%	48.00%	36.36%	0.4137

distinguishing between the one developing and not developing severe symptoms when $0.2 \leq FPR \leq 0.7$.

6.3.4. The impact of multimodal deep learning on the performance of the MMDL model

To show the advantages of multimodal learning for feature extraction and fusion across different modalities of clinical data, we compare the performance of the complete MMDL model with multimodal inputs and the reduced models with separate single-modal inputs only in the testing phase.

Figure 8 (upper) and (middle) compare MMDL using the latest round of exam and lab test results as the model input (*Multistage Input* $=$ 1 and *PredictionStep* $=$ 0) and leveraging the last five consecutive rounds of test data (*Multistage Input* $=$ 5 and *PredictionStep* $=$ 0). As we can see, the overall performance of the MMDL model for assessing the mild group exceeds that of the severe group by a large margin regardless of using single-stage or multistage inputs. Noted that the performance gain is limited for the mild group, particularly for *#Multistage Input* $=$ 1, but significant for the severe group, which grows at least 15% for both *#Multistage Input* $=$ 1 and *#Multistage Input* $=$ 5.

Figure 8 (lower) depicts the bar chart of the F1 score for forecasting a patient's condition four stages away from now (*Prediction Step* $=$ 4). From the diagram, we have the following observations: the achieved F1 score is good for mild-to-mild but, to some extent, terrible for mild-to-severe incidence prediction. It reveals the false-negative rate of the mild-to-severe incidence prediction is high, that is, samples are more prone to be classified as not developing severe symptoms. Nevertheless, MMDL predicting with multimodal inputs outperforms reduced

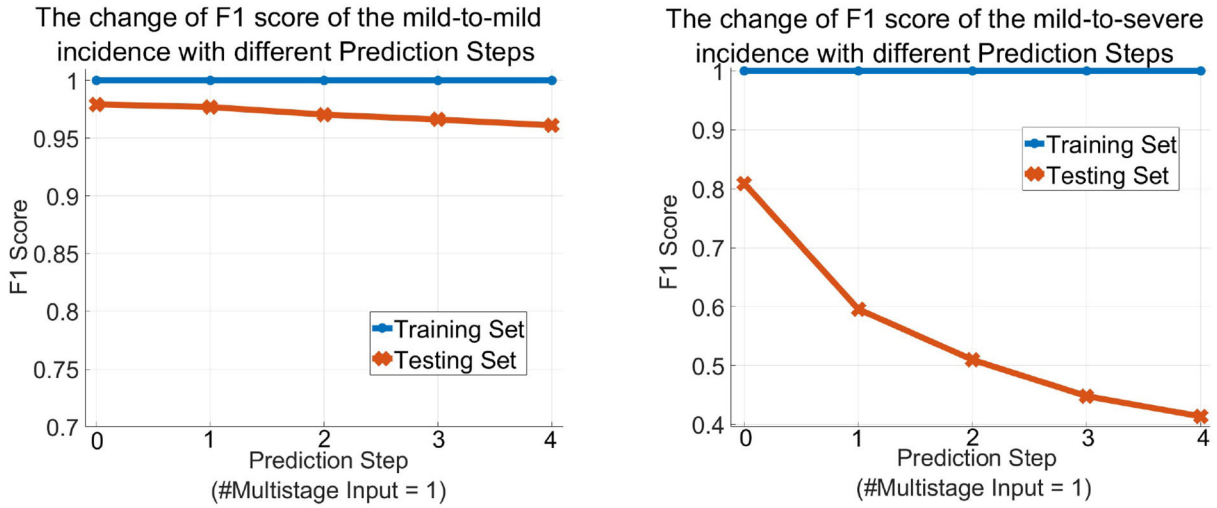


FIGURE 6
The change of the F1 score of the MMDL model as the increase of the prediction step of the mild group **(left)** and the severe group **(right)**.

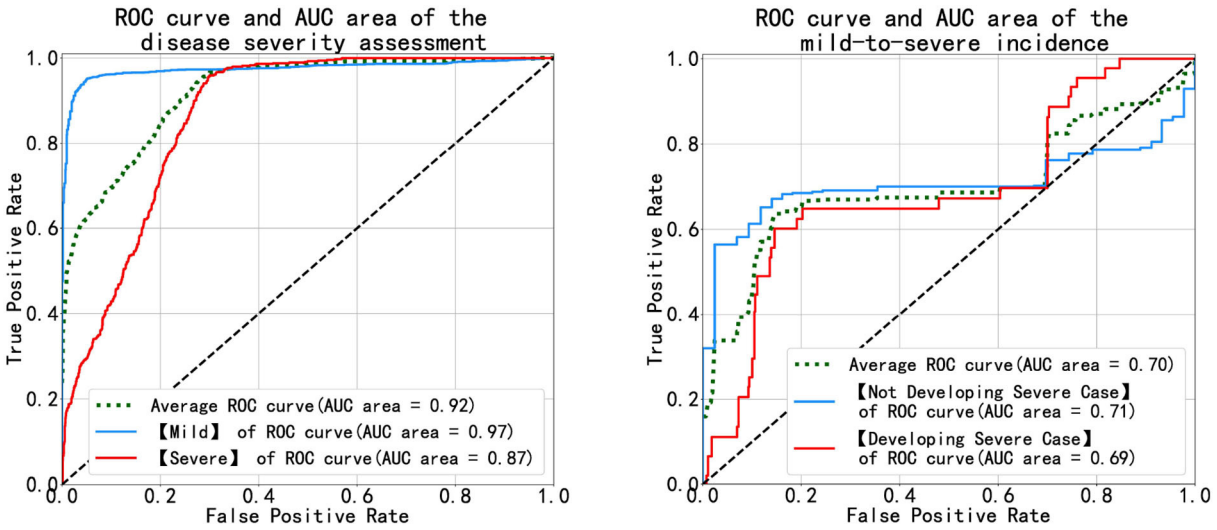


FIGURE 7
Diagrams of the ROC and AUC of the disease severity assessment **(left)** and the disease progression prediction **(right)**.

models using any single-modal clinical data, which validates the superiority of multimodal learning. Furthermore, it is worth pointing out that among all modalities, inflammation, liver function, blood lipids, and arterial blood gas reach much higher F1 than any other modality. Hence, further explorations need to be conducted to discern the effective biomarkers within these modalities, which can be treated as signs to discriminate between mild cases developing and not developing severe symptoms.

7. Discussion

We notice that in the disease severity assessment task, MMDL's classification performance in the severe group is not as good as the mild group irrespective of using single-stage or multistage inputs. Similar observations are made in the disease progression prediction task as well that the prediction results of the mild-to-severe incidence fall far behind the mild-to-mild

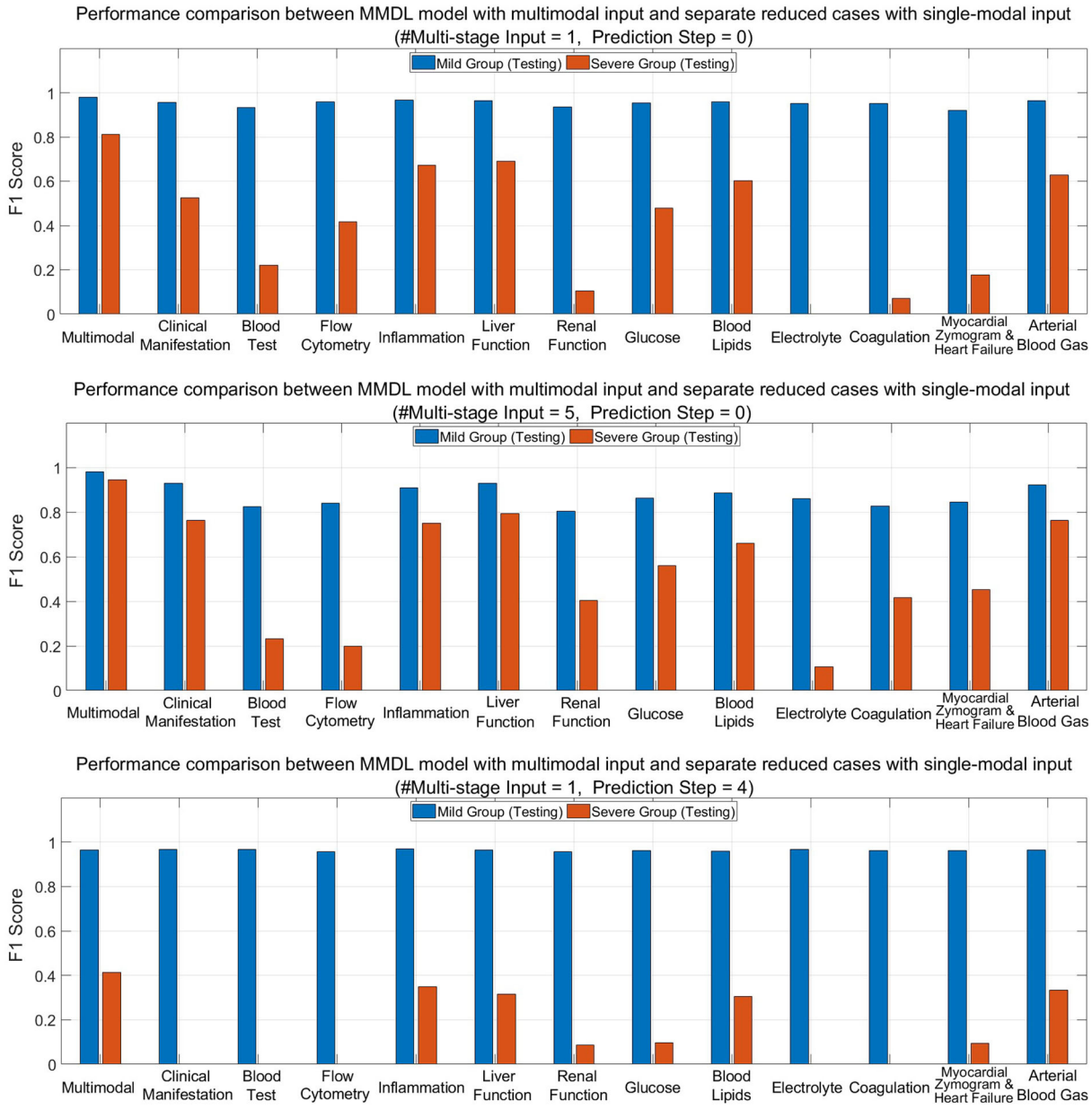


FIGURE 8
Performance comparison between MMDL model with multimodal input and reduced cases with separate single-modal inputs with different *#Multistage Input* and *Prediction Step*.

incidence. From our perspective, the reasons for this are twofold: (1) The patient samples contained in the dataset are quite limited for clinical data analysis and model development. We are only authorized to use these 200+ samples legally that pass the review of the ethics committees (RECs). However, ethics and compliance are extremely important in clinical research, and samples that fail to pass RECs are strictly forbidden to use; (2) What makes the situation even worse is the imbalanced distribution of patient samples (only 30 severe cases). As a result, it is insufficient to learn the characteristics of the patients of the severe group and the transition from mild to severe symptoms.

Besides the small sample learning, another challenge is that patient samples contained in the dataset were collected during the first wave of the pandemic, and the pre-trained model may no longer take effect as the virus has evolved to the Omicron variant in 2022. To address the challenge, we have deployed the prototype of MMDL in Chongqing Public Health Center, China, to validate the effectiveness of MMDL when facing new variants

of COVID-19. Alongside model testing, we also collect new patient samples and attempt to train MMDL using new samples incrementally. Furthermore, to test the MMDL's availability in other chronic diseases, we are extending it to epilepsy prediction characterized by many follow-ups.

Another observation is that MMDL using multiple sequential stages' exam and lab test data outperforms the current stage's data in disease severity assessment. In particular, the latest three rounds' inputs dominate the assessment results, and history long ago has little influence on the model's output. Moreover, in predicting the disease progression, we can observe prediction results deteriorate as *Prediction Step* increases. It is because, according to our point of view, biomarkers show no significant abnormality to discriminate whether patients will turn for the worse in the distant future.

Also, experimental results validate multimodal feature extraction and fusion can provide complementary information to single-modal feature learning. Another interesting finding reveals that either in assessment or prediction, merely leveraging the modality of inflammation, liver function, or blood lipids data, etc., overwhelms any other single-modal input. It suggests that some test items in the inflammation modality and the liver function modality, such as C-reactive protein (CRP), hypersensitive C-reactive protein (hsCRP), γ-glutamyltransferase (GGT), and Albumin (ALB), are potential biomarkers in distinguishing COVID-19 infections.

8. Conclusion

In this paper, we have conceived and implemented a multistage, multimodal deep learning (MMDL) model to assess the disease severity and forecast the disease progression of patients with COVID-19. In summary, the novelty of MMDL embodies sequential stage-wise learning with multimodal inputs. MMDL shows the advantage of studying whole courses of the disease compared to single-stage learning. Also, mining the multimodal clinical data can provide significant performance gains over using single-modal data only. Some potential biomarkers have been identified in the control experiment, such as C-reactive protein (CRP) and hypersensitive C-reactive protein (hsCRP) of the inflammation modality, and γ-glutamyltransferase (GGT) and Albumin (ALB) of the liver function modality. A strong correlation is seen between these potential biomarkers and the assessment/prediction results. In addition, we have deployed the prototype of the MMDL model in Chongqing Public Health Center, China, to test MMDL's robustness to the new variants of COVID-19 and collect more clinical data for further incremental training.

Data availability statement

The datasets presented in this article are not readily available because according to China's COVID-19 regulation and policy, any data related to patients with COVID-19 is not allowed to be disclosed publicly. Requests to access the datasets should be directed to cliff.zhuo.li@gmail.com.

Author contributions

ZL conceived of the presented idea, designed the model, performed the implementation wrote the manuscript, and also encouraged. RX and YS to conduct the data preprocessing work, supervised the findings of this work and were mainly responsible for data cleaning, preprocessing, experiment setup, doing extensive comparison experiments, and analyzed the obtained results. JC contributed to the idea of overall model design and proofreading of the final version of the manuscript. BW provided insights on analyzing the clinical data and finding potential hall markers of infection of COVID-19 from the perspective of a physician. YZ and SL helped collect the multistage multimodal clinical data of examination and lab test results, facilitated the deployment of the prototype of the prediction model, and handled other routine work. All authors discussed the results and contributed to the final manuscript.

Funding

This research is supported by the Ph.D., Scientific Research Sharing Foundation of the Chongqing University of Posts and Telecommunications (Project No. E012A2022026) and the Chongqing Key Special Program for Technology Innovation and Application Development (Project No. cstc2020jscx-fyzxX0023).

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.

Publisher's note

References

1. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A novel coronavirus from patients with pneumonia in China 2019. *N Engl J Med*. (2020) 382:727–33. doi: 10.1056/NEJMoa2001017

2. Zhou P, Yang X, Wang X, Hu B, Zhang L, Zhang W, et al. A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature*. (2020) 579:270–3. doi: 10.1038/s41586-020-2012-7

3. Lu R, Zhao X, Li J, Niu P, Yang B, Wu H, et al. Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. *Lancet*. (2020) 395:565–74. doi: 10.1016/S0140-6736(20)30251-8

4. Guan W, Ni Z, Hu Y, Liang W, Ou C, He J, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. (2020) 382:1708–20. doi: 10.1056/NEJMoa2002032

5. World Health Organization (WHO). *WHO Coronavirus Disease (COVID-19) Dashboard*. (2022). Available online at: https://covid19.who.int/ (accessed on July 1, 2022).

6. World Health Organization (WHO). *Statement on the Second Meeting of the International Health Regulations 2005 Emergency Committee Regarding the Outbreak of Novel Coronavirus (2019-nCoV)*. (2021). Available online at: https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-2005-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov).

7. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet*. (2020) 395:507–13. doi: 10.1016/S0140-6736(20)30211-7

8. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. (2020) 395:497–506. doi: 10.1016/S0140-6736(20)30183-5

9. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. *JAMA*. (2020) 323:1061–9. doi: 10.1001/jama.2020.1585

10. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China. *JAMA*. (2020) 323:1239–42. doi: 10.1001/jama.2020.2648

11. Raoof S, Nava S, Carpati C, Hill NS. High-flow, noninvasive ventilation and awake (nonintubation) proning in patients with COVID-2019 with respiratory failure. *Chest*. (2020) 158:1992–2002. doi: 10.1016/j.chest.2020.07.013

12. Simonnet A, Chetboun M, Poissy J, Raverdy V, Noulette J, Duhamel A, et al. High prevalence of obesity in severe acute respiratory syndrome coronavirus-2 (SARS-Co-2) requiring invasive mechanical ventilation. *Obesity*. (2020) 28:1195–9. doi: 10.1002/oby.22831

13. Granter SR, Beck AH, Papke DJ. AlphaGo, deep learning, and the future of the human microscopist. *Arch Pathol Lab Med*. (2017) 141:619–21. doi: 10.5858/arpa.2016-0471-ED

14. Whitelaw S, Mamas E Mamas A Topol, Van Spall HGC. Applications of digital technology in COVID-19 pandemic planning and response. *Lancet Digit Health*. (2020) 2:E435–40. doi: 10.1016/S2589-7500(20)30142-4

15. Lalmuanawma S, Hussain J, Chhakchhuak L. Applications of machine learning and artificial intelligence for Covid-19 (SARS-CoV-2) pandemic: a review. *Chaos Solitons Fractals*. (2020) 139:59. doi: 10.1016/j.chaos.2020.110059

16. Budd J, Miller BS, Manning EM, Lampos V, Zhuang M, Edelstein M, et al. Digital technologies in the public-health response to COVID-19. *Nat Med*. (2020) 26:1183–92. doi: 10.1038/s41591-020-1011-4

17. Rahman A, Sultan K, Naseer I, Majeed R, Musleh D, Gollapalli M, et al. Supervised machine learning-based prediction of COVID-19. *Comput. Mater. Continua*. (2021) 69:21–34. doi: 10.32604/cmc.2021.013453

18. Zoabi Y, Deri-Rozov S, Shomron N. Machine learning based prediction of COVID-19 diagnosis based on symptoms. *NPJ Digit Med*. (2021) 4:3. doi: 10.1038/s41746-020-00372-6

19. Wynants L, Van Calster B, Collins GS, Riley RD, Heinze G, Schuit E, et al. Prediction models for diagnosis and prognosis of COVID-19: systematic review and critical appraisal. *BMJ*. (2020) 26:1183–92. doi: 10.1136/bmj.m1328

20. Narin A, Kaya C, Pamuk Z. Automatic detection of coronavirus disease (COVID-19) using X-ray images and deep convolutional neural networks. *Pattern Anal Appl*. (2021) 24:1207–20. doi: 10.1007/s10044-021-00984-y

21. Wang S, Zha Y, Li W, Wu Q, Li X, Niu M, et al. A fully automatic deep learning system for COVID-19 diagnostic and prognostic analysis. *Eur Respir J*. (2020) 56:2000775. doi: 10.1183/13993003.00775-2020

22. Ozturk T, Talo M, Yildirim EA, Baloglu UB, Yildirim O, Rajendra Acharya U. Automated detection of COVID-19 cases using deep neural networks with X-ray images. *Comput Biol Med*. (2020) 121:103792. doi: 10.1016/j.compbiomed.2020.103792

23. Yadaw AS, Li Yc, Bose S, Iyengar R, Bunyavanich S, Pandey G. Clinical features of COVID-19 mortality: development and validation of a clinical prediction model. *Lancet Digital Health*. (2020) 2:E516–25. doi: 10.1016/S2589-7500(20)30217-X

24. Jehi L, Ji X, Milinovich A, Erzurum S, Rubin BP, Gordon S, et al. Individualizing risk prediction for positive coronavirus disease 2019 testing: results from 11,672 patients. *Chest*. (2020) 158:1364–75. doi: 10.1016/j.chest.2020.05.580

25. Wu J, Zhang P, Zhang L, Meng W, Li J, Tong C, et al. Rapid and accurate identification of COVID-19 infection through machine learning based on clinical available blood test results. *medRxiv*. (2020) doi: 10.1101/2020.04.02.20051136

26. Elman JL. Finding structure in time. *Cogn Sci*. (1990) 14:179–211. doi: 10.1207/s15516709cog1402_1

27. Ian G, Yoshua B, Aaron C. 6.2.2.3 Softmax Units for Multinoulli Output Distributions. In: *Deep Learning*. MIT Press (2016). p. 180–4.

28. Hochreiter S, Schmidhuber J. Long short-term memory. *Neural Comput*. (1997) 9:1735–80. doi: 10.1162/neco.1997.9.8.1735

29. Cho K, van Merriënboer B, Gulcehre C, Bahdanau D, Bougares F, Schwenk H, et al. Learning phrase representations using RNN encoder-decoder for statistical machine translation. In: *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing*. EMNLP'14 (2014). p. 1724–34.

30. Sutskever I, Vinyals O, Le QV. Sequence to sequence learning with neural networks. In: *Proceedings of the 27th International Conference on Neural Information Processing Systems. Vol. 2 of NIPS'14*. Montreal, QC: MIT Press (2014). p. 3104–12.

31. Nair V, Hinton GE. Rectified linear units improve restricted boltzmann machines. In: *Proceedings of the 27th International Conference on International Conference on Machine Learning. ICML'10*. Haifa: Omnipress (2010). p. 807–14.

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 10 January 2023
DOI 10.3389/fpubh.2022.1029171

OPEN ACCESS

EDITED BY
Zhiwen Hu,
Zhejiang Gongshang University, China

REVIEWED BY
Yeyu Freddie Dai,
China Wireless-Valley Technologies (HK) Ltd., China
Ashish Kumar Kumar Sarangi,
Centurion University of Technology and Management, India

*CORRESPONDENCE
Lili Yu
✉ llyu@must.edu.mo
Xinbing Sui
✉ hzzju@hznu.edu.cn
Qibiao Wu
✉ qbwu@must.edu.mo

†These authors have contributed equally to this work

SPECIALTY SECTION
This article was submitted to Infectious Diseases: Epidemiology and Prevention, a section of the journal Frontiers in Public Health

RECEIVED 26 August 2022
ACCEPTED 16 December 2022
PUBLISHED 10 January 2023

CITATION
Xu C, Wang J, Yu L, Sui X and Wu Q (2023) Omicron subvariant BA.5 is highly contagious but containable: Successful experience from Macau. *Front. Public Health* 10:1029171. doi: 10.3389/fpubh.2022.1029171

Omicron subvariant BA.5 is highly contagious but containable: Successful experience from Macau

Cong Xu[1†], Jue Wang[1†], Lili Yu[1*], Xinbing Sui[2,3*] and Qibiao Wu[1,4,5*]

[1]Faculty of Chinese Medicine, University Hospital, State Key Laboratory of Quality Research in Chinese Medicine, Macau University of Science and Technology, Taipa, Macao SAR, China, [2]College of Pharmacy, Hangzhou Normal University, Hangzhou, Zhejiang, China, [3]Department of Medical Oncology, The Affiliated Hospital of Hangzhou Normal University, Hangzhou Normal University, Hangzhou, Zhejiang, China, [4]Zhuhai Macau University of Science and Technology (MUST) Science and Technology Research Institute, Zhuhai, Guangdong, China, [5]Guangdong-Hong Kong-Macao Joint Laboratory for Contaminants Exposure and Health, Guangdong University of Technology, Guangzhou, China

Introduction: Due to its high transmissibility and immune escape, Omicron subvariant BA.5 has become the dominant strain of the SARS-CoV-2 virus and led to escalating COVID-19 cases, how to cope with it becomes an urgent issue. A BA.5 infection surge burst out on 18 June 2022 and brought an unprecedented challenge to Macau, the most densely populated region worldwide. This study aimed to analyze the characteristics of this outbreak and summarize the useful anti-epidemic measures and experiences during this outbreak.

Methods: All data were obtained from the Government Portal of Macao SAR (https://www.gov.mo), and the Special Webpage Against Epidemics, the Macao Health Bureau (www.ssm.gov.mo). An epidemiologic study was performed to analyze epidemic outcomes, including the infection rate, the proportion of symptomatic cases, the case fatality ratio (CFR), etc. Data were analyzed using SPSS Version 20. A p-value <0.05 was considered statistically significant. The anti-epidemic measures and experience were reviewed and summarized.

Results: The BA.5 outbreak resulted in 1,821 new cases, which was significantly more than the cumulative cases of the previous variants of COVID-19 in Macau. The symptomatic cases accounted for 38.71% of the total cases, which was higher than that of the previous variants. After 6-week concerted efforts, Macau effectively controlled the outbreak, with an infection rate of 0.27%, which was much lower than many BA.5-attacked regions. The CFR was approximately 0.86%, which was not statistically different from that of previous variants. Six victims were chronically ill senior elders and their vaccination rate was much lower than the average level. Macau took a comprehensive anti-epidemic strategy to win a quick victory against BA.5, especially the "relatively static" strategy that was first formulated and applied by Macau for the management of the COVID-19 pandemic. Successful experience

showed that although BA.5 was highly contagious, it could be contained by comprehensive anti-epidemic measures, including adequate anti-epidemic preparation, herd immunity through vaccination, repeated mass nucleic acid tests and rapid antigen tests, KN-95 mask mandate, the "relatively static" strategy, precise prevention and control, epidemiological investigation and tracing, and traditional Chinese medicine treatment, etc.

Discussion: In Macau, compared with the previous subvariants, BA.5 is associated with increased transmissibility and a higher proportion of symptomatic cases, however, the risk of death remains similar, and the infection rate is much lower than that in many other BA.5-attacked regions. BA.5 is highly contagious but still containable, Macau's experience may offer hints for the regions experiencing the BA.5 waves to choose or adjust a more rational anti-epidemic strategy.

KEYWORDS

successful experience, Macau, Omicron subvariant BA.5, "relatively static" strategy, anti-COVID-19, containable

1. Introduction

The BA.5 variant of Omicron was first detected in February 2022 in South Africa (1, 2). Currently, it has been spreading rapidly throughout the world and leads to a significant rise in new cases and health concerns amid the ongoing wave of the COVID-19 pandemic (2, 3). Compared with previous variants (including the Alpha, Beta, Gamma, and Delta variants of SARS-CoV-2, and the BA.1, BA.2., BA.3, BA.4 lineages of Omicron, etc.) (4–7), the latest BA.5 variant is better at evading the immune system and has become the most easily transmissible variant to date (5, 8). It has gradually become the dominant strain of the SARS-CoV-2 virus in many parts of the world and has been associated with the rapidly escalating COVID-19 cases and hospitalizations.

In the U.S., BA.5 has accounted for an estimated 80% of new cases (around 100,000/day), and the number continues to grow (9, 10). The coronavirus hospitalization rate in New York has boomed by 70% in the past month (11). In Europe, the rapid spread of Omicron subvariants (BA.4 and BA.5) has also contributed to a summer surge of COVID-19. New cases have tripled and the hospitalization rates doubled over the past 6 weeks. New cases rose to 3 million in a week, accounting for nearly 50% of global new cases. There will be nearly 3,000 COVID-19 deaths every week due to the rising infection rate in older groups (12, 13). BA.5 is more than four times as vaccine-resistant as its predecessors and appears to be able to infect individuals who have been previously vaccinated and boosted against COVID-19 or have been previously infected with COVID-19 or even both. Due to the characteristics of BA.5 with strong concealment and fast transmission speed, how to cope with it becomes an urgent issue (11–15).

On 18 June, a new outbreak of COVID-19 occurred in Macao Special Administrative Region (SAR), China. As of 28 July, a total of 1,821 new COVID-19 cases have been recorded. Fortunately, adhering to the principles of scientific and precise prevention and control, Macau took a series of timely and effective anti-epidemic measures in response to epidemic changes (16). After 5-week concerted efforts, the spread of the most transmissible variant of COVID-19 has been effectively minimized, the outbreak has been successfully controlled, approaching the ultimate goal of "dynamic zero-COVID-19 strategy" in the community (17).

The COVID-19 Omicron subvariant BA.5.1 was the culprit of this largest spike in infections since the emergence of COVID-19 in Macau. To the best of our knowledge, so far, Macau is the first region in the world that took the "relatively static" control measures and active anti-epidemic strategy to win the battle against the BA.5 epidemic in a very short period (40 days), thus keeping the epidemic under control and resuming the normal socioeconomic activities as soon as possible, successful experience from Macau shows that timely and effective anti-epidemic measures, especially the "relatively static" strategy, may offer hints about the future prevention and control of the BA.5 subvariant, although BA.5 is highly contagious, insidious, and daunting, it can be contained (18).

2. Methods

All data were obtained from the Government Portal of Macao SAR (https://www.gov.mo), and the Special Webpage Against Epidemics, the Macao Health Bureau (www.ssm.gov.mo).

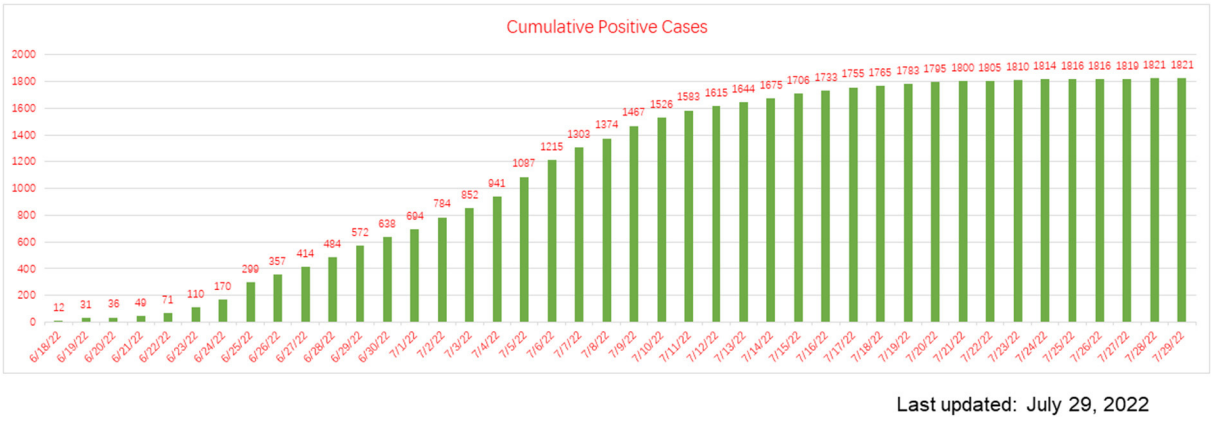


FIGURE 1
Cumulative positive cases during the BA.5 subvariant COVID-19 outbreak in Macau (data from the news bulletin of the Macao Health Bureau, was last updated on July 29, 2022).

An epidemiologic study was performed to analyze the outcomes of the epidemic, including the infection rate of the total population, the proportion of symptomatic cases or asymptomatic cases, and the case fatality ratio among the total BA.5 subvariant cases, etc. The differences between BA.5 and the previous variants were compared. Data were analyzed using SPSS Version 20. A p-value < 0.05 was considered statistically significant. The anti-epidemic measures and experience from Macau during this outbreak of the BA.5 subvariant were reviewed and summarized.

3. Results

3.1. The facts of Omicron subvariant BA.5 in Macao SAR

In the past 2½ years, the cumulative number of COVID-19 cases in Macau was only 335 (the total population: 683.2 thousand), but a BA.5 infection surge burst out on 18 June 2022, resulting in 1,821 new cases, with six deaths, as of July 28 when the last positive case of this outbreak was reported (Figure 1) (17), which was significantly more than the cumulative cases of the previous variants of COVID-19 in Macau, suggesting that BA.5 is more transmissible than the previous subvariants. The symptomatic cases accounted for 38.71% of the total BA.5 subvariant cases, which was higher than that of the previous variants of COVID-19 (SARS-CoV-2 virus, Delta variant, Alpha variant, Omicron BA.1, etc.; 25.67%) in Macau (Table 1) (17). The COVID-19 vaccination rate in Macau was 90.04%, and most positive cases were fully vaccinated, but still infected with BA.5. The facts of Omicron subvariant BA.5 in Macau are consistent with its known characteristics: more transmissible and immune-evading, even people who are fully vaccinated are likely still at risk for BA.5.

TABLE 1 Clinical outcomes of the positive cases with BA.5 or previous subvariants.

Outcomes	Previous subvariants *n* (%)	BA.5 subvariant *n* (%)	*P*-value
Symptomatic cases	86 (25.67%)	705 (38.71%)	<0.0001
Asymptomatic cases	249 (74.33%)	1,116 (61.29%)	
Case fatality ratio (CFR)	0 (0.00%)	6 (0.86%)	0.84

Data from the news bulletin of the Macao Health Bureau, was last updated on July 29, 2022.

The Case Fatality Ratio (CFR) of the BA.5 subvariant of COVID-19 was ~0.86%, which was not statistically different from that of previous variants, suggesting that the risk of death seemed similar between the BA.5 and previous variants (Table 1) (17). All six victims of the BA.5 subvariant were chronically ill senior elders (over 88 years old) and their vaccination rate was much lower than the average level (Table 1) (17). All the patients had a history of chronic diseases, such as heart and lung diseases, brain degeneration, fractures, hyperlipidemia, stroke, and other chronic underlying diseases (Table 2). The facts reminded us again that chronically ill elders are the most vulnerable population during the pandemic and they need focused protection and should get vaccinated or boosted as soon as possible.

3.2. Successful experience from Macao SAR

In response to this epidemic, the Macao SAR government assessed the epidemic development scientifically and adopted a series of comprehensive measures to combat the pandemic, meanwhile keeping the balance between minimizing the virus

TABLE 2 The characteristics of six COVID-19 victims.

Number	Age	Sex	Status of COVID-19 vaccination	Previous medical status
1	94	Female	Had received two doses of inactivated COVID-19 vaccines.	She had a history of hypertension, hyperlipidemia, stroke, and other chronic underlying diseases, she required long-term care.
2	100	Female	Not vaccinated against COVID-19.	She had a history of hypertension, brain degeneration, fractures, and other chronic underlying diseases; she was bedridden and in need of long-term care.
3	88	Female	Not vaccinated against COVID-19.	She was bedridden and in need of long-term care, she had a history of severe diabetes mellitus, heart disease, aortic dissection, etc.
4	94	Female	Not vaccinated against COVID-19.	She was dependent on caregivers, had no self-care ability, and suffered from chronic heart and respiratory failure.
5	86	Female	Had received two doses of inactivated COVID-19 vaccines.	She suffered from chronic renal disease, gastrointestinal bleeding, and other chronic underlying diseases.
6	93	Male	Not vaccinated against COVID-19.	He suffered from chronic heart disease and chronic pulmonary disease and required long-term oxygen therapy at home.

TABLE 3 The comprehensive measures dynamically adjusted by Macau to combat the pandemic.

Phase	Features	Measures (14)
Phase 1 June 18–July 3	A new wave of COVID-19 burst out, and new cases increased every day.	1. The SAR Government announced that Macao SAR went into an immediate state of prevention starting from 1:00 a.m. on 19 June 2022; 2. Updated the conditions for border crossing; 3. Three rounds of citywide nucleic acid tests (NAT); 4. NAT administered for key groups and areas; 5. Rapid antigen tests (RAT) were introduced and RAT kits were distributed. 6. The public entertainment venues such as cinemas, beauty salons, gymnasiums, and bars were closed, as well as provision of dine-in services in all food and beverage establishments has been suspended. 7. The Government urged all residents to stay at home, and avoid going out, except for necessary grocery shopping.
Phase 2 July 4–10	New cases increased every day with a peak of 146 new positive cases on July 5.	1. Repeated citywide NAT, with each round finished in 2 days (36 h); 2. Self-RAT every day and results were reported online; 3. N95 masks were distributed by the government, and wearing N95 masks when in a public area became a mandatory requirement; 4. A mobile sampling team was set up to conduct on-site sampling for those tested positive in mixed samples, all these measures effectively reduced the risk of cross-infection and the daily local cases; 5. Traditional Chinese medicine treatment was used for patients based on their consent and demands.
Phase 3 July 11–22	The proportion of new positive cases in the community was high, and the "relatively static" control measures were taken to prevent the wide spread of BA.5 in communities.	1. Repeated citywide NAT, with each round finished in 2 days (36 h); 2. Self-RAT every day and results were reported online. 3. Suspension of non-essential industries and commercial activities. 4. The "stay-at-home" mandate. 5. Exemptions applied to three categories of activity deemed essential to the community and to the day-to-day lives of the members of the public, including the companies providing basic public services, services deemed necessary for the daily lives of the members of the public, those companies, entities, and venues that have received approval to continue operations from their respective supervising authorities.
The consolidation period. July 23–29	The number of daily new cases was close to zero in the community. Aimed to enable people to gradually return to their normal life.	1. Limited operation of non-essential industries and commercial activities to resume; 2. Public departments provide limited public services; 3. The lowest possible level of non-essential movement in the community; 4. An extra NAT drive was further carried out in the key areas to identify any potentially infected persons who might still be lurking in the local community, people in the key areas were subject to a NAT daily. 5. The public could walk their dogs out under the prerequisite of compliance with the anti-epidemic requirements.

The region-specific, multi-level epidemic prevention and control was launched during all phases: the relevant buildings were classified as "lockdown zones," "red" health codes, and on-site NATs were applied to the individuals there, epidemiological investigation, tracing, and quarantine, etc. (14).

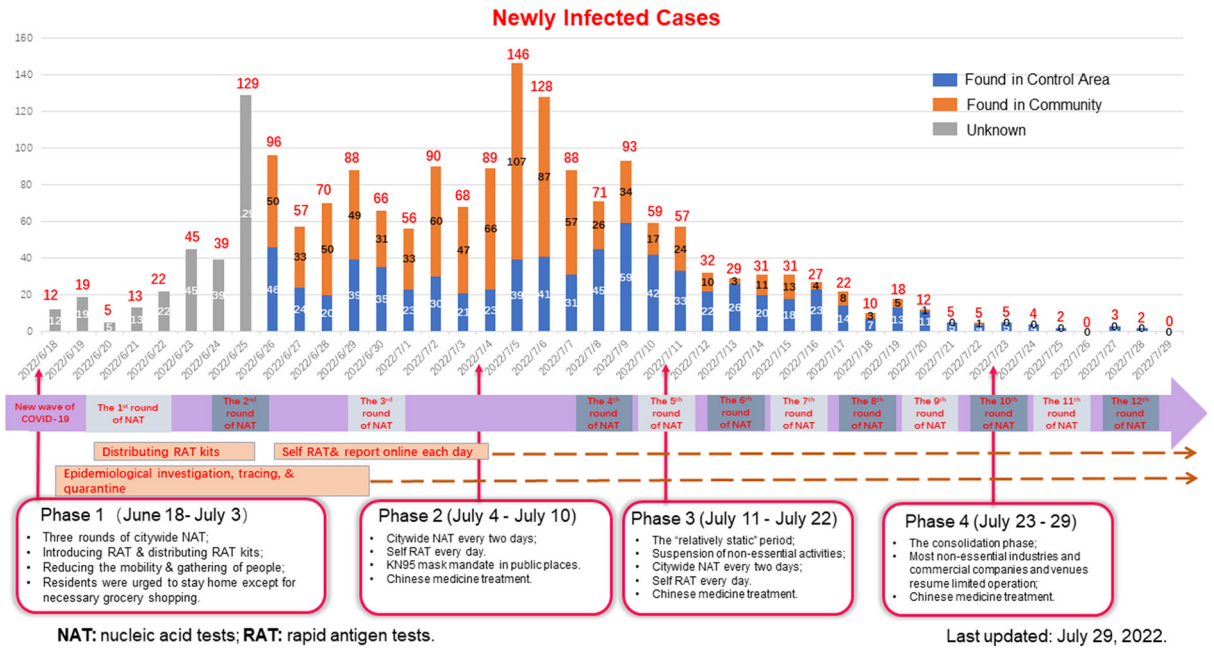


FIGURE 2
Daily positive cases and dynamically adjusted measures during the BA.5 subvariant COVID-19 outbreak in Macau (data from the news bulletin of the Macao Health Bureau, last updated on July 29, 2022).

transmission and ensuring the socio-economic operation and the essential living needs of residents (17). BA.5 brought an unprecedented challenge to Macau, the most densely populated region worldwide. Fortunately, after 6-week concerted efforts, Macau effectively controlled the outbreak, with an infection rate of 0.27% (1,821/6,832,000), which was much lower than that in some BA.5-attacked regions, such as the US and Europe (9–13). Macau took a comprehensive anti-epidemic strategy to win a quick victory against BA.5, especially the "relatively static" strategy that was first formulated and applied by Macau for the management of the COVID-19 pandemic. Macau won the battle against the BA.5 epidemic in a very short period (40 days). Successful experience shows that although BA.5 is highly contagious, it can be conquered by comprehensive anti-epidemic measures, including adequate anti-epidemic preparation, herd immunity through vaccination, repeated mass nucleic acid tests and rapid antigen tests, KN-95 mask mandate, the "relatively static" strategy, precise prevention and control, epidemiological investigation and tracing, etc. The comprehensive measures are as follows, and are roughly summarized in Table 3 and Figure 2 (17).

3.2.1. Adequate anti-epidemic preparation in advance

In case of a large-scale outbreak, the SAR government keeps promoting the precise prevention and control level through science, continuously perfecting anti-epidemic measures, and making adequate preparation in advance. In April 2022, the SAR government prepared and formulated a 118-page "The Contingency Plan Regarding Large-scale COVID-19 Outbreak" to enact a full and rapid deployment and response in case of a large-scale COVID-19 outbreak in Macau (16). The Contingency Plan was released to the public in different languages, and drills were organized, therefore, when the BA.5 epidemic burst out, the well-prepared government, health professionals, social organizations, volunteers, and residents could respond calmly, quickly, and methodically.

Besides, the SAR government prepared and provided free adequate anti-epidemic supplies and services, such as the efficient citywide nucleic acid testing (NAT) capability, sufficient isolation and treatment facilities, information and communication outlets, epidemiological tracing capacity, the KN-95 masks, rapid antigen test (RAT) kits, etc., which laid a solid foundation for the victory in fighting the epidemic.

3.2.2. High COVID-19 vaccination rate

The WHO goal was to achieve 70% COVID-19 immunization coverage by June 2022, which remains a daunting challenge due to limited vaccine supply to some regions (19). In Macau, the COVID-19 vaccination rate has reached 90.04%, and over 86% of residents have received a second COVID-19 booster shot (20), indicating that Macau

residents have achieved herd immunity against COVID-19 before this BA.5 outbreak, which might be one of the important reasons why most infected cases during the outbreak were asymptomatic (61.39%), there were very few hospitalizations or severe cases, and only six victims. The six victims were chronically ill senior elders (over 88 years old) and 4 of them did not get vaccinated (Tables 1, 2). These facts were consistent with the previous findings, although BA.5 is more adept at slipping past immune defenses, vaccination is still the best way to reduce the risks of infection, hospitalization, severe illness, and mortality (21).

Common side effects of the COVID-19 vaccines and statistics of Adverse Events Following Immunization (AEFIs) in Macau were presented in Tables 4, 5. The vaccines have succeeded in preventing severe disease or death, but more novel next-gen COVID-19 vaccines are still necessary for keeping people from catching and spreading the virus because SARS-CoV-2 has become more contagious and it is evolving to dodge the vaccines (7, 22, 23).

3.2.3. The efficient citywide nucleic acid test (NAT) capability

The SAR government kept improving the NAT capacity, the efficient mass NAT capability ensured that each round of citywide NATs for about 680,000 residents could be implemented every 2 days (usually in 36 h) (16, 17). Anyone who refused to take the NAT test would be sent to medical observation for 14 days. Vast numbers of volunteers and civil servants in Macau have participated in the epidemic prevention work with selfless dedication, residents and different sectors of the society have actively cooperated, and frontline anti-epidemic staff have been committed to their duties and responsibilities without complaint. The support of 650 samplers from mainland China significantly enhanced Macau's NAT capability (17).

3.2.4. KN-95 masks

The SAR government distributed KN-95 masks to all residents and it was a mandatory demand that members of the public should wear a KN95 mask at all times when going out or at workplaces (24). KN95 Masks can filter 95% or more airborne particles, a higher filtration rate for fine particles as compared with surgical masks, thus providing sufficient protection against the SARS-CoV-2 Omicron variant (25).

3.2.5. Daily rapid antigen test (RAT)

All people in Macau were required to take RATs every day and report the result *via* the "Macau Health Code app" (26). Self-RAT at home could reduce the mobility of people, the risk of transmission in the community, and the burden on medical and public health services. If the test result was declared as positive, the health code would be converted to a "red code," one should call an ambulance to undergo a NAT as soon as possible. In addition, if one had a positive RAT, his/her roommates were not allowed to go out, and a nucleic acid test would be arranged for all of them by the authorities (26).

3.2.6. Precise prevention and control by zones and levels

Macau abided by a "zone-specific, multi-level targeted approach to epidemic prevention and control," classified buildings with positive cases as medium or high-risk areas, and promptly implemented precise prevention and control measures according to the levels of risk. Areas were classified as "red-coded zones" and "yellow-coded zones," with a tentative quarantine period of 7 days. Comprehensive restriction and closure management were implemented. The government catered to the daily living needs of people in the red- or yellow-coded zones (27).

3.2.7. The "relatively static" control measures

In the mainland of China, a strict lockdown plays a crucial role in the successful control of serious outbreaks of the pandemic, however, which demands huge manpower to ensure that every household in the lockdown areas gets the supply of the necessaries of life, and the precise street- or community-based committees are essential at the operation level. Similar to most countries or regions, Macau lacks the logistics support capacity, and it was almost impossible to implement a strict lockdown in Macau. Therefore, when the proportion of community infections remained high, the SAR government took the "relatively static" control management in the third stage, intending to prevent the wide spread of BA.5 in communities (17, 18).

The "relatively static" strategy (or a relative lockdown) was a unique anti-epidemic measure that Macau adopted according to its situation (a strict lockdown was impossible), which played a key role in the control of the BA.5 outbreak in Macau, measures were adopted to reduce unnecessary movement and gathering of people, to break the chains of virus transmission as soon as possible, and create necessary conditions for achieving "dynamic zero-COVID-19." With the region-specific approach, the lockdown area was defined as small as possible, usually limited to buildings, and the residents outside of the lockdown area were ordered to stay home when community infections rapidly increased, while short trips for essential services, necessaries of life were allowed, for example, going to supermarkets or drugstores for daily necessities or medicines when necessary, thus keeping the balance between adopting rigorous pandemic measures and satisfying the basic demands of residents (17, 18).

TABLE 4 Statistics of Adverse Events Following Immunization (AEFIs).

AEFIs		Total doses administered	Inactivated vaccine (Sinopharm)	BioNTech mRNA vaccine (BioNTech)	Other vaccines (non-local administration)	Total
			1,370,040	309,058	4,704	1,683,802
1. Minor adverse events		1.1. Reaction caused by the vaccine	2,266	1,717	N.R.	3,983
		1.2. Immunization error-related reaction	0	0	N.R.	0
		1.3. Immunization Anxiety-related reaction	22	11	N.R.	33
		1.4. Coincidental event or uncertain	1,101	370	N.R.	1,471
2. Serious adverse events	2.1. Anaphylaxis		1	0	N.R.	1
	2.2. Other serious adverse events	2.2.1. Reaction caused by the vaccine	0	N.R.	N.R.	4
		2.2.2. Immunization error-related reaction	0	0	N.R.	0
		2.2.3. Immunization anxiety-related reaction	0	0	N.R.	0
		2.2.4. Coincidental event or uncertain	3	6	N.R.	9
Total			**3,393**	**2,108**	N.R.	**5,501**

AEFIs, Adverse Events Following Immunization; N.R., not reported.

Data from Serviços de Saúde, Governo da Região Administrativa Especial de Macau. Weekly Bulletin on COVID-19 Vaccination and Adverse Events Following Immunization (AEFI) in Macao, Last updated: December 8, 2022.

10.3389/fpubh.2022.1029171

TABLE 5 Rate of Adverse Events Following Immunization reported (per 1,000 doses).

	Inactivated vaccine (Sinopharm)	mRNA vaccine (BioNTech)	Total
Serious adverse events	0.003	0.033	0.009
Minor adverse events	2.665	6.926	3.484
Total	2.668	6.959	3.493

Serious adverse event: if it results in death, is life-threatening, requires in-patient hospitalization or prolongation of existing hospitalization, results in persistent or significant disability/incapacity, is a congenital anomaly/birth defect, or requires intervention to prevent permanent impairment or damage.
Data from Serviços de Saúde, Governo da Região Administrativa Especial de Macau. Weekly Bulletin on COVID-19 Vaccination and Adverse Events Following Immunization (AEFI) in Macao, Last updated: December 8, 2022.

The implementation of the "relatively static" measure inevitably brought some inconvenience to normal work and life. But, almost all residents could fulfill their civic responsibility, and strictly comply with the relevant laws and regulations on epidemic prevention, contributing to fighting against the epidemic. Since the implementation of "relatively static" management measures on 9 July, the number of new daily positive cases was gradually decreasing, with 10 cases on July 18, 2022. These results suggested that the "relatively static" measures were effective, contributing to achieving the "dynamic zero" goal (17, 18).

3.2.8. The efficient epidemiological investigation and tracing capacity

Macau continues to reinforce and upgrade the epidemiological investigation and tracing capacity, including establishing and perfecting the epidemiological contact tracing database, recruiting and training epidemiological investigation staff, rolling out the "Macao Health Code" Mobile App to receive NAT or RAT reports and record itinerary and risk assessment, posting venue QR codes for residents to scan upon entering to record their itineraries, enhancing the collaboration with the neighboring areas, thus tracing the contacts of any positive cases and its source of infection, determining the chain of infection and risk sites, making recommendations on public health measures, and arranging further examination for various risk groups (17, 18).

3.2.9. Traditional Chinese medicine (TCM) treatment

Evidence-based medicine has confirmed that TCM combined with western medicine may have clinical advantages for COVID-19 patients, such as alleviating symptoms, improving prognosis, etc. (28, 29). WHO Expert Meeting on Evaluation of TCM in the Treatment of COVID-19 recommended Member States consider the potential use of TCM for the management of COVID-19 (29). During this outbreak, the TCM practitioners actively volunteered to participate in the Chinese Medicine Anti-epidemic Team and provided consultations and guidance to the residents. Two hundred and seventy-five TCM practitioners participated in the treatment process and gave medication guidance. Finally, 74.14% (1,500/1,821) positive cases including some foreign nationals chose to receive TCM treatment and took Chinese patent medicines (30), Chinese patent medicines including Lianhua Qingwen capsules (29) and Huoxiang Zhengqi soft capsules / oral solution (31, 32) were most commonly prescribed for the patients based on their consent, which greatly facilitated to improve symptoms and promote recovery (28–32). Two hundred and sixty-eight out of the 408 (67%) foreign patients also chose to receive TCM treatment.

4. Discussion and conclusion

The mutations of novel variants facilitate the virus to dodge the immune of individuals with either vaccination or previous infection, the emergence of new variants, such as BA.5, has posed an increased risk to global public health (15, 33). Macau is the most densely populated region in the world, and the highly contagious Omicron subvariant BA.5 posed an unprecedented challenge to the prevention and treatment of COVID-19 in Macau. Macau could not choose to "lie flat" policy, on the other hand, it was extremely difficult for Macau to enforce a strict lockdown.

Since the pandemic broke out, divides have emerged about the right path out of COVID-19 (34). Currently, most countries have chosen to co-exist with coronavirus, or so-called "lying flat," which means that epidemic control measures are relaxed, mask mandates, mass COVID-19 testing, social distancing, or quarantine is not required. But, along with the worldwide spread of BA.4 or BA.5, many countries or cities are seeing rapid spikes in COVID-19 cases, globally, there are over 6,700,000 new cases and 12,000 deaths in a week (35). Easing coronavirus policies is one of the reasons for the surge of COVID-19 new cases and hospitalizations in the relevant regions. WHO Director-General Tedros Adhanom Ghebreyesus recently expressed his concern that many countries are drastically reducing epidemic control measures (36).

According to their own situation, a few countries/regions think "lying flat" policy may bring disaster to vulnerable populations and overwhelm the healthcare system, therefore they choose to hold on to the "dynamic zero-COVID-19 strategy" goal, which is usually achieved by the strict lockdown measures, but, it is very difficult to enforce a strict lockdown and may cause counterproductive damage to the economy and living of the public (17).

Successful experience from Macao SAR indicates that Omicron subvariant BA.5 is highly contagious but still conquerable, which can be prevented and controlled by

comprehensive measures including adequate preparation, vaccination, mass NAT and RAT, KN-95 masks, precise prevention and control, epidemiological investigation and tracing, TCM treatment, etc. Among them, the "relatively static" strategy is crucial for the success of epidemic control in Macau and may provide a new choice for the global fight against subvariant BA.5, the "relatively static" strategy is a middle way between "lying flat" and lockdown, aiming to strike a balance between pandemic control and enabling residents to live normal lives. The "relatively static" strategy is a unique anti-epidemic measure that Macau took according to its situation and based on the experience of other regions, and it has been proven as effective as a strict lockdown to achieve "dynamic zero-COVID-19 strategy-19" in the community even in a COVID-19 spike caused by the most contagious Omicron BA.5 (17, 18). Macau's experience may offer hints for the regions experiencing the BA.5 waves. The regions experiencing the latest variant waves may be encouraged and inspired by Macau's success and experience, thus choosing or adjusting a more suitable strategy.

Considering that the emergence of the latest Omicron variants has caused a serious situation, and the rapidly spreading viruses have chances to mutate into possibly more devastating variants, it might be necessary for regions that already removed their anti-pandemic measures to reflect and re-evaluate their COVID-19 policies. On the other hand, increasing evidence has suggested that the Omicron variants appear to be more contagious but less deadly than other lineages of the virus, with the potential decrease in toxicity of new Omicron variants and the increasing COVID-19 vaccination rate, in the long run, for those regions that hold on to a strict lockdown policy, there is also a need or a tendency to gradually relax the strict measures, thus promoting the recovery of the normal socioeconomic activities and international exchanges, but it must be a long process of exploration, Macau's experience also provides some perspective for these regions in decision-making on the strategy against the pandemic.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

CX: conceptualization, investigation, methodology, analysis, and writing an original draft. LY and JW: investigation, validation, formal analysis, and writing and editing. XS: validation, investigation, and formal analysis. LY, XS, and QW: conceptualization, supervision, methodology, and review and revision of the draft. All authors contributed to the article and approved the submitted version.

Funding

This study was funded by the Science and Technology Development Fund, Macau SAR (File No.: 0098/2021/A2) and Science and Technology Planning Project of Guangdong Province (2020B1212030008).

Acknowledgments

We thank the Government Portal of Macao SAR and the Macao Health Bureau for sharing the relevant data and formulating professional and effective response strategies, we appreciate the concerted efforts from all health professionals, volunteers, the social public, and anyone who contributed to the victory against the epidemic.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Tegally H, Moir M, Everatt J, Giovanetti M, Scheepers C, Wikinson E, et al. Emergence of SARS-CoV-2 Omicron lineages BA.4 and BA.5 in South Africa. *Nat Med*. (2022) 28:1785–90. doi: 10.1038/s41591-022-01911-2

2. Callaway E. New Omicron relatives BA.4 and BA.5 offer hints about the future of SARS-CoV-2. *Nature*. (2022) 605:204–6. doi: 10.1038/d41586-022-01240-x

3. Callaway E. What Omicron's BA.4 and BA.5 variants mean for the pandemic. *Nature*. (2022) 606:848–9. doi: 10.1038/d41586-022-01730-y

4. Mohapatra RK, Kandi V, Verma S, Dhama K. Challenges of the Omicron (B.1.1.529) variant and its lineages: A global perspective. *Chembiochem*. (2022) 23:e202200059. doi: 10.1002/cbic.202200059

5. Mohapatra RK, Kandi V, Sarangi AK, Verma S, Tuli HS, Chakraborty S, et al. The recently emerged BA.4 and BA.5 lineages of Omicron and their global health concerns amid the ongoing wave of COVID-19 pandemic – Correspondence. *Int J Surg*. (2022) 103:106698. doi: 10.1016/j.ijsu.2022.106698

6. Mohapatra RK, Kandi V, Mishra S, Sarangi AK, Pradhan MK, Mohapatra PK, et al. Emerging novel sub-lineage BA.2.75: The next dominant omicron variant? *Int J Surg*. (2022) 104:106835. doi: 10.1016/j.ijsu.2022.106835

7. Chakraborty C, Bhattacharya M, Sharma AR, Mohapatra RK, Chakraborty S, Pal S, et al. Immediate need for next-generation and mutation-proof vaccine to protect against current emerging Omicron sublineages and future SARS-CoV-2 variants: An urgent call for researchers and vaccine companies – Correspondence. *Int J Surg*. (2022) 106:106903. doi: 10.1016/j.ijsu.2022.106903

8. Shrestha LB, Foster C, Rawlinson W, Tedla N, Bull RA. Evolution of the SARS-CoV-2 omicron variants BA.1 to BA.5: Implications for immune escape and transmission. *Rev Med Virol*. (2022) 20:e2381. doi: 10.1002/rmv.2381

9. Cao Y, Yisimayi A, Jian F, Song W, Xiao Y, Wang L, et al. BA.2.12.1, BA.4 and BA.5 escape antibodies elicited by Omicron infection. *Nature*. (2022) 608:593–602. doi: 10.1101/2022.04.30.489997

10. Phan T, Boes S, McCullough M, Gribschaw J, Marsh JW, Harrison LH, et al. Emergence of SARS-CoV-2 Omicron BA.5 variant of concern in Western Pennsylvania, United States. *J Med Virol*. (2022) 94:4593–4. doi: 10.1002/jmv.27945

11. NBC. *COVID Hospitalization Rate in NYC Soars 70% in Month, ICU Patient Tally Nearly Doubles*. (2022). Available online at: http://www.nbcnewyork.com/news/coronavirus/nys-covid-dashboard-nyc-hospitalization-rate-soars-70-in-ba5-variant-wave/3796713/ (accessed July 29, 2022).

12. SEATTLE. *BA.4 and BA.5 Power a Surge of Infections in Europe, Officials Say*. (2022). Available online at: http://www.seattletimes.com/nation-world/ba-4-and-ba-5-power-a-surge-of-infections-in-europe-officials-say/ (accessed July 29, 2022).

13. WHO. *Rapidly Escalating COVID-19 Cases Amid Reduced Virus Surveillance Forecasts a Challenging Autumn and Winter in the WHO European Region*. (2022). Available online at: http://www.who.int/europe/news/item/19-07-2022-rapidly-escalating-covid-19-cases-amid-reduced-virus-surveillance-forecasts-a-challenging-autumn-and-winter-in-the-who-european-region (accessed July 29, 2022).

14. Tanne JH. COVID-19: BA.5 variant is now dominant in US as infections rise. *Br Med J*. (2022) 378:o1770. doi: 10.1136/bmj.o1770

15. CNN. *Why the Omicron Offshoot BA.5 Is a Big Deal*. (2022). Available online at: https://edition.cnn.com/2022/07/14/health/omicron-ba-5-variant-immunity-severity/index.html (accessed July 24, 2022).

16. SSM. *The Novel Coronavirus Response and Coordination Center, Macao SAR. The Contingency Plan Regarding Large-scale COVID-19 Outbreak (First Version)*. (2022). Available online at: http://www.ssm.gov.mo/docs2/file/p/21928/en (accessed July 24, 2022).

17. Macao SAR Government. *The Novel Coronavirus Response and Coordination Centre, Macao SAR. Combatting the Epidemic With Concerted Efforts, Resuming Normal Order, Life and Production as Soon as Possible*. (2022). Available online at: http://www.gov.mo/en/news/276443/ (accessed July 24, 2022).

18. Macaubusiness.com. *Strict Lockdown Unnecessary and Counterproductive in SAR-UM Research Team*. (2022). Available online at: http://www.macaubusiness.com/strict-lockdown-unnecessary-and-counterproductive-in-sar-um-research-team/ (accessed July 29, 2022).

19. World Health Organization. *COVAX Statement*. (2021). Available online at: https://www.who.int/news/item/23-12-2021-achieving-70-covid-19-immunization-coverage-by-mid-2022

20. SSM. *Special Webpage Against Epidemics*. (2022). Available online at: http://www.ssm.gov.mo/apps1/PreventCOVID-19/en.aspx#clg22916 (accessed July 29, 2022).

21. ETNT Health. *Here's How Worried You Should be About BA.5*. (2022). Available online at: http://www.eatthis.com/new-heres-how-worried-you-should-be-ba5-covid/ (accessed July 29, 2022).

22. Mohapatra RK, Kuppili S, Kumar Suvvari T, Kandi V, Behera A, Verma S, et al. SARS-CoV-2 and its variants of concern including Omicron: A never ending pandemic. *Chem Biol Drug Des*. (2022) 99:769–88. doi: 10.1111/cbdd.14035

23. Holmes B. What Next-Gen Covid-19 Vaccines Might Look Like. Knowable Magazine (2022, March 11). Available online at: https://knowablemagazine.org/article/health-disease/2022/what-nextgen-covid-19-vaccines-might-look-like (accessed December 11, 2022).

24. Macao SAR Government. *Novel Coronavirus Response and Coordination Centre strongly calls on the public to Take Personal Protective Measures*. (2022). Available online at: http://www.gov.mo/en/news273646/ (accessed July 29, 2022).

25. Macao SAR Government. *KN-95 Masks Provided by the Macao SAR Government Conform to National Standards*. (2022). Available online at: http://www.gov.mo/en/news/274004/ (accessed July 29, 2022).

26. Macao SAR Government. *All People in Macao Are Required to Take Rapid Antigen Test Once Every Day, From Tomorrow (29 June) to 30 June*. (2022). Available online at: http://www.gov.mo/en/news/272595/ (accessed July 29, 2022).

27. Macao SAR Government. *Zone-Specific, Multi-Level Targeted Approach to Epidemic Prevention and Control Activated; Closure and Control Measures Implemented on the Living Areas of Confirmed Case*. (2022). Available online at: http://www.gov.mo/en/news/270577/ (accessed July 29, 2022).

28. WHO. *Expert Meeting on Evaluation of Traditional Chinese Medicine in the Treatment of COVID-19*. (2022). Available online at: http://www.who.int/publications/m/item/who-expert-meeting-on-evaluation-of-traditional-chinese-medicine-in-the-treatment-of-covid-19 (accessed July 29, 2022).

29. Hu C, Liang M, Gong F, He B, Zhao D, Zhang G. Efficacy of Lianhua Qingwen compared with conventional drugs in the treatment of common pneumonia and COVID-19 pneumonia: A meta-analysis. *Evid Based Complement Alternat Med*. (2020) 2020:5157089. doi: 10.1155/2020/5157089

30. Macao SAR Government. *People Tested Positive in Nucleic Acid Tests Receiving Proprietary Chinese Medicines as Treatment. Novel Coronavirus Response and Coordination Centre*. (2022). Available online at: http://www.gov.mo/en/news/274643/ (accessed July 29, 2022).

31. Xiao M, Tian J, Zhou Y, Xu X, Min X, Lv Y, et al. Efficacy of Huoxiang Zhengqi dropping pills and Lianhua Qingwen granules in treatment of COVID-19: A randomized controlled trial. *Pharmacol Res*. (2020) 161:105126. doi: 10.1016/j.phrs.2020.105126

32. The Novel Coronavirus Response and Coordination Centre, Macao SAR. *Macao SAR Government's Response to "18 June Outbreak" Summary Report*. Macao. (2022).

33. Harvey WT, Carabelli AM, Jackson B, Gupta RK, Thomson EC, Harrison EM, et al. SARS-CoV-2 variants, spike mutations and immune escape. *Nat Rev Microbiol*. (2021) 19:409–24. doi: 10.1038/s41579-021-00573-0

34. SCMP. *Coronavirus: Time to "Lie Flat?" Divides Emerge on Chinese Internet About Country's Path Out of COVID-19*. (2022). Available online at: http://www.scmp.com/news/people-culture/social-welfare/article/3173364/coronavirus-time-lie-flat-divides-emerge-chinese (accessed July 29, 2022).

35. WHO. *WHO Coronavirus (COVID-19) Dashboard*. (2022). Available online at: https://covid19.who.int/table (accessed July 24, 2022).

36. WHO. *WHO Concerned About Drop in COVID-19 Testing*. Available online at: http://www.voanews.com/a/who-concerned-about-drop-in-covid-19-testing/6477276.html (accessed July 29, 2022).

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 12 January 2023
DOI 10.3389/fpubh.2022.977857

OPEN ACCESS

EDITED BY
Zhiwen Hu,
Zhejiang Gongshang University, China

REVIEWED BY
Jeffrey Harris,
Massachusetts Institute of Technology, United States
Ivana Hromatko,
University of Zagreb, Croatia

*CORRESPONDENCE
Philip Gerretsen
philgerretsen@yahoo.com;
philip.gerretsen@camh.ca

SPECIALTY SECTION
This article was submitted to Infectious Diseases: Epidemiology and Prevention, a section of the journal Frontiers in Public Health

RECEIVED 25 June 2022
ACCEPTED 23 November 2022
PUBLISHED 12 January 2023

CITATION
Gerretsen P, Kim J, Brown EE, Quilty LC, Wells S, Caravaggio F, Song J, Sanches M, Agic B, Pollock BG and Graff-Guerrero A (2023) Determinants of social distancing adherence.
Front. Public Health 10:977857.
doi: 10.3389/fpubh.2022.977857

Determinants of social distancing adherence

Philip Gerretsen[1,2]*, Julia Kim[2], Eric E. Brown[1], Lena C. Quilty[1], Samantha Wells[1,3,4], Fernando Caravaggio[1], Jianmeng Song[2], Marcos Sanches[5], Branka Agic[4,6], Bruce G. Pollock[1,2] and Ariel Graff-Guerrero[1,2]

[1]Centre for Addiction and Mental Health (CAMH) and Department of Psychiatry, Campbell Family Mental Health Research Institute, University of Toronto, Toronto, ON, Canada, [2]Institute of Medical Science, University of Toronto, Toronto, ON, Canada, [3]Institute for Mental Health Policy Research, CAMH, Toronto, ON, Canada, [4]Dalla Lana School of Public Health, University of Toronto, Toronto, ON, Canada, [5]Krembil Centre for Neuroinformatics, CAMH, Toronto, ON, Canada, [6]Provincial System Support Program (PSSP), CAMH, Toronto, ON, Canada

Introduction: Governments and public health authorities across many jurisdictions implemented social (physical) distancing measures to contain the spread of the 2019 novel coronavirus disease (COVID-19). Adherence to these measures is variable and likely influenced by various factors. This study aimed to 1) identify the individual sociodemographic, COVID-19 and social distancing related, and psychological determinants of social distancing adherence, and 2) explore regional differences in social distancing adherence in the United States (U.S.) and English-speaking Canada based on each region's discrepant response to social distancing restrictions.

Methods: A web-based repeated cross-sectional survey was conducted in 4,942 English-speaking participants from the four most populous U.S. states, specifically New York, California, Texas, and Florida, and Canada (www.covid19-database.com). The study was conducted at two timepoints, from May 1 to 5, 2020 (n = 1,019, Canadian participants only) and from July 6 to 10, 2020 (n = 3,923). Separate univariate models were computed for individual sociodemographic, COVID-19 and social distancing related, and psychological determinants of social distancing adherence. To determine the total variance explained, a univariate analysis including all of the determinants was performed. Regional differences in social distancing were compared between the four U.S. states and Canada, and between the U.S. as a whole and Canada.

Results: Adherence to social distancing was higher in May (mean = 4.4/5.0±0.7) compared to July (mean = 4.3/5.0±0.7) [$t_{(4940)}$ = 6.96, p < 0.001], likely a reflection of relaxing restrictions. There were no regional differences in adherence. Sociodemographic, COVID-19 and social distancing related, and psychological determinants explained 10, 36, and 23% of the variance of social distancing adherence, respectively. Higher perceived seriousness of COVID-19 [β (SE) = 0.39 (0.01), p < 0.001, partial η^2 = 0.22], lower risk propensity [β (SE) = −0.15 (0.01), p < 0.001, partial η^2 = 0.06], germ aversion [β (SE) = 0.12 (0.01), p < 0.001, partial η^2 = 0.03], age [β (SE) = 0.01 (0.00), p < 0.001, partial η^2 = 0.02], and greater social support [β (SE) = 0.03 (0.00), p < 0.001, partial η^2 = 0.02] had the largest effects on social distancing adherence.

Conclusion: Public service initiatives to emphasize the serious consequences of infection and targeted interventions toward certain sociodemographic groups, such as younger adults and vulnerable individuals in greater need of social support, may help enhance the public's adherence to social distancing measures during subsequent waves of COVID-19 and future pandemics.

KEYWORDS

COVID-19, pandemic, social distancing adherence, disease prevention, survey, infection prevention and control, sociodemographic determinants, psychological determinants

Introduction

The 2019 novel coronavirus disease (COVID-19) was first identified at the end of 2019 in stallholders working at the South China Seafood Market in Wuhan, a city in the Hubei Province of China. On December 31, 2019, Chinese authorities alerted the World Health Organization (WHO) of an outbreak of a novel coronavirus. The first confirmed cases of COVID-19 were reported in the United States (U.S.) and Canada in January 2020 (1, 2). In March, the WHO characterized the COVID-19 outbreak as a pandemic. As of May 1, 2020, there were 3 million cases of COVID-19 and 224,172 deaths attributable to COVID-19 globally. Two months later, as of July 1, 2020, the global number of cases and deaths increased to 10 million and 508,055, respectively (3).

Government agencies around the world had advised social (physical) distancing and other infection prevention and control measures to prevent the transmission of COVID-19 (4, 5). These included public gathering bans, school and nonessential business closures, and advisements to maintain physical distance from non-household contacts. These interventions are considered essential to 'flatten the curve' (6). The aim of flattening the curve is to avoid overwhelming the healthcare system (7), as occurred in Lombardy, Italy and New York City, U.S. If enacted early, through a coordinated response among public agencies, and with cooperation of the population, mortality attributable to the pandemic can be reduced (6, 8). By pushing cases into the future, social distancing measures allow more time for the creation of additional healthcare infrastructure and the development and testing of antiviral drugs and vaccines.

There is evidence that social distancing measures have been effective in countries that enacted epidemic control measures in a timely manner (Supplementary Figure 1) (9). Prolonged or intermittent social distancing is required to mitigate further transmission of COVID-19 until the adequate dissemination of vaccines (10, 11). Lessons from past pandemics indicate that relaxing social distancing leads to an increase in cases of infection, and that the rate and number of cases is proportional to implementation delays in social distancing restrictions. Communities that enacted prolonged social distancing fared better than those that withdrew social distancing prematurely (6, 12).

Although these measures are advised by the leading health authorities around the world, including the WHO and U.S. Center for Disease Control and Prevention (CDC), other potent factors influence the political decision to maintain or relax social distancing restrictions. Specifically, the economic impact of "nonessential" business closures weighs heavily on the minds of policy decision-makers and is the rationale for loosening restrictions (13, 14). Many jurisdictions have made allowances for some businesses to be reopened and small gatherings permitted. A resurgence of cases may halt or reverse the phased relaxation of government mandated restrictions (15). Additionally, some members of society may oppose social distancing restrictions, for example, by minimizing the seriousness of COVID-19, and in turn, not adhere to infection prevention measures (16), which may undermine the public health response.

With the increase in new COVID-19 cases and deaths around the world, and given the evidence in favor of extended social distancing measures to reduce morality (6), it is important to identify the determinants of social distancing adherence. A scoping review carried out in 2021 that incorporated 84 studies investigating the determinants of social distancing adherence found that "Environmental Context and Resources" and the "Person X Environment Interaction" were the two most coded constructs identified (17). The former refers to a broad category that depicts a person's situation, such as their economic status, their demographic characteristics, the severity of the pandemic in their locality, and the specific public health policies, while the latter represents the interaction between participants' demographic characteristics or personality traits and their environment. Other frequently coded constructs include "Beliefs about Consequences," "Emotion," and "Social influence" (17). Another systematic review that included 28 studies about the barriers to social distancing adherence identified several individual and community level factors. Individual level factors included lacking trust in government and authority, knowledge or misconceptions about the disease,

and perceived lack of threat of COVID-19 (18). Additional influences identified by this review that might hinder social distancing adherence included financial hardship, dependence on social networks and support systems, and social-cultural norms (18). Both reviews highlighted the influence of individual sociodemographic and psychological factors on adherence to social distancing restrictions.

This study aimed to add to the literature investigating the determinants of social distancing adherence. Specifically, the study intended to: (1) identify the individual sociodemographic, COVID-19 and social distancing related, and psychological determinants of social distancing adherence, and (2) explore regional differences in social distancing adherence in the U.S. and English-speaking Canada. We hypothesized a higher degree of adherence to social distancing in New York, California, and Canada compared to Florida and Texas based on each region's discrepant response to the public health recommendations at the time of the study (19).

Methods

Data collection

Responses from a web-based repeated cross-sectional survey were collected from 4,942 participants 18 years of age or older from the most populous U.S. states, including California, New York, Texas, and Florida, and English-speaking Canada (www.covid19-database.com). The survey was conducted from May 1 to 5 (n = 1,019) and from July 6 to 10, 2020 (n = 3,923) (Figure 1). Responses from the U.S. were collected in July only. Our target sample was quota controlled for age. All participants provided written informed consent. Information regarding survey development and quality-control can be found in Supplementary material 1. All participants provided written informed consent prior to starting the survey. The study was approved by the Centre for Addiction and Mental Health's Research Ethics Board.

Measures

We developed the Social Distancing Adherence Scale based on recommendations from the WHO, CDC, and Public Health Agency of Canada (5, 21, 22). The scale consists of 6 items each assessed using a Likert scale, from "1, Never" to "5, Always" (Supplementary material 2). A summary score was calculated to assess the degree of social distancing adherence. The scale items had high internal consistency (Cronbach's alpha = 0.90).

Participants provided sociodemographic information and completed a battery of measures including: Citizen Trust in Government Organizations' Scale (CTGO) (23), Risk Propensity Scale (RPS) (24), Perceived Vulnerability to Disease Questionnaire (PVD) (25), Multidimensional Iowa Suggestibility Scale (MISS) (26), Duke University Religion Index (DRI), religiosity/spirituality subscale (27), Ten-Item Personality Inventory (TIPI) (28), Vaccine Attitude Examination (VAX) (29), Holistic Complementary and Alternative Medicine Questionnaire (HCAM) (30), Brief Locus-of-Control Scale (LOC) (31), General Trust Scale (GTS) (32), Authority Behavior Index (ABI) (33), Positive and Negative Affect Schedule (PANAS) (34), and Experiences in Close Relationships Scale (ECR) (35). A detailed description of each of the above measures and their internal reliability can be found in Supplementary material 3. All variables were categorized as a sociodemographic, COVID-19 and social distancing related, or psychological determinant.

Statistical analyses

Univariate analyses were performed to identify the main determinants of social distancing adherence. A separate model was created for: (1) sociodemographic, (2) COVID-19 and social distancing related, and (3) psychological determinants. Beta (β) and partial eta squared (η^2) values were generated and a threshold of $p < 0.01$ (0.05/3 models) was used to determine significance. Partial η^2 values were used to define small ($\eta^2 = 0.01$), medium ($\eta^2 = 0.06$), and large ($\eta^2 = 0.14$) effect sizes (36, 37). The above analyses were repeated with timepoint as a covariate (i.e., responses collected in May or July). To determine the total variance explained, a univariate analysis including all of the determinants in a single model was performed.

For exploratory purposes, the associations between the determinants and social distancing adherence were examined using spearman correlations and one-way analysis of variance (ANOVA) tests for continuous and categorical determinants, respectively. Correlation coefficients and VIF values were inspected for multicollinearity as defined by correlation coefficients $\geq$0.7 and VIF values $\geq$10.

Regional differences in social distancing adherence were compared between New York, California, Florida, Texas, and Canada, and between the U.S. as a whole and Canada using ANOVA. As no data from the U.S. was collected in May, only the responses from July were used to compare regional differences. A threshold of $p < 0.05$ was used to determine significance.

Statistical analyses were performed using SPSS Statistics (version 26 IBM Corp., Armonk, N.Y., USA).

Subgroup analyses

Univariate analyses using the same methodology described above were performed for the following groups: males and females, and participants >60 years of age.

TABLE 1 Participant characteristics including sociodemographic and clinical, COVID-19 and social distancing related, and psychological determinants[a].

	Mean (SD), Range or *N* (%)
Social distancing adherence score	4.3 (0.7), 1.0–5.0
Sociodemographic and clinical determinants	
Age	44.7 (17.3)
Gender (man/woman)[b]	2,419 (49.2%) / 2,499 (50.8%)
Education (years) ($N = 4,939$)	15.2 (3.9)
Region of residence	
Canada	1,936 (39.2%)
Florida/Texas	1,004 (20.3%)
New York/California	2,002 (40.5%)
Religion (yes/no)	3,133 (66.2%) / 1,602 (33.8%)
Political affiliation	
Communism left wing or socialism	281 (5.7%)
Liberal	1,452 (29.4%)
Center	1,758 (35.6%)
Conservative	1,356 (27.4%)
Fascism right wing or authoritarianism	95 (1.9%)
Employment status	
Unemployed	595 (12.0%)
Employed	2,735 (55.3%)
Student	281 (5.7%)
Retired	1,093 (22.1%)
Household income	
<$20,000	319 (6.9%)
$20,000–$59,999	1,225 (26.4%)
$60,000–$99,999	1,364 (29.4%)
$100,000–$139,999	815 (17.6%)
$140,000 or more	918 (19.8%)
COVID-19 and social distancing related determinants	
Degree of social support (total score[c]) ($N = 4,838$)	13.7 (3.7), 2.0–18.0
Perceived seriousness of COVID-19 ($N = 3,923$)	4.4 (0.9), 1.0–5.0
Knowing someone personally close who	
Is a healthcare worker (yes/no)	1,852 (37.5%) / 3,090 (62.5%)
Is elderly (>60 years) or has underlying health condition (yes/no)	3,131 (63.4%) / 1,811 (36.6%)
Lives in a senior's residence (yes/no)	1,016 (20.6%) / 3,926 (79.4%)
Lives in a long-term care home (yes/no)	862 (17.4%) / 4,080 (82.6%)
Knowing someone personally close who has had COVID-19 and their outcome	
With mild symptoms	467 (9.4%)
Moderate-to-severe without hospitalization	427 (8.6%)
Moderate-to-severe with hospitalization	211 (4.3%)
Required admission to an intensive care unit	107 (2.2%)
Deceased	189 (3.8%)
Does not know anyone affected	3,541 (71.7%)
Prior laboratory testing for COVID-19(Tested +/ Tested -/ Tested and pending/ Never tested)	128 (2.6%) / 590 (11.9%) / 37 (0.7%) / 4,187 (84.7%)
COVID-19 health risk factors (total score[d])	0.7 (1.1), 0.0–8.0
Believing one is infected with COVID-19	1.0 (2.3), 0.0–10.0
Believing one needs testing for COVID-19	2.5 (3.2), 0.0–10.0

(Continued)

TABLE 1 (Continued)

	Mean (SD), Range or *N* (%)
Reduction in income due to COVID-19	2.7 (1.5), 1.0–5.0
Negative impact of social distancing on mental health ($N = 4,838$)	2.9 (1.7), 1.0–6.0
Negative impact of COVID-19 on mental health ($N = 4,838$)	2.8 (1.6), 1,0–6.0
Origin of COVID-19	
It came about naturally likely from animals to humans	3,191 (64.6%)
It was developed intentionally in a lab	951 (19.2%)
It was made accidentally in a lab	413 (8.4%)
It doesn't really exist	58 (1.2%)
I don't know or other	329 (6.7%)
CTGO, trust in government's management of COVID-19	22.3 (8.9), 8.0–40.0
Psychological determinants	
RPS, Risk propensity	3.4 (1.2), 1.0–8.7
PVD, Germ aversion subscale	4.8 (1.0), 1.4–7.0
PVD, Perceived infectability subscale	3.5 (1.1), 1.0–7.0
MISS, Suggestibility	45.4 (18.0), 21.0–105.0
DRI, Religiosity/spirituality subscale	8.6 (4.1), 3.0–15.0
TIPI, Extraversion	3.8 (1.4), 1.0–7.0
TIPI, Agreeableness	4.9 (1.2), 1.0–7.0
TIPI, Conscientiousness	5.3 (1.3), 1.0–7.0
TIPI, Emotional stability	4.7 (1.3), 1.0–7.0
TIPI, Openness to experience	4.6 (1.1), 1.0–7.0
VAX, total score[e]	3.1 (1.0), 1.0–6.0
HCAM, Holistic health subscale[f]	12.1 (4.4), 5.0–30.0
HCAM, Complementary and alternative medicine subscale[f]	23.4 (4.7), 6.0–36.0
LOC, Internal	15.4 (3.3), 3.0–21.0
LOC, Chance	11.4 (4.1), 3.0–21.0
LOC, Powerful others	10.4 (4.8), 3.0–21.0
GTS, General trust	3.5 (0.8), 1.0–5.0
ABI, Attitude toward authority	77.8 (8.2), 42.0–108.0
PANAS, Positive affect score	32.3 (8.1), 10.0–50.0
PANAS, Negative affect score	20.4 (8.9), 10.0–50.0
ECR, Attachment anxiety subscale	28.9 (11.1), 8.0–56.0
ECR, Attachment avoidance subscale	29.7 (7.5), 8.0–56.0

CTGO, Citizen Trust in Government Organizations' Scale; RPS, Risk Propensity Scale; PVD, Perceived Vulnerability to Disease Questionnaire; MISS, Multidimensional Iowa Suggestibility Scale; DRI, Duke Religion/Spirituality Index; TIPI, Ten-Item Personality Inventory; VAX, Vaccination Attitudes Examination Scale; HCAM, Holistic Complementary and Alternative Medicine Questionnaire; LOC, Brief Locus-of-Control Scale; GTS, General Trust Scale; ABI, Authority Behavior Index; PANAS, Positive and Negative Affect Schedule; ECR, Experiences in Close Relationships Scale.

[a]Descriptives for race, healthcare worker status (yes/no), population density, housing situation (dwelling), marital status, substance use including alcohol, cigarettes, electronic cigarettes, and cannabis, and source of health information are included in Supplementary material 4.

[b]Ten participants self-identified as transgender; 10 participants as other; and 4 participants preferred not to answer or indicated that they do not know.

[c]A total score was derived from adding scores for the degree of satisfaction with personal relationships and support from friends.

[d]One point was assigned for each health risk factor (i.e., heart disease, hypertension, lung disease, diabetes, cancer, chronic kidney disease, obesity, and weakened immune system) to derive a total health risk factor score for COVID-19.

[e]Higher scores represent anti-vaccination attitudes.

[f]Higher scores represent a more negative attitude toward holistic complementary and alternative medicine.

FIGURE 1
Weekly number of new confirmed COVID-19 cases per million people in the United States and Canada. The survey data was collected from May 1 to 4, 2020 ($n = 1{,}019$) and from July 6 to 10 ($n = 3{,}923$). Source: COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (20) *via* Our World in Data.

Results

Sample characteristics

Participants were broadly representative of the U.S. and Canadian population with respect to age [mean (SD) = 44.7 (17.3)] and gender (50.8% woman). The majority of participants identified as White/Caucasian (66.8%). The majority of participants identified with a religion (63.4%), with the greatest representation from Christians (45.4%), the majority identifying as Roman Catholics (20.9%). A large proportion of the sample identified as "No religion" (39.5%). The most frequently reported political affiliation was center (35.6%), followed by liberal (29.4%) and conservative (27.4%). Although most of the participants were employed (55.3%), close to 12% of participants were unemployed. Students and retirees represented 5.7 and 22.1% of the sample, respectively. The most frequently reported household income was $60,000–$99,999. The majority of the participants reported drinking alcohol (63.7%). Close to 19, 13, and 18% of the participants endorsed smoking cigarettes, using electronic cigarettes/"vape," and cannabis products in the past week, respectively.

Participants reported knowing someone personally close who is at higher risk of COVID-19, including a healthcare worker (37.5%), someone who is elderly or has an underlying health condition (63.4%), or lives in a senior's residence (20.6%) or a long-term care home (17.4%). At the time of the survey, the majority of participants did not know anyone personally close who is or was infected with COVID-19 (71.7%). Close to 15% of the survey participants indicated that they were tested for COVID-19 and 2.6% reported that they had tested positive. Although the majority of participants believed COVID-19 originated naturally from animals to humans (64.6%), a substantial proportion believed COVID-19 originated intentionally in a lab (19.2%), accidentally in a lab (8.4%), or does not exist (1.2%) (Table 1).

Social distancing adherence

The mean (SD) social distancing adherence score was 4.3/5.0 (0.7). Adherence was higher in May [mean (SD) = 4.4/5.0 (0.7)] compared to July [mean (SD) = 4.3/5.0 (0.7) [$t_{(4940)} = 7.0$, $p < 0.001$], likely a reflection of relaxing restrictions.

There was no regional difference between New York, California, Florida, Texas, and Canada. Social distancing adherence scores were higher in the U.S. compared to Canada [mean (SD) = 4.3 (0.7) and 4.2 (0.7), respectively, $F_{(1,3922)} = 4.68$, $p = 0.031$].

Sociodemographic determinants of social distancing adherence

Sociodemographic determinants explained 10% of the variance of social distancing adherence. Sociodemographic determinants of social distancing adherence with small effects were older age, women, and left-wing political affiliation

(Table 2, Supplementary Figure 2). Controlling for timepoint (i.e., responses collected in May or July) did not change the results.

COVID-19 and social distancing related determinants of social distancing adherence

COVID-19 and social distancing related determinants explained 33% of the variance in social distancing adherence. The main COVID-19 and social distancing related determinant with a large effect was higher perceived seriousness of COVID-19. Greater social support and believing that COVID-19 originated naturally rather than believing that it does not exist had small effects on social distancing adherence (Table 2). Controlling for timepoint did not change the results.

Psychological determinants of social distancing adherence

Psychological determinants explained 26% of the variance in social distancing adherence. The main psychological determinant of social distancing adherence with a medium effect was lower risk propensity. Other psychological determinants with small effects were germ aversion, the personality trait of openness to experience, positive attitudes toward vaccinations and holistic health approaches, higher internal locus-of-control, and general trust in others (Table 2). Controlling for timepoint did not change the results.

The total variance explained by sociodemographic, COVID-19 and social distancing related, and psychological determinants was 40% [$F_{(96,3861)} = 27.58, p < 0.001$] (Figure 2).

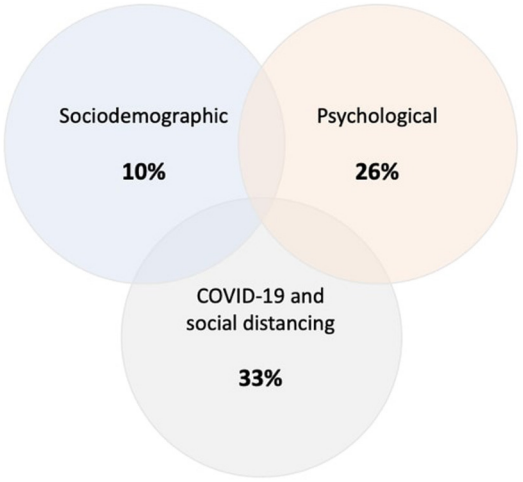


FIGURE 2
Variance of social distancing adherence explained by sociodemographic, COVID-19 and social distancing related, and psychological determinants. The percentages represent R^2 that was derived from separate univariate models for each category. The total variance explained by sociodemographic, COVID-19 and social distancing related, and psychological determinants was 40%.

Exploratory analyses

Exploratory analyses examining the associations between the individual determinants and social distancing adherence are presented in Supplementary material 5.

Subgroup analyses

Descriptive analyses and results of univariate analyses in men, women, and participants 60 years of age or older can be found in Supplementary materials 4–14.

The principal determinants of social distancing adherence identified in the subgroup analyses are consistent with those found in the main analysis. Of note, in women, less negative mental health impact of COVID-19 and source of health information (i.e., preference for television over social media) had a small effect on social distancing adherence. In men, knowing someone personally close who is elderly was associated with a small effect on social distancing adherence. Also, in men, and in participants 60 years of age or older, an avoidant attachment style emerged as a determinant of social distancing adherence with a small effect.

Discussion

At the time of this study, perceptions of COVID-19 and the determinants of adherence to the recommended social distancing measures remained largely unknown. With the number of new cases of COVID-19 rising around much of the world, adherence with social distancing restrictions remained an active issue in relation to the containment and reduction of mortality attributable to COVID-19. While sustained social distancing strategies can save lives (6), prolonged social distancing may have considerable negative consequences, including loneliness, adverse mental health effects (38), and substantial social, educational, and economic disruption.

Our study found that adults in the U.S. and Canada were generally adherent to social distancing measures. At the time of the survey, messaging from the Government of the United States and Canada was to 'Reopen' (14, 39). As a whole, the U.S. states studied were modestly more adherent to social distancing restrictions than Canada. This may be due to reversal

TABLE 2 Univariate analysis examining the association between sociodemographic, COVID-19 and social distancing related, and psychological determinants and social distancing adherence.[1]

	Beta	SE	t	*p*-value	Partial η^2
Sociodemographic and clinical determinants					
Age	0.01	0.00	10.31	<0.001*	0.02[a]
Gender (man/woman[2])	−0.13	0.02	−6.52	<0.001*	0.01[a]
Race					
Indigenous	0.05	0.10	0.52	0.606	0.00
Black	−0.09	0.05	−1.77	0.077	0.00
East Asian	0.11	0.04	3.06	0.002*	0.00
Latinx	0.16	0.04	3.88	<0.001*	0.00
South Asian	0.15	0.06	2.28	0.023	0.00
Other	0.03	0.04	0.74	0.459	0.00
White[2]					
Education (years)	0.01	0.00	2.04	0.041	0.00
Region of residence					
Canada	0.09	0.02	4.00	<0.001*	0.00
Florida/Texas	−0.01	0.03	−0.20	0.839	0.00
New York/California[2]	-	-	-	-	-
Religion (yes/no[2])	0.04	0.02	1.91	0.057	0.00
Population density					
1,000 or less	−0.10	0.06	−1.59	0.111	0.00
1,000 to 29,999	−0.08	0.04	−2.25	0.025	0.00
30,000 to 99,999	−0.02	0.03	−0.78	0.438	0.00
100,000 or more[2]	-	-	-	-	-
Political affiliation					
Communism left wing or socialism	0.15	0.05	3.26	0.001*	0.00
Liberal	0.15	0.03	6.08	<0.001*	0.01[a]
Center[2]	-	-	-	-	-
Conservative	−0.12	0.03	−4.71	<0.001*	0.01[a]
Fascism right wing or authoritarianism	0.04	0.08	0.52	0.607	0.00
Healthcare worker status (yes/no[2])	−0.03	0.03	−0.91	0.362	0.00
Employment status					
Unemployed	0.05	0.03	1.45	0.148	0.00
Employed[2]	-	-	-	-	-
Student	0.10	0.05	2.09	0.037	0.00
Retired	0.07	0.03	1.98	0.048	0.00
Dwelling					
House with a backyard[2]	-	-	-	-	-
House without a backyard	−0.02	0.06	−0.30	0.767	0.00
Apartment/condominium/loft with no or small private outdoor space	−0.06	0.03	−2.44	0.015	0.00
Apartment/condominium/loft with large outdoor space	0.02	0.04	0.51	0.610	0.00
Senior's residence	0.03	0.15	0.19	0.852	0.00
Long-term facility or nursing home	0.30	0.31	0.97	0.334	0.00

(Continued)

TABLE 2 (Continued)

	Beta	SE	t	*p*-value	Partial η^2
Household income					
<$20,000	−0.13	0.05	−2.67	0.008*	0.00
$20,000–$59,999	−0.04	0.03	−1.47	0.141	0.00
$60,000–$99,999[2]	-	-	-	-	-
$100,000–$139,999	−0.05	0.03	−1.44	0.150	0.00
$140,000 or more	0.02	0.03	0.68	0.498	0.00
Marital status (single/married[2])	0.01	0.02	0.37	0.710	0.00
Number of persons in a household	0.02	0.01	2.60	0.009*	0.00
Substance use in the past week					
Alcohol use (yes/no[2])	−0.03	0.02	−1.55	0.120	0.00
Cigarette use (yes/no[2])	−0.03	0.03	−0.91	0.364	0.00
Electronic cigarette use (yes/no[2])	−0.14	0.04	−3.39	0.001*	0.00
Cannabis use (yes/no[2])	0.02	0.03	0.55	0.582	0.00
COVID-19 and social distancing related determinants					
Degree of social support (total score[3])	0.03	0.00	9.07	0.000	0.02[a]
Perceived seriousness of COVID-19	0.39	0.01	33.23	0.000	0.22[c]
Knowing someone personally close who					
Is a healthcare worker (yes/no[2])	−0.02	0.02	−0.69	0.490	0.00
Is elderly (>60 years) or has underlying health condition (yes/no[2])	0.06	0.02	2.55	0.011	0.00
Lives in a senior's residence (yes/no[2])	0.00	0.03	−0.01	0.989	0.00
Lives in a long-term care home (yes/no[2])	−0.06	0.03	−1.78	0.075	0.00
Knowing someone personally close who has had COVID-19 and their outcome					
With mild symptoms	−0.06	0.03	−1.76	0.078	0.00
Moderate-to-severe without hospitalization	−0.04	0.03	−1.08	0.281	0.00
Moderate-to-severe with hospitalization	−0.04	0.05	−0.81	0.421	0.00
Required admission to an intensive care unit	0.00	0.07	−0.06	0.951	0.00
Deceased	−0.07	0.05	−1.37	0.172	0.00
Does not know anyone affected[2]	-	-	-	-	-
Prior laboratory testing for COVID-19					
Tested +	−0.05	0.07	−0.68	0.497	0.00
Tested -	0.01	0.03	0.18	0.858	0.00
Tested and pending	0.07	0.11	0.64	0.524	0.00
Never tested[2]	-	-	-	-	-
COVID-19 health risk factors (total score[4])	0.01	0.01	0.83	0.405	0.00
Believing one is infected with COVID-19	−0.02	0.01	−3.69	0.000	0.00
Believing one need testing for COVID-19	0.00	0.00	−0.08	0.936	0.00
Reduction in income due to COVID-19	0.02	0.01	2.14	0.033	0.00
Negative impact of social distancing on mental health	0.03	0.01	2.42	0.015	0.00
Negative impact of COVID-19 on mental health	−0.04	0.01	−3.75	0.000	0.00
Source of health information					
Friends or family	−0.14	0.05	−2.88	0.004	0.00
Doctor	−0.04	0.03	−1.42	0.156	0.00
Social media	−0.14	0.04	−3.11	0.002	0.00

(Continued)

TABLE 2 (Continued)

	Beta	SE	t	*p*-value	Partial η^2
Internet	−0.04	0.03	−1.54	0.125	0.00
Radio/Podcast	−0.09	0.06	−1.34	0.179	0.00
Newspaper	−0.04	0.05	−0.95	0.342	0.00
Magazines	−0.17	0.18	−0.98	0.327	0.00
Television[2]	-	-	-	-	-
Origin of COVID-19					
It was developed intentionally in a lab	−0.04	0.03	−1.38	0.167	0.00
It was made accidentally in a lab	0.02	0.04	0.68	0.500	0.00
It doesn't really exist	−0.40	0.09	−4.28	0.000	0.01[a]
It came about naturally likely from animals to humans[2]	-	-	-	-	-
CTGO, trust in government's management of COVID-19	0.00	0.00	−0.44	0.659	0.00
Psychological determinants					
RPS, Risk propensity	−0.15	0.01	−17.34	<0.001*	0.06[b]
PVD, Germ aversion subscale	0.12	0.01	11.33	<0.001*	0.03[a]
PVD, Perceived infectability subscale	0.03	0.01	3.08	0.002*	0.00
MISS, Suggestibility	0.00	0.00	−2.87	0.004*	0.00
DRI, Religiosity/spirituality subscale	0.00	0.00	−1.09	0.274	0.00
TIPI, Extraversion	−0.01	0.01	−1.25	0.212	0.00
TIPI, Agreeableness	0.02	0.01	2.44	0.015	0.00
TIPI, Conscientiousness	0.01	0.01	1.10	0.273	0.00
TIPI, Emotional stability	0.01	0.01	1.05	0.293	0.00
TIPI, Openness to experience	0.06	0.01	6.72	<0.001*	0.01[a]
VAX, total score[5]	−0.09	0.01	−8.27	<0.001*	0.01[a]
HCAM, Holistic health subscale[6]	−0.01	0.00	−5.52	<0.001*	0.01[a]
HCAM, Complementary and alternative medicine subscale[6]	0.01	0.00	2.11	0.035	0.00
LOC, Internal	0.02	0.00	5.07	<0.001*	0.01[a]
LOC, Chance	0.01	0.00	2.42	0.016	0.00
LOC, Powerful others	0.00	0.00	0.93	0.355	0.00
GTS, General trust	0.10	0.01	6.98	<0.001*	0.01[a]
ABI, Attitude toward authority	0.00	0.00	0.67	0.503	0.00
PANAS, Positive affect score	0.01	0.00	3.43	0.001*	0.00
PANAS, Negative affect score	0.00	0.00	−0.86	0.390	0.00
ECR, Attachment anxiety subscale	0.00	0.00	0.01	0.996	0.00
ECR, Attachment avoidance subscale	0.01	0.00	3.83	<0.001*	0.00

CTGO, Citizen Trust in Government Organizations' Scale. RPS, Risk Propensity Scale; PVD, Perceived Vulnerability to Disease Questionnaire; MISS, Multidimensional Iowa Suggestibility Scale; DRI, Duke Religion/Spirituality Index; TIPI, Ten-Item Personality Inventory; HCAM, Holistic Complementary and Alternative Medicine Questionnaire; LOC, Brief Locus-of-Control Scale; GTS, General Trust Scale; ABI, Authority Behavior Index; PANAS, Positive and Negative Affect Schedule; ECR, Experiences in Close Relationships Scale.

[1]A separate univariate analysis was conducted for sociodemographic, COVID-19 and social distancing, and psychological determinants. Total adjusted R^2 for sociodemographic determinants: 0.10; COVID-19 and social distancing determinants: 0.33; psychological determinants: 0.26.

[2]Reference variable.

[3]A total score was derived from adding scores for the degree of satisfaction with personal relationships and support from friends.

[4]One point was assigned for each health risk factor (i.e., heart disease, hypertension, lung disease, diabetes, cancer, chronic kidney disease, obesity, and weakened immune system) to derive a total health risk factor score for COVID-19.

[5]Higher scores represent anti-vaccination attitudes.

[6]Higher scores represent a more negative attitude toward holistic complementary and alternative medicine.

[a]Small effect ($\eta^2 = 0.01$); [b]Medium effect ($\eta^2 = 0.06$); [c]Large effect ($\eta^2 = 0.14$); *$p < 0.01$ (0.05/3 univariate models).

of reopening plans at that time due to the rising number of COVID-19 cases in some U.S. states, including California (see Figure 1, Timepoint 2, when regional differences were analyzed) (40).

Sociodemographic and psychological determinants explained 10% and 26% of the variance in social distancing adherence, respectively. COVID-19 and social distancing related factors explained 33% of the variance in social distancing adherence (Figure 2). The main determinant of social distancing adherence was higher perceived seriousness of COVID-19, followed by higher risk propensity. The principal finding that an individual's perception of the of seriousness of COVID-19 is consistent with the results of a systematic review that reported an individual's perception of COIVD-19 as a threat contributes to adherence to social distancing restrictions (18). Risk propensity refers to an individual's general tendency to take risks (24). Few studies have explored the role of risk propensity on social distancing behavior during COVID-19. All of these investigations, however, indicate that individuals with lower risk tolerance are more likely to adhere to social distancing restrictions, independent of the perceived seriousness or objective threat of COVID-19 (41). In contrary, people with higher risk propensity are more likely to engage in behaviors that are considered risky in the context of COVID-19 (42, 43).

In summary, our results describe individuals most likely to be nonadherent with social distancing restrictions as younger men with a right-wing political affiliation. They do not believe COVID-19 is serious or that it exists. They have a higher propensity for risk, negative attitudes toward vaccinations or holistic health approaches, a weak sense of self-agency (i.e., low internal locus of control), and are generally distrusting of others. Although there were minor differences in the determinants of social distancing adherence in men, women, and participants 60 years of age or older, the main determinants of social distancing adherence identified in these subgroups were consistent with those found in the main analysis. Other studies in varied countries have also supported our findings that age, gender, political affiliation, distrust, and perceived self-control are individual determinants that contribute to adherence to social distancing measures (44–48).

Of note, other studies have found that COVID-19 awareness of the COVID-19 pandemic and lack of concrete knowledge about the disease influence social distancing adherence, highlighting the importance of public education (18, 48, 49).

The results of our study are limited by the known biases associated with research participation, namely, individuals that consent to participate in research are often more conscientious and willing to sacrifice their time to support the greater good than are nonparticipants (50). Another limitation that is intrinsic to web-based surveys is that participants who are unfamiliar with using a computer or have no internet access are not represented. However, given the time sensitivity of the study, a web-based survey allowed for reaching a larger number participants within a short period of time without compromising validity and reliability (51). Further, we are unable to comment on the direction of the associations given the cross-sectional nature of the study.

Conclusions

The success of public health interventions, such as social distancing, depend on public support and adherence (6). Our study identified individual sociodemographic, COVID-19 and social distancing related, and psychological determinants that can inform public health and other authorities to develop public service interventions to improve social distancing adherence and contain the spread of COVID-19 and future infections more effectively. These may include public service initiatives to emphasize the seriousness of COVID-19 and future infectious diseases, and tackle false or misleading information about them. Targeted interventions toward certain sociodemographic groups, such as younger men and vulnerable individuals in greater need of social support, and health communications promoting a sense of control over COVID-19 and future infections and their consequences may also be beneficial.

Targeted recommendations

1) *Seriousness of infection:* Emphasize the seriousness of COVID-19, including increasing awareness of the risk of transmission, likelihood of serious illness, and the associated morbidity.

2) *Risk propensity and germ aversion:* Increase knowledge of the risk of transmission without infection prevention measures, including social distancing, and the elevated risk of mortality, particularly in the elderly. Influence perceptions by emphasizing the likelihood of a serious negative outcome with COVID-19 infection. Individuals may minimize the seriousness of COVID-19 after acquiring personal knowledge of individuals with mild cases of the infection.

3) *Social support:* Promote virtual social connection and support to address social isolation. Concerned, consistent, accessible others may alleviate one's sense of social isolation and attachment anxiety (52).

4) *Attitudes toward vaccinations:* Enhance the public's confidence in safety and effectiveness of vaccines and the systems recommending and providing it. Increase awareness that vaccination is required to prevent infection and transmission of COVID-19, and that the benefits of any safe and effective vaccine outweigh the possible consequences.

5) *Perception of holistic health:* Promote a holistic attitude where individuals are mindful of the effects of emotional wellbeing on physical health, i.e. "Mental health is health" (53).

6) *Internal locus-of-control:* Promote individual agency or sense of control over COVID-19 and its consequences (e.g., the

message "Conquering COVID-19 is in my hands! By adopting good hygiene and social distancing practices, I am keeping myself, family, friends, and my community safe," may instill a sense of control over the impact of COVID-19 and enhance one's ability to practice protective behavior).

Data availability statement

The raw data supporting the conclusions of this article are available, without undue reservation, at: http://www.covid19-database.com/.

Ethics statement

All studies involving human participants are reviewed and approved by the Centre for Addiction and Mental Health. Participants provided their written informed consent to participate in this study.

Author contributions

PG, JK, and AG-G: agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors: substantial contributions to the conception or design of the work and/or the acquisition, analysis, or interpretation of data for the work, drafting of the manuscript and/or revising it critically for important intellectual content, final approval of the version to be published.

Funding

This study was funded by Center for Addiction and Mental Health Foundation and Canadian Institutes of Health Research. This work was also supported by the CAMH Foundation, an Academic Scholars Award from the Department of Psychiatry, University of Toronto, and Canadian Institute of Health Research (CIHR) (PJT-159807 to PG).

Conflict of interest

PG reports receiving research support from the Canadian Institute of Health Research (CIHR), Ontario Ministry of Health and Long-Term Care, Ontario Mental Health Foundation (OMHF), and the Center for Addiction and Mental Health (CAMH). FC has received funding from the CIHR Post-doctoral Fellowship Award and the CAMH Foundation. AG-G has received support from the United States National Institute of Health, CIHR, OMHF, Consejo Nacional de Ciencia y Tecnología, the Instituto de Ciencia y Tecnología del DF, the Brain & Behavior Research Foundation (Formerly NARSAD), the Ontario Ministry of Health and Long-Term Care, the Ontario Ministry of Research and Innovation Early Research Award, and Janssen.

The remaining 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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.977857/full#supplementary-material

References

1. Centers for Disease Control and Prevention. First Travel-related Case of 2019 Novel Coronavirus Detected in United States. *Centers for Disease Control and Prevention*. (2020). Available online at: https://www.cdc.gov/media/releases/2020/p0121-novel-coronavirus-travel-case.html (accessed January 18, 2021).

2. Public Health Agency of Canada. *Coronavirus Disease 2019 (COVID-19): Epidemiology Update. Government of Canada*. (2021). Available online at: https://health-infobase.canada.ca/covid-19/epidemiological-summary-covid-19-cases.html (accessed January 18, 2021).

3. World Health Organization. *Coronavirus Disease (COVID-19) Situation Report – 106*. (2020). Available online at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports (accessed January 21, 2021).

4. Centers for Disease Control and Prevention. COVID-19 and Your Health. *Centers for Disease Control and Prevention*. (2020). Available online at: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/social-distancing.html (accessed January 18, 2021).

5. Public Health Agency of Canada. *Coronavirus Disease (COVID-19): Prevention and Risks*. (2020). Available online at: https://www.canada.ca/en/public-health/services/diseases/2019-novel-coronavirus-infection/prevention-risks.html (accessed May 3, 2020).

6. Markel H, Lipman HB, Navarro JA, Sloan A, Michalsen JR, Stern AM, et al. Nonpharmaceutical interventions implemented by US cities during the 1918-1919 influenza pandemic. *JAMA*. (2007) 298:644–54. doi: 10.1001/jama.298.6.644

7. Tuite AR, Fisman DN, Greer AL. Mathematical modelling of COVID-19 transmission and mitigation strategies in the population of Ontario, Canada. *CMAJ.* (2020) 192:E497–E505. doi: 10.1503/cmaj.200476

8. Markel H, Stern AM, Navarro JA, Michalsen JR, Monto AS, DiGiovanni C. Nonpharmaceutical influenza mitigation strategies, US communities, 1918-1920 pandemic. *Emerg Infect Dis.* (2006) 12:1961–4. doi: 10.3201/eid1212.060506

9. Lewnard JA, Lo NC. Scientific and ethical basis for social-distancing interventions against COVID-19. *Lancet Infect Dis.* (2020) 20:P631–633. doi: 10.1016/S1473-3099(20)30190-0

10. Kissler SM, Tedijanto C, Goldstein E, Grad YH, Lipsitch M. Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period. *Science.* (2020) 368:860–8. doi: 10.1126/science.abb5793

11. Public Health Agency of Canada. *COVID-19 in Canada: Using Data and Modelling to Inform Public Health Action*. (2020). Available online at: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/covid-19-using-data-modelling-inform-public-health-action.html (accessed May 4, 2020).

12. Chowell G, Echevarría-Zuno S, Viboud C, Simonsen L, Tamerius J, Miller MA, et al. Characterizing the Epidemiology of the 2009 Influenza A/H1N1 Pandemic in Mexico. *PLoS Med.* (2011) 8:e1000436. doi: 10.1371/journal.pmed.1000436

13. Ontario. *Ontario Unveils Guiding Principles to Reopen the Province.* (2020). Available online at: https://news.ontario.ca/opo/en/2020/04/ontario-unveils-guiding-principles-to-reopen-the-province.html (accessed May 29, 2020).

14. U.S. Department of Health and Human Services, Center for Disease Control and Prevention. *CDC Activities and Initiatives Supporting the COVID-19 Response and the President's Plan for Opening America Up Again*. (2020). Available online at: https://www.whitehouse.gov/openingamerica/ (accessed January 18, 2021).

15. Leung K, Wu JT, Liu D, Leung GM. First-wave COVID-19 transmissibility and severity in China outside Hubei after control measures, and second-wave scenario planning: a modelling impact assessment. *Lancet.* (2020) 395:1382–93. doi: 10.1016/S0140-6736(20)30746-7

16. Draaisma M. *"Bunch of Yahoos": Ontario Premier Slams Anti-lockdown Protesters at Queen's Park | CBC News. CBC.* (2020). Available online at: https://www.cbc.ca/news/canada/toronto/ontario-shutdown-protesters-queens-park-yahoos-1.5545253 (accessed May 18, 2020).

17. Noone C, Warner NZs, Byrne M, Durand H, Lavoie KL, McGuire BE, et al. A scoping review of research on the determinants of adherence to social distancing measures during the COVID-19 pandemic. *Health Psychol Rev.* (2021) 15:350–70. doi: 10.1080/17437199.2021.1934062

18. Sadjadi M, Mörschel KS, Petticrew M. Social distancing measures: barriers to their implementation and how they can be overcome - a systematic review. *Eur J Public Health.* (2021) 31:1249–58. doi: 10.1093/eurpub/ckab103

19. Thompson SA, Serkez Y, Kelley L. *Opinion | How Has Your State Reacted to Social Distancing? The New York Times.* (2020). Available online at: https://www.nytimes.com/interactive/2020/03/23/opinion/coronavirus-economy-recession.html (accessed September 22, 2020).

20. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect Dis.* (2020) 20:533–4. doi: 10.1016/S1473-3099(20)30120-1

21. Centers for Disease Control and Prevention. How to Protect Yourself & Others. *Centers for Disease Control and Prevention.* (2020). Available online at: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html (accessed January 21, 2021).

22. World Health Organization (WHO). *Coronavirus Disease (COVID-19) Advice for the Public*. (2021). Available online at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public (accessed January 21, 2021).

23. Grimmelikhuijsen S, Knies E. Validating a scale for citizen trust in government organizations. *Int Rev Adm Sci.* (2015) 83. doi: 10.1177/0020852315585950

24. Meertens RM, Lion R. Measuring an individual's tendency to take risks: the risk propensity scale. *J Appl Soc Psychol.* (2008) 38:1506–20. doi: 10.1111/j.1559-1816.2008.00357.x

25. Duncan LA, Schaller M, Park JH. Perceived vulnerability to disease: development and validation of a 15-item self-report instrument. *Pers Individ Dif.* (2009) 47:541–6. doi: 10.1016/j.paid.2009.05.001

26. Kotov RI, Bellman SB, Watson DB. *Multidimensional IOWA Suggestibility Scale (MISS) Brief Manual*. (2004). Available online at: https://dspace.sunyconnect.suny.edu/handle/1951/60894 (accessed January 21, 2021).

27. Koenig H, Parkerson GR, Meador KG. Religion index for psychiatric research. *Am J Psychiatry.* (1997) 154:885–6. doi: 10.1176/ajp.154.6.885b

28. Gosling SD, Rentfrow PJ, Swann WB. A very brief measure of the Big-Five personality domains. *J Res Pers.* (2003) 37:504–28. doi: 10.1016/S0092-6566(03)00046-1

29. Martin LR, Petrie KJ. Understanding the dimensions of anti-vaccination attitudes: the vaccination attitudes examination (VAX) scale. *Ann Behav Med.* (2017) 51:652–60. doi: 10.1007/s12160-017-9888-y

30. Hyland ME, Lewith GT, Westoby C. Developing a measure of attitudes: the holistic complementary and alternative medicine questionnaire. *Complement Ther Med.* (2003) 11:33–8. doi: 10.1016/S0965-2299(02)00113-9

31. Sapp SG, Harrod WJ. Reliability and validity of a brief version of Levenson's Locus of Control Scale. *Psychol Rep.* (1993) 72:539–50. doi: 10.2466/pr0.1993.72.2.539

32. Yamagishi T, Yamagishi M. Trust and commitment in the United States and Japan. *Motiv Emot.* (1994) 18:129–66. doi: 10.1007/BF02249397

33. Rigby K. An authority behavior inventory. *J Pers Assess.* (1987) 51:615–25. doi: 10.1207/s15327752jpa5104_14

34. Crawford JR, Henry JD. The positive and negative affect schedule (PANAS): construct validity, measurement properties and normative data in a large non-clinical sample. *Br J Clin Psychol.* (2004) 43:245–65. doi: 10.1348/0144665031752934

35. Brennan KA, Clark CL, Shaver PR. Self-report measurement of adult attachment: An integrative overview. (1998).

36. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. New York: Routledge. (1988).

37. Richardson JTE. Eta squared and partial eta squared as measures of effect size in educational research. *Educ Res Rev.* (2011) 6:135–47. doi: 10.1016/j.edurev.2010.12.001

38. Galea S, Merchant RM, Lurie N. The Mental Health Consequences of COVID-19 and Physical Distancing: The Need for Prevention and Early Intervention. *JAMA Intern Med.* (2020) 180:817–8. doi: 10.1001/jamainternmed.2020.1562

39. CPAC. Federal ministers and health officials provide COVID-19 update – May 4, 2020. *The Cable Public Affairs Channel.* (2020). Available online at: https://www.youtube.com/watch?v=77NLZ403Qvo (1:20 min; 48:38 min) (accessed May 4, 2020).

40. AJMC. *A Timeline of COVID-19 Developments in 2020*. (2021). Available online at: https://www.ajmc.com/view/a-timeline-of-covid19-developments-in-2020 (accessed January 27, 2021).

41. Shou Y, Smithson M, Gulliver A, Murray K, Banfield M, Rodney Harris RM, et al. Risk tolerance and changes in coronavirus disease (COVID) related health behaviors: a longitudinal study. *Health Psychol.* (2022) 41:507. doi: 10.1037/hea0001197

42. Diaconu (Maxim) L. The Behaviour of Airlines' Passengers in the Context of COVID-19 Pandemic. *CES Work Papers.* (2021) 13:230–242. Available online at: https://ceswp.uaic.ro/articles/CESWP2021_XIII2_DIA.pdf

43. Leung XY, Cai R. How pandemic severity moderates digital food ordering risks during COVID-19: An application of prospect theory and risk perception framework. *J Hosp Tour Manag.* (2021) 47:497–505. doi: 10.1016/j.jhtm.2021.05.002

44. Gualda E, Krouwel A, Palacios-Gálvez M, Morales-Marente E, Rodríguez-Pascual I, García-Navarro EB. Social Distancing and COVID-19: Factors Associated With Compliance With Social Distancing Norms in Spain. *Front Psychol.* (2021) 12:727225. doi: 10.3389/fpsyg.2021.727225

45. Farias ST, Mungas D, Reed BR, Cahn-Weiner D, Jagust W, Baynes K, et al. The Measurement of Everyday Cognition (ECog): scale development and psychometric properties. *Neuropsychology.* (2008) 22:531–44. doi: 10.1037/0894-4105.22.4.531

46. Barbieri PN, Bonini B. Political orientation and adherence to social distancing during the COVID-19 pandemic in Italy. *Econ Polit.* (2021) 38:483–504. doi: 10.1007/s40888-021-00224-w

47. Sewpaul R, Mabaso M, Cloete A, Dukhi N, Naidoo I, Davids AS, et al. Social distancing behaviour: avoidance of physical contact and related determinants among South Africans: twelve days into the COVID-19 lockdown. *Psychol Health Med.* (2022) 0:1–19. doi: 10.1080/13548506.2022.2075020

48. Hadizadeh-Talasaz F, Delshad Noghabi A, Mohammadzadeh F. Relationship between socio-demographic factors and adherence to social distancing

recommendations during COVID-19 pandemic in Gonabad, Iran: a cross-sectional study. *Int J Community Based Nurs Midwifery*. (2022) 10:134–45. doi: 10.30476/IJCBNM.2021.90930.1747

49. Wolff W, Martarelli CS, Schüler J, Bieleke M. High boredom proneness and low trait self-control impair adherence to social distancing guidelines during the COVID-19 pandemic. *Int J Environ Res Public Health*. (2020) 17:5420. doi: 10.3390/ijerph17155420

50. Lönnqvist JE, Paunonen S, Verkasalo M, Leikas S, Tuulio-Henriksson A, Lönnqvist J. Personality characteristics of research volunteers. *Eur J Pers*. (2007) 21:1017–30. doi: 10.1002/per.655

51. Risko EF, Quilty LC, Oakman JM. Socially Desirable Responding on the Web: Investigating the Candor Hypothesis. *J Pers Assess*. (2006) 87:269–76. doi: 10.1207/s15327752jpa8703_08

52. Pietromonaco PR, Uchino B, Dunkel Schetter C. Close relationship processes and health: implications of attachment theory for health and disease. *Health Psychol*. (2013) 32:499–513. doi: 10.1037/a0029349

53. CAMH. Mental Health is Health. *CAMH*. (2020). Available online at: https://www.camh.ca/en/driving-change/mental-health-is-health (accessed May 20, 2020).

frontiers | Frontiers in Public Health

TYPE Brief Research Report
PUBLISHED 01 February 2023
DOI 10.3389/fpubh.2023.1041944

OPEN ACCESS

EDITED BY
Zhiwen Hu,
Zhejiang Gongshang University, China

REVIEWED BY
Mingke Wang,
Naval Medical Center, China
Eman Zmaily Dahmash,
Isra University, Jordan

*CORRESPONDENCE
Ashlin Lee
ashlin.lee@csiro.au

SPECIALTY SECTION
This article was submitted to Infectious Diseases: Epidemiology and Prevention, a section of the journal Frontiers in Public Health

RECEIVED 11 September 2022
ACCEPTED 12 January 2023
PUBLISHED 01 February 2023

CITATION
Lee A, Kakoschke N, Higgins L, Reeson A and Brindal E (2023) The invisible burden of managing COVID-19 for Australian women: Cognitive labor and public health information. *Front. Public Health* 11:1041944. doi: 10.3389/fpubh.2023.1041944

The invisible burden of managing COVID-19 for Australian women: Cognitive labor and public health information

Ashlin Lee[1,2]*, Naomi Kakoschke[3], Liesel Higgins[4], Andrew Reeson[5] and Emily Brindal[3]

[1]Environmental Informatics Group, Environment Department, Commonwealth Science and Industrial Research Organisation (CSIRO), Canberra, ACT, Australia, [2]Justice and Technoscience Lab (JusTech), School of Regulation and Global Governance, The Australian National University, Canberra, ACT, Australia, [3]Human Health, Health and Biosecurity Department, Commonwealth Science and Industrial Research Organisation (CSIRO), Adelaide, SA, Australia, [4]Australian E-Health Research Centre, Health and Biosecurity Department, Commonwealth Science and Industrial Research Organisation (CSIRO), Brisbane, QLD, Australia, [5]Humans and Machines Department, Data61, Commonwealth Science and Industrial Research Organisation (CSIRO), Canberra, ACT, Australia

Providing accurate and timely public health information is an ongoing challenge for public health officials. The COVID-19 pandemic has exacerbated such challenges and presented unique difficulties in providing public health information, through the parallel rise of an "infodemic" of mis/dis-information. Understanding why individuals select, use and change their public health information seeking behaviors around COVID-19, and the relationship of these decisions relative to participant characteristics, is therefore an important step in understanding and responding to infodemics. This study used a qualitative survey (n = 255) and free-text qualitative questions to ask (1) Why participants use an information source, (2) How participants used an information source, and (3) How information seeking behavior has changed since the COVID-19 pandemic. Participants were primarily women, born in Australia, with *de-facto*/married relationships, without children at home, with university/college qualifications, and employed full-time or unemployed/retired. Most participants identified "easiness" and "immediacy" as reasons why they chose and used information, with sources primarily used for planning, communication, and decision making. A minority of participants changed their information seeking behavior since the COVID-19 pandemic. Those who did change, desired more immediate and accurate information. Emergent themes of care and anxiety were also noted, raising questions around the impact of mental load and cognitive labor in some female populations. Women may be suffering from increased cognitive labor and a gendering of public health information seeking behavior in the context of COVID-19. The impact of these attributes on women requires greater empirical research and consideration amongst front line practitioners and public health professionals.

KEYWORDS

cognitive labor, information seeking, COVID-19, mental load, public health

Introduction

Providing accurate and timely public health information is an ongoing challenge for public health officials. The COVID-19 pandemic has exacerbated such challenges and presented unique difficulties in providing public health information. One such challenge is misinformation (i.e., misleading information), particularly through digital platforms, which has negatively influenced health behaviors such as vaccine uptake (1–3). As Stein et al. (4) note, the success

of COVID-19 responses such as mask wearing and vaccination is contingent upon what Lippmann (5) calls the pseudo-environment, the mediatory space between an individual and their environment, where public opinion and other stimuli shape our perception of the world. Exposure to anti-vaccination messaging and other forms of health misinformation on these platforms has distorted the pseudo-environment for some populations. This has increased the presence of vaccine hesitant attitudes, that otherwise informed citizens have, toward vaccines (2), it has spurred conspiracy theories (6), and promoted false and dangerous treatments (7), all while degrading faith in proven measures like vaccines. As Knight et al. (8) note, whilst social media platforms can contribute to vaccine hesitancy, they also possess the potential to improve vaccine uptake. The latter suggests that the relationship between public health information sources and the public varies, and that information seeking behaviors might change depending on the context and medium (9). For example, users might be using different social media platforms to as a part of different information seeking behaviors; they may (hypothetically) be exposed to, and respond to, misinformation on Twitter, but seek out trustworthy sources on TikTok, depending on their external circumstances.

Relatedly, health information seeking during COVID-19 has been impacted by an over-abundance of information, or an "infodemic." Excessive amounts of information make it more challenging to locate health-related information from trusted sources (9). A recent systematic review identified five key contributors to infodemics, including information sources, communication channels, and message content (3). However, there is currently little qualitative research regarding this.

Evidence suggests that information seeking sources may also vary depending on personal characteristics. For example, women have been shown to more frequently access public health related information than men, and to take the role of "health information gatekeepers" of their family (10). During the COVID-19 pandemic, the burden of care for women increased, whilst their wellbeing decreased (11). One potential reason for this is that women and mothers experienced a greater than usual "mental load" or "cognitive labor" particularly during lockdowns. These terms describe responsibilities such as planning, decision making, and monitoring, required as a part of everyday life (12, 13), for which women are disproportionately responsible even in the absence of a global pandemic (14). However, it remains unclear whether an increased burden of care is attributable to not only physical but cognitive dimensions of labor, and whether the latter could be attributed to increased health information seeking behavior.

The current study aimed to provide preliminary insights into why participants selected, used, and changed their sources of public health information during COVID-19, and the relationship of these decisions relative to participant characteristics.

Methods

Participants and design

Adults aged over 18 years who were currently residing in South Australia and not currently isolating or in lockdown were eligible to participate in the study. Participants were recruited *via* the CSIRO Nutrition and Health Clinic volunteer database (a standing database of interested research participants) to evaluate website content containing resources related to COVID-19 and then asked optional questions about information seeking. All volunteers in the stated database were invited to take part in the study. The current study employed a mixed-methods cross-sectional study design.

Materials

This study employed an online survey comprising questions about public health information seeking behavior and COVID-19, which were included as part of a larger study evaluating a COVID-19 self-isolation preparedness checklist. Questions for this study subsection were developed through a brainstorm of potential COVID-19 information sources, which were distilled into clear categories and used as closed choice survey questions. These categories are consistent with other previous studies, and cover different online sources, social and mobile media sources, personal sources, and community sources (15–17). To ascertain the meaning behind these choices and collective qualitative data on these meanings, three open questions followed (see the "Open ended questions" section in the results). The other questions related to the COVID-19 preparedness materials are not relevant for this analysis.

Procedure

The study was approved by the CSIRO Human Research Ethics Low Risk Review Panel (#2021_105_LR), before invitations were emailed to participants registered on an existing volunteer database. Interested participants accessed an anonymous online survey hosted on the Alchemer survey platform where consent and information sheets were provided. Participants then reviewed materials for the preparedness checklist (18) and completed a short feedback questionnaire relating to these materials. Information seeking questions were included at the end of the survey. Completing the survey took ∼30 mins, and those who completed the survey were offered the chance to win 1 of 3 $100 AUD vouchers. The data was collected throughout December of 2021.

Data analysis

The quantitative data are presented descriptively and compared using Chi-Square analyses. Chi-Square was applied to compare use (vs. not) across demographics including gender, age group, employment status, education level, marital status and whether participants were born in Australia (or not) for the top five information sources. Given repeated analyses, significance levels were adjusted to $p < 0.01$.

For the qualitative data, an abductive thematic analysis was conducted using NVivo 12 (Melbourne, Australia) with data constantly being reflected upon *vis-a-vis* existing theory and data. Results were generated using Green et al.'s (19) approach to achieving rigor in qualitative analysis. This consisted of (1) data immersion through reading and reflection, (2) open code generation, (3) sorting codes into descriptive categories, and (4) developing explanatory themes informed by appropriate theory.

TABLE 1 Participant characteristics for those who provided open-ended responses.

Variables	*n*	%	Variables	*n*	%
Gender			**Highest level of education**		
Male	65	25.5	Year 9 or below[b]	2	0.8
Female	187	73.3	Year 10[b]	16	6.3
Non-binary	2	0.8	Year 11[b]	13	5.1
Prefer not to answer	1	0.4	Year 12	20	7.8
Born in Australia?			Certificate 2 or 3[c*]	15	5.9
Yes	183	71.8	Certificate 4 or 5[c^]	12	4.7
No	70	27.5	Diploma or advanced diploma	45	17.6
Prefer not to answer	2	0.8	Bachelor/ undergraduate degree	57	22.4
Marital status			Graduate diploma/graduate certificate[d]	20	7.8
Single	52	20.4	Postgraduate degree[d]	48	18.8
De facto/married	157	61.6	Certificate not further defined[c#]	5	2.0
Divorced[a]	37	14.5	Level not determined	2	0.8
Widowed[a]	9	3.5	**Employment status**		
Child living with you?			Part-time	42	16.5
Yes	75	29.4	Full-time	89	34.9
No	179	70.2	Casual	18	7.1
Prefer not to answer	1	0.4	Unemployed	104	40.8
			Prefer not to answer	2	0.8

[a,b,c,d]Shared superscripts indicate categories that were combined in further analyses.
*Basic or skilled vocational qualifications.
^An associate diploma or above.
#An undefined vocational qualification.

Results

Participant characteristics

The survey was sent to ∼18,000 participants on the volunteer database and a total of $N = 438$ commenced it (2.4%). Based on the eligibility screening questions, $n = 61$ participants were deemed ineligible from further participation due to not residing in South Australia ($n = 15$) or being in isolation or lockdown ($n = 46$). Of the remaining $n = 377$ participants, $n = 123$ had missing data. The final sample comprised $n = 255$ adults aged 18–84 years (female: 73.3%, $n = 187$). We received the majority of our results from women, born in Australia, with a *de facto* or married relationship status, without children living at home, with university/college qualifications, and employed full-time or unemployed. Sample characteristics are presented based on the sample included in the current research analysis (see Table 1).

COVID-19 information sources

Australian Government sources were the most widely used, with the majority of participants selecting this source type, followed by privately owned mainstream media (Figure 1). Professional sources, closely followed by personal/familiar sources were the next most used. "Other" responses included newspapers and workplaces.

For the top five information sources, use of Australian Government sources varied significantly by level of education (see Table 2 for inferential statistics). Participants who had not completed high school were less likely than expected to use Australian Government sources relative to the sample's average (64.5% vs. 87.8%). Use of mainstream media sources varied significantly by employment status. Participants with full-time employment were less likely than expected to use mainstream media sources relative to the sample average (62.9% vs. 77.3%).

Online resources were used by almost three quarters of the sample who preferred online methods for accessing information such as webpages, whilst only half of the sample used television (see Figure 2). Nevertheless, traditional media sources such as television, radio, and print are still relevant for much of the sample, and 38.0% ($n = 95$) used two to three of these sources in combination. Search engines were also amongst the key methods for accessing information about COVID-19.

Open-ended questions

We observed a large gap in unique coding references for female participants compared to male participants, in line with the female bias of our sample. Comparison of coding frequency and gender illustrates this issue with Question 1 split 265 vs. 83, Question 2 split 179 to 61, and Question 3 split 364 vs. 124, all in favor of female vs. male participants.[1] Thus, the qualitative results should be interpreted with caution as they may provide greater insights into female participants only.

Question 1: Why do you use these information sources?

Participants' responses focused on immediacy and quality. Immediacy (20) refers to whether information sources reflect convenience and easiness in their interaction with the participant. For example:

1 Note that coding frequency refers to the number of unique references made in a participant's statement. Depending on the length and depth of statements, multiple references may be appropriate. This means that it is possible for the number of coding references to exceed the number of participants, as is the case with Question 3. The purpose of referring to this is to indicate that female participants not only provide more text, but that their responses were of greater qualitative depth, raising more themes than male participants.

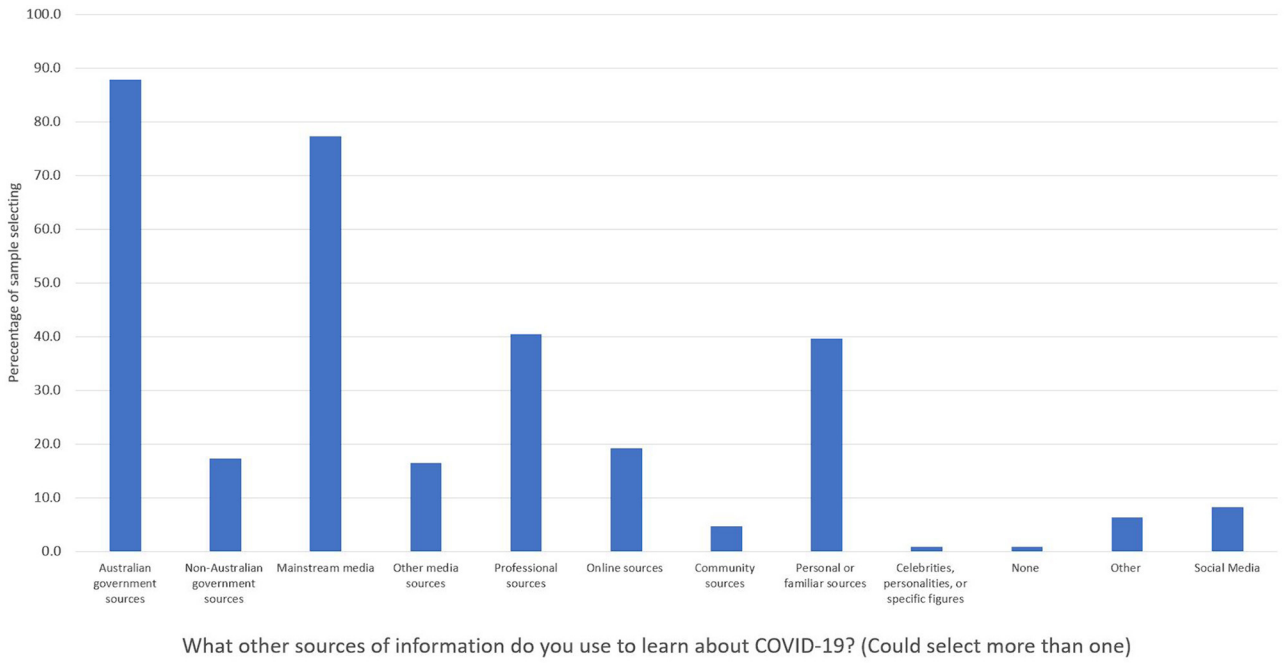


FIGURE 1
Percentage of people selecting (vs. not selecting) information sources used to learn about COVID-19. Participants ($n = 255$) could select multiple options.

TABLE 2 Chi-square values for comparisons between use (vs. not) of top five sources of information by key participant characteristics ($n = 255$).

Characteristics		Sources of COVID-19 related information									
		Australian government		Mainstream media		Professional		Personal		Online	
	df	Chi-square	*p*	Chi-square	*p*	Chi-square	*p*	Chi-square	*p*	Chi-square	*p*
Gender[a]	1, 252	0	>0.99	1.52	0.218	0.25	0.62	1.25	0.264	3.80	0.051
Age Group	9, 255	11.23	0.261	33.12	<.001	8.71	0.465	9.95	0.354	10.52	0.310
Marital status	2, 255	2.95	0.229	2.44	0.296	1.32	0.516	6.76	0.034	0.36	0.836
Employment status	3, 253	6.6	0.086	16.82	0.001	1.08	0.783	0.34	0.953	1.74	0.628
Level of education	5, 253	18.07	0.003	9.63	0.087	4.14	0.529	5.91	0.315	3.71	0.593
Australian born	1, 253	1.22	0.269	2.02	0.155	0.31	0.577	0.59	0.443	0.827	0.363

[a]Excludes non-binary due to small cell size (n = 3).

> *Easier and can be accessed anywhere and anytime. The information is more current (Participant 34—F).*
>
> *Easily accessible. Simple, succinct to read. Links to other websites/news sources if I want to read more (Participant 16—F).*
>
> *They are available when I have the time. I can re-read things to better understand what is being said. I don't have to be polite to people (Participant 137—M).*

Accessing and using preferred sources is not limited by time and space; they have desirable physical and user interface qualities (such as succinctness and privacy), and also easily connect to further content (i.e., links to other sources). These allow the preferred source to fit seamlessly into a participant's existing context.

The importance of connectivity amongst sources accentuates the theme of quality. Rapidly accessing information is a necessary condition for selecting a source, but there are also sufficient requirements reflecting the quality and validity of a source:

> *The television news is easy to access and gives an overview of the current state of affairs. If I want to access more accurate information, I use the Government COVID app or website. I don't want to read "opinion" of people based on their fame. I only want facts and hope that the information I get from government websites reflect professional medical opinion (Participant 80—F).*
>
> *Easily accessible and substantially authoritative (Participant 225—M).*
>
> *Reliable, trusted, unbiased, every day, plus free sources (Participant 147—F).*
>
> *They are generally reliable with the best up to date information and can be cross checked (Participant 125—F).*

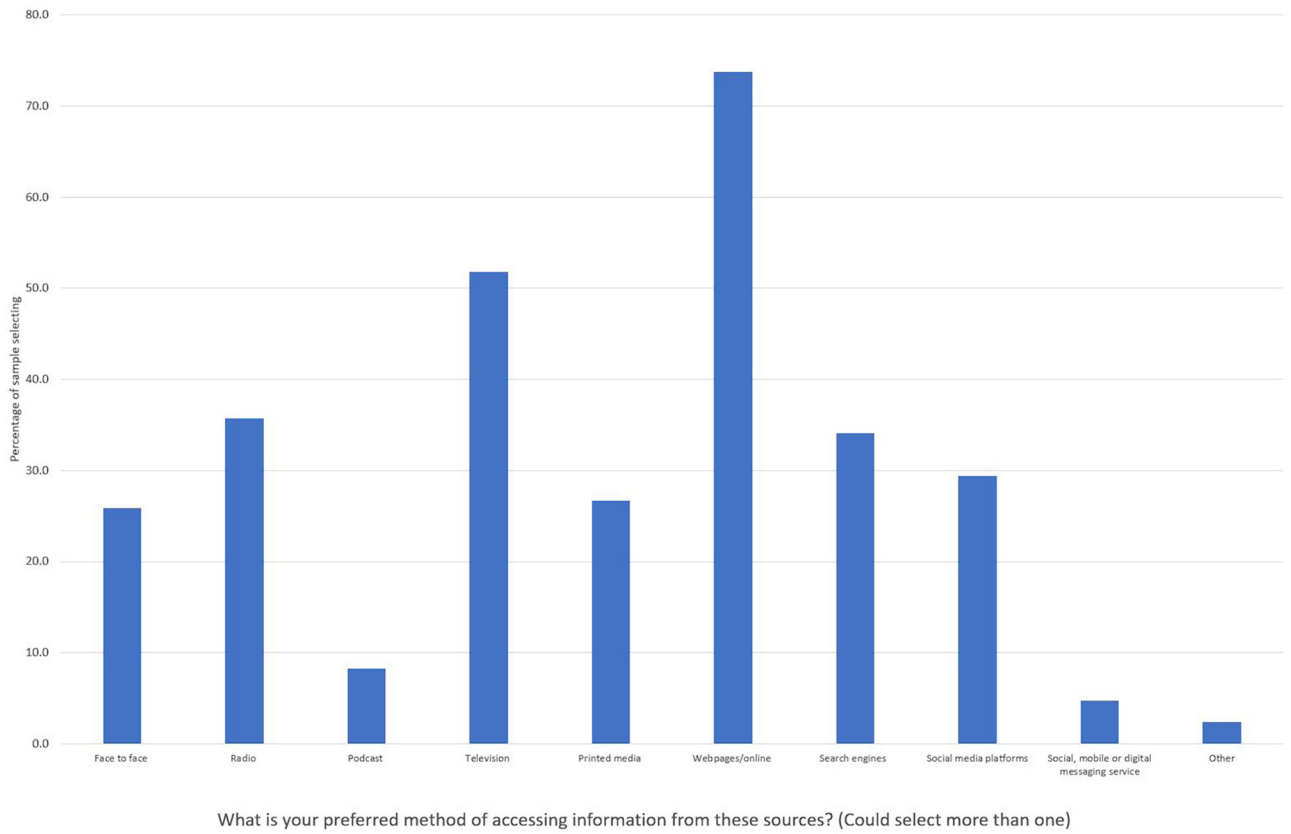


FIGURE 2
Percentage of method of access (vs. not) for different sources of information ($n = 255$).

There is no competition of themes here, but a contingency; sources are preferable only if they are truthful, but this truth needs to be easily accessible.

Question 2: How have you used these sources to respond to, or prepare for COVID-19 related events?

Remaining informed and coordinating responses to COVID-19 are the primary reasons that participants use the identified sources. Changing COVID-19 restrictions and outbreak locations meant participants leveraged accessible and trustworthy sources to stay abreast of a rapidly changing situation:

> *I have checked government websites carefully to make sure I am following the latest COVID guidelines. People also share information socially but it's important to check the news and government websites to make sure the information is objective and accurate (Participant 228—F).*
>
> *Up to date and relevant information and keeping abreast of changes and how they will impact me and my family (Participant 89—F).*

By staying up-to-date with changes, participants are able to better coordinate how they, or those immediately around them, are able to respond to the pandemic:

> *Warnings for changes to restrictions, including mask requirements. Changing interstate travel plans. Locating vaccine suppliers and arranging appointments as well as being aware of rules changing for my employment (Participant 1—F).*
>
> *Kept up with outbreaks, local rules and stocked the house with essentials (Participant 114—F).*
>
> *Checked on restrictions when considering travelling interstate and what was required when arriving in another state. Also checking on where outbreaks may have occurred (Participant 145—F).*

These coordination activities reveal the range of impacts individuals responded to during the pandemic. Rapidly changing, and sometimes complex, rules meant changes to individual and familial tasks. This includes the need to negotiate travel restrictions across different jurisdictions, a need to monitor potential exposure sites for infection risks, and changes to how to find appropriate medical care. Essential workers were especially vulnerable to these rapid changes.

Question 3: How has your information seeking behavior changed?

Like the way that accuracy is a contingent quality for choosing information sources, participants ($n = 100$) who indicated that they

have changed their behavior indicated accuracy and truthfulness as a motivator:

> *At the start of the pandemic, I read and listened to as much as possible about the situation. This included all media, Facebook posts, friends, and international news. These days I have concluded that there is too much misleading information and opinion-based information, so I try to look only to "official" sources. I hope that these sources are providing true information (Participant 80—F).*
>
> *Too much misinformation circulating on social media and in conversation. I seek out peer reviewed materials, and guidance from Health authorities (Participant 156—F).*

Dual concerns of information overload and misinformation encouraged participants to change their practices, which often meant switching sources:

> *Go straight to government sites. Do not use social platforms, e.g., Facebook (Participant 32—F).*

Or changing the focus of their information seeking to topics of the most immediate saliency and importance:

> *I seek to know less about the virus and how it's impacting other countries/states in terms of healthcare, welfare, social etc. I now just want to know local information like exposure sites etc. I just want quick facts now (Participant 16—F).*

Emergent themes

We also examined our data for any crosscutting, emerging themes. Although no all-encompassing narrative was found, we noted "care" and "anxiety" as themes worthy of further discussion in the context of COVID-19, especially given recent research on cognitive labor.

Care

The desire to care for others extended across multiple questions. For example, in responding to Question 2, participants described a consideration of those immediately around themselves, and the potential impacts of COVID-19 on these groups as a reason for their public health information seeking:

> *Awareness of what might be brewing, instructions for workplace compliance, awareness of how my family might be feeling about issues (Participant 47—F).*
>
> *Consideration of risks to me and my family so we can try to be as safe as possible (Participant 142—F).*
>
> *[. . .]I am particularly mindful of my elderly mother whom I care for as if she were to contract the virus, is most likely to come from me given my work (Participant 229—F).*

Female participants foregrounded care more often than males, with only one male participant mentioning family relationships (specifically to Question 3). While references to care understandably emphasize family, it does not exclude other situations, as Participant 47 notes compliance with their workplace's rules, as important in their information seeking rationales.

Anxiety

Participants also noted feeling overwhelmed and emotionally distressed at the amount and quality of information available to them, and consequently reduced their information seeking:

> *In the beginning I was monitoring multiple sources of information as I wanted to know what was going on at all times. Over time I have reduced the number of sources I monitor, as I found it became overwhelming and I was spending too much time obsessing over every small detail (Participant 177—F).*
>
> *I try and limit any unofficial content because I don't trust the "noise." I only read/watch what I have to because it makes me anxious to process too much (Participant 47—F).*

The need to moderate the information one consumes also appears to merge with issues of care, as one participant succinctly described:

> *I have kept myself and my family healthy, by not listening to the news I am not swept up into the stress and anxiety of everything, I try to understand how the virus works to the best of my knowledge through credible sources, kept my house stocked up and knowing we will have sufficient items during a lockdown (Participant 19—F).*

Managing both the amount of information and emotional consequences of information overload is as important as keeping the participant and their family healthy, as selecting the right source. These choices play out through practical caregiving activities, such as managing the family's groceries.

Discussion

Our study aimed to explore why individuals selected, used, and changed their public health information seeking behaviors in the context of COVID-19. The relationship of these decisions, relative to participant characteristics, was also explored. Responses were unintentionally skewed toward female, born in Australia, educated, older, married/de-facto participants, without children at home, and while not representative, do provide qualitative insights into how public health information is being experienced (21). This paper notes the following findings: (a) that source selection is motivated by easiness, immediacy and quality, (b) that people use sources to support decision making and to keep up-to-date, (c) that a minority of people have changed their information seeking behaviors and those who do, seek easiness or quality, and (d) that there are emergent themes of care and anxiety worthy of further investigation, especially around themes of cognitive labor.

Regarding information sources, the majority of people relied on online resources provided by the government or mainstream media. Our qualitative findings illustrate the continued importance of providing high quality public health information in an accessible and immediate way attuned to individuals' situational needs. The finding that only 100 participants (i.e., 39%) changed their information seeking behavior and are motived by the validity of information, aligns with existing research on public health information (22). We observed minimal gender differences in the sources and delivery of

COVID-19 information, but did observe significant differences in level of education, with participants without a high school education less likely to use government information.

Crosstabulation of qualitative themes against demographic variables indicated that most information seeking practices and responses were provided by female participants across all three questions. While neither the emergent themes nor primary questions capture causal or representative answers, there are interesting questions raised concerning the intersections of gender, public health information seeking behaviors. Particularly regarding our understanding of the gendered nature of public health information behaviors in the context of COVID-19. By providing the greatest number of detailed responses, women seem more engaged in public health information seeking behaviors relating to COVID-19. However, this engagement may also connect to experiences of care provision and anxiety, which suggests women may (un)willingly assume a greater burden of responsibility for managing information during complex health situations such as the COVID-19 pandemic. These observations, however, should be considered in the context of limitations of this study (see below).

The latter findings connects to emerging research on concepts including cognitive labor (12) or mental load (13). In the context of family life, Daminger (12) notes that this labor can be gendered, with women taking on more work even when male partners are uniquely qualified in cognitive labor (for instance, when male partners were professional project managers). Dean et al. further develop this noting intersections with emotional labor (23), especially within the contexts of COVID-19 related lockdowns. Here, women were increasingly burdened with household chores, work-from-home employment, social isolation, and potentially childcare arrangements, in a way that was neither recognized or rewarded by decision makers or partners alike (24, 25).

In the context of this article and public health information behavior research more broadly, this finding raises questions around how cognitive labor mediates public health information. The need for accessible, quality information sources may reflect the greater burden women face in managing situational needs in the context of COVID-19 given that they are already mentally and emotionally overworked and may desire immediate and truthful answers. The minority result for changing information seeking behaviors may be viewed less as the preferred choice, but instead the reality that women lack the time and mental space to change their information seeking through reflection and deeper engagement. The latter may connect to the caring work that participants describe, and how additional burdens of care work are placing an increasing cognitive burden upon women in the context of COVID-19. Given that previous research (26) has established that women are more likely to respond to health information and seek appropriate medical care, establishing how an experience, like cognitive labor, impacts women is an important public health question, particularly given that public health relies heavily on health communication techniques. Those practicing in public health need to consider the invisible burden that excessive and constant change has, as well as how this could unequally impact those already being further burdened by the health issue.

The practical implications of these initial findings for public health professionals are that cognitive labor may mediate how public health information is being received by women, and that consideration should be given to whether this represents a gender disparity in public health. Given the resources that people often rely on, this may be even more important for online government resources. For public health professionals in government, they may also wish to consider how they approach engaging with demographics who have lower levels of education, as they appear less reliant on government sources of information and may respond better to other non-government sources of influence.

If women are expected to engage in the cognitive labor of managing COVID-19 information sources, this adds further demands to their lives. Unequitable cognitive labor compounds existing disparities in care work (27–30) and the complications of COVID-19. This overburdening may be detrimental to the emotional, physical, and cognitive wellbeing of women, and may negatively mediate their experience of public health information seeking, such as through seeking quick and easy sources, leaving them vulnerable to misinformation. Given that women also act as gatekeepers for health information (31–33), it is important that cognitive labor is further investigated and its impacts gauged and appropriately responded to by public health practitioners. Aiming to alleviate existing structural disparities, designing messaging that accounts for cognitive labor and women's contexts, and finding ways to identify excessive or unnecessary cognitive labor in frontline engagements, are all potential practical pathways if increased cognitive labor is identified. An alternative solution would be to empower alternative members of social groupings to become gatekeepers for this information through improving engagement and self-efficacy of these groups.

Our study does not claim to be representative of all women, but instead signposts experiences potentially important in understanding public health information seeking in context, but which requires further investigation to validate. While we note the potential implications of cognitive labor, and call for greater investigation into its effects, we acknowledge limitations to our research. The qualitative sample was skewed, and whilst it did yield important insights into women's experiences, we have attempted to position the significance of these findings within this limitation. We further wish to emphasize that the low number of male participants means these results should be treated cautiously, and as indicative of a potentially important area for public health research and practice. This should not be considered as a generalizable truth on the experiences of COVID-19 information seeking behaviors, or the relationship of these with gender. Furthermore, given that female participants are more likely to complete survey research, there is the possibility of a cofounding variable at play, although this does not detract from the qualitative stories that participants shared. Further research is required to validate the gendered nature of cognitive labor, including studies that better capture male and gender-diverse populations. Despite these limitations, we positively associate the validity of this study with emerging research highlighting the gendered nature of labor in the context of COVID-19 (24, 25), and on the gendered nature of information seeking behaviors (34–36).

Conclusion

Participants' listed government sources, followed by mainstream media, professional sources, and familial sources, as their preferred health information sources for COVID-19. Use of government sources varied depending on education level, with mainstream media use varying depending on employment status. The qualitative

data collected and thematically analyzed here captured key themes around how people seek information relating to COVID-19. Our findings have generated a potentially novel direction of further investigation on cognitive labor, which may mediate public health information seeking. Further research on cognitive labor, healthcare, and COVID-19 will improve the rigor of this initial finding and develop practical actions that might be used to support both better health information seeking, and a more equitable relationship between gender, healthcare, and information seeking.

Data availability statement

The datasets presented in this article are not readily available because sharing of qualitative datasets potentially violates ethics and privacy requirements for this research, as there is the potential for identifiable data to be shared. Sharing of quantitative datasets may be possible with checks to ensure privacy and ethical compliance. Requests to access the datasets should be directed to emily.brindal@csiro.au or ashlin.lee@csiro.au.

Ethics statement

The study was assessed and approved by the CSIRO Human Research Ethics Low Risk Review Panel (#2021_105_LR). Written, informed consent was given by participants for this research. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AL: background research, conceptualization, qualitative data analysis and write up, and manuscript writing and rewriting. NK: manuscript writing and rewriting, quantitative data analysis and write up, critical feedback, and conceptual development. LH: critical feedback, editing, and proofing. AR: critical feedback. EB: critical feedback, quantitative data analysis, and table building. All authors contributed to the article and approved the submitted version.

Acknowledgments

We thank our internal reviewers Dr. Kaley Butten and Dr. Jane Li for their helpful advice on improving this paper.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1041944/full#supplementary-material

References

1. Durant W. How do we respond to the challenge of vaccine misinformation? *Perspect Public Health.* (2019) 139:280–2. doi: 10.1177/1757913919878655

2. Gildea F. Tackling sheepishness about a COVID-19 vaccine for the sake of herd immunity. *Perspect Public Health.* (2020) 140:301–2. doi: 10.1177/1757913920963012

3. Alvarez-Galvez J, Suarez-Lledo V, Rojas-Garcia A. Determinants of infodemics during disease outbreaks: a systematic review. *Front Public Health.* (2021) 9:603603. doi: 10.3389/fpubh.2021.603603

4. Stein RA, Ometa O, Broker TR. COVID-19: The pseudo-environment and the need for a paradigm change. *Germs.* (2021) 11:468–77. doi: 10.18683/germs.2021.1283

5. Lippmann W. *Public Opinion*. New York: Simon and Schuster (1997).

6. Jolley D, Douglas KM. Prevention is better than cure: addressing anti-vaccine conspiracy theories. *J Appl Soc Psychol.* (2017) 47:459–69. doi: 10.1111/jasp.12453

7. Mian A, Khan S. Coronavirus: the spread of misinformation. *BMC Med.* (2020) 18:89. doi: 10.1186/s12916-020-01556-3

8. Knight H, Jia R, Ayling K, Blake H, Morling J, Villalon A, et al. The changing vaccine landscape: rates of COVID-19 vaccine acceptance and hesitancy in young adults during vaccine rollout. *Perspect Public Health*. (2022) 2022:175791392210947. doi: 10.1177/17579139221094750

9. EPI-WIN. *World Health Organization's Epidemic Information Network*. (2022). Available online at: https://www.who.int/teams/epi-win (accessed June 6, 2022).

10. Beach DJ, Jackson HOPE. Family influences on health: a framework to organize research and guide intervention. In: Vangelista AL, editor. *Handbook of Family Communication*. Mahwah, NJ. p. 647–672

11. Schurer S, Atalay K, Glozier N, Vera-Toscano E, Wooden M. Zero-COVID policies: Melbourne's 112-day hard lockdown experiment harmed mostly mothers. *medRxiv* (2022)

12. Daminger A. The cognitive dimension of household labor. *Am Sociol Rev.* (2019) 84:609–33. doi: 10.1177/0003122419859007

13. Dean L, Churchill B, Ruppanner L. The mental load: building a deeper theoretical understanding of how cognitive and emotional labor over *load* women and mothers. *Community Work Fam.* (2022) 25:13–29. doi: 10.1080/13668803.2021.2002813

14. Czymara CS, Langenkamp A, Cano T. Cause for concerns: gender inequality in experiencing the COVID-19 lockdown in Germany. *Eur Soc.* (2021) 23:S68–81. doi: 10.1080/14616696.2020.1808692

15. Olaimat AN, Aolymat I, Shahbaz HM, Holley RA. Knowledge and information sources about COVID-19 among University students in Jordan: a cross-sectional study. *Front Public Health.* (2020) 8:254. doi: 10.3389/fpubh.2020.00254

16. Farooq A, Laato S, Islam AKMN, Isoaho J. Understanding the impact of information sources on COVID-19 related preventive measures in Finland. *Technol Socy.* (2021) 65:101573. doi: 10.1016/j.techsoc.2021.101573

17. Ali SH, Foreman J, Tozan Y, Capasso A, Jones AM, DiClemente RJ. Trends and predictors of COVID-19 information sources and their relationship with knowledge and

beliefs related to the pandemic: nationwide cross-sectional study. *JMIR Public Health Surveill.* (2020) 6:e21071. doi: 10.2196/21071

18. CSIRO. CSIRO—Behavioural Insights Lab of the Future. *Behavioural Insights Lab of the Future*. Available online at: https://research.csiro.au/cbil/ (accessed November 11, 2022).

19. Green J, Willis K, Hughes E, Small R, Welch N. Gibbs L, et al. Generating best evidence from qualitative research: the role of data analysis. *Aust NZ J Public Health.* (2007) 31:545–50. doi: 10.1111/j.1753-6405.2007.00141.x

20. Lee A, Cook PS. The conditions of exposure and immediacy: Internet surveillance and Generation Y. *J Sociol.* (2015) 51:674–88. doi: 10.1177/1440783314522870

21. Bergeron CD, Ory M, Goltz HH, Towne Jr SD, Ahn S, Mier N, et al. Preferred health information sources: an examination of vulnerable middle-aged and older women. *J Family Strengths*. (2017) 17:8. Available at: https://digitalcommons.library.tmc.edu/jfs/vol17/iss1/8 (accessed June 6, 2022).

22. Sun Y, Zhang Y, Gwizdka J, Trace CB. Consumer evaluation of the quality of online health information: systematic literature review of relevant criteria and indicators. *J Med Internet Res.* (2019) 21:e12522. doi: 10.2196/12522

23. Hochschild AR. *The Managed Heart: Commercialization of Human Feeling, With a New Afterword*. Los Angeles, CA: University of California Press (2003).

24. Del Boca D, Oggero N, Profeta P, Rossi M. Women's and men's work, housework and childcare, before and during COVID-19. *Rev Econ Household.* (2020) 18:1001–17. doi: 10.1007/s11150-020-09502-1

25. Xue B, McMunn A. Gender differences in unpaid care work and psychological distress in the UK Covid-19 lockdown. *PLoS ONE.* (2021) 16:e0247959. doi: 10.1371/journal.pone.0247959

26. Ek S. Gender differences in health information behaviour: a Finnish population-based survey. *Health Promot Int.* (2015) 30:736–45. doi: 10.1093/heapro/dat063

27. Grigoryeva A. Own gender, sibling's gender, parent's gender: the division of elderly parent care among adult children. *Am Sociol Rev.* (2017) 82:116–46. doi: 10.1177/0003122416686521

28. Gerstel N, Clawson D, Zussman R, editors. *Families at Work: Expanding the Bounds*. Nashville: Vanderbilt University Press (2002). doi: 10.2307/j.ctv16f6j36

29. Elson D. Recognize, reduce, and redistribute unpaid care work: how to close the gender gap. *New Labor Forum.* (2017) 26:52–61. doi: 10.1177/1095796017700135

30. Bittman M, England P, Sayer L, Folbre N, Matheson G. When does gender trump money? Bargaining and time in household work. *Am J Sociol.* (2003) 109:186–214. doi: 10.1086/378341

31. Rowley J, Johnson F, Sbaffi L. Gender as an influencer of online health information-seeking and evaluation behavior. *J Assoc Inf Sci and Technol.* (2017) 68:36–47. doi: 10.1002/asi.23597

32. Stern MJ, Cotten SR, Drentea P. The separate spheres of online health: gender, parenting, and online health information searching in the information age. *J Family Issues.* (2012) 33:1324–50. doi: 10.1177/0192513X11425459

33. Nikoloudakis IA, Vandelanotte C, Rebar AL, Schoeppe S, Alley S, Duncan MJ, et al. Examining the correlates of online health information–seeking behavior among men compared with women. *Am J Men's Health.* (2018) 12:1358–67. doi: 10.1177/1557988316650625

34. Manierre MJ. Gaps in knowledge: tracking and explaining gender differences in health information seeking. *Soc Sci Med.* (2015) 128:151–8. doi: 10.1016/j.socscimed.2015.01.028

35. Hallyburton A, Evarts LA. Gender and online health information seeking: a five survey meta-analysis. *JConsum Health Internet.* (2014) 18:128–42. doi: 10.1080/15398285.2014.902268

36. Baumann E, Czerwinski F, Reifegerste D. Gender-specific determinants and patterns of online health information seeking: results from a representative German health survey. *J Med Internet Res.* (2017) 19:e6668. doi: 10.2196/jmir.6668

frontiers | Frontiers in Education

TYPE Review
PUBLISHED 09 February 2023
DOI 10.3389/feduc.2023.979544

OPEN ACCESS

EDITED BY
Zhiwen Hu,
Zhejiang Gongshang University,
China

REVIEWED BY
Mohammad Ali,
La Trobe University,
Australia
Ronicka Mudaly,
University of KwaZulu-Natal,
South Africa

*CORRESPONDENCE
Tracy Nissan
✉ tracy.nissan@su.se
Md Zahidul Islam Pranjol
✉ z.pranjol@sussex.ac.uk

SPECIALTY SECTION
This article was submitted to Language, Culture and Diversity, a section of the journal Frontiers in Education

RECEIVED 27 June 2022
ACCEPTED 26 January 2023
PUBLISHED 09 February 2023

CITATION
Hu A, Nissan T and Pranjol MZ (2023) Reflecting on COVID-19 vaccine hesitancy among South Asian communities in the UK: A learning curve to decolonising the secondary school curriculum.
Front. Educ. 8:979544.
doi: 10.3389/feduc.2023.979544

Reflecting on COVID-19 vaccine hesitancy among South Asian communities in the UK: A learning curve to decolonising the secondary school curriculum

Anqi Hu[1], Tracy Nissan[2]* and Md Zahidul Islam Pranjol[1]*

[1]Department of Biochemistry and Biomedicine, School of Life Sciences, University of Sussex, Brighton, United Kingdom, [2]Department of Molecular Biosciences, The Wenner-Gren Institute, Stockholm University, Stockholm, Sweden

COVID-19 has brought to light the systemic racism faced by ethnic minorities in the UK. During the pandemic, we saw an increase in anti-Asian hate crimes and a lack of support from the government given to both patients and healthcare workers from minority backgrounds on the front lines. This lack of support potentially contributed to the increased susceptibility of ethnic minorities to COVID-19 and also their hesitancy toward the vaccine, particularly the south Asian communities. In this paper we discuss potential reasons for COVID-19 vaccine hesitancy among south Asian groups. Additionally, we propose that introducing a decolonised curriculum in secondary school may enhance cultural awareness with historical context among the white British populations, allowing for more inclusion for south Asian communities. By exploring ways to decolonise specific subjects in the secondary curriculum, this paper aims to set out a guideline for teachers and education professionals on expanding secondary school pupils' knowledge of racial issues and equality, to start the process of educating a new generation appropriately. We propose that decolonising the secondary school curriculum is a potential long-term solution to eradicating racism and discrimination.

KEYWORDS

vaccine hesitancy, racism, discrimination, decolonisation, secondary school curriculum

1. Introduction

COVID-19 (Coronavirus disease 2019) is a disease caused by the SARS-CoV-2 virus, originating in Wuhan, China, with the first known case identified in December of 2019. Since then, this disease has spread worldwide and was declared a pandemic by the World Health Organization (WHO) in March of 2020. There have been over 251 million cases of COVID-19 worldwide and it has claimed the lives of over 5 million people to date with over 9 million of cases and approximately 143 thousand deaths in the UK (WHO, 2021). The COVID-19 pandemic has thus been a prevalent and ongoing event across the world and indeed the UK in the last 2 years as cases rose and fell through the first and second major waves. However, studies have shown that for south Asian communities in the United Kingdom in particular, the pandemic has been exceptionally taxing.

Public Health England (PHE) COVID-19 surveillance report presents cumulative data from 29 June 2020 to 29 September 2020 which states that 24.2% of all COVID-19 cases and 12.8% of all mortalities belonged to Asian/ Asian British people (PHE, 2020). Yet this group makes up only 7.5% of the total UK population, suggesting that the south Asian community in the UK has been

disproportionally affected by this disease (Gov.uk, 2018). Furthermore, research has found that south Asian patients were 1.54 times as likely to be admitted to the intensive care unit as white ethnic patients even though they were on average younger in age. Additionally, the mortality rate of this population was 1.49 times higher than their white counterparts (Apea et al., 2021). The data is suggestive of major ethnic disparities which have been brought to light by COVID-19, these include biological factors, socio-economic conditions, educational and environmental factors. These factors contribute to the significant increased risk of infection and death faced by south Asian communities in the UK.

Compounding their increased susceptibility to COVID-19, south Asian communities in the UK currently face COVID-19 vaccine hesitancy. The UK Household Longitudinal Study in 2020 showed that, after Black respondents with 71.8% unlikely to take up the vaccine, 42.3% of people from Pakistani and Bangladeshi (Asian or Asian British) backgrounds were unlikely or very unlikely to take the vaccine, whereas only 15.6% of white British people were hesitant (SAGE, 2020). With almost half of the south Asian population in the UK unwilling to take the vaccine, this paper will also consider the possible reasons for a collective reluctance of ethnic communities to have the COVID-19 vaccines, even though it could decrease cases and deaths. A major issue encompassing this vaccine hesitancy could potentially be the racism, xenophobia and prejudice faced by south Asian people both during recent events and throughout history (Corbie-Smith, 2021). Before and during the pandemic, ethnic communities have always been confronted with discrimination (Le et al., 2020). This systemic racism comes from a long history of colonialism and the resulting coloniality (Maldonado-Torres, 2007). However, surprisingly, the education system in the UK, particularly at secondary school level, does not teach the negative impacts of colonialism the British had worldwide. Therefore, it is important that in a multicultural society like the UK, the impacts that the colonial system had and continue to have today are taught. By having these taught, south Asian, and other minorities can develop trust in the system and white students can develop empathy and understanding of the south Asian experience. This paper will briefly explore how Britain's history of colonialism, imperialism and expansionism has shaped its society today, and how a decolonised secondary school curriculum could ultimately reduce discrimination faced by the UK south Asian communities and build trust within the communities. These effects could augment future government-led intervention to improve national health such as vaccine uptake.

In this paper, we will be focusing on south Asian communities in the United Kingdom. The data provided by the UK Government on ethnicity facts and figures characterizes people of south Asian descent into the groups Bangladeshi, Indian and Pakistani with all other Asian statistics grouped as "Asian Other" (UK Government RDU, n.d.). This is reflected in the importance of the south Asian community as an immigrant group in the UK. Therefore, while many minority ethnicities have faced a history a racism and hardship in light of COVID-19, this paper will focus on south Asian communities in the UK.

2. Why are people from South Asian ethnic minorities more at risk of COVID-19 in the UK?

There are both biological and sociological factors that affect people of south Asian ethnicity's susceptibility to COVID-19. The biological factors include lower vitamin D levels and higher rates of diabetes. These highlight the exceptional importance of vaccination in these communities. Whereas the sociological factors are much more varied and include careers, living conditions and access to health care.

These risks are likely the cause of the significantly higher rate of COVID-19 case rate within the south Asian community (Table 1). People of Bangladeshi background had a 390.6 COVID-19 case rate per 100,000 people-weeks in the second wave of the pandemic and Indian ethnicity had 240.7 case rate. In comparison, people with white British backgrounds suffered a 166-case rate.

Vitamin D levels tend to be low in south Asian population which implicates a higher risk of diabetes, heart disease and tuberculosis (Shaw, 2002; Martineau et al., 2017; Pardhan et al., 2020; Jayawardena et al., 2021). More relevantly, low Vitamin D is also associated with an increased susceptibility to upper respiratory tract infections, similar to that of COVID-19 (Martineau et al., 2017; Mitchell, 2020). Vitamin D plays a significant role in supporting the fight against infection by the production of antimicrobial agents in the respiratory system and also its ability to reduce the inflammatory response to such infection (Mitchell, 2020). This has led researchers to suggest that there is a strong connection between vitamin D levels and COVID-19 susceptibility (Martineau and Forouhi, 2020). In the early 2000s, there was a resurgence of vitamin D deficiency reported in south Asian children all over the UK (Shaw, 2002). As a result of this, south Asian populations in the UK during the pandemic are substantially more vulnerable to COVID-19 than their white counterparts due partially to their vitamin D deficiency.

Additionally, a common comorbidity of COVID-19 is diabetes mellitus. Studies have shown that there is evidence of increased severity and incidence of COVID-19 in patients with pre-existing diabetes (Singh et al., 2020). Diabetes is more prevalent in south Asian men and women than in white people (Simmons et al., 1989), as diabetes tends to develop at a younger age in south Asian populations (Ramachandran et al., 2010). Furthermore, diabetes induces a more severe case of COVID-19 in patients and even doubles the mortality risk due to negative pulmonary and cardiac involvement (Peric and Stulnig, 2020). Hence, diabetes contributes to the growing list of factors that ultimately causes people of south Asian descent to be more at risk of COVID-19.

Although biological factors are significant in understanding south Asian people's particularly high susceptibility to COVID-19, we must also consider the prevailing socio-economic conditions that surround and influence this topic. People of ethnic minorities tend to work in more "at-risk" jobs (Table 2) such as medical and dental practitioners,

TABLE 1 COVID-19 case rates by ethnic group according to Public Health England categories in the second wave of the pandemic, England (case rate per 100,000 person-weeks) (Larsen et al., 2021).

Ethnicity	Case rate
Bangladeshi	390.6
African	202.5
Caribbean	186
Chinese	93
Indian	269.5
Mixed	184.7
Other	240.7
White British	166

TABLE 2 Percentage of workers in each ethnic group employed in different occupations UK, 2018 (Gov.uk, 2021a).

	All	Asian	Indian	Pakistani, Bangladeshi	Asian other	Black	Mixed	White	White British	White other	Other
Occupation	%	%	%	%	%	%	%	%	%	%	%
Managers, directors and senior officials	11	10	11	8	9	5	9	11	11	10	10
Professional	21	27	33	18	29	21	23	20	20	21	21
Associate professional and technical	15	12	14	10	11	12	19	15	15	13	12
Administrative and secretarial	10	9	9	8	9	9	9	10	11	8	7
Skilled trades	10	6	5	7	6	6	6	11	11	10	10
Caring, leisure and other service	9	8	7	8	9	18	9	9	9	7	9
Sales and customer service	8	10	7	14	9	7	9	7	8	5	7
Process, plant and machine operatives	6	9	5	15	5	7	5	6	6	10	8
Elementary	10	11	9	12	12	16	12	10	10	15	15

opticians, nurses and medical technicians (ONS, 2020a). For example, people from Asian backgrounds make up 27% of the professional workforce whereas white British accounts for 20%. Professional occupations include paramedics, nurses, and all kinds of health care professionals. Thus, especially in the midst of the COVID-19 pandemic, these occupations, especially medical practitioners, and nurses harbor the most risk of infection as they are to be in close contact with those who are infected every-day. These figures reflect that occupation had a drastic effect on the risk of contracting COVID-19 and that Asian people working in the frontlines were extremely at-risk.

Another socio-economic factor that influences COVID-19 susceptibility are living conditions. Reports have shown that people over the age of 70 of south Asian descent are most likely to live in a multi-generational household (ONS, 2020b). During the UK national lockdown, vulnerable people such as those of old age were recommended to isolate. In south Asian multigenerational households, it would be more difficult to maintain isolation and uphold safety for those who are at risk, due to the combination of key workers and older vulnerable people living in close quarters. In the UK, ethnic communities are more likely to be based in urban, built up areas that are more deprived (ONS, 2018). This socio-economic factor has contributed to south Asian communities' higher death rates from COVID-19 as reports have shown that COVID-19 has had a proportionally higher impact on the deprived areas of the UK (ONS, 2020c). This was also shown in Bangladesh where vaccine hesitancy was significantly high among unemployed population and people with lower or equal education level to high school (Ali and Hossain, 2021; Ali, 2022). Overall, socio-economic conditions play a significant part in increasing the likelihood of COVID-19 infection in south Asian people. In both their home and work environments, Asian communities are at a higher risk of contracting COVID-19. At home they face overcrowding, which hinders them from following social distancing guidelines. In the workplace, many have occupations in sectors such as caring, transportations, catering and security that cannot be performed at home meaning that they have to attend work, often on the front line, leading to an increased exposure to COVID-19 (PHE, 2020). Furthermore, as Table 3 shows, people of Asian descent are faced with a higher risk of death due to these various factors. People of Bangladeshi/Pakistani and Indian descent are on average 1.91 and 1.38 times, respectively, more likely to die of COVID-19 compared to those of white ethnicity. Biological, socio-economic, and environmental factors that influence the risk of COVID-19 infection and death in people of south Asian descent contribute to the health inequality faced by ethnic minorities in the UK.

Furthermore, there is a concerning health gap in the UK for ethnic minorities (Szczepura, 2005). According to Raleigh and Holmes, people from ethnic minority groups in the UK are more likely to report poorer health and experiences using health services than their white counterparts (Raleigh and Holmes, 2021). This is further supported by statistics from the UK Government website for "Ethnicity facts and figures" where it is shown that east and south Asian ethnicities in particular had a lower-than-average percentage rate of reporting a positive experience for both primary care and hospital care (UK Government RDU, n.d.). This suggests that there could be unfair treatment of south Asian ethnic minorities and unequal access to health care in the UK for these people as in the same set of statistics, it was shown that they also had a lower-than-average percentage rate of reporting a positive experience making a GP appointment. If south Asian minorities are experiencing negative interactions while trying to access primary health care, it could be the cause of a significant health care gap in the UK. During COVID-19, this gap has become more prevalent, as many of the south Asian health care workers who contracted COVID-19 on the front lines could have been avoided. As senior clinicians in specialities from foreign countries such as countries in Asia have to temporarily work as junior front-line workers due to long approval times from the General Medical Council (GMC) to be registered (Chaudhry et al., 2020). Additionally, sources have stated that 64% of BAME (Black, Asian and minority ethnic) doctors in the UK have been pressured into working in the front line with inadequate PPE in comparison to 33% of white doctors (Cooper, 2020). This source has not provided a specific ethnic group breakdown. However, south Asian demographics are included in BAME groups. Therefore, a significant factor that contributes to an increased risk of COVID-19 in ethnic minorities such as south Asian is the systemic discrimination they are faced with. Having poorer access to health care as a patient and having unequal treatment as a health care worker is due to the ingrained racial

TABLE 3 Risk of COVID-19 related death by ethnic group and sex in England and Wales (White and Nafilyan, 2021).

Ethnicity	Sex	Odds ratio compared to white
Black	Male	1.93
Black	Female	1.89
Bangladeshi/Pakistani	Male	1.81
Bangladeshi/Pakistani	Female	1.61
Indian	Male	1.32
Indian	Female	1.43
Chinese	Male	1.18
Chinese	Female	0.75
Mixed	Male	1.03
Mixed	Female	1.03
Other	Male	1.34
Other	Female	1.08

prejudice in our society that could be the cause for them to be so at-risk in this pandemic.

3. Vaccine hesitancy and modern-day racism

Although the south Asian communities in the UK are one of the most at-risk ethnic groups for life long illnesses, they are the second most unwilling to be vaccinated in the UK (SAGE, 2020). Historically, ethnic minority groups are less likely to take vaccines in general in the UK (Razai et al., 2021). This is a significant issue especially during a global pandemic. The likely cause of such ethnic disparities in vaccine hesitancy is discrimination as well as both systemic and cultural racism (Razai et al., 2021). As COVID-19 originated in Wuhan, China, many individuals have placed the blame of the pandemic on those of East Asian origin. These individuals include people of significant power and influence such as Donald Trump who referred to COVID-19 as the "China virus" and "kung flu" (Jaworsky and Qiaoan, 2020; Jia and Lu, 2021). Often only epidemics and pandemics originating in non-white populated countries are proceeded by a period of extreme xenophobia. The Ebola epidemic in 2013 provides another example of disease being an excuse to augment existing racist and xenophobic views to the forefront of people's minds (Kim et al., 2016).

People with political influence in the United States and Europe have promoted xenophobic expression in both verbal and the physical form. In 2020 there was a reported 300% increase in anti-Asian hate crime reports (Coates, 2020; Gover et al., 2020; Bahia, 2021; Gao and Sai, 2021; Haynes, 2021), with limited media coverage on this topic. Anti-Asian hate crime in the UK is perpetuated by a lack of action taken by the government and thus causes further distrust in the authorities by minority communities (Razai et al., 2021).

These patterns may extend a feeling of another generation of British-Asians feeling ostracized, unsafe, and underrepresented by their government. In light of this, how can these communities trust a vaccine program that is completely government run and controlled? The specific type of vaccine given to individuals is dictated by these government-led programs and is mostly dependent on accessibility, supply and region, which may contribute to inequalities (Campos-Matos et al., 2021). For instance, initially, UK National Health Service (NHS) national booking service, predominantly an online booking service available, was launched in English which meant that minority ethnic groups, particularly the first generation, may not have been able to access and book appointments (NHS, 2021; Watkinson et al., 2022). Although there were letters posted to patients and GPs inviting patients over telephone calls, the majority of vaccination appointments available were located in out of town in mass vaccination centers or hospital hubs, creating additional barriers to access the vaccines (Watkinson et al., 2022). When compared with seasonal flu vaccine uptake from 19/20, COVID-19 vaccine uptake was found to be significantly low among the most vulnerable Bangladeshi and Pakistani people living in the most deprived areas in the UK due to low trust and accessibility to the vaccination program, exacerbating pre-existing health inequalities in vaccine uptake (Watkinson et al., 2022).

A total of 90, 895 racially and religiously aggravated offenses were recorded in 2020/21 year in the UK, a rise of 12% from 2019/20 (Gov.uk, 2021b). Schumann and Moore investigated on how COVID-19 has affected racially motivated hate crimes in the UK where they conducted a victimization survey which was completed by a total of 393 East Asian, South Asian, Caribbean, and African individuals in the UK. Participants were asked whether since the first of February 2020, if they had experienced hateful comments or behavior which was believed to be racially motivated. They were further asked to clarify how many times they had been victimized since that date. They were also asked to provide a more detailed account of the crime (s) or incident (s). Finally, the participants were asked whether they had reported the crime/incident to the police and where it had happened. This study assessed accounts occurring on 1 February 2020 (before lockdown), 24 March - 13 May 2020 (during lockdown), and since 14 May 2020 (after lockdown). Findings showed that after the outbreak of COVID-19, ethnic communities such as south Asians, experienced a higher likelihood of hate crime victimization (Schumann and Moore, 2021), which correlated with low uptake of vaccines among these populations in the UK (SAGE, 2020). For instance, media portrayal of the "Indian variant" increased an anti-Indian sentiment among the population (Bahia, 2021). Racial hate crime incidents in the UK increased exponentially during April of 2020, when COVID-19 lockdowns were extended (Schumann and Moore, 2021). This was likely due to the government implementing a national lockdown in March of that year and proceeded to extend lockdown in April (IFG, 2021). This unprecedented event likely came as a shock to the UK public, causing uninformed individuals to channel their fear and displeasure into south Asian communities such as Indian community in Britain (Bahia, 2021).

Although it may seem anti-Asian hate crimes would decrease during national lockdowns when there is less interaction between individuals, it actually increased after lockdown was initiated (Schumann and Moore, 2021). This is due to technology's impact on today's society, as Williams et al. (2019) states, online hate speech is now widely recognized as a major social problem and is likely the form of many of the racial hate crimes reported (Williams et al., 2019). Hate speech can now be released in the form of messages and comments on various social media platforms, leaving south Asian communities unable to escape from the hate they face due to COVID-19. Thus, this pandemic has aroused deeply ingrained racist and xenophobic beliefs in the western public. Historic beliefs still play a significant part in modern day society. For example, the connection between race and disease comes from the 1800's where people believed that races were biologically distinct and racial minorities were biologically and socially inferior (Gee et al., 2020).

The ease and rapidity of Chinese people becoming the scapegoats of this pandemic is a prime example of the deep-rooted racism in western society; without reformation of the government or the public, it is inevitable that even positive scientific contributions from the government such as vaccines with the aim to combat the pandemic, will be subsequently met with doubt and criticism from the wronged communities.

A history of racism in the UK has ultimately led to the eventual distrust of the government by south Asian communities. As recent Asian hate crime events have shown, racial prejudice is embedded into western society and to fully understand how this came to be, we must first explore these views' link to an imperialistic history. For south Asia, one of the most prevalent historical events was the century of exploitation and unfair trade by the East India Company that acted on behalf of British imperialism in India (Lawson, 2014). This event has influenced India's history, even until recently, as they became independent from the United Kingdom only in 1947 (Chandra, 2000). A critical influence Britain's rule had on India was that their cultural development was put on hold as the progression was infiltrated by western influences for nearly a century.

As south Asian communities in the UK are made up of mainly first- and second-generation immigrants (Dustmann et al., 2010), they either have these memories of the colonial transgressions fresh in their memory or have had family of a different generation inform them on these significant historical events to their culture. As these events are not widely discussed in the UK's media, history books and education curriculum, this influential part of the country's history is seemingly unaddressed (Taylor et al., 2021). Therefore, it suggests that the UK government does not deem these actions important enough to properly address and take accountability for. Ultimately, the actions of the leaders of the UK both historically and currently contributes to build significant distrust. In order to achieve successful vaccine uptake from south Asian ethnic communities, the government must address past wrongdoings in an attempt to build trust, confidence, and faith from the people.

Overall, a history of imperialism and racial prejudice from the colonial past has been ingrained into the minds of south Asian communities in the UK, and a subsequent distrust in the government in these communities feeling like they need to fend for themselves in both social and medical environments. This is demonstrated by health disparities. One example is the severe underrepresentation of ethnic minorities in recent COVID-19 research. People of white descent constituted 74–91% of participants in UK COVID-19 studies, leaving 9–24% representation for all ethnic minorities and therefore even less for south Asian minorities (Etti et al., 2021). In the past, this underrepresentation was due to systemic racism and white people being considered the standard of medical research. However, researchers are now highlighting the difficulty in recruiting for diverse studies and trials. Even when researchers are willing to diversify, south Asians are now often reluctant to participate due to the fear of discrimination, stemming from the same systemic racism (Hussain-Gambles et al., 2004; Ioannidis et al., 2021).

How can south Asian communities feel assured that the government offered vaccine has the same positive effects on them as they do on white people when the government itself has failed to properly represent them in vaccine trials? Moreover, the ongoing racism which are highlighted in media does very little to encourage south Asian communities to uptake government-led vaccine interventions. Initiatives such as "grab-a-jab," where participants were asked to be vaccinated in walk-in centers, have demonstrated improvements in vaccine uptake from ethnic minorities however, we believe that more substantial, systemic changes need introducing to change this perception and to eliminate distrust on government (NHS, 2021).

The concerning health gap in the UK is also a potential problem in regard to vaccine hesitancy in south Asian communities. Modern day discrimination in health care is clear as south Asian ethnic minorities experience less-than-average patient satisfaction in hospital and primary health care (UK Government RDU, n.d.). With this underlying negative view of the British health care system, south Asian communities are more inclined to dismiss the COVID-19 vaccine in fear of having a negative experience and not being treated equally by the system. Furthermore, during this pandemic, ethnic minorities have been overlooked. For example, the UK National Health Service recently warned that the pulse oximeter device which is used to measure oxygen levels in COVID-19 patients by beaming light through the skin may not be as effective on darker skin tones (Fierce Biotech, 2021).

The oversight of the government and health services on issues such as this proves how inadequate they were on securing the safety of ethnic minorities during the COVID-19 pandemic. Oversights such as these perpetuates distrust in the government, especially on COVID-19 related matters such as the vaccine programs. Additionally, only recently has the UK approved China-manufactured Sinovac and India-manufactured Covaxin vaccines (Duffy, 2021). Previously, only people with one of four vaccines have been approved to be considered as fully vaccinated for travel. These includes the Janssen vaccine from the Netherlands, Moderna and Pfizer from the US, and AstraZeneca from the UK. More relevantly, the Astra Zeneca vaccine produced in India was considered suspect by the EU and the British public (Fierce Pharma, 2021). Disapproving of vaccines manufactured in countries that are from developing countries could reinforce ingrained discrimination. They have set an example to south Asian communities in the UK of the distrust and fear of vaccines made by non-western nations.

To tackle vaccine hesitancy, crucial changes need to be introduced in a sector such as the secondary education system as a way to tackle a systemic racist belief to target the minds of pupils in early education. It is important to educate learners from a young age to shape their view of the ethnic minority communities that they live alongside for enhanced social integration. Educating secondary school pupils, who will become integral members of society (e.g., government policy makers), in equality, diversity and inclusion through a decolonised curriculum could potentially ensure that everyone is treated fairly and with respect regardless of their ethnic origin. Focusing on early education and decolonising the secondary school curriculum could be a long-term solution, more substantial to our societal problems regarding systemic racism.

4. Decolonising the UK secondary school curriculum to tackle racism- a potential solution

Decolonising the curriculum is to not only start teaching the history of colonialism and targeting academics and teachers but to open a dialog to all members of society to help create a space for people to both learn and think about cultures and diversity. Opening up an environment where people can respect each other can help begin to rebuild both an education system and a society where everyone is supported and understood equally.

In late 2020, an official UK government and Parliament petition was made to "Teach Britain's colonial past as part of the UK's compulsory curriculum" (Petition 324,092) (Long et al., 2021). As stated in the details of the petition, currently, it is not compulsory for primary or secondary schools in the UK to teach Britain's colonial past. However, teaching such topics in school's curriculum can help educate pupils at a young age of the truth behind Britain's historical power. The education system now showcases Britain's past of being a strong nation and yet does not delve deeply into the exact reasons and their consequences. The curriculum focuses on Britain's vision throughout history, lacking perspective on the consequences of certain historical decisions and not addressing injustices imposed by Britain during those times (Parsons, 2020).

Changes to the curriculum could involve alternative perspective accounts of historical events (Parsons, 2020). This can teach pupils to empathize with the ever-broadening multi-cultural side of history instead of learning to dehumanize ethnic minorities following the current curriculum. Learning to treat people of other races as equals at a young age is an important step to decreasing deeply conditioned racial prejudice in adult life. As we strive for eradicating racism and therefore hopefully making people of south Asian ethnic minorities feel safe enough to consider the vaccine program, we must start with education.

In regard to decolonising the secondary curriculum in the UK, having a secondary school curriculum that glorifies Britain's past of colonialism and imperialism can be very damaging toward south Asian-British pupils' perceptions of themselves. Knowledge of the real history behind their own countries and the struggle with Britain's past imperialism tend to come from parents and family educating these learners. Having it overlooked in the UK history syllabus creates an unnecessary sense of divide between their country of origin and their country of residence from a young age. This perpetuates the idea that the UK must be somehow against them and their family, as these south Asian-British pupils are told by the curriculum that real hardships faced by their family/ancestors were not significant in British history. It is vital that the secondary school curriculum is targeted in particular as learners are beginning to learn about detailed parts of British history in which colonialism plays a significant part (DoE, 2013). If at this learning stage, the past actions of the British Empire are "white-washed," there is a risk of normalizing racial prejudice at a young age.

To decolonise the curriculum is to teach Britain's history in full, without skipping over the major events of colonialism and imperialism that had built up the British Empire. Furthermore, these events must be taught from a factual point of view, to recognize that the power Britain had often stemmed from oppression of others.

The Department of Education's history key stage 3 (secondary school year 7 to 9) national curriculum in England states to aim to "gain and deploy a historically grounded understanding of abstract terms such as 'empire', 'civilisation', 'parliament' and 'peasantry'" (DoE, 2013). A crucial step in aiding the curriculum is to add terms such as 'colonialism' into the syllabus alongside 'empire'. The education system needs to open the usage of key words such as 'colonialism' to start the discussion of the morals and ethics surrounding Britain's actions in history rather than glorifying them. Being open with Britain's past, such as the events discussed in this paper, and considering the effects and outcome for the south Asian people in the curriculum can help promote empathy in learners. Whereas the current curriculum strongly depicts a sense of divide between Britain and Asian countries and also promotes a lack of empathy within white students, ultimately leading to many learners growing up internalizing the idea that systemic racism is acceptable.

It is clear that racism is a problem from a young age. From 2016 to 2021, UK schools reported more than 60,000 racist incidents (Batty and Parveen, 2021). Additionally, teachers of black and minority ethnic backgrounds also reported racism is a contributory factor to the underrepresentation in position of leadership in schools in England (Elonga Mboyo, 2017). Therefore, it seems necessary to start educating learners in these important historical events early in secondary education as well as embedding decolonisation in teachers' training. Furthermore, it is important to represent every race in the classroom. As this source states, pupils of ethnic backgrounds are often taught about their own heritage by their parents and when their true versions of history they know clash with that of the school curriculum, it causes distress (BBC, 2020). By decolonising the curriculum, we are attempting to look at history from the viewpoint of other ethnic groups. This way of teaching may help represent pupils with minority ethnic backgrounds in the classroom and encourage them to learn accurate History of the interacting with non-Western cultures.

Another secondary subject that should be targeted in this curriculum change is geography. As Puttick and Murrey state, the word 'race' does not appear once in the Key stage 3 or GCSE geography curriculum (Anderson, 2021; Puttick and Murrey, 2021). As a subject that revolves around human activity such as anthropology, countries and therefore race, the absence of the word 'race' is shocking. Geography emerged as the science of European imperialism, in regards to exploration and colonial geography (De Rugy, 2020). Implicit racism can come from the observation in class that Europeans "discovered" lands and naming it their territory, without regard for the native inhabitants (Beck, 2021). The curriculum makes no effort to delve deeper into the ethics and consequences of this. In geography as well as history, the key to decolonising the curriculum is to teach from other perspectives and viewpoints.

Although there is a very little room in the secondary science curriculum to include topics on race and equality, many improvements could be adopted elsewhere to positively impact learners' views on STEM subjects. For example, modules in history such as History of Medicine can promote learners' understanding of the revolution of science and ethical aspects of medicine in different countries in the world and different cultural backgrounds. Currently, the syllabus consists of mainly Western medicine such as inoculations developed by Edward Jenner and the importance of Louis Pasteur (AQA, 2019). Modules such as this is a significant opportunity to teach about unethical science applied by westerners onto minority ethnic groups from their home countries. For example, secondary school students could be taught how discoveries of drugs and vaccines were trialed unethically on ethnic minorities. This is not only from history, such as the injection of asbestos into black prisoners by Pfizer in the 1970s, which recently came to light, but also more recent events. A prominent example is Pfizer's unapproved trailing of an antibiotic trovafloxacin during a 1996 meningitis epidemic in Nigeria (Lenzer, 2006). These examples of recent historical events in medicine and science could allow for inclusion, empathy, and integration among pupils.

Another subject that can integrate the decolonisation of science is citizenship, which can help tackle the modern-day racial issues surrounding science. The specification of the current citizenship syllabus underlines the need for students to learn "the human, moral, legal and political rights and the duties, equalities and freedoms of citizens" (AQA, 2022). This subject can become a space for discussion to talk about current racial issues to both make ethnic minority students feel represented and heard and to educate sympathy and compassion in other students. These discussions and inclusion of the history of science

is important as the science subjects are so full of facts and impartial information that racial issues get looked over.

This is a conundrum as science focused on major discoveries, which have occurred in the past, when the overwhelming majority of scientists were white males. For example, all pupils are taught in biology that Watson and Crick discovered the DNA helix, however there is no mention of James Watson's racist and misogynistic viewpoints (Klug, 1968). Another key component that could be taught is eugenics and its influence within the education and societal systems. According to Galton, Eugenics is "the science which deals with all influences that improve the inborn qualities of a race; also with those that develop them to the utmost advantage"(Atherton and Steels, 2015). The effect of eugenics is ongoing and impacts our societal systems and educational policies (reviewed in (Lowe, 1998; Bessant, 2016)), which should be taught at secondary school. These views promoted by influential white males who dominate the British society still persist in today's education system which need to be addressed and dismantled. Therefore, it can be other subjects such as history or citizenship that brings to light these racial issues in science, so that pupils can understand the underlying unfounded biases that men such as Watson exemplify.

The English literature subject can also be decolonised. As the current curriculum has mainly books and poems by white authors, there is room for literature by authors of other ethnicities and also to demonstrate the systematic system of oppression of non-Western peoples, whether it be in the colonial era or for their descendants who live in the United Kingdom today. However, even literature depicting day to day lives of south Asian or British south Asian people can be beneficial for students to learn about, as being able to see people of other ethnicities in normal stories at school can improve learners' understanding of other cultures and how they live day to day life. This example can also be encouraged in areas outside of English literature, as in subjects such as citizenship and history where case studies are used to improve learning, these case studies can benefit by including a wider range of ethnicities. Reading and learning about a diverse range of perspectives in English can be extremely beneficial to learners as it opens up their minds to other points of view. This extends to the media that is used in English lessons, movies made by ethnic minorities or made about racial topics and historical events can also be advantageous as it is a great opportunity to introduce pupils to these concepts in an engaging format.

Encouragement of ethnic minority pupils into STEM fields and higher education is also important. This can be done by increasing funding for outreach programs for disadvantaged students and deprived areas. The University of Manchester operates a Black, Asian and minority ethnic program with the aim to reduce barriers between black and minority ethnic students and higher education (UoM, n.d.). This project also partners with schools, colleges, and community groups to inspire learners and celebrate black and minority ethnic achievements. More funding for programs such as this and more access to them for minority ethnic students can provide them with opportunities. To ensure this we can incorporate these programs with the secondary curriculum so that all ethnic minority pupils can have access to this. Overall, the new curriculum should teach students about both the history of ethnic minorities in different subjects and also their current affairs and achievements. This allows for inclusion, proper representation in the curriculum for students of ethnic minority backgrounds and also gives them access to programs to further develop themselves.

Decolonising the curriculum, education of learners in various subjects and actively promoting anti-racism in schools, leading to more adults supporting racial equality could have potentially saved south Asian people from harassment and hate-crime during this pandemic, which reinforced alienation from the broader British public. Furthermore, if immigrant south Asian communities were not faced with discrimination and received more support and recognition from the government and associated services, perhaps they would be more confident in up taking the COVID-19 vaccine. Decolonising the secondary school curriculum can help ensure that people of ethnic minorities in the UK will rest assured that their peers in the workplace, school and society are sufficiently educated in racial history. Furthermore, future members of the government can benefit from learning about ethnicities other than white from a young age, leading, potentially, to a government that promotes racial equality. From COVID-19 we have learnt how important government and social support for Asian ethnic minorities are. With this reform in secondary education, the aim is to ensure than in the event of another pandemic, ethnic minorities are supported by the government and society rather than racially targeted and blamed, allowing them to feel safe and trust necessary government-led schemes such as the COVID-19 vaccines.

More than just education, decolonisation is a means to end the cycle of prejudice and marginalization faced by ethnic minorities. For example, although the Tuskegee syphilis study, ended well before the 21st century, the underlying issue of treating ethnic minorities as 'lesser' people is still just as prevalent. Even though times have changed, and the scenarios ethnic minorities find themselves in are different throughout history, the underlying issues they face and the discrimination they must overcome in their lives remain. The racial disparities caused by unethical medical testing in history as well as present day racial discrimination has led to mistrust in present day medical research. For instance, Pfizer, a western pharmaceutical company, conducted a drug trial during meningitis outbreak in Nigeria in 1996 which resulted in numerous deaths (Lenzer, 2007). The trial was concluded illegal in a report leaked to the Washington Post in May 2006. As shown by a study conducted by Devlin et al., which concluded that racial discrimination while seeking medical care lowered the likelihood of patients' participation in clinical trials (Devlin et al., 2020). Therefore, confirming that racial discrimination is still an ongoing and prevalent issue within the medical research sector. Furthermore, its effect on medical testing participation results in less ethnic minority representation in crucial modern-day clinical trials, which in turn causes a cycle of discrimination, as ethnic minority communities are then less likely to trust even a beneficial drug or vaccine that has little to no representation of their own race.

To decolonise is to create a society that no longer treats ethnic minorities as less valued members, where they can live free of the discrimination that were faced by their ancestors. We must overcome the idea that just because the situations and crimes are less extreme, that they are still just as prevalent in the eyes of the people who face them and should be taken seriously.

Decolonisation should be seen and treated as reaching equity rather than an extra step for the benefit of the minority. It's a voice for the people who have been marginalized and should be viewed as the bare minimum to achieve true equality in society. As Gillborn's analysis concludes, "the most dangerous form of 'white supremacy' is not the most obvious and extreme fascist posturing of small neo-Nazi groups, but rather the taken-for-granted routine privileging of white interests that goes unremarked in the political mainstream" (Gillborn, 2005).

Ultimately, decolonisation can undeniably benefit the lives of ethnic minorities, however, the true goal of decolonisation and achieving equality is to also enhance the knowledge and empathy of everyone in

society and expose how colonialism has shaped the global south and impacted British society today. We can stride toward creating an environment where learners of different ethnicities can grow up with equal opportunities and not be pushed into a box, having their futures decided by their ethnic background. This society can also further reach true equality by first taking this first step of being inclusive of difference. We can already see the younger generations strong desire for this change. Meda brings to light university student's demand for a decolonised curriculum, the study found that student's views on decolonisation were "distinct, congruent and unambiguous" (Meda, 2020). This further emphasizes that society is ready to take on this challenge for change and that decolonisation is not a distant goal but something that can be achieved now.

However, there is resistance toward the decolonisation movement, as Hall et al. (2021) argue, institutions such as some universities in the UK still reinforce whiteness and dissipates radical energy (Hall et al., 2021). This also applies to secondary school where teachers are predominantly white (Lander, 2014; Katsha, 2022). This means that the systemic implementation of the decolonisation concept into education will be a long and trying process, however, this also implicates that the suggestion of facing this issue by targeting the young generation in hopes of invoking change in society as a whole may be the only solution. As learners notice race from a young age and the absence of dialog about race can allow stereotypes, biases, and racism to be reinforced (Lingras, 2021). Therefore, if the education system were to be reformed to adequately teach them about race and racism at this crucial age, the future generation will already have successfully implemented decolonisation into their society.

5. Conclusion

In conclusion, COVID-19 has brought to light the systemic racism that is present against south Asian communities in today's society. From the racial hate crimes due to fear of COVID-19 to the vaccine hesitancy among south Asian communities in the UK, there is a clear problem with the way ethnic minorities are perceived by both the public and the UK government. Decolonising the secondary curriculum can be the first step to achieving a racially equal society in the UK as it allows for early learning on cultural awareness. Although this will take a long time, it can enhance integration and compassion between white and black, asian and minority ethnic pupils from a young age and eventually lead to a society that is safe and understanding for all races. Further research into the exact curriculum changes needs to take place to fully restructure the secondary syllabus to include thorough representation of ethnic minorities in all taught subjects.

Author contributions

AH drafted the paper. TN critically reviewed and revised the paper. MP conceptualized, supervised, revised and critically reviewed the paper. All authors contributed to the article and approved the submitted version.

Funding

This work was supported by a grant from Vetenskapsrådet (The Swedish Research Council) 2017–04663.

Acknowledgments

Dedicated to the memory of Stephen Hare, Structural biologist at the University of Sussex who was passionate about racial equality and diversity in science. We would also like to thank Daniel Akinbosede for our numerous ongoing discussion on this topic.

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.

Publisher's note

References

Ali, M. (2022). What is driving unwillingness to receive the COVID-19 vaccine in adult Bangladeshi after one year of vaccine rollout? Analysis of observational data. *IJID Reg.* 3, 177–182. doi: 10.1016/j.ijregi.2022.03.022

Ali, M., and Hossain, A. (2021). What is the extent of COVID-19 vaccine hesitancy in Bangladesh? A cross-sectional rapid national survey. *BMJ Open* 11:e050303. doi: 10.1136/bmjopen-2021-050303

Anderson, N.. (2021). *Decolonise Geography*. Available at: https://decolonisegeography.com/blog/2021/02/why-do-we-need-to-decolonise-geography/

Apea, V. J., Wan, Y. I., Dhairyawan, R., Puthucheary, Z. A., Pearse, R. M., Orkin, C. M., et al. (2021). Ethnicity and outcomes in patients hospitalised with COVID-19 infection in East London: an observational cohort study. *BMJ Open* 11:e042140. doi: 10.1136/bmjopen-2020-042140

AQA. (2022). *Life in Modern Britain*. Manchester, United Kingdom: AQA. Available at: https://www.aqa.org.uk/subjects/citizenship/gcse/citizenship-studies-8100/subject-content/life-in-modern-britain

AQA. (2019). *Shaping the Nation: AA Britain: Health and the People: C1000 to the Present Day*. Available at: https://www.aqa.org.uk/subjects/history/gcse/history-8145/subject-content/shaping-the-nation

Atherton, H. L., and Steels, S. L. (2015). A hidden history. *J. Intellect. Disabil.* 20, 371–385. doi: 10.1177/1744629515619253

Bahia, J. (2021). *Indian Variant and Travel Bans: COVID-19 Warnings Should be Rooted in Science, not Anti-South Asian Racism: The Conversation*. Available at: https://theconversation.com/indian-variant-and-travel-bans-covid-19-warnings-should-be-rooted-in-science-not-anti-south-asian-racism-160072

Batty, D., and Parveen, N.. (2021). *UK Schools Record more than 60,000 Racist Incidents in Five Years*. Race in Education.

BBC. (2020). *Decolonising the Curriculum*. BBC Bitesize. Available at: https://www.bbc.co.uk/bitesize/articles/z7g66v4

Beck, L. (2021). Euro-settler place naming practices for North America through a gendered and racialized lens. *Terrae Incognitae* 53, 5–25. doi: 10.1080/00822884.2021.1893046

Bessant, J. (2016). Tracing bio-political and eugenic connections in education and treatment of 'youth problems'. *Aust. J. Educ.* 39, 249–264. doi: 10.1177/000494195039003003

Campos-Matos, I., Mandal, S., Yates, J., Ramsay, M., Wilson, J., and Lim, W. S. (2021). Maximising benefit, reducing inequalities and ensuring deliverability: prioritisation of COVID-19 vaccination in the UK. *Lancet Reg. Health Europe* 2:100021. doi: 10.1016/j.lanepe.2020.100021

Chandra, B. (2000). *India after Independence: 1947–2000*: Westminster: Penguin UK.

Chaudhry, F. B., Raza, S., Raja, K. Z., and Ahmad, U. (2020). COVID 19 and BAME health care staff: wrong place at the wrong time. *J. Glob. Health* 10. doi: 10.7189/jogh.10.020358

Coates, M. (2020). Covid-19 and the rise of racism. *BMJ* 369:m1384. doi: 10.1136/bmj.m1384

Cooper, K. (2020). *BAME Doctors Hit Worse by Lack of PPE*. Tavistock Square, London: British Medical Association. Available at: https://www.bma.org.uk/news-and-opinion/bame-doctors-hit-worse-by-lack-of-ppe2020

Corbie-Smith, G. (2021). Vaccine hesitancy is a scapegoat for structural racism. *JAMA Health Forum* 2:e210434. doi: 10.1001/jamahealthforum.2021.0434

De Rugy, M. (2020). *Geography in the Colonial Contex. Encyclopédie D'histoire Numérique de l'Europe*. Available at: https://ehne.fr/en/encyclopedia/themes/europe-europeans-and-world/colonial-expansion-and-imperialisms/geography-in-colonial-contex

Devlin, A., Gonzalez, E., Ramsey, F., Esnaola, N., and Fisher, S. (2020). The effect of discrimination on likelihood of participation in a clinical trial. *J. Racial Ethn. Health Disparities* 7, 1124–1129. doi: 10.1007/s40615-020-00735-5

DoE. (2013). *History Programmes of Study: Key Stage 3*. Department for Education. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/239075/SECONDARY_national_curriculum_-_History.pdf

Duffy, N. (2021). *UK Travel Restrictions: Tourists with India and China-made Covid Vaccines no Longer have to Isolate on Arrival*. News.

Dustmann, C., Frattini, T., and Theodoropoulos, N.. (2010). *Ethnicity and Second Generation Immigrants in Britain*. CReAM Discussion Paper No 04/10.

Elonga Mboyo, J. P. (2017). School leadership and black and minority ethnic career prospects in England: the choice between being a group prototype or deviant head teacher. *Educ. Manag. Adm. Leadersh.* 47, 110–128. doi: 10.1177/1741143217725326

Etti, M., Fofie, H., Razai, M., Crawshaw, A. F., Hargreaves, S., and Goldsmith, L. P. (2021). Ethnic minority and migrant underrepresentation in Covid-19 research: causes and solutions. *EClinicalMedicine* 36:100903. doi: 10.1016/j.eclinm.2021.100903

Fierce Biotech. (2021). *UK Launches Review of Racial, Gender Biases in Medical Devices, Sparked by Disproportionate COVID Deaths*. Newton, MA: Fierce Biotech. https://www.fiercebiotech.com/medtech/uk-launches-review-racial-gender-bias-medical-devices-sparked-by-disproportionate-covid

Fierce Pharma. (2021). *AstraZeneca's COVID-19 Vaccine Faces Distrust in Europe, Even as it Gets Rave Reviews in Neighboring U.K., Survey Finds*. Fierce Pharma. Available at: https://www.fiercepharma.com/marketing/yougov-poll-finds-distrust-astrazeneca-vaccine-europe

Gao, G., and Sai, L. (2021). Opposing the toxic apartheid: the painted veil of the COVID-19 pandemic, race and racism. *Gend. Work Organ.* 28, 183–189. doi: 10.1111/gwao.12523

Gee, G. C., Ro, M. J., and Rimoin, A. W. (2020). Seven reasons to care about racism and COVID-19 and seven things to do to stop it. *Am. J. Public Health* 110, 954–955. doi: 10.2105/AJPH.2020.305712

Gillborn, D. (2005). Education policy as an act of white supremacy: whiteness, critical race theory and education reform. *J. Educ. Policy* 20, 485–505. doi: 10.1080/02680930500132346

Gov.uk. (2018). *Population of England and Wales*. Available at: https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity/national-and-regional-populations/population-of-england-and-wales/latest

Gov.uk. (2021a). *Employment by Occupation*. Office for National Statistics. Available at: https://www.ethnicity-facts-figures.service.gov.uk/work-pay-and-benefits/employment/employment-by-occupation/latest

Gov.uk. (2021b). *Official Statistics. Hate Crime, England and Wales, 2020 to 2021*. Crime JaL, Home Office. Available at: https://www.gov.uk/government/statistics/hate-crime-england-and-wales-2020-to-2021/hate-crime-england-and-wales-2020-to-2021

Gover, A. R., Harper, S. B., and Langton, L. (2020). Anti-Asian hate crime during the COVID-19 pandemic: exploring the reproduction of inequality. *Am. J. Crim. Justice* 45, 647–667. doi: 10.1007/s12103-020-09545-1

Hall, R., Ansley, L., Connolly, P., Loonat, S., Patel, K., and Whitham, B. (2021). Struggling for the anti-racist university: learning from an institution-wide response to curriculum decolonisation. *Teach. High. Educ.* 26, 902–919. doi: 10.1080/13562517.2021.1911987

Haynes, S. (2021). '*This Isn't just a Problem for North America. The Atlanta Shooting Highlights the Painful Reality of Rising Anti-Asian Violence around the World, Race*. TIME Newsletter.

Hussain-Gambles, M., Leese, B., Atkin, K., Brown, J., Mason, S., and Tovey, P. (2004). Involving south Asian patients in clinical trials. *Health Technol. Assess.* 8, 1–109. doi: 10.3310/hta8420

IFG. (2021). *Timeline of UK Government Coronavirus Lockdowns and Measures, March 2020 to December 2021*. Institute for Government. https://www.instituteforgovernment.org.uk/charts/uk-government-coronavirus-lockdowns

Ioannidis, J. P., Powe, N. R., and Yancy, C. (2021). Recalibrating the use of race in medical research. *JAMA* 325, 623–624. doi: 10.1001/jama.2021.0003

Jaworsky, B. N., and Qiaoan, R. (2020). The politics of blaming: the narrative Battle between China and the US over COVID-19. *J. Chin. Polit. Sci.* 26, 295–315. doi: 10.1007/s11366-020-09690-8

Jayawardena, R., Jeyakumar, D. T., Francis, T. V., and Misra, A. (2021). Impact of the vitamin D deficiency on COVID-19 infection and mortality in Asian countries. *Diabetes Metab. Syndr.* 15, 757–764. doi: 10.1016/j.dsx.2021.03.006

Jia, W., and Lu, F. (2021). US media's coverage of China's handling of COVID-19: playing the role of the fourth branch of government or the fourth estate? *Glob. Media China* 6, 8–23. doi: 10.1177/2059436421994003

Katsha, H. (2022). *Most English School Kids will only ever be taught by White Teachers*. New York: The Huffingtonpost.

Kim, H. S., Sherman, D. K., and Updegraff, J. A. (2016). Fear of Ebola. *Psychol. Sci.* 27, 935–944. doi: 10.1177/0956797616642596

Klug, A. (1968). Rosalind Franklin and the discovery of the structure of DNA. *Nature* 219, 808–810. doi: 10.1038/219808a0

Lander, V. (2014). "Initial teacher education: the practice of whiteness" in *Advancing Race and Ethnicity in Education*. eds. C. Schmidt and J. Chneider (Berlin: Springer), 93–110.

Larsen, T., Bosworth, M., and Nafilyan, V.. (2021). *Coronavirus (COVID-19) Case Rates by socio-demographic characteristics, England: 1 September 2020 to 25 July 2021*. Office for National Statistics. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/coronaviruscovid19caseratesbysociodemographiccharacteristicsengland/1september2020to25july2021

Lawson, P. (2014). *The East India Company: A History*. Milton Park: Routledge.

Le, T. K., Cha, L., Han, H.-R., and Tseng, W. (2020). Anti-Asian xenophobia and Asian American COVID-19 disparities. *Am. J. Public Health* 110, 1371–1373. doi: 10.2105/AJPH.2020.305846

Lenzer, J. (2006). Secret report surfaces showing that Pfizer was at fault in Nigerian drug tests. *BMJ* 332:1233. doi: 10.1136/bmj.332.7552.1233-a

Lenzer, J. (2007). Nigeria files criminal charges against Pfizer. *BMJ* 334:1181. doi: 10.1136/bmj.39237.658171.DB

Lingras, K. A. (2021). Talking with children about race and racism. *J. Health Serv. Psychol.* 47, 9–16. doi: 10.1007/s42843-021-00027-4

Long, R., Roberts, N., and Kulakiewicz, A.. (2021). *Black History and Cultural Diversity of the Curriculum*. House of Commons Library. Available at: https://researchbriefings.files.parliament.uk/documents/CDP-2021-0102/CDP-2021-0102.pdf

Lowe, R. (1998). The educational impact of the eugenics movement. *Int. J. Educ. Res.* 27, 647–660. doi: 10.1016/S0883-0355(98)00003-2

Maldonado-Torres, N. (2007). On the coloniality of being: contributions to the development of a concept. *Cult. Stud.* 21, 240–270. doi: 10.1080/09502380601162548

Martineau, A. R., and Forouhi, N. G. (2020). Vitamin D for COVID-19: a case to answer? *Lancet Diabetes Endocrinol.* 8, 735–736. doi: 10.1016/S2213-8587(20)30268-0

Martineau, A. R., Jolliffe, D. A., Hooper, R. L., Greenberg, L., Aloia, J. F., Bergman, P., et al. (2017). Vitamin D supplementation to prevent acute respiratory tract infections: systematic review and meta-analysis of individual participant data. *BMJ* 356:i6583. doi: 10.1136/bmj.i6583

Meda, L. (2020). Decolonising the curriculum: Students' perspectives. *Afr. Educ. Rev.* 17, 88–103. doi: 10.1080/18146627.2018.1519372

Mitchell, F. (2020). Vitamin-D and COVID-19: do deficient risk a poorer outcome? *Lancet Diabetes Endocrinol.* 8:570. doi: 10.1016/S2213-8587(20)30183-2

NHS. (2021). *Book or Manage a Coronavirus (COVID-19) Vaccination*. United Kingdom: National Health Service: National Health Service. Available at: https://www.nhs.uk/conditions/coronavirus-covid-19/coronavirus-vaccination/book-coronavirus-vaccination/

NHS. (2021). *NHS COVID "Grab-a-Jab" Initiative Boosts Ethnic Minority Vaccinations NHS England*. England: NHS England. Available from: https://www.england.nhs.uk/2021/08/nhs-covid-grab-a-jab-initiative-boosts-ethnic-minority-vaccinations/

ONS. (2018). *Regional Ethnic Diversity*. United Kingdom: Office for National Statistics. Available at: https://www.ethnicity-facts-figures.service.gov.uk/uk-population-by-ethnicity/national-and-regional-populations/regional-ethnic-diversity/latest

ONS. (2020a). *Why have Black and South Asian People been Hit Hardest by COVID-19?* Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/articles/whyhaveblackandsouthasianpeoplebeenhithardestbycovid19/2020-12-14

ONS. (2020b). *Coronavirus (COVID-19) Roundup, 13 to 17 July 2020*. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/articles/coronaviruscovid19roundup13to17july2020/2020-07-17#multigenerational-households

ONS. (2020c). *Coronavirus (COVID-19) Infection Survey: Characteristics of People Testing Positive for COVID-19 in England: October 2020*. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/articles/coronaviruscovid19infectionsinthecommunityinengland/october2020

Pardhan, S., Smith, L., and Sapkota, R. P. (2020). Vitamin D deficiency as an important biomarker for the increased risk of coronavirus (COVID-19) in people from black and Asian ethnic minority groups. *Front. Public Health* 8:613462. doi: 10.3389/fpubh.2020.613462

Parsons, C. (2020). A curriculum to think with: British colonialism, corporate kleptocracy, enduring white privilege and locating mechanisms for change. *J. Crit. Educ. Policy Stud.* 18, 196–226.

Peric, S., and Stulnig, T. M. (2020). Diabetes and COVID-19. *Wien. Klin. Wochenschr.* 132, 356–361. doi: 10.1007/s00508-020-01672-3

PHE. (2020). *The Weekly Surveillance Report in England*. Weekly Data: 23 September 2020 to 29 September 2020. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/923665/COVID19_Weekly_Report_30_September_2020.pdf

PHE. (2020). *Disparities in the Risk and Outcomes of COVID-19*. England: Public Health England. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/908434/Disparities_in_the_risk_and_outcomes_of_COVID_August_2020_update.pdf

Puttick, S., and Murrey, A. (2021). Confronting the deafening silence on race in geography education in England: learning from anti-racist, decolonial and black geographies. *Geography* 105, 126–134. doi: 10.1080/00167487.2020.12106474

Raleigh, V., and Holmes, J. (2021). *The Health of People from Ethnic Minority Groups in England*. The Kings Fund. https://www.kingsfund.org.uk/publications/health-people-ethnic-minority-groups-england

Ramachandran, A., Wan Ma, R. C., and Snehalatha, C. (2010). Diabetes in Asia. *Lancet* 375, 408–418. doi: 10.1016/S0140-6736(09)60937-5

Razai, M. S., Osama, T., McKechnie, D. G. J., and Majeed, A. (2021). Covid-19 vaccine hesitancy among ethnic minority groups. *BMJ* 372:n513. doi: 10.1136/bmj.n1138

SAGE. (2020). *Factors Influencing COVID-19 Vaccine Uptake among Minority Ethnic Groups*. Available at: https://www.gov.uk/government/publications/factors-influencing-covid-19-vaccine-uptake-among-minority-ethnic-groups-17-december-2020

Schumann, S., and Moore, Y.. (2021). The COVID-19 outbreak as a trigger event for sinophobic hate crimes in the United Kingdom. *Br. J. Criminol.* 2022:azac015. doi: 10.1093/bjc/azac015

Shaw, N. J. (2002). Vitamin D deficiency in UK Asian families: activating a new concern. *Arch. Dis. Child.* 86, 147–149. doi: 10.1136/adc.86.3.147

Simmons, D., Williams, D. R., and Powell, M. J. (1989). Prevalence of diabetes in a predominantly Asian community: preliminary findings of the Coventry diabetes study. *BMJ* 298, 18–21. doi: 10.1136/bmj.298.6665.18

Singh, A. K., Gupta, R., Ghosh, A., and Misra, A. (2020). Diabetes in COVID-19: prevalence, pathophysiology, prognosis and practical considerations. *Diabetes Metab. Syndr. Clin. Res. Rev.* 14, 303–310. doi: 10.1016/j.dsx.2020.04.004

Szczepura, A. (2005). Access to health care for ethnic minority populations. *Postgrad. Med. J.* 81, 141–147. doi: 10.1136/pgmj.2004.026237

Taylor, M., Hung, J., Che, T. E., Akinbosede, D., Petherick, K. J., and Pranjol, M. Z. I. (2021). Laying the groundwork to investigate diversity of life sciences Reading lists in higher education and its link to awarding gaps. *Educ. Sci.* 11:359. doi: 10.3390/educsci11070359

UK Government RDU. (n.d.). *Health, Ethnicity Facts and Figures*. Available at: https://www.ethnicity-facts-figures.service.gov.uk/health

UoM. (n.d.). *The Black, Asian and Minority Ethnic Programme*. The University of Manchester. Available at: https://www.manchester.ac.uk/connect/teachers/students/widening-participation/bame-programme

Watkinson, R. E., Williams, R., Gillibrand, S., Sanders, C., and Sutton, M. (2022). Ethnic inequalities in COVID-19 vaccine uptake and comparison to seasonal influenza vaccine uptake in greater Manchester, UK: a cohort study. *PLoS Med.* 19:e1003932. doi: 10.1371/journal.pmed.1003932

White, C., and Nafilyan, V.. (2021). *Coronavirus (COVID-19) Related Deaths by Ethnic Group, England and Wales: 2 march 2020 to 10 April 2020*. Office for National Statistics. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/coronavirusrelateddeathsbyethnicgroupenglandandwales/2march2020to10april2020

WHO. (2021). *Coronavirus (COVID-19) Dashboard*. Geneva: World Healyth Organization. Available at: https://covid19.who.int/table2021

Williams, M. L., Burnap, P., Javed, A., Liu, H., and Ozalp, S. (2019). Hate in the machine: anti-black and anti-Muslim social media posts as predictors of offline racially and religiously aggravated crime. *Br. J. Criminol.* 60, 93–117. doi: 10.1093/bjc/azz049

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 24 February 2023
DOI 10.3389/fpubh.2023.1043247

OPEN ACCESS

EDITED BY
Zhiwen Hu,
Zhejiang Gongshang University, China

REVIEWED BY
Bojan Obrenovic,
Zagreb School of Economics and Management, Croatia
Neeti Rustagi,
All India Institute of Medical Sciences Jodhpur, India

*CORRESPONDENCE
Yi Liu
✉ liuyi2016@cqu.edu.cn

SPECIALTY SECTION
This article was submitted to Infectious Diseases: Epidemiology and Prevention, a section of the journal Frontiers in Public Health

RECEIVED 02 November 2022
ACCEPTED 08 February 2023
PUBLISHED 24 February 2023

CITATION
Liu Y and Jiang X (2023) Application of protection motivation theory and cultural tightness-looseness for predicting individuals' compliance with the government's recommended preventive measures during regular prevention and control of the COVID-19 pandemic in China. *Front. Public Health* 11:1043247. doi: 10.3389/fpubh.2023.1043247

Application of protection motivation theory and cultural tightness-looseness for predicting individuals' compliance with the government's recommended preventive measures during regular prevention and control of the COVID-19 pandemic in China

Yi Liu* and Xiaoyuan Jiang

School of Journalism and Communication, Chongqing University, Chongqing, China

Introduction: In the period of regular prevention and control of the COVID-19 pandemic, the public must continue to comply with the government's recommended preventive measures to further curb the pandemic. Based on the theories of protection motivation and cultural tightness-looseness, this study investigates individuals' compliance with the government's recommended preventive measures during this period in China. It also establishes a moderated mediation model to explore the underlying mechanisms.

Methods: We used structural equation modeling and latent model structural equations to analyze data from an online survey of 443 participants.

Results: The analysis showed that media exposure significantly predicted perceived severity, maladaptive rewards, self-efficacy, response efficacy, and response cost. Perceived severity, self-efficacy, and response efficacy were positively associated with protection motivation, which, in turn, was positively associated with individuals' compliance. Additionally, protection motivation positively affected individuals' compliance *via* implementation intention, and perceived cultural tightness-looseness significantly moderated the association between protection motivation and implementation intention.

Discussion: This study helps to better understand individuals' compliance from a theoretical perspective and provide practical advice on promoting individuals' compliance with the government's precautionary measures.

KEYWORDS

media exposure to COVID-19-related information, the government's recommended preventive measures, protection motivation theory, perceived cultural tightness-looseness, moderated mediation model

1. Introduction

The COVID-19 pandemic posed a serious threat to the public's physical and mental health, with rising cases of suicide and depressive disorder (1). It also caused a huge impact on the national economy, as seen in the stock price crash risk (2). To deal with these negative effects, the government has issued some precautionary measures which were seen as the key to containing the pandemic. In China, the government's actions, including quarantine, social distancing, and isolation of infected cases, helped contain the pandemic well in the early period (3), finally leading to the period of regular prevention and control of the COVID-19 pandemic (4). This means that the public should take preventive measures in their daily life. As there continue to be infected cases in this period, the government has accordingly adopted some precautions as regular prevention and control protocol to further curb the pandemic (5). For instance, the Chinese Centers for Disease Control and Prevention developed the "COVID-19 Prevention Guidelines", which was recommended as the basic rule for citizen health behaviors (6). The public must comply with the government's recommended preventive measures during regular prevention and control—a directive that deserves to be examined with rigor. A large body of empirical research has examined individuals' preventive behaviors against the pandemic [e.g., (7, 8)]. Nonetheless, individuals' preventive behaviors during regular prevention and control remains unclear. Some scholars have conducted research on regular prevention and control, but their research has mainly focused on individuals' mental health and spontaneous behaviors [e.g., (4, 9)], without considering government's recommended measures. To address the above research gap, this study aims to investigate individuals' compliance with the government's recommended preventive measures during the period of regular prevention and control of the COVID-19 pandemic.

Protection motivation theory (PMT) provides a conceptual explanation for the cognitive processes underlying attitudinal and behavioral change (10). According to PMT, after receiving risk messages or encountering health issues, individuals would take adaptive or maladaptive responses that were predicted by protection motivation and the perception of the threat and the recommended actions. Therefore, PMT may be suitable for examining individuals' compliance with recommended preventive behaviors against the COVID-19 pandemic. In fact, in the context of the COVID-19 pandemic, PMT has been widely used to investigate people's preventive behaviors and has an ideal predictive effect [e.g., (11, 12)]. In addition to PMT, extended parallel process model (EPPM) has also been utilized to predict individuals' compliance behaviors against the pandemic (13, 14). EPPM is seen as an integration of the main theories, including PMT, of fear appeals. Although it is very similar to PMT, it removes the construct's maladaptive rewards and response cost (15). However, research has also found that maladaptive rewards and response cost significantly predicted individuals' preventive behaviors (16, 17). Consequently, to be more comprehensive, this study takes PMT as the basic theory to predict individuals' preventive behaviors against the COVID-19 pandemic.

Additionally, culture has been considered a crucial factor in examining individuals' preventive behaviors against the pandemic (15). According to the cultural tightness-looseness theory, tight-culture societies have strong norms and a low tolerance of deviant behaviors, and promote people to perform behaviors with features of conformity, risk avoidance, and stability seeking. On the other hand, loose-culture societies are represented by relatively flexible norms and a high tolerance for undesirable behaviors, motivating people to perform behaviors with characteristics of deviance and risk seeking (18). Therefore, people in the tight-culture societies may adopt government's measures more than those in the loose-culture societies. Previous research has provided some empirical evidence that people in China showed better compliance with mask-wearing and other preventive measures than those in European countries (19). Likewise, people in Asian countries reportedly adopted more preventive behaviors than those in Europe and the United States (20). In addition to country-level differences, cultural tightness-looseness varies across individuals within a certain country (18). It means that influenced by perceived cultural tightness-looseness, people in the same country may also perform different preventive measures against the COVID-19 pandemic. However, there is minimal empirical evidence supporting the above view, and little is known about the influence of cultural tightness-looseness on preventive behaviors at the individual level. To address this research gap, this study introduces perceived cultural tightness-looseness and examines its effect on individuals' compliance with the government's recommended preventive measures.

In brief, this study mainly has the following contributions. In terms of theoretical significance, this study establishes a theoretical framework based on PMT and cultural tightness-looseness to better understand individuals' compliance with the government's recommendations during regular COVID-19 pandemic prevention and control. It not only expands the theoretical perspective of cultural tightness-looseness, but also contributes to the literature on individuals' preventive behaviors. Besides, it provides practical guidance for promoting individuals' compliance behaviors against the pandemic. More detailed implications are presented in the discussion.

2. Literature review and research hypotheses

2.1. The government's recommended preventive measures

At different times of the COVID-19 pandemic, the government has taken different types of preventive measures or policies. In the early stage of the pandemic, some mandatory measures, such as mandatory vaccination and mask-wearing were adopted to limit the pandemic (21, 22). For these mandatory measures, the public showed good compliance; for instance, about 74% of participants supported mandatory vaccination and 62% intended to get vaccinated for the COVID-19 in Greece (21). Similarly, people showed a high level of acceptance for mask-wearing in China (22). With the pandemic gradually under control, the period of regular prevention and control has arrived; nevertheless, there were still some cases of local and imported infections. This means that the pandemic may persist for a long time, and prevention and control may also be a long-term task. Accordingly, the

government took some preventive measures as regular prevention and control protocol and suggested that individuals should follow these recommended precautions in daily life. For example, the Chinese Centers for Disease Control and Prevention developed the "COVID-19 Prevention Guidelines" (6). It includes the following recommended measures: washing hands frequently, wearing masks scientifically, reducing gathering, keeping toilets clean, implementing individual serving, cleaning disinfection and ventilation, observing social etiquette, and maintaining a healthy life. It is essential to abide by these recommended measures to further curb the pandemic. As mentioned above, previous research reported that the mandatory measures were well observed. However, few studies have investigated individuals' obedience to the government's recommendations during regular prevention and control of the pandemic; hence, this study intends to explore individuals' compliance with the government's recommended preventive measures during the regular prevention and control phase of the COVID-19 pandemic in China.

2.2. Protection motivation theory

PMT initially emerged to explain the effect of fear-inducing messages in fear appeals (10). Rogers (23) modified PMT into a more comprehensive version that proposed the cognitive processes underlying individuals' attitudinal changes and expanded the broader information sources. Specifically, it assumes that the components of a fear appeal arouse individuals' cognitive processes, which, in turn, shape their protection motivation in the form of an intention to perform protective behaviors. Two cognitive processes were proposed: threat appraisal refers to the components related to how threatened individuals feel; coping appraisal refers to individuals' assessment of the recommended responses (23). Threat appraisal is composed of perceived severity, perceived vulnerability, and maladaptive rewards, and coping appraisal is composed of self-efficacy, response efficacy, and response cost.

According to PMT, individuals would adopt adaptive or maladaptive responses in the face of significant health issues. A large body of empirical evidence supports that PMT is useful for explaining individuals' health protection behaviors [e.g., (24, 25)]. More recently, PMT has been commonly applied and has effectively predicted individuals' preventive behaviors against the COVID-19 pandemic [e.g., (16, 26)]. PMT could potentially explain individuals' compliance behaviors in the context of the COVID-19 pandemic. Thus, this study uses PMT as the theoretical framework to examine individuals' compliance with the government's recommended preventive measures during regular prevention and control.

2.3. Media exposure to COVID-19-related information

In PMT, a wide range of information sources, including fear appeals, observational learning, and prior experience, were included as materials that might trigger individuals' cognitive processes leading to protection motivation. Among them, media information is seen as one of the antecedents of cognitive processes (27). Four media information components, including magnitude of seriousness, probability of occurrence, self-efficacy depictions, and response efficacy depictions, cause corresponding cognitive processes. Specifically, the magnitude of seriousness influences perceived severity, probability of occurrence influences perceived vulnerability, and self-efficacy and response efficacy depictions influence perceived self-efficacy and response efficacy (27). Empirical evidence suggests that when individuals are exposed to increased media information about public health emergencies, their perceived severity and vulnerability tended to be higher (28); likewise, individuals who accessed more risky media information details were more likely to exhibit higher perceived self-efficacy and response efficacy for performing risky behaviors (29). Therefore, it is reasonable to assume that media information related to COVID-19 might initiate the cognitive processes of threat and coping appraisals.

As mentioned above, the magnitude of seriousness and probability of occurrence among media information components result in increased perceived severity and vulnerability (27). In the context of COVID-19 pandemic prevention and control, Truong et al.'s (30) study investigated how the media influenced perceptions of the pandemic among Vietnamese people. They showed that media exposure was directly related to increased perceived severity and vulnerability. Likewise, exposure to COVID-19 information from both mass media and social media was found to increase individuals' perceptions of severity and vulnerability of the pandemic (31). In other words, media information might be the source that positively drives people's threat appraisal. Besides, media exposure to the COVID-19 information was found to significantly increase individuals' knowledge about the pandemic, which, in turn, positively affected their coping appraisal and health-related behaviors against the pandemic (30, 32). Thus, if individuals perceive a high level of information about the pandemic, they tend to believe it is necessary to take adaptive coping behaviors; on the contrary, they may not be aware of the benefits of performing maladaptive responses. Thus, media exposure may reduce individuals' maladaptive rewards. Consequently, we assume that media exposure to COVID-19-related information increases perceived severity and perceived vulnerability, and decreases maladaptive rewards. The following research hypotheses are proposed:

H1a: Individuals' media exposure to COVID-19-related information is positively associated with perceived severity.
H1b: Individuals' media exposure to COVID-19-related information is positively associated with perceived vulnerability.
H1c: Individuals' media exposure to COVID-19-related information is negatively associated with maladaptive rewards.

Furthermore, self-efficacy and response efficacy depictions of media information lead to individuals' self-efficacy and response efficacy (27). As a pre-condition for coping appraisal, existing research has explored how media information about COVID-19 influenced individuals' efficacy beliefs [e.g., (33, 34)]. Social cognitive theory provides a conceptual framework to analyze the determinants and mechanisms through which symbolic

communication affects human thought, emotion, and behavior (35). In terms of the direct pathway, informing, enabling, motivating, and guiding promote changes in people; in the socially mediated mechanism, media links individuals to social networks that provide incentives and guidance for changes. As such, according to social cognitive theory, media is one of the sources for behaviors through which observational learning occurs (35), which in turn strengthens people's efficacy beliefs to motivate behavioral intention (36). In the context of the COVID-19 pandemic, on the one hand, positive information may increase people's efficacy beliefs; on the other hand, exposure to negative information, such as false news and the increasing number of infected people, may have an adverse impact on efficacy beliefs. In either scenario, media information plays a significant role in shaping people's perceptions of the COVID-19 pandemic (34). Empirical studies have found that media exposure to information about the pandemic increased individuals' self-efficacy and response efficacy (30, 33). In other words, individuals who are exposed to more media information tend to perceive high self-efficacy and response efficacy, whereas they are not inclined to perceive response cost. Based on these considerations, we suppose that media exposure to COVID-19-related information may increase individuals' self-efficacy and response efficacy, and decrease response cost. Thus, the following hypotheses are proposed:

H2a: Individuals' media exposure to COVID-19-related information is positively associated with self-efficacy.
H2b: Individuals' media exposure to COVID-19-related information is positively associated with response efficacy.
H2c: Individuals' media exposure to COVID-19-related information is negatively associated with response cost.

2.4. Protection motivation and its predictors

According to PMT, both threat and coping appraisals shape individuals' motivation to protect themselves *via* the modality of behavioral intentions (23). Specifically, protection motivation is the reason and impetus for individuals to adopt protective behaviors. Some scholars consider it as the intention of individuals to engage in actions that protect them from threats (24). In the existing research, protection motivation was partially evolved into behavioral intention according to the specific context. For instance, Farooqet al. (37) investigated, based on PMT, the impacts of online information on individual-level intention to voluntarily self-isolate during the COVID-19 pandemic. Considering the context of preventing the pandemic, they redefined protection motivation as the intention to voluntarily self-isolate as the outcome of threat and coping appraisals. Thus, in the current study, protection motivation is assumed to evolve into individuals' intention to comply with the government's recommended preventive measures and is assessed based on behavioral intentions. For protection motivation or behavioral intention, a positive impact is generated from the perceptions that: (a) the threat is serious, (b) the individual is susceptible to the threat, (c) the individual is able to perform the recommended response, (d) the recommended response is effective, while there is a negative impact of the perceptions, (e) it is beneficial to not perform the recommended response, and (f) it is costly to perform the recommended response (24). Thus, for protection motivation, perceived severity, perceived vulnerability, self-efficacy, and response efficacy are positive predictors; meanwhile, maladaptive rewards and response cost are negative predictors.

More specifically, for threat appraisal, when individuals perceive high severity and vulnerability, and low maladaptive rewards, they will develop strong protection motivation. Existing research on the COVID-19 pandemic prevention and control has provided empirical evidence for the association between threat appraisal and protection motivation [e.g., (16, 38)]. Rad et al. (16) applied PMT to explain individuals' preventive behaviors against the pandemic and found that perceived severity and vulnerability positively influenced their motivation to maintain protective behaviors. In contrast, the results showed that maladaptive rewards negatively affected their protection motivation. Likewise, based on PMT, Chen et al. (38) explored the differences in people's motivation for getting vaccinated against COVID-19. The study suggested that perceived severity and vulnerability were positively associated with their protection motivation and maladaptive rewards negatively predicted them. Thus, we assume that when individuals perceive high severity and vulnerability of the COVID-19 pandemic and perceive low maladaptive rewards for the government's recommendations, they might tend to formulate a strong protection motivation. Hence, we propose the following research hypotheses:

H3a: Individuals' perceived severity is positively associated with protection motivation.
H3b: Individuals' perceived vulnerability is positively associated with protection motivation.
H3c: Individuals' maladaptive rewards is negatively associated with protection motivation.

For coping appraisal, self-efficacy and response efficacy would strengthen protection motivation in the form of intentions, while response cost would weaken protection motivation. In the context of the COVID-19 pandemic prevention and control, some research has examined the factors influencing individuals' intention to adopt or maintain preventive behaviors [e.g., (17, 37)]. On one hand, Farooq et al.'s study (37) reported that self-efficacy was positively associated with individuals' intention to adopt the self-isolation strategy, while response cost had an adverse influence on their behavioral intention. On the other hand, He et al.'s study (17) also found that for individuals' intention to maintain social distancing and mask-wearing, self-efficacy played the role of a positive predictor; on the contrary, response cost was a negative predictor. Besides, self-efficacy and response efficacy positively influenced individuals' adherence to social distancing (33). That is, individuals who perceive high self-efficacy and response efficacy, and low response cost for the recommended precautions, might be inclined to form a strong motivation to protect themselves from the COVID-19 pandemic. Hence, the following research hypotheses are proposed:

H4a: Individuals' self-efficacy is positively associated with protection motivation.

H4b: Individuals' response efficacy is positively associated with protection motivation.
H4c: Individuals' response cost is negatively associated with protection motivation.

Additionally, protection motivation further promotes individuals' protective behaviors (23), which indicates that the stronger the protection motivation individuals have, the more likely they are to perform protective behaviors. There are several empirical studies on preventive behaviors against the COVID-19 pandemic [e.g., (12, 39)]. Lahiri et al. (12) and Grano et al. (39) explored the predictors of individuals' protective behaviors during the COVID-19 pandemic and consistently found that protection motivation was positively associated with individuals' actual preventive behaviors, such as washing hands, wearing masks, and maintaining social distance. Hence, we suppose that if individuals have a strong motivation to protect themselves from the COVID-19 pandemic, they might be more likely to comply with the government's recommended preventive measures. The following research hypothesis is proposed:

H5: Individuals' protection motivation is positively associated with compliance with the governments' recommended preventive measures.

2.5. Implementation intention

Intention is a proximal factor of individuals' behaviors and is even considered the best predictor in some intention-based theories (40). However, the predictive effect was not as ideal as the theory suggests, just explaining 19–38% of the variance in some empirical research (41). In this regard, Gollwitzer (42) divided the intention into goal intention and implementation intention to represent varying degrees of proximity to behaviors. Goal intention puts more emphasis on thinking about performing certain actions, whereas implementation intention is more focused on the specific plan for performing certain actions. Thus, in general, when individuals formulate the implementation intention, their actual behaviors would correspond more to their intended behaviors (42). Compared to goal intention, implementation intention might be a more proximal predictor of people's actual behaviors. Many studies have provided empirical support for the above view [e.g., (43, 44)]. Milkman et al. (43) investigated individuals' vaccination rate in the context of influenza and found that people who accepted the more specific prompt had a higher vaccination rate. Even so, implementation intention promotes individuals' actual vaccination. More importantly, a comparison of the predictive power of goal intention and implementation intention suggested that both goal intention and implementation intention predicted individuals' health behaviors during rehabilitation, and implementation intention was more frequently predictive (44). Based on these considerations, this study uses implementation intention to predict individuals' compliance with the government's recommended preventive measures. This could contribute to a better understanding of individuals' preventive behaviors during regular prevention and control.

Gollwitzer argued that implementation intention could transfer control over goal-directed behaviors to situational cues, thereby automating the initiation of behaviors (42). In other words, implementation intention facilitates the transition of goal intention into actual behaviors. Specifically, in the stage of thinking, goal intention promotes individuals to form an "unequivocal behavioral orientation" (45). However, it does not guarantee the practice of behavioral orientation. Implementation intention comes into play by connecting a certain goal intention with situational cues. It makes a more detailed plan to promote the efficient execution of goal intention, which means that implementation intention generally serves one or another goal intention (45). Therefore, the stronger the goal intention is, the stronger might be the implementation intention. Furthermore, individuals might be more likely to engage in actual behaviors. In the current study, protection motivation, synonymous with behavioral intention (24), represents individuals' orientation to protect themselves from the COVID-19 pandemic. Thus, we assume that protection motivation might positively influence implementation intention regarding specific situational cues, which, in turn, promotes individuals' compliance with the government's recommended preventive measures. Consequently, the following hypotheses are proposed:

H6: Individuals' protection motivation is positively associated with implementation intention.
H7: Individuals' implementation intention is positively associated with compliance with the government's recommended preventive measures.

Moreover, implementation intention promotes the conversion from intention to action, which helps address the intention-behavior gap (46). It strengthens the relationship between expected situations and target behaviors. As such, implementation intention is considered an important mediator between intention and behavior (47). In the current study, implementation intention is a more proximal factor of individuals' compliance than protection motivation. Moreover, it might facilitate the conversion from protection motivation to individuals' compliance. Thus, we try to examine the mediating effect of implementation intention to reveal the underlying mechanism. Protection motivation might affect individuals' compliance with the government's recommendations *via* the mediation of the implementation intention. Thus, we propose the following hypothesis:

H8: Implementation intention has a significant mediating effect between protection motivation and individuals' compliance with the government's recommended preventive measures.

2.6. Perceived cultural tightness-looseness

Cultural tightness-looseness has increasingly become an important construct for differentiating cultures, and it contributes to understanding cultural differences in social behaviors (48). Gelfand et al. (18) developed the theory of cultural tightness-looseness to represent the strength of social norms and the degree of sanctioning within societies from a cross-cultural perspective. In fact, it is largely similar to social norms—the accepted standard of human behavior in a particular social context (49). Individuals' behavioral intention will change under the influence of social

norms. For instance, a study on preventive behaviors against the COVID-19 pandemic found that social norms positively affected individuals' intention to follow social distancing guidelines (50). According to the theory of cultural tightness-looseness, tight culture expresses more distinct and definite social norms, while loose culture expresses social norms indirectly and inclusively (48). Accordingly, individuals' behaviors would also be influenced by cultural tightness-looseness. Specifically, individuals tend to perform behaviors with features of conformity, risk avoidance, and stability seeking in the tight culture, whereas they tend to perform behaviors with characteristics of deviance and risk seeking in the loose culture. More recently, in the context of COVID-19 pandemic prevention and control, the above ideas have been supported empirically. For instance, Schmidt-Petri et al. (51) investigated people's preventive behaviors against the pandemic in Germany and Japan and found that in two tight cultural countries, the majority of participants enacted preventive behaviors and avoided risk behaviors, such as washing hands and avoiding crowds. Moreover, perceived cultural tightness-looseness was positively associated with their health-related behaviors, such as washing hands and wearing masks (52). In other words, cultural tightness-looseness might be a significant predictor of individuals' intention to perform preventive behaviors against the pandemic. Therefore, this study introduced perceived cultural tightness-looseness to better understand individuals' preventive behaviors during regular prevention and control.

In this study, the government's recommended preventive measures, such as washing hands frequently, wearing masks scientifically, and minimizing gathering, are important for avoiding risky behaviors against the COVID-19 pandemic. Implementation intention to comply with the government's recommendations is behavioral intention with characteristics of conformity, risk avoidance, and stability seeking. As mentioned above, unlike loose culture, tight culture promotes people to perform behaviors with features of conformity, risk avoidance, and stability seeking. Therefore, we assume that perceived cultural tightness might strengthen individuals' implementation intention to comply with the government's recommended preventive measures. Additionally, the moderating role of cultural tightness-looseness has been confirmed in existing research (53, 54). For instance, Dong et al. (53) explored the role of cultural tightness in relation to psychological disorders during the COVID-19 pandemic. The results indicated that risk perception positively predicted psychological disorders; however, the increase in psychological disorders with risk perception was less pronounced among people in tight cultural areas. To further reveal the mechanism of individuals' compliance behaviors, this study attempts to explore the moderating effect of perceived cultural tightness-looseness. We presume that perceived cultural tightness-looseness might significantly moderate the effect of protection motivation on implementation intention. Consequently, we posit the following hypothesis:

H9: Individuals' perceived cultural tightness-looseness is positively associated with implementation intention.

H10: Individuals' perceived cultural tightness-looseness has a significant moderating effect on the relationship between protection motivation and implementation intention.

Based on H8 and H10, we try to explore the moderated mediating effect to further examine the mechanism underlying individuals' compliance. The mediating effect of implementation intention may also be different at the different levels of perceived cultural tightness-looseness. Hence, we posit the following hypothesis:

H11: Individuals' perceived cultural tightness-looseness moderates the mediating effect of implementation intention between protection motivation and individuals' compliance.

The research model for this study was developed based on the above literature review and research hypotheses (see Figure 1).

3. Materials and methods

3.1. Participants

We conducted a nationwide questionnaire survey in July 2022 through Wen-Juan-Wang, one of the largest real-name registration online platforms in the Chinese mainland. The platform randomly sent questionnaires to real-name registered users in the database. Finally, we collected 538 questionnaires from 30 provinces, municipalities, and autonomous regions in the Chinese mainland. After screening with attention-test items, a total of 443 valid questionnaires were collected.

Table 1 presents the sample characteristics. The average age of participants was 28.4 years ($SD = 8.1$). Among all the participants, 162 were male (36.6%) and 281 were female (63.4%). Most had a college education (75.2%) and had a monthly household income of 10,000 CNY and more (35.9%). Besides, only 0.7% had been infected with the COVID-19.

3.2. Measurements

Measurements for each variable in the study were adapted from previous research and modified to fit the context of this study with 5-point Likert scales (see Appendix 1).

Media exposure refers to the degree of accessing certain information in the media (55). We used three items adapted from Liu et al. (56) to measure media exposure to COVID-19-related information ($M = 4.21$, $SD = 0.68$). Since formative measurement was used, its internal consistency reliability was not presented. Next, we adopted items from Prasetyo et al. (57) to measure perceived severity ($M = 4.09$, $SD = 0.82$, and Cronbach's $\alpha = 0.81$) and vulnerability ($M = 2.75$, $SD = 1.19$, and Cronbach's $\alpha = 0.91$), which respectively refer to individuals' belief that the threat would be serious to themselves and that they are susceptible to the threat (24). The variable maladaptive rewards is defined as perceived benefits of not performing the recommended responses (24), and three items adapted from Kim et al. (58) were used to measure maladaptive rewards ($M = 1.84$, $SD = 1.20$, and Cronbach's $\alpha = 0.95$). Self-efficacy and response efficacy refer to the beliefs that the individual possesses the ability to perform the recommended responses and that they will be effective, while response cost refers to the beliefs of how costly individuals perform the recommended responses (24). We adapted previous scales from

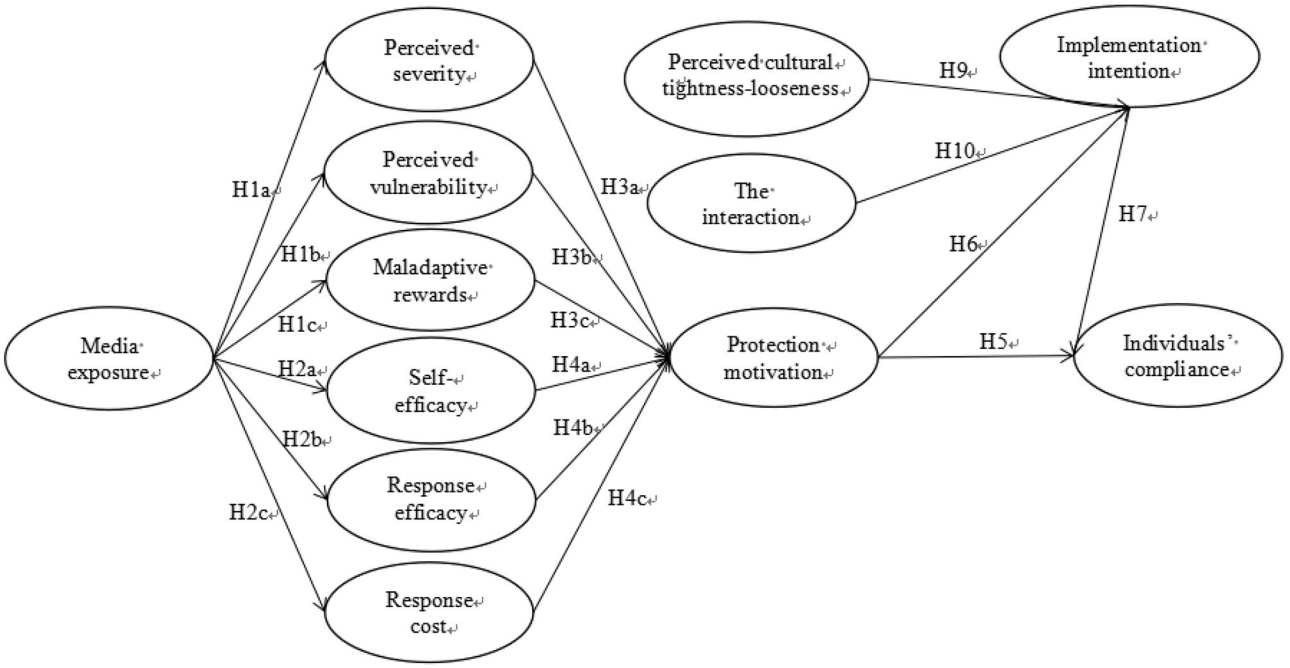


FIGURE 1
The research model. The interaction of protection motivation and perceived cultural tightness-looseness.

Kim et al. (58) to measure self-efficacy ($M = 4.45$, $SD = 0.67$, and Cronbach's $\alpha = 0.84$), response efficacy ($M = 4.34$, $SD = 0.72$, and Cronbach's $\alpha = 0.87$), and response cost ($M = 2.55$, $SD = 1.25$, and Cronbach's $\alpha = 0.94$). Three items were adapted from Ling et al. (59) to measure protection motivation ($M = 4.33$, $SD = 0.73$, and Cronbach's $\alpha = 0.88$), which refers to individuals' psychological disposition to adopt protective behaviors (60). Cultural tightness-looseness is defined as the degree to which cultures impose clear social norms and reliably provide sanctions for deviation from social norms (48). We used six items adapted from Gelfand et al. (61) to measure perceived cultural tightness-looseness ($M = 4.05$, $SD = 0.64$, and Cronbach's $\alpha = 0.80$). To maintain the internal consistency reliability, we removed the reverse-scored item "In this country, in most cases, people have a lot of freedom to decide what they want to do." Implementation intention refers to when, where, and how individuals perform planned behaviors in the future (42). We utilized three items adapted from Ziegelmann et al. (44) to measure implementation intention ($M = 4.21$, $SD = 0.76$, and Cronbach's $\alpha = 0.87$). Additionally, according to the "COVID-19 Prevention Guidelines" developed by the Chinese Centers for Disease Control and Prevention (6), eight items were used to measure individuals' compliance with the government's recommended preventive measures ($M = 4.49$, $SD = 0.55$). As formative measurement was used, its internal consistency reliability was not calculated.

3.3. Data analysis

We used SPSS 25.0 and Mplus 8.0 to conduct data analysis. First, we conducted confirmatory factor analysis (CFA) to test the measurement model. Second, we treated participants' age, gender, education, monthly household income, and infection with COVID-19 or not as control variables, and adopted the structural equation model (SEM) to test Model 0 (null model where the interaction was not estimated). Third, based on Model 0, we used implementation intention and tightness-looseness as the mediator and moderator, respectively, and applied the latent moderated structural (LMS) equations to test the moderated mediation model.

4. Results

4.1. Testing the measurement model

The results indicated a good fit of measurement model [$\chi^2/df = 1.98$, comparative fit index (CFI) = 0.94, Tucker-Lewis index (TLI) = 0.94, standardized root mean squared residual (SRMR) = 0.04, and root mean square error of approximation (RMSEA) = 0.05] (Table 2). We also examined factor loading, average variance extracted (AVE), and composite reliability (CR) to ensure convergent and discriminant validity (Table 3). Factor loadings of all items were higher than 0.55, suggesting acceptable measurement validity (66). For CRs, all values <0.60 were desirable (67). The AVEs for media exposure and perceived cultural tightness-looseness were <0.36, but that of others were higher than 0.50, which was acceptable (68). Overall, it indicated acceptable convergent validity.

Moreover, we evaluated discriminant validity by the square root of AVE (SRAVE). The results showed all SRAVEs were greater than the correlations between each pair of variables (Table 4), suggesting good discriminant validity (69). Additionally, we tested

TABLE 1 Baseline characteristics of the participants ($N = 443$).

Characteristics	Category	Sample	
		Number	Percentage (%)
Age (years)	<30	265	59.8
	30–39	140	31.6
	40–49	28	6.3
	50–60	10	2.3
Gender	Male	162	36.6
	Female	281	63.4
Education	Primary and below	4	0.9
	Secondary and equivalent education	60	13.5
	College and equivalent education	333	75.2
	Postgraduate	46	10.4
Monthly household income	<2,000	20	4.5
	2,000–3,999	45	10.2
	4,000–5,999	72	16.3
	6,000–7,999	71	16.0
	8,000–9,999	76	17.2
	≥10,000	159	35.9
Infection with COVID-19 or not	Yes	440	99.3
	No	3	0.7

TABLE 2 Model fit indices for measurement and structural models.

Model fit indices	CFA	Model 0	Recommended values
χ^2/df	1.98	2.25	<5.00 (62)
CFI	0.94	0.91	≥0.90 (63)
TLI	0.94	0.90	≥0.90 (63)
RMSEA	0.05	0.05	<0.10 (64)
SRMR	0.04	0.07	<0.08 (65)

CFA, confirmatory factor analysis; CFI, comparative fit index; TLI, Tucker-Lewis index; RMSEA, root mean square error of approximation; SRMR, standardized root mean squared residual. Model 0: null model where the interaction was not estimated.

the multicollinearity and found that the maximum variance inflation factor was 2.84, which suggested that multicollinearity was not significant (70).

4.2. Testing the moderated mediation model

A two-step method was proposed to assess the LMS model fit. First, we run Model 0 (null model where the interaction is not estimated) to obtain general model fit indices, such as χ^2/df, CFI, TLI, SRMR, and RMSEA. Second, use a log-likelihood ratio test to

TABLE 3 Convergent validity test.

Variables	Items	Factor loading	AVE	CR
Media exposure (ME)	ME1	0.71	0.42	0.68
	ME2	0.62		
	ME3	0.61		
Perceived severity (PS)	PS1	0.81	0.59	0.81
	PS2	0.65		
	PS3	0.84		
Perceived vulnerability (PV)	PV1	0.89	0.78	0.91
	PV2	0.94		
	PV3	0.81		
Maladaptive rewards (MR)	MR1	0.92	0.86	0.95
	MR2	0.93		
	MR3	0.93		
Self-efficacy (SE)	SE1	0.77	0.64	0.84
	SE2	0.78		
	SE3	0.85		
Response efficacy (RE)	RE1	0.83	0.68	0.86
	RE2	0.84		
	RE3	0.80		
Response cost (RC)	RC1	0.95	0.85	0.94
	RC2	0.91		
	RC3	0.90		
Protection motivation (PM)	PM1	0.90	0.73	0.89
	PM2	0.81		
	PM3	0.85		
Perceived cultural tightness-looseness (PCTL)	PCTL1	0.59	0.46	0.81
	PCTL2	0.75		
	PCTL3	0.76		
	PCTL4	0.60		
	PCTL5	0.67		
Implementation intention (II)	II1	0.88	0.69	0.87
	II2	0.77		
	II3	0.84		

(Continued)

TABLE 3 (Continued)

Variables	Items	Factor loading	AVE	CR
Individuals' compliance (IC)	IC1	0.74	0.52	0.89
	IC2	0.71		
	IC3	0.75		
	IC4	0.73		
	IC5	0.60		
	IC6	0.76		
	IC7	0.69		
	IC8	0.75		

AVE, average variance extracted; CR, composite reliability.

compare the relative fit of Model 0 and Model 1 (alternative model where the interaction is estimated). If Model 0 fits well, and Model 0 represents a significant loss in fit relative to Model 1, Model 1 will be a well-fitted model (71). Besides, researchers have adopted Akaike Information Criterion (AIC) to assess model fit. AIC represents the degree of information loss. Ideally, the model with the smallest AIC is the optimal one (72).

In this study, we first run SEM analysis to test Model 0, using participants' age, gender, education, monthly household income, and infection with COVID-19 or not as control variables. The results suggested a good fit (χ^2/df = 2.25, CFI = 0.91, TLI = 0.90, SRMR = 0.07, and RMSEA = 0.05) (see Table 2). We then applied LMS to test Model 1 (moderated mediation model) through 3,000 bootstrapped samples, treating implementation intention and tightness-looseness as the mediator and moderator, respectively. We assessed the significance of log-likelihood ratio change (see Table 5). The p-value was >0.05, indicating that Model 0 represented a significant loss in fit relative to Model 1. Besides, the AIC for Model 1 (36,024.17) was smaller than that for Model 0 (36,028.13) (Table 5). Thus, Model 1 is well-fitted.

The results of the moderated mediation model explained 54.3% of the variance in individuals' compliance with the government's recommended preventive measures (Figure 2). Media exposure was positively associated with perceived severity (β = 0.52 and p < 0.001), whereas it was negatively associated with maladaptive rewards (β = −0.40 and p < 0.001), supporting H1a and H1c. Next, media exposure was positively associated with self-efficacy (β = 0.87 and p < 0.001) and response efficacy (β = 0.91 and p < 0.001), whereas it was negatively associated with response cost (β = −0.40 and p < 0.001), thereby supporting H2a, H2b, and H2c. Perceived severity (β = 0.17 and p < 0.001), self-efficacy (β = 0.39 and p < 0.001), and response efficacy (β = 0.37 and p < 0.001) were positively associated with protection motivation, thereby supporting H3a, H4a, and H4b. Lastly, protection motivation was positively associated with individuals' compliance (β = 0.55 and p < 0.001), thereby supporting H5.

With respect to the mediating effect, protection motivation was positively associated with implementation intention (β = 0.50 and p < 0.001), which was positively related to individuals' compliance (β = 0.22 and p < 0.001), thereby supporting H6 and H7. Additionally, implementation intention had a significant mediating effect between protection motivation and individuals' compliance [Effect = 0.08, SE = 0.03 and 95% boot CI = (0.02, 0.13)] (Table 6), thereby supporting H8. In terms of the moderating effect, perceived cultural tightness-looseness was positively associated with implementation intention (β = 0.42 and p < 0.001), thereby supporting H9. The interaction of protection motivation and perceived cultural tightness-looseness was negatively associated with implementation intention (β = −0.08 and p < 0.05), thereby supporting H10.

Besides, the results of conditional mediating effect were presented (Table 6). When perceived cultural tightness-looseness was low (M – SD), implementation intention had a significant mediating effect [Effect = 0.10, SE = 0.03 and 95% boot CI = (0.03, 0.17)]. When perceived cultural tightness-looseness was high (M + SD), implementation intention also had a significant mediating effect [Effect = 0.05, SE = 0.02 and 95% boot CI = (0.01, 0.10)]. This suggests that perceived cultural tightness-looseness significantly moderated the indirect effect of protection motivation on individuals' compliance *via* implementation intention. Specifically, as perceived cultural tightness-looseness increased, the mediating effect decreased. Thus, H11 was supported.

5. Discussion

The current study introduces perceived cultural tightness-looseness in PMT to explore influencing factors and mechanisms of individuals' compliance with the government's recommended preventive measures during the regular phase of COVID-19 pandemic prevention and control. It generated several noteworthy findings that help to better understand individuals' compliance behaviors.

First, the findings showed that media exposure partially predicted individuals' threat appraisal for the COVID-19 pandemic. Consistent with previous research (30), we found that media exposure positively influenced perceived severity, while it had no significant impact on perceived vulnerability. This could be because with the arrival of the period of regular prevention and control, individuals' perception about vulnerability to the COVID-19 pandemic was relatively low (M = 2.75 and SD = 1.19); therefore, media exposure did not significantly influence perceived vulnerability (30). Besides, the findings showed that media exposure was negatively associated with maladaptive rewards, which is rarely confirmed in previous research. This may be explained by exposure to COVID-19 information increasing perceived knowledge, which, in turn, promotes individuals to actively response to the pandemic (32). Thus, individuals who are exposed to more COVID-19 information are less likely to perceive the benefits of not performing the government's recommendations.

In addition, the findings also indicated that media exposure significantly influenced individuals' coping appraisal. Specifically, we found that media exposure positively predicted self-efficacy, which is in accordance with existing research (30). Meanwhile, we discovered that media exposure positively influenced response efficacy and negatively predicted response cost, which has been

TABLE 4 Discriminant validity test.

	ME	PS	PV	MR	SE	RE	RC	PM	PCTL	II	IC
ME	0.65										
PS	0.41***	0.77									
PV	−0.06	0.14**	0.88								
MR	−0.21***	−0.08	0.32***	0.93							
SE	0.49***	0.33***	−0.02	−0.35***	0.80						
RE	0.54***	0.41***	−0.03	−0.33***	0.69***	0.82					
RC	−0.22***	−0.20***	0.21***	0.60***	−0.26***	−0.39***	0.92				
PM	0.48***	0.46***	−0.01	−0.32***	0.65***	0.69***	−0.35***	0.85			
PCTL	0.46***	0.36***	0.03	−0.13**	0.58***	0.58***	−0.15**	0.61***	0.68		
II	0.47***	0.36***	−0.01	−0.24***	0.62***	0.61***	−0.23***	0.69***	0.62***	0.83	
IC	0.57***	0.38***	−0.10*	−0.36***	0.56***	0.58***	−0.35***	0.61***	0.49***	0.61***	0.72

ME, media exposure; PS, perceived severity; PV, perceived vulnerability; MR, maladaptive rewards; SE, self-efficacy; RE, response efficacy; RC, response cost; PM, protection motivation; PCTL, perceived cultural tightness-looseness; II, implementation intention; IC, individuals' compliance; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; The values on the diagonal are the square root of average variance extracted (SRAVE).

found in few studies. According to social cognitive theory, media exposure is an important information source of obtaining knowledge and indirect behavioral experience, which enhances individuals' perceived efficacy (36). Thus, when individuals are exposed to more media information, they are more likely to have a high perception of efficacy for the government's recommendations. Consequently, they tend to believe the recommended measures can reduce the threat of the pandemic, and they are able to perform them; inversely, they are less likely to perceive the cost of execution. The above findings confirm that information is the antecedent of cognitive processes and provide new empirical evidence for the association between media exposure and cognitive processes in the context of COVID-19 pandemic prevention and control.

We then examined how threat and coping appraisals affected protection motivation. Existing research reported that all the components of threat and coping appraisals were significantly related to protection motivation (16). Inconsistently, we just found that when individuals perceived high severity, self-efficacy, and response efficacy, they were inclined to form strong protection motivation. The reason for conflicting findings may be that individuals have different perceptions at different times in the pandemic. Specifically, during from March 2020 to April 2020, COVID-19 was declared a pandemic with a lot of uncertainties (73), and no definitive treatment or vaccine had been developed. Thus, at that time, individuals perceived relatively high susceptibility, maladaptive rewards, and response cost (16). In contrast, during regular prevention and control, the pandemic has been effectively controlled (5). Thus, in this period, individuals' perception about vulnerability ($M = 2.75$), maladaptive rewards ($M = 1.84$), and response cost ($M = 2.55$) were relatively low. Thereby, no significant influence was observed.

Besides, the findings showed that protection motivation was positively associated with individuals' preventive behaviors, which is consistent with previous studies (16, 39). Specifically, we found that protection motivation promoted individuals to comply with the government's recommended preventive measures.

TABLE 5 Model fit indices for Model 0 and Model 1.

Model fit indices	Model 0	Model 1
Akaike information criterion (AIC)	36,028.13	36,024.17
Log-likelihood	−17,823.06	−17,820.08
Number of free parameters	191	192

Model 0: null model where the interaction was not estimated; Model 1: moderated mediation model.

Similar to other kinds of motivation, protection motivation can arouse, sustain, and direct behaviors (74). The stronger the protection motivation, the stronger the evocation effect on individuals' subsequent behaviors. Thus, when individuals had a strong motivation to protect themselves from the COVID-19 pandemic, they were more likely to abide by the government's recommendations.

In terms of implementation intention, the findings indicated that it played a significant mediating role between protection motivation and individuals' compliance. Specifically, we found that individuals' motivation to protect themselves positively affected implementation intention, which, in turn, was positively related to individuals' compliance. Actually, most studies simply considered behavioral intention as the predictor of individuals' actual behaviors (41). However, they did not make a specific distinction between the goal intention and implementation intention, and ignored the predictive role of implementation intention. This study not only found that the implementation intention significantly predicted individuals' compliance behavior, but also revealed a mediating mechanism in the "intention-behavior" association. These findings provide new empirical evidence for the theoretical viewpoint that implementation intention is a more proximal predictor of human behaviors. In this study, implementation intention changed individuals' behaviors by forming a stimulate-response connection (75). If the relationship between the goal-oriented action and specific situation (when, where, and how)

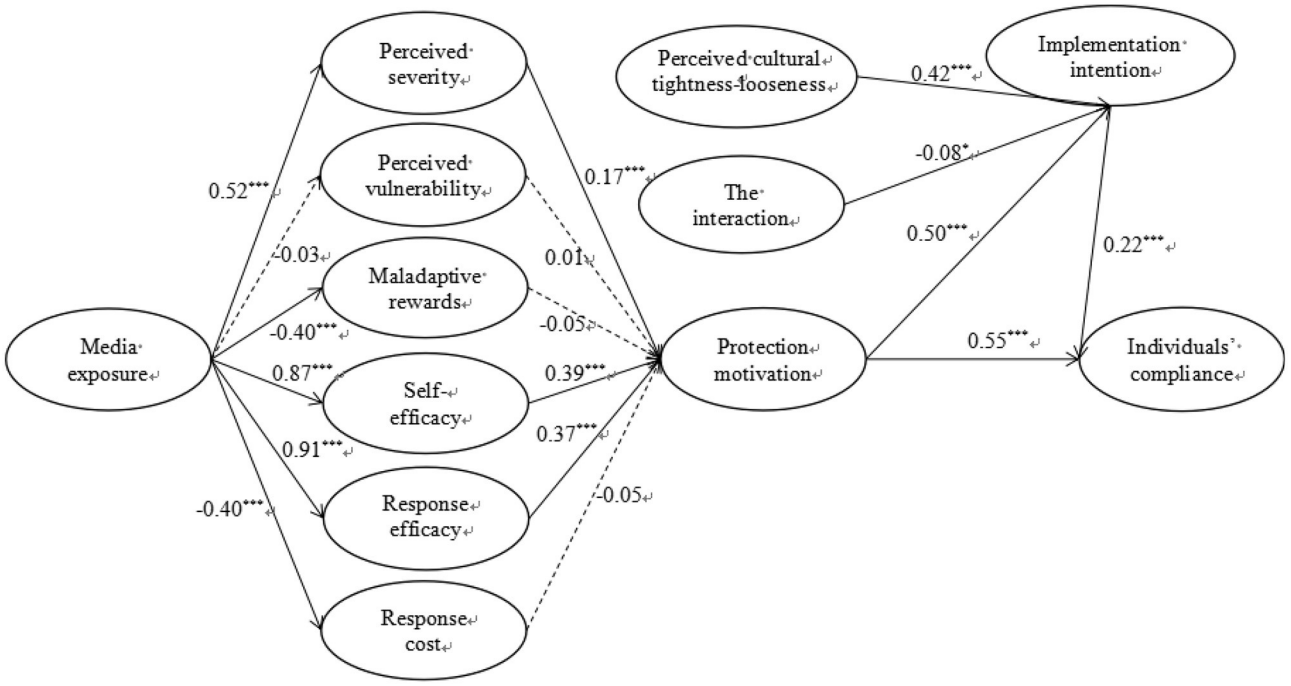


FIGURE 2
The moderated mediation model. Solid lines represent significant paths, and dotted lines represent insignificant paths. The interaction of protection motivation and perceived cultural tightness-looseness; *$p < 0.05$, ***$p < 0.001$.

TABLE 6 Mediating effect and conditional mediating effect.

	Effect	SE	Bootstrap LL 95%CI	Bootstrap UL 95% CI
The mediating effect of implementation intention				
	0.08	0.03	0.02	0.13
Conditional mediating effect at different levels of perceived cultural tightness-looseness				
M – *SD*	0.10	0.04	0.03	0.17
M + SD	0.05	0.02	0.01	0.10

is stronger, individuals will be more likely to transform the goal intention into actual behaviors. Therefore, when individuals formulate the implementation intention regarding when, where, and how to perform the government's recommendations, they are inclined to translate protection motivation into actual compliance.

More importantly, we explored the impact of perceived cultural tightness-looseness and found that it positively predicted implementation intention to comply with the government's recommendations. Although culture is seen as an important construct to explain individuals' preventive behavior during the COVID-19 pandemic (15), few studies have examined the role of culture. Some scholars tried to compare preventive behaviors between German and Japanese people from the perspective of cultural tightness-looseness (51). However, they simply defined Germany and Japan as tight-culture countries, without specifically assessing individuals' perception of cultural tightness-looseness. This study provided empirical support and explanation for the impact of cultural tightness-looseness at the individual-level. According to the cultural tightness-looseness theory, tight culture expresses stricter social norms, and subsequently, tight culture would promote people to perform behaviors in line with social norms (48). Therefore, individuals who perceived high cultural tightness were inclined to intend to comply with the government's recommendations. Additionally, the findings suggested that perceived cultural tightness-looseness significantly moderated not only the association between protection motivation and implementation intention, but also the mediating effect of implementation intention between protection motivation and individuals' compliance. Specifically, at the high level of perceived cultural tightness-looseness, the influence of protection motivation on implementation intention and the mediating effect of implementation intention would be decreased. It is worth noting that although both protection motivation ($\beta = 0.50$ and $p < 0.001$) and perceived cultural tightness-looseness ($\beta = 0.42$ and $p < 0.001$) were each positively associated with implementation intention, the interaction was negative ($\beta = -0.08$ and $p < 0.05$). According to the existing literature, it is the third pattern of interaction named interference or antagonistic interaction (76). Specifically, protection motivation and perceived cultural tightness-looseness might be a substitute for each other. That is, there may be a partially "either-or" pattern of effect of the two factors on implementation intention. Hofstede (77) argued that individuals are culturally coded from early childhood, and in general, their behaviors are also culturally determined. For individuals' compliance, cultural tightness-looseness may be the more profound and stable influencing factor whose effect could replace that of protection motivation. As such, at the high level of perceived

cultural tightness-looseness, culture played a more significant role, which to some extent, decreased the positive effect of protection motivation on implementation intention. On the contrary, at the low level of perceived cultural tightness-looseness, the influence of culture was weakened, while the positive influence of protection motivation was gradually revealed. Likewise, implementation intention played a strong mediating effect when perceived cultural tightness-looseness was low. The above findings revealed the role of cultural tightness-looseness, which contributes to understanding individuals' compliance from a cultural perspective. It can be seen that tight culture promotes individuals' compliance with the government's recommended preventive measures or policies. As such, it might be the critical factor to explain the differences in people's adaptive or maladaptive responses to the COVID-19 pandemic across countries, for instance, people in Asian countries, including China, Japan, and Singapore, showed greater acceptance of preventive measures than those in Europe and the United States (20).

5.1. Implications and limitations

The current study has both theoretical and practical implications. In terms of theoretical implications, this study investigated individuals' compliance with the government's recommended preventive measures during regular prevention and control. The findings help to better predict individuals' compliance and contribute to relevant literature. First, this study enriches the literature on regular COVID-19 pandemic prevention and control. Researchers have investigated individuals' preventive behaviors against the COVID-19 pandemic (19). At present, many countries have entered the regular prevention and control phase, during which the government's precautions against the pandemic have also become normalized (78). However, little is known about individuals' compliance. Thus, it is imperative to conduct research to examine individuals' compliance during regular prevention and control. Second, this study introduced the construct of perceived cultural tightness-looseness, which extend PMT and provides a theoretical angle for examining individuals' compliance. Unlike previous research that largely focused on the country or state level of cultural tightness-looseness (52), the current study examined the effect of perceived cultural tightness-looseness at the individual level. Furthermore, the findings indicated that perceived cultural tightness-looseness had a positive impact on individuals' implementation intention. It not only helps to explain individuals' compliance from a cultural perspective, but also contributes to the literature on cultural tightness-looseness. Third, this study explored the mediating effect of implementation intention and the moderating effect of perceived cultural tightness-looseness. It reveals mechanisms behind individuals' compliance, which extends PMT. Prior research has suggested that PMT effectively predicted individuals' preventive behaviors against the COVID-19 pandemic (26). However, limited research has explored how protection motivation affects individuals' preventive behaviors. To reveal the mechanism, the current study examined the moderated mediating effect, among which implementation intention and perceived cultural tightness-looseness served as the mediator and moderator, respectively. These findings significantly contribute to the literature on PMT and on COVID-19 pandemic prevention and control.

In terms of practical implications, this study revealed the influencing factors and mechanisms behind individuals' compliance. The findings contribute to understanding individuals' compliance, while also providing some practical evidence to promote individuals to follow the government's precautions against the COVID-19 pandemic. First, media exposure significantly influenced threat and coping appraisals, which, in turn, shaped protection motivation. Multimedia channels could be adopted to disseminate information about the COVID-19 pandemic. As such, individuals would be exposed to more relevant information and form correct cognition of the COVID-19 pandemic and preventive measures. Second, protection motivation positively predicted individuals' compliance *via* the mediation of implementation intention. Individuals should be encouraged to establish specific implementation intentions, which helps individuals transform protection motivation into actual preventive behaviors. Third, perceived cultural tightness-looseness positively influenced implementation intention. Moreover, it played a significant moderating effect named interference or antagonistic interaction. It suggests that during regular prevention and control, a moderate tight culture should be created, and it is inappropriate to overemphasize social norms. In this way, protection motivation would have a relatively high effect on implementation intention. Meanwhile, implementation intention would play a relatively large role in promoting individuals to comply with the government's recommendations.

However, this study has some limitations that should be addressed in future research. First, the study was conducted in the Chinese cultural context, which represents a definite tight culture. All findings, particularly the role of perceived cultural tightness-looseness, were specific to individuals in the context of Chinese culture. Thus, researchers should be cautious while generalizing our findings to other cultural contexts, especially to loose cultures. Future research should apply our proposed theoretical model to other cultural contexts to examine the applicability and explanation of the model. Second, this study investigated individuals' compliance with the government's recommendations. However, it did not examine government-related influencing factors that may serve as potential antecedents of individuals' obedience. Future research should consider government-related influencing factors and explore how these factors affect individuals' compliance.

6. Conclusion

This study provides a theoretical and empirical basis for predicting individuals' compliance with the government's recommended preventive measures during the regular prevention and control phase of the COVID-19 pandemic. The findings indicate that media exposure to COVID-19-related information positively predict perceived severity, self-efficacy, and response efficacy, whereas it is negatively associated with maladaptive rewards and response cost. Furthermore, perceived severity, self-efficacy, and response efficacy positively influence protection motivation, which, in turn, promotes individuals' compliance. More importantly, we revealed a moderated mediating mechanism behind individuals' compliance. Specifically, when individuals

perceived high cultural tightness-looseness, the positive effect of protection motivation on implementation intention gradually decreased; likewise, the mediating effect of implementation intention between protection motivation and individuals' compliance exhibited a decreasing trend. These findings lead to several contributions. On the one hand, this study addressed the research gap regarding individuals' compliance with the government's recommendations during regular prevention and control. On the other hand, this study expands PMT *via* integrating perceived cultural tightness-looseness in the context of COVID-19 pandemic prevention and control. We also offer several suggestions to promote individuals' compliance with the government's recommendations. We hope future research will continue to explore more potential influencing factors and mechanisms behind individuals' compliance with the government's recommended preventive measures.

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

YL: research designing, data collection, analysis, writing and revision, and supervision. XJ: data collection, analysis, and writing and revision. All authors contributed to this study and approved the submitted version.

Funding

This study was supported by the Fundamental Research Funds for the Central Universities of China (Nos. 2021CDJSKJC35 and 2020CDSKXYXW008).

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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1043247/full#supplementary-material

References

1. Zhang L, Cai H, Bai W, Zou SY, Feng KX Li YC, et al. Prevalence of suicidality in clinically stable patients with major depressive disorder during the C OVID-19 pandemic. *J Affect Disord.* (2022) 307:142–8. doi: 10.1016/j.jad.2022.03.042

2. Huang S, Liu H. Impact of COVID-19 on stock price crash risk: evidence from Chinese energy firms. *Energ Econ.* (2021) 101:105431. doi: 10.1016/j.eneco.2021.105431

3. Anderson RM, Heesterbeek H, Klinkenberg D, Hollingsworth TD. How will country-based mitigation measures influence the course of the COVID-19 epidemic? *Lancet.* (2020) 395:931–4. doi: 10.1016/S0140-6736(20)30567-5

4. Zheng Y, Xiao L, Xie Y, Wang H, Wang G. Prevalence and characteristics of obsessive-compulsive disorder among urban residents in Wuhan during the stage of regular control of coronavirus disease-19 epidemic. *Front Psychiatry.* (2020) 11:594167. doi: 10.3389/fpsyt.2020.594167

5. Wu Z, Chen Z, Long S, Wu A, Wang H. Incidence of pulmonary tuberculosis under the regular COVID-19 epidemic prevention and control in China. *BMC Infect Dis.* (2022) 22:641. doi: 10.1186/s12879-022-07620-y

6. Centers for Disease Control and Prevention. *COVID-19 Prevention Guidelines* (2021). Available online at: http://www.nhc.gov.cn/jkj/s5898bm/202109/42c94a375a9d4b3ab186573f53ccd481.shtml (accessed July 28, 2022).

7. Pakpour AH, Liu CH, Hou WL, Chen YP, Li YP, Kuo YJ, et al. Comparing fear of COVID-19 and preventive COVID-19 infection behaviors between Iranian and Taiwanese older people: early reaction may be a key. *Front Public Health.* (2021) 9:740333. doi: 10.3389/fpubh.2021.740333

8. Šurina S, Martinsone K, Perepjolkina V, Kolesnikova J, Vainik U, RuŽa A, et al. Factors related to COVID-19 preventive behaviors: a structural equation model. *Front Psychol.* (2021) 12:676521. doi: 10.3389/fpsyg.2021.676521

9. Jiang Z, Wang S, Shen Z, Zhao X, Wang F, Chen Y, et al. Nurses' experience of work stress related to COVID-19 regular prevention and control in China: a qualitative study. *J Nurs Manag.* (2022) 30:375–83. doi: 10.1111/jonm.13528

10. Rogers RW. A protection motivation theory of fear appeals and attitude change[1]. *J Psychol.* (1975) 91:93–114. doi: 10.1080/00223980.1975.9915803

11. Yazdanpanah M, Abadi B, Komendantova N, Zobeidi T, Sieber S. Some at risk for COVID-19 are reluctant to take precautions, but others are not: a case from rural in Southern Iran. *Front Public Health.* (2020) 8:562300. doi: 10.3389/fpubh.2020.562300

12. Lahiri A, Jha SS, Chakraborty A, Dobe M, Dey A. Role of threat and coping appraisal in protection motivation for adoption of preventive behavior during COVID-19 pandemic. *Front Public Health.* (2021) 9:678566. doi: 10.3389/fpubh.2021.678566

13. Zhang XA. Understanding the cultural orientations of fear appeal variables: a cross-cultural comparison of pandemic risk perceptions, efficacy perceptions, and behaviors. *J Risk Res.* (2021) 24:432–48. doi: 10.1080/13669877.2021.1887326

14. Tsoy D, Godinic D, Tong Q, Obrenovic B, Khudaykulov A, Kurpayanidi K. Impact of social media, extended parallel process model (EPPM) on the intention to stay at home during the COVID-19 pandemic. *Sustainability.* (2022) 14:7192. doi: 10.3390/su14127192

15. Demirtaş-Madran HA. Accepting restrictions and compliance with recommended preventive behaviors for COVID-19: a discussion based on the key approaches and current research on fear appeals. *Front Psychol.* (2021) 12:558437. doi: 10.3389/fpsyg.2021.558437

16. Ezati Rad R, Mohseni S, Kamalzadeh Takhti H, Hassani Azad M, Shahabi N, Aghamolaei T, et al. Application of the protection motivation theory for predicting COVID-19 preventive behaviors in Hormozgan, Iran: a cross-sectional study. *BMC Public Health.* (2021) 21:1–11. doi: 10.1186/s12889-021-10500-w

17. He M, Chen JH, Wu AMS, Tong KK. Intention to maintain and willingness to stop: applying a dual-process model to understanding the maintenance of COVID-19 preventive behaviors. *Appl Psychol Health Well Being.* (2022) 15:1–22. doi: 10.1111/aphw.12381

18. Gelfand MJ, Nishii LH, Raver JL. On the nature and importance of cultural tightness-looseness. *J Appl Psychol.* (2006) 91:1225–44. doi: 10.1037/0021-9010.91.6.1225

19. Zhao X, Knobel P. Face mask wearing during the COVID-19 pandemic: comparing perceptions in China and three European countries. *Transl Behav Med.* (2021) 11:1199–204. doi: 10.1093/tbm/ibab043

20. Anaki D, Sergay J. Predicting health behavior in response to the coronavirus disease (COVID-19): worldwide survey results from early March 2020. *PLoS ONE.* (2021) 16:e0244534. doi: 10.1371/journal.pone.0244534

21. Giannouchos TV, Steletou E, Saridi M, Souliotis K. Mandatory vaccination support and intentions to get vaccinated for COVID-19: results from a nationally representative general population survey in October 2020 in Greece. *J Eval Clin Pract.* (2021) 27:996–1003. doi: 10.1111/jep.13588

22. Qin JJ, Xing YF, Ren JH, Chen YJ, Gan YF, Jiang YQ, et al. Mandatory mask-wearing and hand hygiene Associated with decreased infectious diseases among patients undergoing regular hemodialysis: a historical-control study. *Front Public Health.* (2021) 9:678738. doi: 10.3389/fpubh.2021.678738

23. Rogers RW. Cognitive and psychological processes in fear appeals and attitude change: a revised theory of protection motivation. *Social Psychophysiology: A sourcebook.* (1983) 19:153–76.

24. Milne S, Sheeran P, Orbell S. Prediction and intervention in health-related behavior: a meta-analytic review of protection motivation theory. *J Appl Soc Psychol.* (2000) 30:106–43. doi: 10.1111/j.1559-1816.2000.tb02308.x

25. Babazadeh T, Nadrian H, Banayejeddi M, Rezapour B. Determinants of skin cancer preventive behaviors among rural farmers in Iran: an application of protection motivation theory. *J Cancer Educ.* (2017) 32:604–12. doi: 10.1007/s13187-016-1004-7

26. Kowalski RM, Black KJ. Protection motivation and the COVID-19 virus. *Health Commun.* (2021) 36:15–22. doi: 10.1080/10410236.2020.1847448

27. Maddux JE, Rogers RW. Protection motivation and self-efficacy: a revised theory of fear appeals and attitude change. *J Exp Soc Psychol.* (1983) 19:469–79. doi: 10.1016/0022-1031(83)90023-9

28. Li XG. Media exposure, perceived efficacy, and protective behaviors in a public health emergency. *Int J Commun-US.* (2018) 12:2641–60.

29. Lewis N, Eliash H. Exposure to risk information detail (RID) in news coverage of anorexia increases self-efficacy to perform risky behaviors. *Health Commun.* (2022) 37:708–16. doi: 10.1080/10410236.2020.1864890

30. Truong NX, Ngoc BH, Ha NT. The impacts of media exposure on COVID-19 preventive behaviors among Vietnamese people: evidence using expanded protection motivation theory. *Sage Open.* (2022) 12:1–13. doi: 10.1177/21582440221096129

31. Ranjit YS, Shin H, First JM, Houston JB. COVID-19 protective model: the role of threat perceptions and informational cues in influencing behavior. *J Risk Res.* (2021) 24:449–65. doi: 10.1080/13669877.2021.1887328

32. Melki J, Tamim H, Hadid D, Farhat S, Makki M, Ghandour L, et al. Media exposure and health behavior during pandemics: the mediating effect of perceived knowledge and fear on compliance with COVID-19 prevention measures. *Health Commun.* (2022) 37:586–96. doi: 10.1080/10410236.2020.1858564

33. Al-Hasan A, Khuntia J, Yim D. Threat, coping, and social distance adherence during COVID-19: cross-continental comparison using an online cross-sectional survey. *J Med Internet Res.* (2022) 22:e23019. doi: 10.2196/23019

34. Tsoy D, Tirasawasdichai T, Kurpayanidi KI. Role of social media in shaping public risk perception during COVID-19 pandemic: a theoretical review. *Int J Manag Sci Bus Admin.* (2021) 7:35–41. doi: 10.18775/ijmsba.1849-5664-5419.2014.72.1005

35. Bandura A. Social cognitive theory of mass communication. *Media Psychol.* (2001) 3:265–99. doi: 10.1207/S1532785XMEP0303_03

36. Rimal RN. Closing the knowledge-behavior gap in health promotion: the mediating role of self-efficacy. *Health Commun.* (2000) 12:219–37. doi: 10.1207/S15327027HC1203_01

37. Farooq A, Laato S, Islam AKMN. Impact of online information on self-isolation intention during the COVID-19 pandemic: cross-sectional study. *J Med Internet Res.* (2020) 22:e19128. doi: 10.2196/19128

38. Chen YL, Lin YJ, Chang YP, Chou WJ, Yen CF. Differences in the protection motivation theory constructs between people with various latent classes of motivation for vaccination and preventive behaviors against COVID-19 in Taiwan. *Int J Env Res Pub He.* (2021) 18:7042. doi: 10.3390/ijerph18137042

39. Grano C, Singh Solorzano C, Di Pucchio A. Predictors of protective behaviors during the Italian COVID-19 pandemic: an application of protection motivation theory. *Psychol Health.* (2022) 4:1–21. doi: 10.1080/08870446.2022.2062355

40. Ajzen I. The theory of planned behavior. *Organ behav Hum Dec.* (1991) 50:179–211. doi: 10.1016/0749-5978(91)90020-T

41. Sutton S. Predicting and explaining intentions and behavior: how well are we doing? *J Appl Soc Psychol.* (1998) 28:1317–38. doi: 10.1111/j.1559-1816.1998.tb01679.x

42. Gollwitzer PM. Implementation intentions: strong effects of simple plans. *Am Psychologist.* (1999) 54:493–503. doi: 10.1037/0003-066X.54.7.493

43. Milkman KL, Beshears J, Choi JJ, Madrian BC. Using implementation intentions prompts to enhance influenza vaccination rates. *P Natl A Sci.* (2011) 108:10415–20. doi: 10.1073/pnas.1103170108

44. Ziegelmann JP, Luszczynska A, Lippke S, Schwarzer R. Are goal intentions or implementation intentions better predictors of health behavior? A longitudinal study in orthopedic rehabilitation. *Rehabil Psychol.* (2007) 52:97–102. doi: 10.1037/0090-5550.52.1.97

45. Gollwitzer PM. Goal achievement: the role of intentions. *Eur Rev Soc Psychol.* (1993) 4:141–85. doi: 10.1080/14792779343000059

46. Ort A, Fahr A. Mental contrasting with implementation intentions as a technique for media-mediated persuasive health communication. *Health Psychol Rev.* (2021) 16:1–20. doi: 10.1080/17437199.2021.1988866

47. Pfeffer I, Strobach T. Executive functions, trait self-control, and the intention-behavior gap in physical activity behavior. *J Sport Exercise Psy.* (2017) 39:277–92. doi: 10.1123/jsep.2017-0112

48. Chan DKS. Tightness-looseness revisited: some preliminary analyses in Japan and the United States. *Int J Psychol.* (1996) 31:1–12. doi: 10.1080/002075996401179

49. McEachan RRC, Conner M, Taylor NJ, Lawton RJ. Prospective prediction of health-related behaviours with the theory of planned behaviour: a meta-analysis. *Health Psychol Rev.* (2011) 5:97–144. doi: 10.1080/17437199.2010.521684

50. Frounfelker RL, Santavicca T, Li ZY, Miconi D, Venkatesh V, Rousseau C. COVID-19 experiences and social distancing: insights from the theory of planned behavior. *Am J Health Promot.* (2021) 35:1095–104. doi: 10.1177/08901171211020997

51. Schmidt-Petri C, Schröder C, Okubo T, Graeber D, Rieger T. Social norms and preventive behaviors in Japan and Germany during the COVID-19 pandemic. *Front Public Health.* (2022) 10:842177. doi: 10.3389/fpubh.2022.842177

52. Gilliam A, Schwartz DB, Godoy R, Boduroglu A, Gutchess A. Does state tightness-looseness predict behavior and attitudes early in the COVID-19 pandemic in the USA? *J Cross cult Psychol.* (2022) 53:522–42. doi: 10.1177/00220221221077710

53. Dong D, Chen Z, Zong M, Zhang P, Gu W, Feng Y, et al. What protects us against the COVID-19 threat? Cultural tightness matters. *BMC Public Health.* (2021) 21:1–11. doi: 10.1186/s12889-021-12161-1

54. Tang Z, Chen L, Zhou Z, Warkentin M, Gillenson ML. The effects of social media use on control of corruption and moderating role of cultural tightness-looseness. *Gov Inform Q.* (2019) 36:101384. doi: 10.1016/j.giq.2019.06.001

55. Slater MD. Operationalizing and analyzing exposure: the foundation of media effects research. *J Mass Commun Q.* (2004) 81:168–83. doi: 10.1177/107769900408100112

56. Liu M, Zhang H, Huang H. Media exposure to COVID-19 information, risk perception, social and geographical proximity, and self-rated anxiety in China. *BMC Public Health.* (2020) 20:1–8. doi: 10.1186/s12889-020-09761-8

57. Prasetyo YT, Castillo AM, Salonga LJ, Sia JA, Seneta JA. Factors affecting perceived effectiveness of COVID-19 prevention measures among Filipinos during enhanced community quarantine in Luzon, Philippines: integrating protection motivation theory and extended theory of planned behavior. *Int J Infect Dis.* (2020) 99:312–23. doi: 10.1016/j.ijid.2020.07.074

58. Kim J, Yang K, Min J, White B. Hope, fear, and consumer behavioral change amid COVID-19: application of protection motivation theory. *Int J Consum Stud.* (2022) 46:558–74. doi: 10.1111/ijcs.12700

59. Hodgkins S, Orbell S. Can protection motivation theory predict behavior? A longitudinal test exploring the role of previous behavior. *Psychol Health.* (1998) 13:237–50. doi: 10.1080/08870449808406749

60. Ling M, Kothe EJ, Mullan BA. Predicting intention to receive a seasonal influenza vaccination using protection motivation theory. *Soc Sci Med.* (2019) 233:87–92. doi: 10.1016/j.socscimed.2019.06.002

61. Gelfand MJ, Raver JL, Nishii L, Leslie LM, Lun J, Lim BC, et al. Differences between tight and loose cultures: a 33-nation study. *Science.* (2011) 332:1100–4. doi: 10.1126/science.1197754

62. Wheaton B. Assessment of fit in overidentified models with latent variables. *Sociol Methods Res.* (1987) 16:118–54. doi: 10.1177/0049124187016001005

63. Bentler PM, Bonett DG. Significance tests and goodness of fit in the analysis of covariance structures. *Psychol Bull.* (1980) 88:588. doi: 10.1037/0033-2909.88.3.588

64. Steiger JH. Structural model evaluation and modification: an interval estimation approach. *Multivar Behav Res.* (1990) 25:173–80. doi: 10.1207/s15327906mbr2502_4

65. Hu L, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct Equ Modeling.* (1999) 6:1–55. doi: 10.1080/10705519909540118

66. Tabachnick BG, Fidell LS, Ullman JB. *Using Multivariate Statistics*. Boston, MA: Pearson (2007).

67. Bagozzi RP, Yi Y. On the evaluation of structural equation models. *J Acad Market Sci.* (1998) 16:74–94. doi: 10.1007/BF02723327

68. Yin N. The influencing outcomes of job engagement: an interpretation from the social exchange theory. *Int J Product Perfor.* (2018) 67:873–89. doi: 10.1108/IJPPM-03-2017-0054

69. Fornell C, Larcker DF. Structural equation models with unobservable variables and measurement error: algebra and statistics. *J Marketing Res.* (1981) 18:382–8. doi: 10.1177/002224378101800313

70. James WL, Hatten KJ. Further evidence on the validity of the self typing paragraph approach: miles and snow strategic archetypes in banking. *Strategic Manage J.* (1995) 16:161–8. doi: 10.1002/smj.4250160206

71. Maslowsky J, Jager J, Hemken D. Estimating and interpreting latent variable interactions: a tutorial for applying the latent moderated structural equations method. *Int J Behav Dev.* (2015) 39:87–96. doi: 10.1177/0165025414552301

72. Sardeshmukh SR, Vandenberg RJ. Integrating moderation and mediation: a structural equation modeling approach. *Organ Res Methods.* (2017) 20:721–45. doi: 10.1177/1094428115621609

73. World Health Organization. *General's Opening Remarks at the Media Briefing on COVID-19.* Available online at: https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarksat-the-media-briefing-on-covid-19-$-$11-march-2020 (accessed July 28, 2022).

74. Floyd D L, Prentice-Dunn S, Rogers RW. A meta-analysis of research on protection motivation theory. *J Appl Soc Psychol.* (2000) 30:407–29. doi: 10.1111/j.1559-1816.2000.tb02323.x

75. Adriaanse MA, de Ridder DTD, de Wit JBF. Finding the critical cue: implementation intentions to change one's diet work best when tailored to personally relevant reasons for unhealthy eating. *Pers Soc Psychol B.* (2009) 35:60–71. doi: 10.1177/0146167208325612

76. Cohen J, Cohen P, West SG, Aiken LS. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences.* 3rd edn. New York, NY: Lawrence Erlbaum Associates (2003).

77. Hofstede G. *Culture's Consequences: International Differences in Work-related Values*. London: Sage (1984).

78. Gao L, Deng X, Yang W, Fang J. COVID-19 related stressors and mental health outcomes of expatriates in international construction. *Front Public Health.* (2022) 2257:e961726. doi: 10.3389/fpubh.2022.961726

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 21 March 2023
DOI 10.3389/fpubh.2023.960500

OPEN ACCESS

EDITED BY
Pier Luigi Sacco,
University of Studies G. d'Annunzio Chieti and Pescara, Italy

REVIEWED BY
Amin Talebi Bezmin Abadi,
Tarbiat Modares University, Iran
Fatemeh Baghernezhad Hesary,
Birjand University of Medical Sciences, Iran

*CORRESPONDENCE
Romi Bhakti Hartarto
✉ romi.hartarto@umy.ac.id

†PRESENT ADDRESS
Rakhmat Ari Wibowo,
Moray House School of Education and Sport, The University of Edinburgh, Edinburgh, United Kingdom

SPECIALTY SECTION
This article was submitted to Infectious Diseases: Epidemiology and Prevention, a section of the journal Frontiers in Public Health

RECEIVED 07 June 2022
ACCEPTED 24 February 2023
PUBLISHED 21 March 2023

CITATION
Wibowo RA, Hartarto RB, Bhattacharjee A, Wardani DTK, Sambodo NP, Santoso Utomo P, Annisa L, Hakim MS, Sofyana M and Dewi FST (2023) Facilitators and barriers of preventive behaviors against COVID-19 during Ramadan: A phenomenology of Indonesian adults. *Front. Public Health* 11:960500. doi: 10.3389/fpubh.2023.960500

Facilitators and barriers of preventive behaviors against COVID-19 during Ramadan: A phenomenology of Indonesian adults

Rakhmat Ari Wibowo[1†], Romi Bhakti Hartarto[2*], Arnab Bhattacharjee[3,4], Dyah Titis Kusuma Wardani[2], Novat Pugo Sambodo[5,6], Prattama Santoso Utomo[7], Luthvia Annisa[8], Mohamad Saifudin Hakim[8], Meida Sofyana[1] and Fatwa Sari Tetra Dewi[9]

[1]Department of Physiology, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia, [2]Department of Economics, Faculty of Economics and Business, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia, [3]Edinburgh Business School, Heriot-Watt University, Edinburgh, United Kingdom, [4]The National Institute of Economic and Social Research, London, United Kingdom, [5]Center for Health Financing Policy and Health Insurance Management, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia, [6]Department of Economics, Faculty of Economics and Business, Universitas Gadjah Mada, Yogyakarta, Indonesia, [7]Department of Medical Education and Bioethics, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia, [8]Department of Microbiology, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia, [9]Department of Health Behavior, Environment and Social Medicine, Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia

Introduction: Intercity mobility restriction, physical distancing, and mask-wearing are preventive behaviors to reduce the transmission of COVID-19. However, strong cultural and religious traditions become particular challenges in Indonesia. This study uses the Behavior Change Wheel to explore barriers and facilitators for intercity mobility restriction, physical distancing, and mask-wearing during Ramadan.

Methods: Semi-structured in-depth interviews with 50 Indonesian adults were conducted between 10 April and 4 June 2020. Having mapped codes into the Capacity, Opportunity, Motivation – Behavior (COM-B), and Theoretical Domain Framework (TDF) model, we conducted summative content analysis to analyze the most identified factors to preventive behaviors and proposed interventions to address those factors.

Results: Belief about the consequence of preventive behaviors was the most mentioned facilitator to all preventive behaviors among compliers. However, optimism as a TDF factor was commonly mentioned as a barrier to preventive behaviors among non-compliers, while environmental context and resources were the most commonly mentioned factors for intercity mobility restriction.

Conclusions: Public health intervention should be implemented considering the persuasion and involvement of religious and local leaders. Concerning job and economic context, policy related to the intercity mobility restriction should be reconsidered to prevent a counterproductive effect.

KEYWORDS

COVID-19, preventive behavior, mobility restriction, physical distancing, face mask

1. Introduction

The occurrence of novel coronavirus disease 2019 (COVID-19) caused by infection of SARS-CoV-2 viruses has spread dramatically worldwide since its first cluster of cases was reported in December 2019 in Wuhan city, Hubei Province, China. It is a highly transmissible disease that is primarily transmitted via droplets from sneezing or coughing and via fomites and airborne aerosols in certain situations (1–6). Due to the high transmission of COVID-19 to many countries with a continuous and high rise in morbidity and mortality, the WHO has declared a public health emergency since January 30, 2020. Given that there was no vaccine or effective pharmaceutical treatment at that time, behavioral interventions promoting hand washing, physical distancing, and wearing a face mask were recommended to reduce the SARS-CoV-2 transmission (7, 8). In addition, international public health officials have proposed several cordon-sanitaire measures to mitigate the virus transmission, such as lockdowns, strict quarantine measures, and restraining flights from and to infected countries (9, 10). However, it took many more weeks for many countries to implement precautionary measures, including Indonesia.

Official data report that the severity of COVID-19 has been less alarming in Indonesia than that in many other countries. The Indonesian Government was at first condemned for not responding promptly and obviously to the emergence of the COVID-19 outbreak (11–13). When two neighboring countries, Malaysia and Singapore, observed sharp growth in the COVID-19 spread, Indonesia claimed to have zero cases throughout February 2020 (14). Only on March 2, 2020, the first two confirmed cases were reported in Indonesia. The Indonesian Government ruled out lockdowns, highlighting their severe economic impact in India. The Government then opted to promote some preventive behaviors to reduce the transmission of COVID-19, such as frequent handwashing with soap or hand sanitizer, wearing a face mask, and applying physical distancing. People were also encouraged to stay at home and work from home to reduce physical contact between infected and uninfected individuals. While the health promotion successfully increased public handwashing practice, public compliance with physical distancing and wearing a face mask was below the required level for curtailing the COVID-19 burden (15, 16). In the absence of stringent preventive measures, the confirmed cases of COVID-19 were subsequently found in all of Indonesia's 34 provinces only a month after the first reported case.

The Indonesian Government's efforts to curb the spread of COVID-19 became increasingly challenging, especially when it came to Ramadan and Eid Al-Fitr in May 2020. As a country with the largest Muslim population, Indonesia has some traditions during Ramadan and Eid Al-Fitr, such as homecoming, Ramadan dinner gathering, congregational night prayer, congregational Eid prayer, visiting cemeteries, and *halal bi halal* (asking forgiveness from one another by handshaking). All these traditions bring many people to the same place simultaneously, which consequently presents certain challenges to the efforts toward COVID-19 prevention in Indonesia.

To deter further transmission of COVID-19 to other regions, the Government decided to implement large-scale mobility restrictions by imposing a ban on homecoming activities 1 month before Eid Al-Fitr through Regulation of the Minister of Transportation No. 25 of 2020. Along with the two of the most prominent Islamic organizations (Muhammadiyah and Nahdlatul Ulama), The Government also suggested that all Muslims pray Eid at home rather than in the mosque or open space and encourage the public to comply with the preventive behaviors during the practice of cultural and religious tradition, such as allowing stretching out the prayer rows and wearing a face mask in congregational prayer during the pandemic situation. However, the COVID-19 National Task Force revealed that people neglected preventive measures and celebrated cultural and religious traditions, as usual, resulting in a spike in COVID-19 cases in Indonesia after Eid Al-Fitr (17, 18). The public adherence to preventive behaviors dropped further until the Government implemented a policy involving the local community, called micro-scale restrictions which were imposed on public activities. The situation is still relevant nowadays, especially when adherence to preventive behaviors continuously declined since the new year 2022 (19), followed by a dramatic upsurge of new daily cases caused by the omicron variants (20).

The present study explores how individuals respond to three precautionary measures of COVID-19 during the annual Ramadan month, including travel restrictions, physical distancing, and wearing face masks. Identifying what facilitates and obstructs compliance with preventive measures is pivotal to informing public health interventions and policies. Designing interventions and policies based on theoretical frameworks have been suggested to improve effectiveness (21). The Behavior Change Wheel (BCW) provides comprehensive tools for designing behavioral interventions (22). Assessing factors that influence behavior helps tailor behavior interventions (23, 24). The Capability, Opportunity, Motivation – Behavior (COM-B) model in the center of the BCW is adopted to identify facilitators and barriers of several health behaviors as a basis for designing behavioral interventions (25–30).

Different from the existing literature (31–33), this study examined preventive behaviors in a developing country with strong tradition and cultural factors in a particular annual religious event. The present study uses the COM-B model to explore the barriers and enablers of intercity mobility restriction, physical distancing, and wearing a mask and discuss the proposed interventions and policies to promote these preventive behaviors.

2. Methods

2.1. Study design

This qualitative research applied a phenomenology approach. Semi-structured interviews with Indonesian adults were conducted from 10 April to 4 June 2020. The phenomenology design was used to investigate individual experiences on COVID-19 preventive behaviors during Ramadan. The design aimed to enhance understanding of the various responses and perspectives on the particular phenomenon (34). This study has obtained ethical approval from the Medical and Health Research Ethics Committee of the Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada No: KE-FK-0788-EC-2020 and Social

Sciences Ethics Committee of Heriot-Watt University No. 2020-0433-1353. We reported our findings following the Standards for Reporting Qualitative Research (SRQR) checklist (35).

2.2. Informants and data collections

A purposive sampling technique was performed by five field epidemiologists representing five regions in Java to endeavor a maximum sample variation (i.e., age, work type and status, religion, ethnicity, income level, comorbidity, and region of domicile), hence opinions could be collected from multiple perspectives following the BCW framework (22, 36). Maximum variation of the sample might ensure the adequacy and authenticity of the obtained data (34). Participation in the interviews was voluntary so long as the informants met inclusion criteria such as being 18 years or older, willing to be contacted by phone for an interview, and living in Greater Jakarta, West Java, Central Java, Yogyakarta, or East Java.

The selection of the above areas is based on most of Indonesia's confirmed cases coming from Java, the most densely populated island in the country (37). The capital city of Jakarta was the epicenter of the pandemic, contributing half of the total positive cases in Indonesia during the first month, and even two-thirds if involving adjacent urban districts that constitute Greater Jakarta (38). Following Jakarta, West Java, Yogyakarta, Central Java, and East Java are other provinces in Java with high numbers of confirmed daily cases.

Study informants were purposively selected based on a database provided by the represented epidemiologist in each district using a quota system based on age, gender, work type and status, income level, comorbidity, and domicile. This study aimed to account for the heterogeneity of the informants about adherence to mobility restriction, physical distancing and wearing a face mask. All interviews used the local language (Java and Madura) and Bahasa Indonesia and were conducted by experienced interviewers who were familiar with the research topic and did not have any personal relationship with informants. Written consent was provided in advance of the interview, and verbal consent was carried out before commencing the interview. We started by interviewing ten informants, and various themes emerged in response to the interview questions. We stopped recruiting informants for interviews if we approached data saturation from recurring responses, i.e., additional informants did not reveal new themes (39). This resulted in 50 informants being interviewed, while interviews lasted between 40 and 60 min.

Semi-structured in-depth interviews were conducted since they were regarded as most appropriate for exploring informants' capacity, opportunity, and motivation to comply or not comply with mobility restrictions and other preventive measures. The semi-structured interview was chosen to ensure informants could express their thoughts without influence from others so the interview could capture more details than the focus group discussion (40, 41). Due to mobility restrictions and physical distancing measures during unusual conditions, the survey was carried out *via* phone interviews to prevent virus transmission.

The interview schedule consisting of open-ended questions and prompts was developed to explore informants' demographic information, general knowledge, perceived compliance to preventive behaviors, and perceptions of enablers and barriers to preventive behaviors. Additional probes and prompts were added based on new topics introduced by informants (42). Two epidemiology experts evaluated the relevance of the survey questions, and the interview guide was modified as suggested.

2.3. Analysis

The phone interviews were audio-recorded and transcribed verbatim into Bahasa Indonesia, then translated into English. Transcripts were iteratively coded using inductive thematic analysis to identify common perceptions and opinions, following the analysis process by Braun and Clarke (43). Audio recording and transcript files were stored in encrypted cloud storage. First, we assigned pseudonyms to protect the identities of informants. Then, RAW, a public health researcher, and RBH, a social science researcher, analyzed the interview transcripts independently to allow researcher triangulation. Each of them looked through the transcripts carefully and then generated label codes. Each code was noted as either "facilitators" or "barriers", depending on the context of the code captured from the informant. Each researcher also kept a reflective note to ensure an obvious coding process. The following process included comparing and cross-checking the coding by two researchers to agree upon common codes. Discrepancies in codes were discussed and resolved with the research team until a consensus was reached. This process ensured credibility and trustworthiness since no key themes were missed. Selected quotes from the informants about what would facilitate or hinder compliance toward mobility restriction and other preventive measures are presented in the results section.

Having reached an agreement on the codes, RAW and RBH independently categorized each code into fourteen domains using the Theoretical Domain Framework (TDF) and mapped it onto the COM-B components (22, 44). Discussion between researchers was conducted to resolve any difference in the TDF and COM-B model code mapping. After agreement on TDF and COM-B mapping had been made, RAW conducted the summative content analysis by discovering the occurrences of codes and calculating the frequency count of coding for each TDF and COM-B domain (45). RAW then made a rank-ordered TDF and COM-B domain according to the frequency coding to point out which TDF and COM-B components were the main facilitators and barriers to compliance with a mobility restriction, physical distancing, and wearing a mask behavior.

The COM-B model has been applied in various contexts (46–48). This model is introduced by Michie et al. (22), positing that people need capability (C), opportunity (O), and motivation (M) to effectuate a behavior (B). This model aims to guide understanding of behavior and develop behavioral targets to be a foundation for intervention design. The model suggests that for individuals to engage in a specific behavior (B), they must be psychologically and physically able (C) and supported by physical and social opportunity (O) to execute the behavior, while the motivation

TABLE 1 Characteristics of the participants.

Gender	Male	27
	Female	23
Age	>45	10
	≤ 45	40
Essential work	Yes	16
	No	34
Monthly income	Yes	33
	No	17
Above regional income	Yes	24
	No	14
	Prefer not to say	12
Presence of comorbid	Yes	47
	No	3
Level of education	Elementary degree	1
	High school degree	10
	College degree	20
	Prefer not to say	19
Domicile	Greater Jakarta	10
	West Java and Banten	10
	Central Java	10
	Yogyakarta	10
	East Java and Madura	10
Perceived their self as compliers to a mobility restriction	Yes	20
	No	30
Perceived their self as compliers to physical distancing	Yes	16
	No	34
Perceived their self as compliers to wearing a face mask	Yes	34
	No	16

encompasses basic drivers such as habit and impulses (automatic process) as well as intention and choice (reflective process). The COM-B model can be elaborated with more details by the TDF consisting of fourteen domains, allowing researchers to analyze the most important domain-specific aspects related to the target behavior (49–51). Analyzing the factors influencing the behavior will help design interventions based on nine intervention functions and seven policy categories (22).

3. Results

A total of fifty informants were interviewed (27 males, and 23 females). The percentage of informants who complied with the mobility restriction, physical distancing, and wearing a face mask behavior during the survey period was 40, 32, and 64%, respectively. Table 1 presents the demographic and other characteristics of informants.

3.1. Behavior analysis using the TDF and COM-B model

Table 2 reports the COM-B components' frequency that influences the intercity mobility restriction, physical distancing, and face mask-wearing behavior. In total, factors that influence physical distancing were mentioned 336 times, making this behavior have the highest number of mentioned factors while wearing a face mask has the least number of mentioned factors. There are some differences in the pattern of COM-B components as mentioned by compilers and non-compliers and the pattern of factors that influence each behavior. Among compliers, they mentioned more facilitators than barriers. In contrast, non-compliers mentioned more barriers than facilitators, except for wearing a face mask. Motivation was the most frequently mentioned facilitator of preventive behavior, except for the intercity mobility restriction since the most frequently mentioned facilitator among non-compliers was the opportunity.

The most commonly reported TDF domains that hinder the intercity mobility restriction were almost similar between compliers and non-compliers, including emotion, environmental context and resource, and social influence (Supplemental File 1). While the environmental context and resource domain was the most mentioned facilitator to the intercity mobility restriction among both compilers and non-compliers, this domain was also the most mentioned barrier to the physical distancing behavior. Belief about consequence was found in the top three mentioned facilitators to the intercity mobility restriction and physical distancing among compliers. However, this domain was not found in the top three mentioned facilitators to the other two preventive behaviors among non-compliers.

On the other hand, optimism was among the most commonly mentioned barriers to applying physical distancing and wearing a face mask among non-compliers. However, this domain was not found in the most commonly mentioned barriers to these two-preventive behaviors among compliers. Physical skill as the most mentioned barriers to wearing a face mask, emotion and belief about consequence as the most commonly mentioned facilitators to wearing a face mask were found among both compilers and non-compliers of this behavior. Meanwhile, memory was only mentioned in wearing a face mask behavior.

In total, the determinants of physical distancing were categorized into 56 sub-themes as preventive behavior with the most varied sub-themes compared to those of other preventive behaviors (Supplemental File 2). Intercity mobility restriction and wearing a face mask behavior only had 45, and 44 mentioned influencing factors, respectively.

3.2. Intercity mobility restriction

Concerning intercity mobility restriction, emotion, social influences, and environmental context and resources were the most commonly mentioned TDF domain, which hampers intercity mobility restriction (Figure 1). In addition to the environmental context and resource domain, compliers mentioned beliefs about consequence and emotion as their common facilitators. However, non-compliers mentioned reinforcement and social influences as their common facilitators.

10.3389/fpubh.2023.960500

TABLE 2 Summary of COM-B components.

Behavior	Compliance	Barriers			Facilitators		
		COM-B	Frequency of mentions	Percentage of mentions	COM-B	Frequency of mentions	Percentage of mentions
Mobility restriction	Compliers	Motivation	6	75%	Motivation	27	46%
		Opportunity	2	100%	Opportunity	26	44%
		Capability	0	0%	Capability	6	10%
	Total mentions		8			59	
	Non-compliers	Opportunity	70	63%	Opportunity	31	54%
		Motivation	42	37%	Motivation	24	42%
		Capability	3	3%	Capability	2	4%
	Total mentions		115			57	
Physical distancing	Compliers	Opportunity	18	75%	Motivation	33	40%
		Motivation	6	25%	Opportunity	28	34%
		Capability	0	0%	Capability	22	27%
	Total mentions		24			83	
	Non-compliers	Opportunity	66	52%	Motivation	45	48%
		Motivation	60	44%	Opportunity	38	40%
		Capability	9	7%	Capability	11	12%
	Total mentions		135			94	
Wearing a face mask	Compliers	Capability	29	88%	Motivation	77	53%
		Opportunity	4	11%	Opportunity	37	26%
		Motivation	2	6%	Capability	31	21%
	Total mentions		35			145	
	Non-compliers	Capability	20	59%	Motivation	29	67%
		Motivation	14	35%	Opportunity	12	28%
		Opportunity	6	15%	Capability	2	5%
	Total mentions		40			43	

Environmental context and resources domain was the most commonly mentioned factors influencing intercity mobility restriction. Job-related and transportation-related contexts could either facilitate or hinder informants from avoiding intercity mobility. On the other hand, participants perceived that they could not stay in the region if religious, family and cultural events were held in other regions during Ramadan and Eid Al-Fitr.

> "As Indonesians, normally we do homecoming for doing *sungkeman* (kneeling down) tradition." (Informant 019, M, <45 years old, the implementer of mobility restriction).
>
> "I have to travel between regions because my office is outside the region" (Participant 005, F, <45 years old, non-implementer of mobility restriction).

Informants mentioned that emotions such as boredom, homesickness, loneliness, and fear of planned lockdown had hindered them to stay in their area of residence. Belief about consequences, such as believing that staying in their region would protect them from COVID-19 infection and could end the pandemic, emerged as one of the most commonly mentioned facilitators of intercity mobility restriction.

> "I miss my wife since she works in Yogyakarta." (Informant 001, M, > 45 years old, Non-implementer of mobility restriction).
>
> "I remain staying in this city so that the pandemic will end soon." (Informant 002, F, >45 years old, Implementer of mobility restriction).

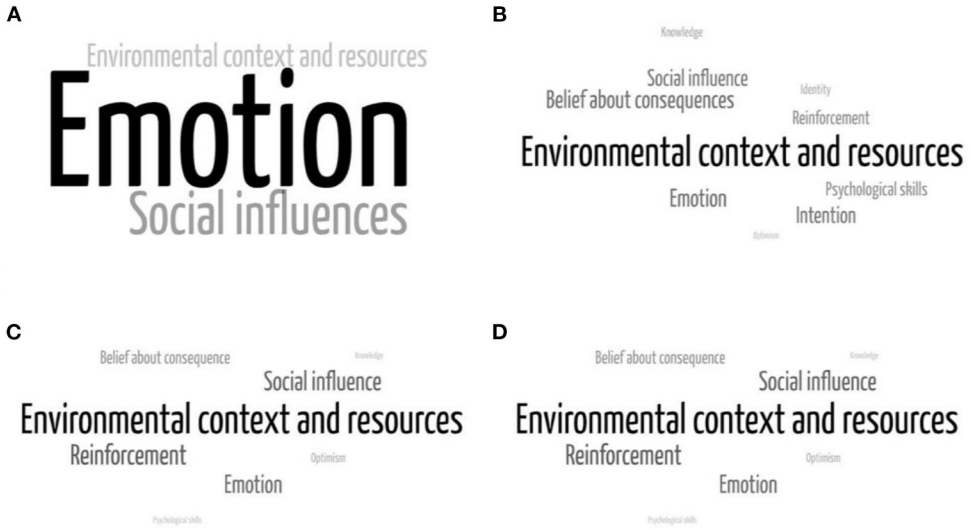


FIGURE 1
Factors influencing intercity mobility restriction: **(A)** barriers among compliers, **(B)** facilitators among compliers, **(C)** barriers among non-compliers, and **(D)** facilitators among compliers.

3.3. Physical distancing

Among both compilers and non-compliers, environmental context and resource domain were the most commonly mentioned either as barriers or facilitators. At the same time, social influence was the most commonly mentioned barrier to physical distancing behavior (Figure 2). In addition to the environmental and social influence domain, compliers mentioned emotion, while non-compliers, on the contrary, mentioned optimism as a barrier to physical distancing. Compliers also mentioned knowledge and belief about consequences as their facilitators to physical distancing behavior, while in contrast, emotion and social influence were mentioned by non-compliers as their facilitators.

Compliers mentioned their knowledge as a facilitator of physical distancing behavior. They perceived that they could do physical distancing because they knew how to implement it, the government advice on physical distancing, and the risk of COVID-19 transmission. Furthermore, instead of knowledge related to COVID-19, compliers also mentioned that their knowledge of home exercise and productive activities during leisure time could facilitate their compliance with physical distancing measures.

> "At Primary Health Care, I waited outside. When the convenience store was full, I also waited outside. I avoid such risks because I know, and I need to be able to keep my distance from other people. However, I know that each person has a different understanding." (Informant 001, >45 years old, the implementer of physical distancing).

Within the environmental context and resources domain, informants felt that public facilities-related context influenced their compliance with physical distancing. In addition to environmental context and resources, social influences, including influence from family, colleagues, neighbors, elders, religious leaders, and health experts, and cutting in-line culture, influenced informants' compliance with physical distancing.

> While in the bank, the queue has been arranged, so there is a safe distance. However, due to the many visitors, it was still impossible to perform physical distancing in the queue (Informant 007, M, <45 years old, non-implementer of physical distancing).
>
> During Friday prayers, the imam advised keeping the distance between the shaft. However, another imam instead asked to close the shaft during the Eid prayer (Participant 007, M, <45 years old, non-implementer of physical distancing).
>
> When I was at a restaurant, I couldn't keep my distance because people were crammed into the queue (Participant 013, M, <45 years old, non-implementer of physical distancing).

Compliers mentioned feeling awkward as their barrier to physical distancing. On the other hand, non-compliers mentioned that their sense of security hindered them from physical distancing *via* interaction with a close person, asymptomatic condition, zonation, and health screening results. In addition, their optimism that COVID-19 is not dangerous was also mentioned as a barrier to physical distancing measures. While the non-compliers mentioned fear of contracting and transmitting COVID-19 as their facilitators to apply safe distance to others, the compliers mentioned that their belief in physical distancing could protect them from COVID-19 infection, end the pandemic, provide benefits for family interaction, and grant religious rewards as their facilitators to apply physical distancing.

> "Physical distancing advice is in line with religious dogma which advises men to keep a distance from women and reduce unnecessary hanging out." (Informant 045, M, >45 years old, the implementer of physical distancing).

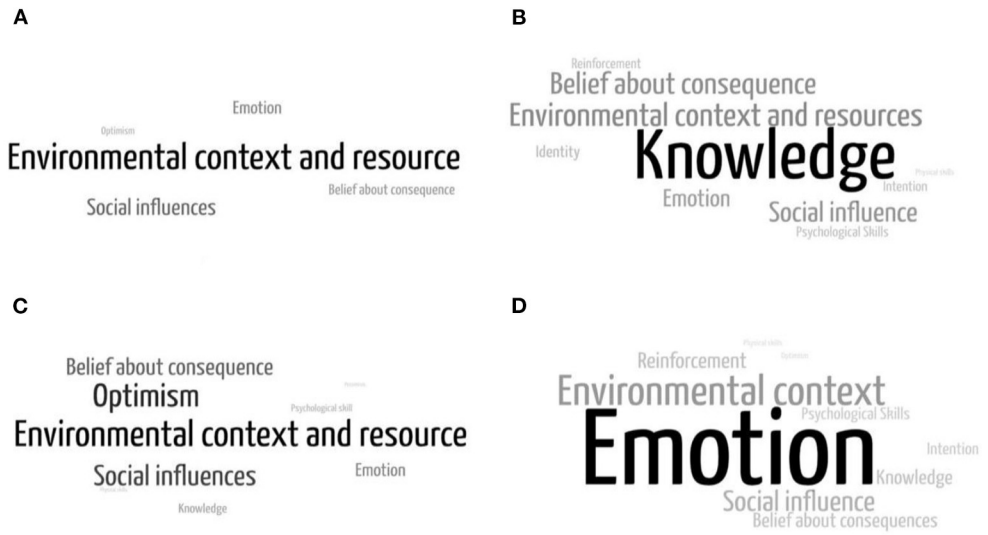


FIGURE 2
Factors influencing physical distancing: **(A)** barriers among compliers, **(B)** facilitators among compliers, **(C)** barriers among non-compliers, and **(D)** facilitators among compliers.

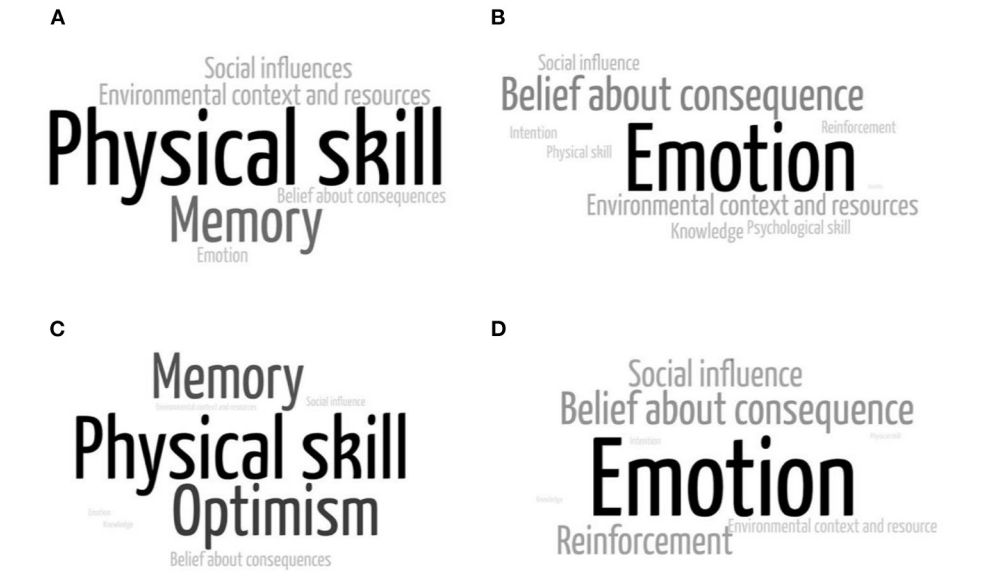


FIGURE 3
Factors influencing wearing a face mask: **(A)** barriers among compliers, **(B)** facilitators among compliers, **(C)** barriers among non-compliers, and **(D)** facilitators among compliers.

"I try to think positively because it can increase immunity so that I can avoid the disease without being bothered by physical distancing." (Participant 026, F, <45 years old, non-implementer of physical distancing).

"If possible, I will do physical distancing because it can protect myself and my family" (Participant 005, F, <45 years old, non-implementer of physical distancing).

3.4. Wearing a face mask

Physical skills and memory as barriers to wearing a face mask were mentioned among both compliers and non-compliers. In addition to physical skills and memory, compliers mentioned the environmental domain as their barrier to wearing a face mask. However, non-compliers mentioned optimism as their barrier to wearing a face mask (Figure 3). Among compliers, emotion, and

belief about consequences as well as environmental domain were mentioned as facilitators to wearing a face mask. Meanwhile, reinforcement was mostly found as a facilitator of wearing a face mask among non-compliers.

Both compilers and non-compliers mentioned some barriers to wearing a face mask, such as being harder to breathe, having difficulty in communication, wearing dewy glasses, causing pain in the ears, and carelessness. In addition to those barriers, a job that requires clear speaking and administrative work that prohibit face mask could deter compliers from wearing a face mask. Compliers also repeatedly mentioned a sense of security caused by the asymptomatic condition or close personal interaction and their belief that COVID-19 is not dangerous as a barrier to wearing a face mask. On the other hand, non-compliers mentioned fine for a facilitator to wear a face mask. In contrast, compilers mentioned environmental factors, including supply of masks, availability of reusable masks, comfortableness of masks, mask price, provision of masks in public and workplaces, availability of alternative objects to be used as a face masks, increase of COVID-19 cases in surrounding areas, and living together with people with comorbidities as their facilitators to wear a face mask.

> "Why do I have to wear a face mask? I feel healthy, so I will not carry the virus." (Informant 013, M, <45 years old, not adhere to wearing a face mask behavior).
>
> "In the village, I do not need to wear a mask. They are my neighbors, so it is relatively safe." (Informant 033, M, <45 years old, not adhere to wearing mask behavior).
>
> "I believe that COVID-19 is not dangerous. I do not follow government recommendations such as maintaining hand hygiene, limiting trips out of town, physical distancing, and wearing masks. My family and I have remained healthy now." (Informant 050, M, <45 years old, non-implementer of mobility restriction).

4. Discussion

Our current study investigated behavioral factors that influence three preventive measures for COVID-19, consisting of intercity mobility restriction, physical distancing, and wearing a face mask. Results from summative content analysis suggested the most commonly mentioned COM- B components and TDF domains as either facilitators or barriers to the three preventive behaviors based on compliance of the informants. The most prominent enablers and barriers to preventive behaviors can be used by practitioners and policymakers to choose to prioritize developing interventions and policies. Researchers can also use the identified determinants to further develop process models or determinant frameworks to guide practitioners in implementing preventive behaviors (52).

It could be seen that motivation factors, such as belief about consequences of the preventive behaviors, were the most frequently mentioned facilitator for either mobility restriction, physical distancing, and mask use behavior by compilers. In contrast, non-compliers were less frequently mentioned about motivation factors. This is consistent with results from other studies, which revealed that motivation for individual and community protection was the strongest facilitator of physical distancing and hand hygiene practice (31, 53). Previous studies highlighted the role of religious and community leaders in improving people's belief in the intended health behavior (54–56). In addition, informants also mentioned "social influences," indicating the importance of advice from religious and community leaders. Therefore, involving religious and community leaders is suggested to increase people's belief about the positive consequences of mobility restriction, physical distancing, and mask-wearing behavior through persuasion and modeling (22).

On the contrary, optimism, a TDF domain categorized in the motivation component, which consisted of a sense of security and perception that COVID-19 was not dangerous, was the most frequently mentioned barrier to physical distancing and mask use behaviors among non-compliers. This is consistent with other studies which found that biased risk assessment could prevent people from sustaining preventive behaviors (57–60). It is also in accordance with the data published by Statistics Indonesia (61), which revealed that more than a quarter of Indonesian confidently felt that they would not be infected with COVID-19. The COVID-19 characteristics, which take advantage of human optimism and the increasing number of misinformation, could worsen this situation (62–64). Persuasion to increase a good understanding of the perceived threat and empowering people to take preventive behaviors for threat reduction could be suggested to reduce unrealistic optimism as barriers for physical distancing and mask-wearing (22, 65–67).

Sense of security caused by other unjustified preventive behaviors, commonly mentioned as the barrier of physical distancing, and wearing a face mask in the optimism domain, should also be taken into consideration. Informants in a previous study also perceived that their belief in other preventive behaviors as sufficient measures could hamper them from complying with physical distancing measures (68). Intervention and policy should be designed to highlight and focus more on the prioritized preventive behaviors, including physical distancing and wearing a face mask. Inattentive intervention and policy might result in people choosing their favorable behaviors and neglecting the prioritized behaviors (69–72). In addition to including messaging to communicate perceived threats and involving religious and community leaders, persuasion should also use positive framing around physical distancing and wearing a face mask to improve people's adoption of these intended behaviors (73, 74). Positively framed messaging around physical distancing and wearing a face mask could include messages that these intended behaviors could effectively protect oneself, family, and community (74, 75). The needs for clear and appropriate messaging around physical distancing and wearing a face mask are still relevant nowadays when the COVID-19 vaccination coverage in Indonesia is still low (76). While the country is still confronted with challenges in improving the COVID-19 vaccine acceptance (77), appropriate messages for the COVID-19 vaccination, physical distancing, and wearing a face mask should be considered to prevent the reduction of adherence to physical distancing and wearing a face mask (78).

The need for health promotion message nudging motivation factors could be explained by the neuroscience process of human decisions on behavior. The neo-mammal brain, especially the

pre-frontal cortex (PFC), enables rationally driven behavior, and the paleo-mammal brain contributes altruistic qualities to the neocortex, including empathy, foresight, and conscience. The paleomammalian brain (limbic system) also plays a role in affective behavior, including emotions, both from the positive side (order, beliefs, and certain types of behaviors) and the negative side (need for power, egoism, intolerance, etc.). While the neo-mammalian brain maintains primitive brain functions by regulating the flow of its functions and even overriding it, the decision carried out by the neo-mammalian brain requires more complex cognitive function than the decision carried out by the paleomammalian brain, which is commonly influenced by emotional and other automatic motivation (79). In addition, our limited and incomplete information about COVID-19 could reduce the role of cognition; hence emotion dominates cognition in the process of decision-making (80).

Positively framed messaging about preventive behavior was also needed to override the influence of optimism as a barrier to preventive behavior. People tend to alter their beliefs to a greater extent in response to favorable compared with unfavorable information (81). For favorable information, stronger connectivity between the left inferior frontal gyrus (IFG) and left subcortical regions (including the amygdala, hippocampus, thalamus, putamen, and pallidum), insular cortex, is associated with greater change in belief. However, for unfavorable information, stronger connectivity between the left IFG and left pallidum, putamen, and insular cortex is associated with reduced beliefs (82).

Physical opportunities, such as job-related opportunities and economic context, emerged as barriers to mobility restriction among both compliers and non-compliers. Therefore, mobility restrictions should not be implemented in the long term since policies and interventions to modify barriers due to job-related and economic contexts were not feasible. In addition, implementing policy resulting in economic insecurity could be counterproductive to other preventive behaviors (30). While intercity travel restrictions might be useful for limiting the spread of COVID-19 in the early pandemic, other preventive behaviors such as physical distancing and mask-wearing had a bigger impact on reducing COVID-19 transmission (83). Implementation of health screening tests as a part of intercity mobility restrictions should also be evaluated. We found that some informants thought they did not need to wear a face mask and apply physical distancing since they felt a sense of security caused by the health screening test. A Cochrane systematic review also questioned the usefulness of the health screening test (84). It is because entry or exit screening without polymerase chain reaction (PCR) testing and subsequent quarantine and observation were not effectively detecting new cases to prevent transmission (84, 85).

In addition, implementing the COVID-19 screening test as a travel requirement is costly for society, and this requires national commitment and substantial additional financing. Although the fiscal, macroeconomic, and health benefits of rapid screening testing programs far exceed their costs (86), the signal value of the screening test itself is low, leading to more concerns about adherence. For some people, adherence is difficult because of living circumstances and financial-related matters. There are some concerns that low specificity (a high rate of false positives) would undercut the credibility of the screening program, reducing adherence to restrict mobility (85). Even with partial adherence to mobility restriction, low specificity would drag down the economy further by placing many health workers in isolation. Furthermore, low sensitivity allows infected individuals to fall through the cracks (85). These concerns raise questions about the public health and economic benefits of imperfect screening tests.

Overall, this study has notable strengths. First, this study draws on the triangulation metaphor and related epistemological and ontological perspectives, which determine analytic preferences and thus yield different forms of knowledge. This study shows how triangulating perspectives could extend individual-level results and how researchers should go beyond a descriptive level of analysis for convergent and inharmonious accounts to realize the potential of Multiple Perspective Interviews (MPIs). Triangulation of perspectives may be used to examine the same phenomenon from multiple perspectives and enrich understanding by allowing for new or deeper dimensions to emerge from the analysis. Second, the quality and quantity of samples in this study were collected with maximum variation (authenticity and adequacy). Third, qualitative analysis is contrasted with the COM-B model so that the findings can be meaningful for similar contexts (generalizability or resonance).

There are also several limitations to this study. The scope of the research is only Java and Madura, although economic, educational, religious, and occupational factors are representative, there are still other cultures, and differences in health facilities, technology, and infrastructure outside the two islands. The classification of compliance is only based on self-reported data; therefore, it is still subjective. Although direct observation is the best method, it is not possible to do it during the pandemic. Thus, several proxy questions were created to minimize subjectivity in this study. Respondent validations were not conducted because of the high number of informants. On the other hand, data saturation reached in 50 informants resulted in rich findings which represented our study's validity.

5. Conclusion

Identifying barriers and facilitators to preventive behaviors such as physical distancing and mask-wearing will be necessary for designing intervention and policy that aims to increase public adherence, especially when preparing for a future similar pandemic. Based on the most identified barriers and facilitators, persuasion and modeling involving religious leaders should be considered to improve public adherence to physical distancing and wearing a face mask. Concerning the opportunity factors that consist of the job and economic contexts, policy related to the intercity mobility restriction should be reconsidered to prevent a counterproductive result to other preventive behaviors.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the Medical and Health Research Ethics Committee of the Faculty of Medicine, Public Health, and Nursing UGM. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RW: conceptualization, methodology, investigation, formal analysis, visualization, writing—original draft, and writing—review and editing. RH: conceptualization, investigation, project administration, funding acquisition, and writing—review and editing. AB: conceptualization, methodology, writing—review and editing, and supervision. DW: project administration, investigation, and writing—review and editing. NS: conceptualization, investigation, and writing—review and editing. PS: methodology and writing—review and editing. LA: conceptualization and methodology. MH: conceptualization and writing—review and editing. FD: methodology. All authors contributed to the article and approved the submitted version.

Funding

This work was supported by the Global Challenges Research Fund – Scottish Funding Council, Heriot-Watt University [Grant agreement number Round N.3 COVID-19 SFC-GCRF 2019-2020 (Project ID 843259)]. This funding source had no role in the design of this study and will not have any role during its execution, analyses, interpretation of the data, or decision to submit results.

Acknowledgments

We would like to express our gratitude to Global Challenges Research Fund – Scottish Funding Council, Heriot-Watt University for providing the research grant. Our deep appreciation also goes to Prof. Rizal Yaya, the Dean of the Faculty of Economics and Business Universitas Muhammadiyah Yogyakarta and Dr. Ova Emilia, the Dean of the Faculty of Medicine, Public Health and Nursing Universitas Gadjah Mada, for supporting this research collaboration. Many thanks go to the questionnaire and interview respondents for their time and for making this research possible. Also, big thanks to all interviewers for collecting the data and research assistants for transcribing the interview records, and the staff of Klinik Bahasa in the Office of Research and Publication FKKMK UGM for proofreading the manuscript. Finally, we want to thank Dr. Corona Rintawan, Dr. Henry Surendra, Dr. Joko Mulyanto, and Prof. Sutaryo for their valuable suggestions.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.960500/full#supplementary-material

References

1. Noorimotlagh Z, Jaafarzadeh N, Martínez SS, Mirzaee SA. A systematic review of possible airborne transmission of the COVID-19 virus (SARS-CoV-2) in the indoor air environment. *Environ Res.* (2021) 193:110612. doi: 10.1016/j.envres.2020.110612

2. Rahman HS, Aziz MS, Hussein RH, Othman HH, Salih Omer SH, Khalid ES, et al. The transmission modes and sources of COVID-19: a systematic review. *Int J Surg Open.* (2020) 26:125–36. doi: 10.1016/j.ijso.2020.08.017

3. Tang JW, Marr LC, Li Y, Dancer SJ. COVID-19 has redefined airborne transmission. *BMJ.* (2021) 373:n913. doi: 10.1136/bmj.n913

4. Weber TP, Stilianakis NI. Fomites, hands, and the transmission of respiratory viruses. *J Occup Environ Hyg.* (2021) 18:1–3. doi: 10.1080/15459624.2020.1845343

5. Rahimi F, Abadi ATB. Implications of the emergence of a new variant of SARS-CoV-2, VUI-202012/01. *Arch Med Res.* (2021) 52:569–71. doi: 10.1016/j.arcmed.2021.01.001

6. Sanyaolu A, Okorie C, Marinkovic A, Haider N, Abbasi AF, Jaferi U, et al. The emerging SARS-CoV-2 variants of concern. *Ther Adv Inf Disease.* (2021) 8:20499361211024372. doi: 10.1177/20499361211024372

7. Prem K, Liu Y, Russell TW, Kucharski AJ, Eggo RM, Davies N, et al. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modeling study. *Lancet Public Heal.* (2020) 5: e261–70. doi: 10.1016/S2468-2667(20)30073-6

8. West R, Michie S, Rubin GJ, Amlôt R. Applying principles of behaviour change to reduce SARS-CoV-2 transmission. *Nat Hum Behav.* (2020) 4:451–9. doi: 10.1038/s41562-020-0887-9

9. Leung K, Wu JT, Liu D, Leung GM. First-wave COVID-19 transmissibility and severity in China outside Hubei after control measures, and second-wave scenario planning: a modelling impact assessment. *Lancet.* (2020) 395:1382–93. doi: 10.1016/S0140-6736(20)30746-7

10. Zhang S, Wang Z, Chang R, Wang H, Xu C, Yu X, et al. COVID-19 containment: China provides important lessons for global response. *Front Med.* (2020) 14:215–9. doi: 10.1007/s11684-020-0766-9

11. Chairil T. Indonesian government's COVID-19 measures, January-May 2020: Late response and public health securitization. *J Ilmu Sos dan Ilmu Polit.* (2020) 24:128–52. doi: 10.22146/jsp.55863

12. De Salazar P, Niehus R, Taylor A, Buckee C, Lipsitch M. Using predicted imports of 2019-nCoV cases to determine locations that may not be identifying all imported cases. *medRxiv.* (2020) 11:1–13. doi: 10.1101/2020.02.04.20020495

13. Djalante R, Lassa J, Setiamarga D, Sudjatma A, Indrawan M, Haryanto B, et al. Review and analysis of current responses to COVID-19 in Indonesia: period of January to March 2020. *Prog Disaster Sci.* (2020) 6:100091. doi: 10.1016/j.pdisas.2020.100091

14. Mahendradhata Y, Lestari T, Djalante R. Strengthening government's response to COVID-19 in Indonesia: a modified Delphi study of medical and health academics. *medRxiv*. (2020) 17:e20228270. doi: 10.1101/2020.11.09.20228270

15. Chang SL, Harding N, Zachreson C, Cliff OM, Prokopenko M. Modelling transmission and control of the COVID-19 pandemic in Australia. *Nat Commun.* (2020) 11:5710. doi: 10.1038/s41467-020-19393-6

16. Ngonghala CN, Iboi E, Eikenberry S, Scotch M, MacIntyre CR, Bonds MH, et al. Mathematical assessment of the impact of non-pharmaceutical interventions on curtailing the 2019 novel Coronavirus. *Math Biosci.* (2020) 325:108364. doi: 10.1016/j.mbs.2020.108364

17. Satuan Tugas Penanganan COVID-19. (2020). Available online at: https://covid19.go.id/p/berita/infografis-covid-19-26-mei-2020 (accessed November 11, 2020).

18. CNN Indonesia. (2020). Available online at: https://www.cnnindonesia.com/nasional/20210520062939-20-644516/kasus-prokes-dan-kecelakaan-masa-lebaran-2021-naik-100-persen (accessed November 12, 2020).

19. Satuan Tugas Penanganan COVID-19. https://covid19.go.id/monitoring-kepatuhan-protokol-kesehatan (accessed November 12, 2020).

20. Satuan Tugas Penanganan COVID-19. (2022). Available online at: https://covid19.go.id/artikel/2022/01/16/analisis-data-covid-19-indonesia-update-9-januari-2022 (accessed January 9, 2022).

21. Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ.* (2008) 337:a1655. doi: 10.1136/bmj.a1655

22. Michie S, Atkins L, West R. *The Behaviour Change Wheel: A Guide To Designing Interventions*. New York, NY: Silverback Publishing (2014).

23. Baker R, Camosso-Stefinovic J, Gillies C, Shaw EJ, Cheater F, Flottorp S, et al. Tailored interventions to address determinants of practice. *Cochrane Database Syst Rev.* (2015) 4:5470. doi: 10.1002/14651858.CD005470.pub3

24. Proctor EK, Powell BJ, Baumann AA, Hamilton AM, Santens RL. Writing implementation research grant proposals: ten key ingredients. *Implement Sci.* (2012) 7:1–13. doi: 10.1186/1748-5908-7-96

25. Connell LA, McMahon NE, Tyson SF, Watkins CL, Eng JJ. Mechanisms of action of an implementation intervention in stroke rehabilitation: a qualitative interview study. *BMC Health Serv Res.* (2016) 16:534. doi: 10.1186/s12913-016-1793-8

26. Courtenay M, Rowbotham S, Lim R, Peters S, Yates K, Chater A, et al. Examining influences on antibiotic prescribing by nurse and pharmacist prescribers: a qualitative study using the theoretical domains framework and COM-B. *BMJ Open.* (2019) 9:177. doi: 10.1136/bmjopen-2019-029177

27. Ellis K, Pears S, Sutton S. Behavioural analysis of postnatal physical activity in the UK according to the COM-B model: a multi-methods study. *BMJ Open.* (2019) 9:682. doi: 10.1136/bmjopen-2018-028682

28. Fulton E, Brown K, Kwah K, Wild S. StopApp: using the Behaviour Change Wheel to develop an app to increase uptake and attendance at NHS Stop Smoking Services. *Healthcare.* (2016) 4:31. doi: 10.3390/healthcare4020031

29. Handley MA, Harleman E, Gonzalez-Mendez E, Stotland NE, Althavale P, Fisher L, et al. Applying the COM-B model to creation of an IT-enabled health coaching and resource linkage program for low-income Latina moms with recent gestational diabetes: The STAR MAMA program. *Implement Sci.* (2016) 11:1–15. doi: 10.1186/s13012-016-0426-2

30. Ojo SO, Bailey DP, Hewson DJ, Chater AM. Perceived barriers and facilitators to breaking up sitting time among desk-based office workers: a qualitative investigation using the TDF and COM-B. *Int J Environ Res Public Health.* (2019) 16:903. doi: 10.3390/ijerph16162903

31. Coroiu A, Moran C, Campbell T, Geller AC. Barriers and facilitators of adherence to social distancing recommendations during COVID-19 among a large international sample of adults. *Capraro V, editor PLoS One.* (2020) 15:e0239795. doi: 10.1371/journal.pone.0239795

32. Shin SH, Ji H, Lim H. Heterogeneity in preventive behaviors during COVID-19: Health risk, economic insecurity, and slanted information. *Soc Sci Med.* (2021) 278:113944. doi: 10.1016/j.socscimed.2021.113944

33. Benham JL, Lang R, Burns KK, MacKean G, Léveillé T, McCormack B, et al. Attitudes, current behaviours and barriers to public health measures that reduce COVID-19 transmission: a qualitative study to inform public health messaging. *PLoS ONE.* (2021) 16:1–14. doi: 10.1371/journal.pone.0246941

34. Cristancho S, Goldszmidt M, Lingard L, Watling C. Qualitative research essentials for medical education. *Singapore Med J.* (2018) 59:622–7. doi: 10.11622/smedj.2018093

35. O'Brien BC, Harris IB, Beckman TJ, Reed DA, Cook DA. Standards for reporting qualitative research: a synthesis of recommendations. *Acad Med.* (2014) 89:1245–51. doi: 10.1097/ACM.0000000000000388

36. Braun V, Clarke V. *Successful Qualitative Research in Psychology: A Practical Guide for Beginners*. London: SAGE. (2013).

37. World Health Organization - Indonesia. https://cdn.who.int/media/docs/default-source/searo/indonesia/who-situation-report-2.pdf?sfvrsn=fc754e00_2 (accessed November 13, 2020).

38. Olivia S, Gibson J, Nasrudin R. Indonesia in the time of COVID-19. *Bull Indones Econ Stud.* (2020) 56:143–74. doi: 10.1080/00074918.2020.1798581

39. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Heal Care.* (2007) 19:349–57. doi: 10.1093/intqhc/mzm042

40. Kidd PS, Parshall MB. Getting the focus and the group: Enhancing analytical rigor in focus group research. *Qual Health Res.* (2000) 10:293–308. doi: 10.1177/104973200129118453

41. Leung FH, Savithiri R. Spotlight on focus groups. *Can Fam Physician.* (2009) 55:218–9.

42. DeJonckheere M, Vaughn LM. Semistructured interviewing in primary care research: a balance of relationship and rigour. *Family Med Commun Health.* (2019) 7:e000057. doi: 10.1136/fmch-2018-000057

43. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol.* (2006) 3:77–101. doi: 10.1191/1478088706qp063oa

44. Boyatzis R. *Transforming Qualitative Information*. London: SAGE Publications. (1998).

45. Hsieh HF, Shannon SE. Three approaches to qualitative content analysis. *Qual Health Res.* (2005) 15:1277–88. doi: 10.1177/1049732305276687

46. Jackson C, Eliasson L, Barber N, Weinman J. Applying COM-B to medication adherence: a suggested framework for research and interventions. *Bull Eur Heal Psychol Soc.* (2014) 16:7–17.

47. Barker F, Atkins L, Lusignan de. Applying the COM-B behaviour model and behaviour change wheel to develop an intervention to improve hearing-aid use in adult auditory rehabilitation. *Int J Audiol.* (2016) 55:S90–8. doi: 10.3109/14992027.2015.1120894

48. Hartarto RB, Wardani DTK, Azizurrohman M. A Qualitative study of conditional cash transfer and education aspirations: evidence from Yogyakarta. *J Soc Serv Res.* (2021) 47:1–10. doi: 10.1080/01488376.2021.1918314

49. Bussiere AE, Patey AM, Francis JJ, Sales AE, Grimshaw JM, Canada PRIme Plus Team. Identifying factors likely to influence compliance with diagnostic imaging guideline recommendations for spine disorders among chiropractors in North America: a focus group study using the theoretical domains framework. *Implement Sci.* (2012) 7:2–11. doi: 10.1186/1748-5908-7-82

50. Cane J, O'Connor D, Michie S. Validation of the theoretical framework. *Implement Sci.* (2012) 7:37. doi: 10.1186/1748-5908-7-37

51. Lake AJ, Browne JL, Rees G, Speight J. What factors influence uptake of retinal screening among young adults with type 2 diabetes: a qualitative study informed by the theoretical domains framework. *J Diabetes Complications.* (2017) 31:997–1006. doi: 10.1016/j.jdiacomp.2017.02.020

52. Nilsen P. Making sense of implementation theories, models and frameworks. *Impl Sci.* (2015) 53:1–13. doi: 10.1186/s13012-015-0242-0

53. Gibson Miller J, Hartman TK, Levita L, Martinez AP, Mason L, McBride O, et al. Capability, opportunity, and motivation to enact hygienic practices in the early stages of the COVID-19 outbreak in the United Kingdom. *Br J Health Psychol.* (2020) 25:856–64. doi: 10.1111/bjhp.12426

54. Padmawati RS, Heywood A, Sitaresmi MN, Atthobari J, MacIntyre CR, Soenarto Y, et al. Religious and community leaders' acceptance of rotavirus vaccine introduction in Yogyakarta, Indonesia: a qualitative study. *BMC Public Health.* (2019) 19:368. doi: 10.1186/s12889-019-6706-4

55. Syiroj ATR, Pardosi JF, Heywood AE. Exploring parents' reasons for incomplete childhood immunisation in Indonesia. *Vaccine.* (2019) 37:6486–93. doi: 10.1016/j.vaccine.2019.08.081

56. Byron MJ, Cohen JE, Gittelsohn J, Frattaroli S, Nuryunawati R, Jernigan DH. Influence of religious organisations' statements on compliance with a smoke-free law in Bogor, Indonesia: a qualitative study. *BMJ Open.* (2015) 5:8111 doi: 10.1136/bmjopen-2015-008111

57. Floyd DL, Prentice-Dunn S, Rogers RW. A meta-analysis of research on protection motivation theory. *J Appl Soc Psychol.* (2000) 30:407–29. doi: 10.1111/j.1559-1816.2000.tb02323.x

58. Fragkaki I, Maciejewski DF, Weijman EL, Feltes J, Cima M. Human responses to COVID-19: the role of optimism bias, perceived severity, and anxiety. *Pers Individ Dif.* (2020) 176:110781. doi: 10.1016/j.paid.2021.110781

59. Kuzmanovic B, Rigoux L. Valence-dependent belief updating: computational validation. *Front Psychol.* (2017) 8:1–11. doi: 10.3389/fpsyg.2017.01087

60. Sharot T, Korn CW, Dolan RJ. How unrealistic optimism is maintained in the face of reality. *Nat Neurosci.* (2011) 14:1475–9. doi: 10.1038/nn.2949

61. Badan Pusat Statistik. *Perilaku Masyarakat di Masa Pandemi COVID-19*. Indonesia: Badan Pusat Statistik (2020).

62. Bottemanne H, Morlaàs O, Fossati P, Schmidt L. Does the Coronavirus epidemic take advantage of human optimism bias? *Front Psychol.* (2020) 11:1–5. doi: 10.3389/fpsyg.2020.02001

63. Laato S, Islam AKMN, Islam MN, Whelan E. What drives unverified information sharing and cyberchondria during the COVID-19 pandemic? *Eur J Inf Syst.* (2020) 29:288–305. doi: 10.1080/0960085X.2020.1770632

64. Romer D, Jamieson KH. Conspiracy theories as barriers to controlling the spread of COVID-19 in the U.S. *Soc Sci Med.* (2020) 263:113356. doi: 10.1016/j.socscimed.2020.113356

65. Dowd JB, Andriano L, Brazel DM, Rotondi V, Block P, Ding X, et al. Demographic science aids in understanding the spread and fatality rates of COVID-19. *Proc Natl Acad Sci U S A.* (2020) 117:9696–8. doi: 10.1073/pnas.2004911117

66. Pearce JM, Lindekilde L, Parker D, Rogers MB. Communicating with the public about marauding terrorist firearms attacks: results from a survey experiment on factors influencing intention to "Run, Hide, Tell" in the United Kingdom and Denmark. *Risk Anal.* (2019) 39:1675–94. doi: 10.1111/risa.13301

67. Peters GJY, Ruiter RAC, Kok G. Threatening communication: a critical re-analysis and a revised meta-analytic test of fear appeal theory. *Health Psychol Rev.* (2013) 7:8–31. doi: 10.1080/17437199.2012.703527

68. Moore RC, Lee A, Hancock JT, Halley M, Linos E. Experience with social distancing rarly in the COVID-19 pandemic in the United States: implications for public health messaging. *medRxiv.* (2020). doi: 10.1101/2020.04.08.20057067

69. Best K. *Study of COVID-19 Risk Communication Finds 'Optimistic Bias' Slows Preventive Behavior - UConn Today: UConn Communications*. (2020). Available online at: https://today.uconn.edu/2020/04/study-covid-19-risk-communication-finds-optimistic-bias-slows-preventive-behavior/# (accessed November 14, 2020).

70. Hedlund J. Haddon Memorial Lecture. *Inj Prev.* (2000) 1:82–9.

71. Luckman A, Zeitoun H, Isoni A, Loomes G, Vlaev I, Powdthavee N, et al. Risk compensation during COVID-19: the impact of face mask usage on social distancing. *Osf.* (2020) 355:722. doi: 10.31219/osf.io/rb8he

72. Mantzari E, Rubin GJ, Marteau TM. Is risk compensation threatening public health in the COVID-19 pandemic? *BMJ.* (2020) 370:m2913. doi: 10.1136/bmj.m2913

73. Gallagher KM, Updegraff JA. Health message framing effects on attitudes, intentions, and behavior: a meta-analytic review. *Ann Behav Med.* (2012) 43:101–16. doi: 10.1007/s12160-011-9308-7

74. Michie S, West R, Rogers MB, Bonell C, Rubin GJ, Amlôt R, et al. Reducing SARS-CoV-2 transmission in the UK: a behavioural science approach to identifying options for increasing adherence to social distancing and shielding vulnerable people. *Br J Health Psychol.* (2020) 25:945–56. doi: 10.1111/bjhp.12428

75. Koon AD, Mendenhall E, Eich L, Adams A, Borus ZA. A spectrum of (Dis)Belief: Coronavirus frames in a rural midwestern town in the United States. *Soc Sci Med.* (2021) 272:113743. doi: 10.1016/j.socscimed.2021.113743

76. Sutarsa N. *Indonesia's Vaccine Campaign Hits Speed Bumps | East Asia Forum. East Asia Forum*. (2021). Available online at: https://www.eastasiaforum.org/2021/05/15/indonesias-vaccine-campaign-hits-speed-bumps/ (accessed June 29, 2021).

77. Harapan H, Wagner AL, Yufika A, Winardi W, Anwar S, Gan AK, et al. Acceptance of a COVID-19 vaccine in Southeast Asia: a cross-sectional study in Indonesia. *Front Publ Health.* (2020) 8:381. doi: 10.3389/fpubh.2020.00381

78. Trogen B, Caplan A. Risk compensation and COVID-19 vaccines. *Ann Intern Med.* (2021) 174:858–9. doi: 10.7326/M20-8251

79. Keyes CD. Ethical judgment and brain function: an interpretation of Paul D. *MacLean's hypothesis J Soc Evol Syst.* (1992) 15:387–98. doi: 10.1016/1061-7361(92)90025-9

80. Luo J, Yu R. Follow the heart or the head: The interactive influence model of emotion and cognition. *Front Psychol.* (2015) 6:1–14. doi: 10.3389/fpsyg.2015.00573

81. Eil D, Rao JM. The Good News-Bad News effect: asymmetric processing of objective information about yourself. *Am Econ J Microeconomics.* (2011) 3:114–38. doi: 10.1257/mic.3.2.114

82. Moutsiana C, Charpentier CJ, Garrett N, Cohen MX, Sharot T. Human frontal–subcortical circuit and asymmetric belief updating. *J Neurosci.* (2015) 35:14077–85. doi: 10.1523/JNEUROSCI.1120-15.2015

83. Quilty BJ, Diamond C, Liu Y, Gibbs H, Russell TW, Jarvis CI, et al. The effect of travel restrictions on the geographical spread of COVID-19 between large cities in China: a modelling study. *BMC Med.* (2020) 18:1–10. doi: 10.1186/s12916-020-01712-9

84. Burns J, Movsisyan A, Stratil JM, Coenen M, Emmert-Fees KM, Geffert K, et al. Travel- related control measures to contain the COVID-19 pandemic: a rapid review. *Cochrane Database Syst Rev.* (2020) 28:717. doi: 10.1002/14651858.CD013717

85. Pettengill MA, McAdam AJ. Can we test our way out of the COVID-19 pandemic? *J Clin Microbiol.* (2020) 58:1–5. doi: 10.1128/JCM.02225-20

86. Atkeson A, Droste M, Mina M, Stock J. *Economic Benefits of COVID-19 Screening Tests*. Cambridge, MA: Cambridge University Press (2020).

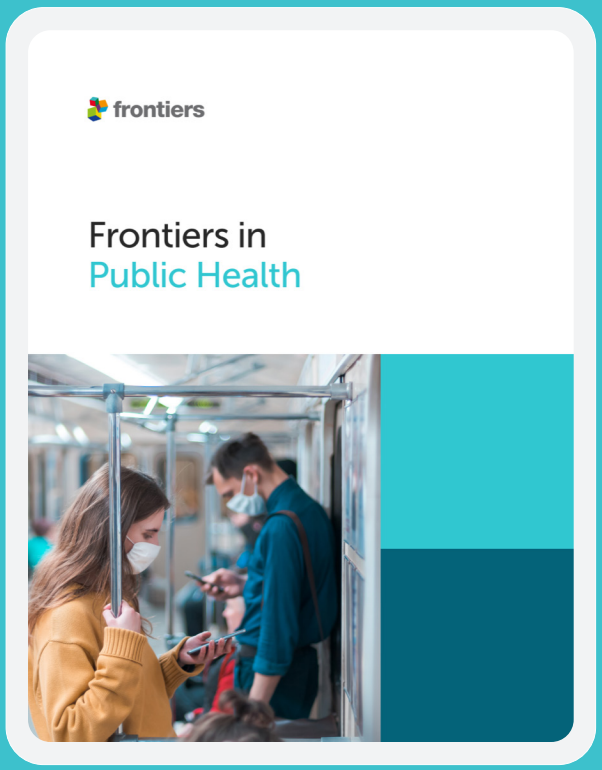
Frontiers in Public Health

Explores and addresses today's fast-moving healthcare challenges

One of the most cited journals in its field, which promotes discussion around inter-sectoral public health challenges spanning health promotion to climate change, transportation, environmental change and even species diversity.

Discover the latest Research Topics

See more →



Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact