

World health day Impact of COVID-19 on health and socioeconomic inequities 2022

Edited by

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World health day 2022: Impact of COVID-19 on health and socioeconomic inequities

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Table of contents

- 05 **Editorial: World health day 2022: Impact of COVID-19 on health and socioeconomic inequities**
Martin Amogre Ayanore, Amanda Rodrigues Amorim Adegboye, Hubert Amu, Chandan Kumar and Rasheda Khanam
- 08 **Chinese Younger Parents' Quality of Life During the COVID-19 Pandemic: Do Job Changes and Family Conflicts Matter?**
Xiaohan Liu, Yashuang Bai, Ning Huang, Farooq Ahmed, Muhammad Shahid and Jing Guo
- 17 **Impact of COVID 19 Pandemic and Big Data on China's International Trade: Challenges and Countermeasures**
Shuang Zhao
- 27 **COVID-19 Pandemic and SMEs Performance Decline: The Mediating Role of Management Innovation and Organizational Resilience**
Yunjian Li, Hongchuan Chen, Lulu Wei and Luqing Wei
- 42 **Area Deprivation and COVID-19 Incidence and Mortality in Bavaria, Germany: A Bayesian Geographical Analysis**
Kirsi Marjaana Manz, Lars Schwettmann, Ulrich Mansmann and Werner Maier
- 55 **When Lack of Trust in the Government and in Scientists Reinforces Social Inequalities in Vaccination Against COVID-19**
Nathalie Bajos, Alexis Spire, Léna Silberzan, Antoine Sireyjol, Florence Jusot, Laurence Meyer, Jeanna-Eve Franck, Josiane Warszawski the EpiCov study group
- 66 **Vulnerable populations during COVID-19 response: Health-related quality of life among Chinese population and its influence due to socio-demographic factors and loneliness**
Eliza Lai-Yi Wong, Jia Li, Shannon Yuen, Angel Hor-Yan Lai, Annie Wai-Ling Cheung, Peter Sen-Yung Yau and Eng-Kiong Yeoh
- 81 **Health economic burden of COVID-19 in Saudi Arabia**
Khalidah A. Alenzi, Hamdan S. Al-malky, Ali F. Altebainawi, Hamidah Q. Abushomi, Fahad O. Alatawi, Moosa H. Atwadi, Moosa A. Khobrani, Dlal A. Almazrou, Nariman Alrubeh, Zainab A. Alsoliabi, Abdulaziz M. Kardam, Shahr A. Alghamdi, Abdulrahman Alasiri, Maher H. Albalwi and Thamir M. Alshammari
- 91 **Participatory development and implementation of inclusive digital health communication on COVID-19 with homeless people**
Anabell Specht, Navina Sarma, Tabea Linzbach, Theresa Hellmund, Merle Horig, Mia Wintel, Gabriela Equihua Martinez, Joachim Seybold and Andreas K. Lindner

- 105 **Substantial increase in perceived benefits over harms of COVID-19 outbreak but persistent socioeconomic disparities: Comparison of two cross-sectional surveys in Hong Kong from 2020 to 2021**
Hiu Tin Leung, Wei Jie Gong, Shirley Man Man Sit, Agnes Yuen Kwan Lai, Sai Yin Ho, Man Ping Wang and Tai Hing Lam
- 117 **The need for COVID-19 clinical trials in LMICs**
Fatima Saleh



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Editorial: World health day 2022: Impact of COVID-19 on health and socioeconomic inequities

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World health day 2022, COVID-19, socioeconomic inequalities and health, Sustainable Development Goals (SDGs), equity in health

Editorial on the Research Topic

World health day 2022: Impact of COVID-19 on health and socioeconomic inequities

Growing health and socioeconomic inequalities within and across countries are a defining challenge of our times and remain a huge obstacle to the realization of the United Nations Sustainable Development Goals (SDGs) (1). Overall, COVID-19 has revealed a pandemic of inequality, including access to vaccines in many settings in the world (2).

Building resilient health systems post-COVID-19 will require identifying cost-effective interventions, employing a health system learning approach that assists us build-back what was lost in the pandemic, and providing opportunities to address health inequalities. Overall, there is a need for policy-oriented research that reveal how health emergencies, such as the COVID-19 pandemic exacerbates and expose existing inequalities in society (3).

Given the impact of the COVID-19 pandemic on global affairs, we present and highlight the impact of the pandemic on health and socioeconomic inequities in this Research Topic. Since WHO's founding in 1948, it has led the way in advancing and promoting health across the world; from post-world world II recovery efforts to advance health to the Alma Atta declaration, to the enactment of the Millennium Development Goals (MDGs) in 2000 and now the SDGs from 2015-2030 (4).

In this collection, we accepted and published nine original research and one opinion piece. The ten publications are classified into four domains; quality of life pre/post the pandemic, COVID-19, and welfare loss (economic social, and human), COVID-19 and social trust for pandemic control, and clinical and technological innovations for enhancing health systems for current and future pandemics.

First, two studies in the Chinese population examined social and economic factors that influenced health related quality of life (HRQoL). These studies show that social disruptions brought about during pandemics shape QoL outcomes. Specifically, welfare forces such as job change, and family conflicts due to the pandemic decreased the quality of life (QoL). Other studies in other context have highlighted job and wage losses and changes

in mental and psychosocial health as social disruptions due to COVID-19. [Liu et al.](#) established that the interaction effects of job changes and family conflict on QoL were significant among fathers and one-child families, highlighting the crucial role of social disruptions at the family structure level, during pandemics.

On the other hand, [Wong et al.](#) found that loneliness exacerbated by the pandemic influenced poor QoL outcomes, particularly among older adults.

During pandemics, social and economic disruptions impact on mental health and wellbeing (5, 6). In addition, the existence of a pandemic may cause low priority actions for local epidemics, as the case in Ghana (7) during the first wave of the COVID-19 pandemic when health systems were yet adjusting to deal with the pandemic. To address QoL inequalities during pandemics, social protection policies that identify and prioritize vulnerable groups and provide safety nets to meet social needs such as housing, loneliness, job, and welfare losses can assist address psychosocial health needs and bridge health inequalities in the population.

Second, COVID-19 manifested economic, social, and human losses. [Alenzi et al.](#) from their study found the economic burden of COVID-19 to have impacted negatively on households and the health system, particularly for the vulnerable. During health emergencies, increased demand and pressure on health systems raise both direct and indirect healthcare costs, with implications for poor and vulnerable groups' access to healthcare services. In instances where catastrophic payments are experienced, inequalities are further deepened in society.

[Leung et al.](#) also reported from their study that socioeconomic disparities of perceived benefits and harms existed in Saudi Arabia amid the pandemic. To address socioeconomic disparities and reduce economic burden during emergencies, policy actions that address financial risk protection and reduce disparities in access to social care services are vital for long-term progress.

During pandemics, data science can play a significantly role by providing context evidence for localized pandemic control actions, as exemplified by [Manz et al.](#) in Germany. For example, in deprived areas in Bavaria, Germany, the estimation of standardized incidence and mortality ratios allowed for deeper understanding of disease burden in deprived districts. This application for data science is vital for targeting during pandemics, particularly population groups that are worse off or disadvantaged in a pandemic. Aside human and social disruptions, the pandemic affected business and supply chain systems globally, with negative repercussions on world economies as reported by [Zhao](#). Despite the negative effects of the pandemic on business enterprises, a small window of opportunity was also presented for innovation as highlighted by [Li et al.](#), however, this evidence remains scanty and not uniform. Future studies need to explore the wealth or opportunity that pandemics present for business innovations in many contexts.

Third, building strong social trust for pandemic control highlight the construct of citizen trust in governments and scientist as vital in the management of the COVID-19 pandemic as reported by [Bajos et al.](#) Trust allows a person with low knowledge and power to make decisions that align with their wellbeing and is historically a very important component of healthcare (8). The study highlights the urgent need for pandemic response strategies

to include depoliticized approaches that target disadvantaged groups while ensuring social inclusion in risk communication and vaccine programs.

Lastly, the pandemic witnessed a surge in digital innovations in the health industry. [Specht et al.](#) illustrated how digital innovations during the pandemic provided an opportunity to address homeless and vulnerable healthcare needs. During the early period of the first doses of COVID-19 vaccines, data show the Gini coefficients for COVID-19 vaccines were 0.91 and 0.88 on June 7 and December 7, 2021, respectively while between June 7 and December 7, 2021, the Gini coefficients were 0.57 and 0.61, respectively, indicating severe inequality thresholds in all cases (9).

Inequality in vaccine distribution was attributed to economic, financial support and human factors, infrastructure, and health system, legal and political, epidemiologic and demographic factors (10). The opinion expressed by [Saleh](#) shows the need for LMIC to invest in Research and Development (R&D) through the active establishment and promotion of clinical trials as an entry point to address future vaccine inequalities and address specific population groups' access to equitable healthcare. Such a bold and decisive step will ensure LMIC and HIC health systems adopt a health system learning approach to context health problems.

In conclusion, our Research Topic highlights pathways where inequalities were exacerbated during the pandemic. COVID-19 has highlighted the relevance of policy actions that address broadly social determinants of health to mitigate the impacts of future pandemics on health inequalities. The Research Topic also emphasizes the relevance of digital health and technology in addressing health equity goals, particularly the SDGs. Future studies on randomized control trials and those that enable causality relationships to be established are further encouraged.

Author contributions

MA conceptualized and wrote the initial draft. HA reviewed first draft. AA, CK, and RK reviewed the revised draft and made inputs into the final draft. All authors read and approved the manuscript for submission.

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Conflict of interest

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Chinese Younger Parents' Quality of Life During the COVID-19 Pandemic: Do Job Changes and Family Conflicts Matter?

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The quality of life (QoL) might have been decreased owing to social disruptions in daily life and basic functioning after the coronavirus disease (COVID-19) pandemic. This work aims to examine the relationship between job changes, family conflicts, and QoL among parents during COVID-19 in China. We recruited 1,209 adults through an online cross-sectional survey in China during the COVID-19 lockdown from April 21 to April 28, 2020. Convenient and cluster sampling methods were used to recruit parents. The global health items in the Patient-Reported Outcomes Measurement Information System (PROMIS) were used as a measurement for QoL. Data were mainly analyzed by multiple linear regression with SPSS. Both marital conflict ($\beta = -0.243, p < 0.001$) and parent-child conflict ($\beta = -0.119, p = 0.001$) were negatively associated with the QoL among parents during the lockdown. Job changes moderated the relationship between marital conflict and QoL ($\beta = -0.256, p = 0.022$). In addition, the interaction effects of job changes and family conflict on QoL were significant only among fathers and one-child families. This study indicated that family conflict was a crucial factor correlated with QoL among young parents in the backdrop of the COVID-19 lockdown. Job changes could interact with marital conflict and parent-child conflict on the quality of life.

Keywords: quality of life, job changes, family conflict, Chinese parents, COVID-19

INTRODUCTION

Coronavirus disease 19 (COVID-19), which emerged in Wuhan, China, has reached the level of a pandemic, attracting enormous concern from around the world (1). Several countries took drastic mitigation measures, including community-wide lockdowns, home quarantines, closure of schools, working-from-home, and social distancing to protect the population (2). However, these swift actions have created a host of new challenges that have brought profound changes and affected the normal routines of daily work and lifestyles for people, such as restricting outdoor activities or increasing family conflicts, reducing income, high rates of unemployment (3), and consequently worsening the quality of life (QoL) (4).

Quality of life is a multidimensional concept that usually includes individuals' physical health, psychological state, and level of independence (5). Widespread outbreaks of COVID-19 may adversely affect the multidimensional QoL, especially in parents who have children below 10 years old. Emerging research has shown that parents of young children are more affected by the COVID-19 pandemic (6). Since young children need more supervision and care, the pandemic may bring a unique challenge to parents of young children (7). Specifically, parents with young children may have more childcare responsibilities at home due to the reduced social network and the swift closure of schools and childcare centers (7). In addition, they had to balance remote working with home-schooling their children and confront more work-family conflict (8). Thus, in this difficult time, more attention is required to the younger parents' QoL.

Job Changes and QoL

Job changes are significant life stressors, and losing a job takes several years to recover psychologically (9). According to the family stress model (10), economic instability (including unemployment, debt, and receipt of income transfers) places considerable strain on parents. The COVID-19 pandemic has forced parents to quickly transition to a new way of work (11). These transitions present all kinds of stressors, which might have repercussions on parents' capacities to be psychologically flexible, thus putting their QoL at risk (11).

Family Conflict and QoL

Active opposition of various forms, including verbal, physical, sexual, financial, or psychological, among family members is often referred to as family conflict (12). According to adult attachment theory, high-quality close relationships, including marital relationships and parent-child relationships, have been consistently linked to better health, while conflicting relationships may influence parents' physiological responses to stress, risky health behaviors, susceptibility to physical illness, and poorer disease outcomes (13). When parents were asked to stay at home during the pandemic, they faced problems getting along with their family members and dealing with conflicts with their partner and children. There is evidence that a close relationship between family members could affect parents' QoL, and parents' health status can further affect children's development and well-being, creating a vicious circle in such a difficult period (14, 15).

Conceptual Framework

Theories and empirical results based on role stress theory indicate that the combination of family and employment often creates more demands than one can handle, leading to role overload (16). Consequently, both job changes and family conflict can bring more stress and psychological problems for parents of young children.

The interaction effect of job changes and family conflicts on QoL may be different for mothers and fathers. COVID-19 has indeed changed parents' experiences with employment outside the household and the division of labor at home (17). Compared with fathers, mothers have reduced their working hours more and

spent more time on childcare duties (18). Moreover, school and daycare closures increased caregiving responsibilities. Arguably, these changes increased the burden on women more than on men (19). Therefore, this work anticipates that mothers have experienced more job changes, perceived more family conflicts, and low QoL than fathers.

Additionally, the interaction role between job changes and family conflict on QoL may differentiate across the number of children. The traditional belief, "more children, more happiness," is still entrenched in China (20). Evidence has shown that parents can obtain more emotional support from their children in a family with multiple children (21), and parents with more children perceive a higher level of life satisfaction. In addition, parents tend to rear more children if they can easily integrate work and family roles to reduce the double burden (22). Thus, the association between family conflict and QoL in a multichild family may not be enhanced by job changes.

Aims and Hypothesis

The objective of this work was to examine the relationship between job changes, family conflict, and QoL among parents with a child aged 0–10, to assess the interaction effects between job changes and family conflict, and to explore the difference in gender and family size among them. We hypothesized that either job changes or family conflicts correlated with parents' poor QoL. We further hypothesized that pandemic-related job changes enhanced the relationship between family conflict and poor QoL. Moreover, we assumed that the abovementioned moderating effects varied across genders and families with different numbers of children.

METHODS

Study Design and Population

This study was conducted based on an online survey (a web-based platform, <https://www.wjx.cn/app/survey.aspx>) from April 21 to April 28, 2020, during the COVID-19 lockdown in China. To nationally reflect the mental health status of parents affected by the pandemic and enlarge the sample size, Hubei province, the area most affected by COVID-19, and its neighboring province Henan and non-adjacent province Guangdong were selected for sample investigation.

We used various sampling techniques to reduce bias in situations where there were large populations in China. Random sampling is practically impossible because families have difficulty reaching during the pandemic. The advantages of convenience sampling approaches, such as collecting data quickly, were suitable for data collection during pandemics with school closures. In addition, we used cluster sampling because this method is usually adopted to recruit subjects in the school. Convenience sampling was used to select primary schools. The cluster sampling method was used to choose participants from selected schools. The selected schools were stratified by grade. Then, all classes were selected from each grade of the selected school, and all the students in these classes joined the survey. The head teachers helped us distribute the questionnaires to the subjects online.

Parents aged 18 years and above who had a child or children aged between 0 and 10 years old were invited to participate. The rationale for restricting the sample to parents with at least one 10-year-old or younger child was that younger children necessitate more direct supervision; therefore, it was expected that the COVID-19 pandemic may pose more specific challenges to them, such as more work–family conflict. These parents were instructed about how to answer the questionnaires by online guidance and to complete the questionnaires independently. In total, 1,286 parents participated in the survey. As 77 parents were excluded because they had no job, the final number of participants became 1,209. Each question of the online questionnaire was required to be answered; thus, no missing data were reported in our study. The study protocol was approved by the Institutional Review Board of Peking University, Beijing, China. All participants gave electronic consent after being informed of the aims of the survey and their rights to refuse to participate.

Measures

Quality of life was assessed with the global health items in the patient-reported outcomes measurement information system (PROMIS) (23). The checklist includes 6 items, which were answered on a five-point scale, Excellent(1)–Poor(5). See the attachment for details. The total scores were calculated by the sum of all items, with a higher score indicative of better QoL. Cronbach's alpha of QoL in this study was 0.916.

Job changes were assessed with a subset of items from the questionnaire of the COVID-19 and perinatal experiences study (COPE Study, <https://osf.io/uqhcw/>). The scale contained 15 questions about the changes in jobs related to the COVID-19 pandemic, such as telecommuting, reduced working hours, extended working hours, pay cuts, increased responsibility, increased supervision and reporting, and declining job security. For each question, 0 represented “No,” while 1 represented “Yes.” All items were summed to obtain a total score for job changes. A higher score represented more job changes. The internal consistency of job changes was 0.881.

Family conflict was measured with a 6-item self-made questionnaire about specific conflict behaviors, including marital conflict and parent–child conflict. Among them, three questions examined marital conflict, and three other items examined parent–child conflict. Each item was rated on a five-point scale ranging from never (1 score) to always (5 scores). For details, please see the attachment. Higher scores indicated more frequent marital and parent–child conflict. The Cronbach's α were 0.696 and 0.726, respectively. The questionnaire items were vetted by some sociological professors, and they agreed that there were no items that were culturally insensitive.

Confounding variables included demographic and socioeconomic characteristics as follows: exposure to COVID-19 (yes, no), gender (male, female), province (Hubei, Henan, Guangdong, else), number of children (1, 2, 3 or more), education (junior school and below, high school, college, undergraduate, and above), marital status (married, else), occupation (stable, unstable), and annual income ($\leq 50,000$,

$50,000$ – $1,00,000$, $\geq 1,00,000$). In the study, this term (stable job) refers to work that is continuous and safe employment, and there are no sudden layoffs or labor strife. By unstable jobs we mean work that is uncertain, insecure, irregular, and in which employees bear the risks of work and receive limited social benefits, relatively low income, and statutory protections (i.e., In China, employees work in state-owned enterprises, and public institutions are regarded as having a stable job. Unstable job employees refer to freelancer and gig workers). All covariates were selected according to previous related studies (24, 25).

Statistical Analyses

Data in this study were analyzed with SPSS version 22.0. Descriptive statistics were calculated to describe the demographic characteristics of the subjects. Since QoL as the dependent variable is continuous, multiple linear regression analysis was performed, and each model controlled the same confounding variables, including exposure, gender, province, number of children, education, marital status, occupation, and annual income.

The main analyses consisted of multiple regressions on QoL in two steps. In model 0, each of the predictors was included separately to estimate their “raw” contribution to the prediction of QoL, and in model 1, the three predictors of job changes, marital conflict, and parent–child conflict were introduced to examine which component would be the most powerful predictor.

In the next multivariable linear regression analysis, job changes, marital conflict, and parent–child conflict and their interaction terms (job changes*marital conflict and job changes*parent–child conflict) were all standardized and entered to estimate the moderating effects of job changes on the relationships between marital conflict, parent–child conflict, and QoL.

In addition, the whole sample was divided into 2 groups by gender to examine gender differences in the moderating effects of job changes on the relationships between marital conflict, parent–child conflict, and QoL. In the final linear regression models, the whole sample was divided into 3 groups by the number of children in a family.

RESULTS

The study included 1,209 parents (median age 36 years [SD = 5.16]) in China, 317 (26%) of whom were fathers and 892 (74%) of whom were mothers. A total of 21% of participants were from Hubei. Around 47.2% of the parents reported having one child and 18.7% reported that someone in their family, neighborhood, or friends had suffered or were suffering from COVID-19. Around 6.9% parents did not experience any job changes. Many of parents experienced family conflict (97.7%). The average number of job changes was 17.85, and the mean QoL score was 23.85 (SD = 3.60) (Table 1).

Table 2 shows the results of the multivariable linear regression analysis. In model 0, increased job changes, marital conflict, and parent–child conflict were associated with lower QoL. In model 1, marital conflict explained the largest variance in QoL. More

TABLE 1 | Descriptive data on social-demographics ($N = 1,209$).

		Total		Father		Mother		P
		N	%	N	%	N	%	
Exposure	No	983	81.3	253	79.8	730	81.8	0.200
	Yes	226	18.7	64	20.2	162	18.2	
Parents	Father	317	26.2					0.142
	Mother	892	73.8					
Province	Hubei	256	21.2	71	22.4	185	20.7	0.089
	Henan	182	15.1	54	17.0	128	14.3	
	Guangdong	510	42.2	110	34.7	400	44.8	
	Else	261	21.6	82	25.9	179	20.1	
Number of children	1	571	47.2	163	51.4	408	45.7	0.477
	2	569	47.1	140	44.2	429	48.1	
	3+	69	5.7	14	4.4	55	6.2	
Education	Junior school and below	329	27.2	89	28.1	240	26.9	0.002
	High school	222	18.4	43	13.6	179	20.1	
	College	444	36.7	119	37.5	325	36.4	
	Undergraduate and above	214	17.7	66	20.8	148	16.6	
Marital status	Married	1151	95.2	304	95.9	847	95.0	0.226
	Else	58	4.8	13	4.1	45	5.0	
Occupation	Stable job	673	55.7	215	67.8	458	51.3	0.050
	Unstable job	536	44.3	102	32.2	434	48.7	
Annual income	≤50,000	347	28.7	69	21.8	278	31.2	0.368
	50,000–100,000	376	31.1	99	31.2	277	31.1	
	≥100,000	486	40.2	149	47.0	337	37.8	
		Mean	SD	Mean	SD	Mean	SD	
Parents' age		36.121	5.162	36.852	5.427	35.861	5.042	0.001
First child's age		8.393	4.150	8.500	4.436	8.355	4.045	0.119

Bold values are statistically significant at $p < 0.05$.

TABLE 2 | The relationship between job changes, family conflicts, and quality of life.

	Model 0				Model 1			
	B	SE	Beta	P	B	SE	Beta	P
Parents (ref: father)								
Mother	−0.370	0.244	−0.045	0.130	−0.039	0.233	−0.005	0.866
Number of children(ref: 3+)								
1	0.319	0.486	0.044	0.512	0.332	0.464	0.046	0.475
2	0.006	0.470	0.001	0.989	−0.005	0.446	−0.001	0.990
Job changes	−0.258	0.109	−0.071	0.019	−0.076	0.105	−0.021	0.473
Marital conflict	−0.899	0.131	−0.241	<0.001	−0.905	0.133	−0.243	<0.001
Parent–child conflict	−0.464	0.131	−0.125	<0.001	−0.441	0.133	−0.119	0.001

B, non-standardized coefficients; SE, standard error; Beta, Standardized coefficients; bold values are statistically significant at $p < 0.05$; Model 0 is crude estimates, and Model 1 is the estimates accounting for all three independent variables (job changes, marital conflict, and parent–child conflict). All models were controlled for exposure, province, age, education, marital status, income, occupation, and first child age.

marital conflict was associated with lower QoL ($\beta = -0.243$). Additionally, parent–child conflict was inversely correlated with QoL ($\beta = -0.441$, $P = 0.001$). However, no significant changes in QoL scores were observed in association with job changes.

A significant moderator by family conflict interaction was observed for job changes (Table 3). Parents with more job

changes and marital conflict were more likely to receive lower QoL scores ($\beta = -0.256$, $p = 0.022$; Figures 1A,B). However, the interaction of job changes and parent–child conflict did not reach significance.

Table 4 displays gender differences in the interaction roles between job changes and family conflict. The interaction effects

TABLE 3 | Analysis of the interaction effects between job changes and family conflicts on quality of life.

	Model 2			
	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>P</i>
Parents (ref: father)				
Mother	−0.067	0.234	−0.008	0.775
Number of children (ref: 3+)				
1	0.334	0.463	0.046	0.470
2	−0.012	0.446	−0.002	0.979
Job changes	−0.071	0.105	−0.020	0.498
Marital conflict	−0.824	0.137	−0.221	<0.001
Parent–child conflict	−0.497	0.135	−0.134	<0.001
Job changes* marital conflict	−0.256	0.111	−0.077	0.022
Job changes*parent–child conflict	0.219	0.124	0.058	0.077

B, non-standardized coefficients; *SE*, standard error; *Beta*, standardized coefficients; **Bold values are statistically significant at $p < 0.05$** ; All models have been controlled exposure, province, age, education, marital status, income, occupation, first child age.

of job changes with marital conflict ($\beta = -0.421$, $p = 0.024$) and parent–child conflict ($\beta = 0.747$, $p = 0.002$) were only found for fathers, indicating that job changes reinforced the negative effect of marital conflict while alleviating the adverse effect of parent–child conflict on the QoL among fathers (see **Figures 1C,D**). **Table 5** presents the interaction results of job changes with family conflict across families with a different number of children. The moderation effects of job changes with marital conflict and parent–child conflict were found only in the one-child family ($\beta = -0.304$, $p = 0.024$ and $\beta = 0.412$, $p = 0.011$, respectively). As presented in **Figures 1E,F**, the negative effect of marital conflict on QoL could be strengthened by job changes among parents with one child, whereas the adverse correlation between parent–child conflict and QoL would be weakened.

DISCUSSION AND IMPLICATIONS

This work focused on the QoL among Chinese parents of young children during the COVID-19 pandemic and examined the relationship between job changes, family conflict, and QoL. Our findings suggested that individuals with more frequent marital conflict and parent–child conflict had worse QoL. We found that job changes significantly enhanced the negative correlation between marital conflict and QoL, but did not significantly buffer the negative relationship between parent–child conflict and QoL among the whole sample. In addition, both of the moderation effects differed across gender and family structure, and they were only significant for fathers and one-child family.

Our results indicated that parents who experienced marital conflict and parent–child conflict reported a lower level of QoL. Marital conflict may decrease marital QoL by increasing negative affect and physiological arousal, according to a social psychophysiological model of marriage (26). In addition, stress process perspectives proposed that chronic strains in the marital role could cause stress, which

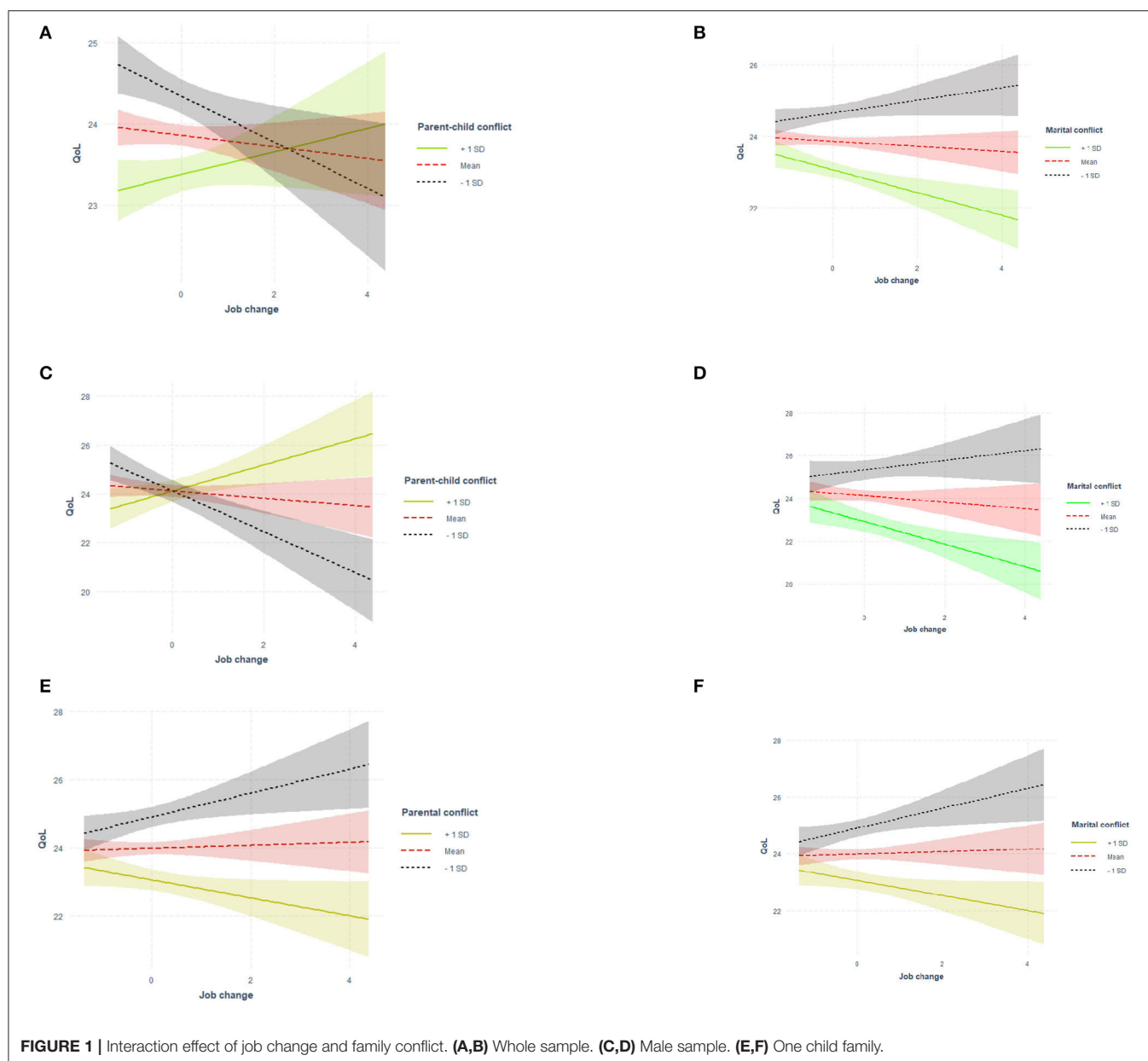
typically manifests in the form of physical or psychological distress, as indicated by poor QoL (27). Similarly, parent–child conflict might be regarded as a chronic stressor or stressful life event that influences parents' mental health (28). Empirical research has demonstrated that parents in families with a high level of parent–child conflict might more likely suffer depressive symptoms (29), which may reduce parental QoL.

Furthermore, job changes did act as a moderator between family conflict and QoL. On the one hand, job changes accelerated the negative effect of marital conflict on QoL. This could be explained by family stress theory (30). Financial stress that comes with job change, as an uppermost topic of marital disagreement, could cause more emotional distress and then heighten marital conflict (31). Moreover, role theory argues that the role pressures from family and work domains are mutually incompatible in some respects, and job stress would negatively spill over into home life (32), which may cause increased conflicts with spouses. Thus, when facing job changes, individuals who suffer from marital conflict may perceive a lower QoL.

On the other hand, job changes could moderate the negative correlation between parent–child conflict and QoL. Some special features of job changes during COVID-19, such as flexible work time, telework, and working from home, could make these parents have more time to spend with their children at home, thus improving the relationship between parents and children (33). It is also helpful to meet the expectations of parental roles such as caring for children, especially for young Chinese parents who always experience overtime work with less time to interact with family members (34). Therefore, job changes could mitigate the negative effect of parent–child conflict on parents' QoL. Given that the impacts of the COVID-19 pandemic on the economy, work, and home life are manifold and will potentially last for a long time (35), understanding such interactions will be important to provide services for the improvement of QoL among parents.

Of note, the moderating role of job changes was confirmed only for Chinese fathers. Since traditional gender values that “fathers are regarded as the primary breadwinners and mothers as primary caregivers” are still the most far-reaching and prevalent in China (36), work factors would spill over into family more for Chinese men than women, based on gender role theory (37). Specifically, the financial loss coming with job changes during the pandemic may more likely make Chinese husbands as family economic pillars feel stressed than their wives (38), thus enhancing the negative relationship of marital conflict and QoL among fathers. Job changes are more likely to increase positive interactions with children for fathers, such as playing games, which could improve the father–child relationship (39, 40) and thus weaken the association between parent–child conflict and fathers' QoL.

In addition, job changes only moderated the association between family conflict and parents' QoL in the one-child family. This could be explained using resource dilution theory (41); children in the one-child family could receive more



attention and resources from parents (42), which means that parents with only children can more easily meet their children's demands using job resources from job changes than parents with multiple children (43). Therefore, job changes could only buffer the adverse effect of parent-child conflict in one-child families.

Moreover, the association between marital conflict and QoL could only be enhanced by job changes in the one-child family. This is because parents with fewer children in collectivistic cultures may have lower marital happiness (44). In addition, previous research examined the quality-quantity trade-off theory based on the relaxation of China's one-child policy (45). This result suggested that Chinese parents with one child might have a

strong preference for quality and devote more time, energy, and money to their children's development than other parents (46). Therefore, extended working hours, pay cuts, or unemployment would increase child-rearing pressure on parents with an only child, while the pressure could be mitigated in the multichild family owing to more support and assistance from children (19).

Limitation and Implication

Several limitations of this study should be acknowledged. First, the selective bias resulting from convenient sampling methods used in our study might constrain the generalizability of our findings. Second, the proportion of fathers was <30% in our

TABLE 4 | Interaction effects analysis between job changes and family conflicts on quality of life in the gender subgroup.

	Model 3: father				Model 4: mother			
	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>P</i>	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>P</i>
Number of children (ref: 3+)								
1	0.889	1.008	0.120	0.378	0.172	0.522	0.024	0.741
2	0.320	0.992	0.043	0.747	−0.002	0.500	0.000	0.997
Job changes	−0.124	0.217	−0.034	0.568	0.003	0.123	0.001	0.980
Marital conflict	−1.354	0.344	−0.326	<0.001	−0.672	0.151	−0.186	<0.001
Parent–child conflict	0.002	0.315	0.000	0.996	−0.653	0.151	−0.181	<0.001
Job changes * marital conflict	−0.421	0.186	−0.153	0.024	0.005	0.151	0.001	0.974
Job changes *parent–child conflict	0.747	0.242	0.188	0.002	−0.091	0.152	−0.025	0.550

B, Non-standardized coefficients; *SE*, standard error; *Beta*, Standardized coefficients; Bold values are statistically significant at $p < 0.05$; All models have been controlled exposure, province, age, education, marital status, income, occupation, first child age.

TABLE 5 | Interaction effects analysis between job changes and family conflicts on quality of life in the number of children subgroup.

	Model 5: one child family				Model 6: two children family				Model 7: multiple children family (3+)			
	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>P</i>	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>P</i>	<i>B</i>	<i>SE</i>	<i>Beta</i>	<i>P</i>
Parents (ref: father)												
Mother												
Changes in job	0.075	0.162	0.020	0.643	−0.073	0.156	−0.020	0.640	−0.331	0.453	−0.108	0.469
Marital conflict	−0.857	0.183	−0.254	<0.001	−0.738	0.219	−0.180	0.001	−1.001	1.162	−0.219	0.393
Parent–child conflict	−0.439	0.189	−0.121	0.021	−0.655	0.207	−0.171	0.002	−0.411	0.916	−0.116	0.655
Job changes* marital conflict	−0.304	0.135	−0.106	0.024	−0.250	0.225	−0.063	0.266	1.230	0.902	0.335	0.179
Job changes*parent–child conflict	0.412	0.161	0.115	0.011	−0.017	0.228	−0.004	0.940	−0.395	0.639	−0.127	0.539

B, Non-standardized coefficients; *SE*, standard error; *Beta*, Standardized coefficients; Bold values are statistically significant at $p < 0.05$; All models have been controlled exposure, province, age, education, marital status, income, occupation, first child age.

study, which may suggest that we may miss the data from fathers who are quiet busy with their job or other things. Thus, we should be cautious in generalizing our results. Third, our study only included limited job change forms without consulting vocational psychology, which may fail to fully reflect the relationship between job changes and young parents' QoL. Fifth, with the cross-sectional design of the current research, it is difficult to make a causal inference. Longitudinal designs are expected in future studies to help clarify the causal relationships.

Despite these limitations, the findings of this study have significant implications. First, the QoL among young parents experiencing job changes and family conflict should be given adequate attention during COVID-19 confinement, and corresponding proactive and applicable interventions can be proposed. For example, community organizations and social workers should pay more attention to the prevention of family conflict. In addition, fathers and one-child families need to implement psychological interventions (that mitigate marital conflict) and work insurance (that reduce financial pressure).

CONCLUSION

This study indicates that family conflict is an important factor related to QoL among younger Chinese parents. Job changes are found to moderate the association between family conflict and QoL. In addition, we find that these interaction effects differ across gender and family structure, and they are only significant for fathers and one-child family. The findings suggest that work insurance programs and professional family support from government and community social workers may be beneficial to improve the QoL of younger parents.

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 Peking University. The patients/participants

provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

XL analyzed and interpreted the data and wrote the first draft of the manuscript. YB, FA, MS, and NH commented and revised the manuscript. JG conceptualized the study design, supervised the work, and revised the manuscript. All authors read and approved the final manuscript.

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Impact of COVID 19 Pandemic and Big Data on China's International Trade: Challenges and Countermeasures

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Early 2020 witnessed the coronavirus disease 2019 (COVID-19) pandemic followed by a nationwide lockdown in the whole history for the first time. In this raising dilemma, multiple countries had a serious impact on their international trade, especially during the lockdown. It is also widely accepted that the lives of individuals had been changing ever since the spread of COVID-19. Several other sectors were badly affected during the pandemic. For the above reasons, service industries had a significant impact before and after the pandemic. Based on the data collected, it was identified that the pandemic affected the service industries, enterprises, and other organizations that contribute to the economic growth of the nation. It was also found that the pandemic has adversely impacted private and public enterprises. In addition, the study examined the impact of COVID-19 on China's international trade using artificial intelligence and blockchain technology. Another objective of the article is to examine the impact of big data on China's international trade. The study suggests upgrading the trading policies of China to deal with the challenges being faced in the trading industry.

Keywords: psychological approach, nursing, cancer patients, quality of life, big data, blockchain, artificial intelligence

INTRODUCTION

The unexpected outbreak of coronavirus disease 2019 (COVID-19) in the year 2020 caused several changes in the social and economic lives of the people. To slow down the spread of COVID-19, several businesses and enterprises have decided to impose restrictions on their economic activities. Almost every country in the world declared a nationwide lockdown, banned entry of people from various countries, and imposed social distancing norms (1, 2). Particularly, strict restrictions were followed all around the world. However, these restrictions were lifted gradually. Even the economic activities were started and contributed to the economic growth of the nation. The Gross Domestic Product of China started increasing after the first wave. Though the second wave hit many countries, the learnings and experiences of the first wave allowed people to manage their social and economic activities in the second pandemic (3). The social, political, and economic activities of the countries were badly affected as a result of the pandemic outbreak. The majority of the businesses adopted strict measures, such as wearing masks, following quarantine, and social distancing norms, to curb the spread of the pandemic (4). The economic growth of the country suffered a huge shock,

which was transferred to the traders spread across the world. In short, the international trading chain was hit hard, disrupting the supply chain management, reducing the global production, cross-border investment, and trade. China was the first country affected by the pandemic, due to which exports, imports, and trade faced uncertainty.

Several studies have been conducted to investigate the impact of a pandemic on China's international trade. For this, the studies analyzed the data collected from January 2019 to September 2020 on trading. Results of the studies stated that the COVID-19 pandemic predominantly affected trading at the international level at various levels (5). The scales of production, scales of import, scales of export, and the supply of products all slowed down, especially after the pandemic outbreak. There was a decline in the operations across the industries. Due to the decrease in demand for the product during the pandemic, the trading industry had to experience collateral damage, particularly after COVID-19. In other words, the COVID-19 outbreak has negatively affected trading. It has even changed society and even the lives of people. However, it is hoped that these negative effects of the pandemic on international trade will reduce after the first pandemic (6).

During the pandemic, the restrictions laid for trading adversely damaged the international trading system. The growth of international trading began to slow down as a consequence of the destructive effects of the pandemic. In the year 2019, the growth of trade was identified to be sluggish. The pandemic had a negative effect on global trade and made it even more sluggish than ever before. Since the service industry of China is heterogeneous in nature, the effect of the outbreak on the industry was quite different. China is popularly known as the best country for international trading, and hence they started using the internet and big data operations in promoting the trade of the industries (7–11). Big data, generally, uses technology to conduct deep research and analysis (7–9, 12–14). Therefore, the current study also tries to examine the impact of big data on China's international trade, as big data exert impact on the trading enterprises. This article follows the layout given below. LITERATURE REVIEW Section presents the examination of the available literature review. METHODOLOGY Section discusses the methodology adopted in the study and the ways to gather data. RESULTS AND DISCUSSION Section presents the prominent findings derived from the study, followed by a discussion. CONCLUSION Section presents the conclusion of the article.

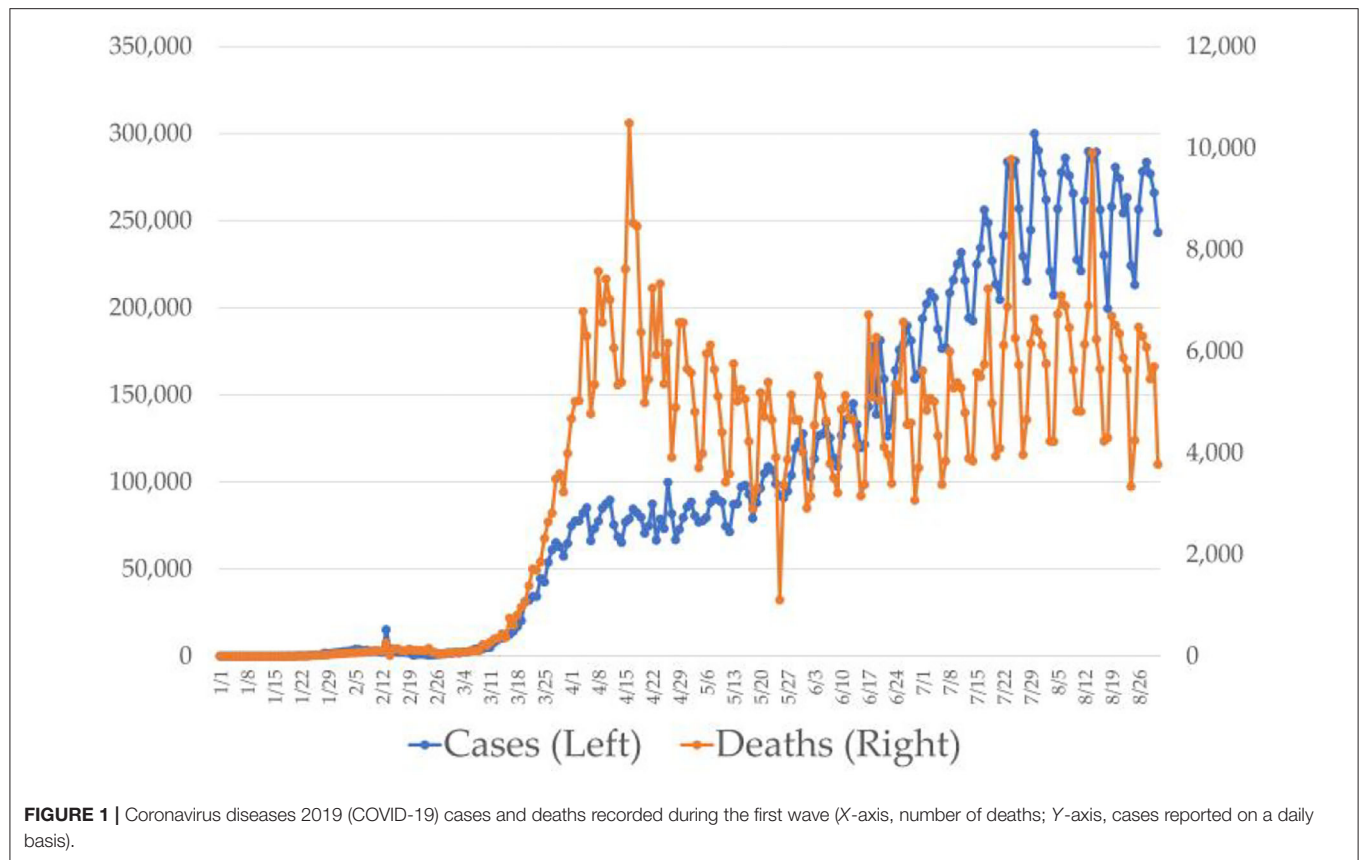
LITERATURE REVIEW

An ever-increasing body of literature examines the impact of COVID-19 in those countries that perform international trading and finds that the rapid spread of the outbreak gravely affected the social, political, and economic activities of a country (15). Due to the strict lockdown measures, such as following social distancing norms, banning people from entering the countries, and following quarantine measures, the movement of people from one place to another was reduced. All the educational

institutions, workplaces, and tourist spots were closed for a long period of time. The number of cases and deaths was increasing rapidly and as a result, work forces were reduced within the industries. COVID-19 was identified as one of the prolonged diseases and thus it reduced the human resources. For these above reasons, supply chain management was hit hard, which led to a reduction in the supply of goods. The trading curve of China moved upward and much steeper (16). The COVID-19 pandemic negatively affected the trading countries as their lockdown measures interrupted the transportation sector. When the transportation sectors were disrupted, the cost of exporting and importing doubled.

Several studies have put forward that COVID-19 has poorly scaled down the production, supply, and trading, thereby affecting the international trading of the country. However, the degree of damage would differ from one industry to another, based on their heterogeneity (17). These studies also proposed that those industries that supply essential products would not find it difficult to trade their products and will have less damage than industries that produce non-essential services. The essential services include medical products and food, while non-essential products include machines, electronics, and automobiles (17). The supply of essential products was not restricted as it was a universal need. Hence, the manufacturers of the essential products were not affected due to the lockdown measures. Hence, these countries that supplied essential products were able to supply these products to the needy even during the lockdown period. Moreover, shutting down the factories was not exceptionally applicable to those industries (17).

Despite all these damages, most of the industries started operating remotely, which partially reduced the negative impacts of the pandemic on the industries. With the help of information technology and telecommunication services, industries could successfully move to remote work and thereby reduce the shocks in the supply of goods and services, especially in the manufacturing services (18). Most countries are successful in maintaining their economic activities by the means of advanced information technology (IT) and telecommunication services. Indeed, these services could largely mitigate the negative effects of the pandemic on international trade. Surprisingly, these new advancements also increased the productivity and efficiency of the scale of production, which helped the manufacturers to increase scales of production. By doing so, the industries could increase their trading performance (19). Most importantly, a lot of industries moved to remote work from on-site production services after analyzing their success rate. On the other hand, those industries that continue to work on-site observed a decrease in international trading, despite adapting to the advanced technology services. Industries, such as footwear, textile, leather, retail, machinery, and transportation sectors, find it extremely difficult to increase their scales of production when they do not shift from operating on-site to remote (20, 21). Few other studies also pointed out the fact that the production of goods and services generally demands the presence of an individual and it is considered critical. Of all the manufacturing jobs, only 22% of them can be done remotely, while others would require the presence of a person.



Countries that are importing products or services will be mainly affected in terms of cost. The lockdown measures will be a hindrance to the people's earnings, and thus their demand for the products will naturally come down. As the earnings of the people will be affected due to the strict lockdown norms, the governments will cut down the demands to meet the needs of the people who need support. This can lead to shrinkage of the demands, resulting in supply shocks (22). Most importantly, the spread of disease in a rapid manner discourages people from visiting supermarkets and other essential outlets, which can also lead to a shrinkage in demand. This demand shock negatively impacts the industries. A few authors have also examined the impact of the recession on international trade and found that people who are facing such shock spend less on durable products than on non-durable products, as the latter can be deferred (23). Therefore, the demand shock for durable products, such as footwear, machinery, wood products, textiles, rubber, plastics, leather products, glass products, and precious metals, can be much higher.

A large number of enterprises have relatively started using big data technology to seek information/data. As part of economic globalization, many countries have adapted big data to meet specific requirements (24, 25). The current advancements in the field of IT are commonly referred to as big data. As data handling becomes difficult each day due to rapid development in the internet databases, enterprises find it difficult to manage

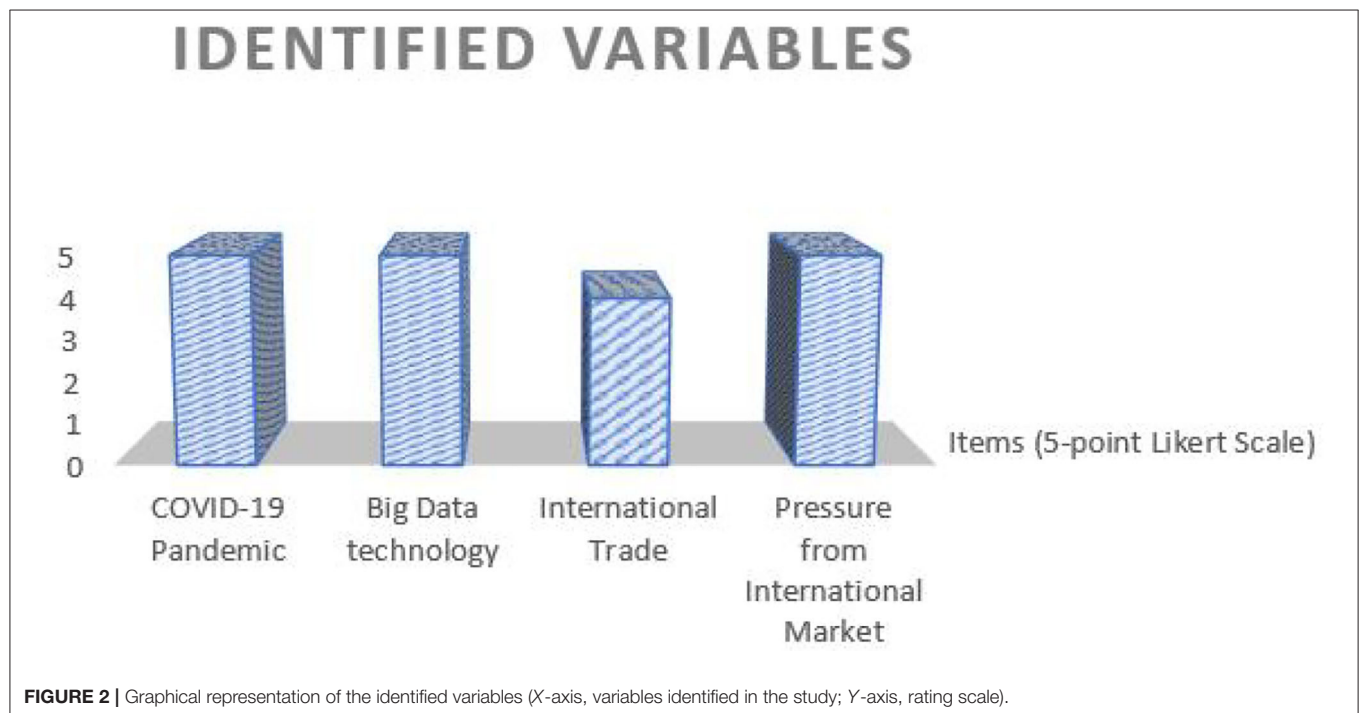
TABLE 1 | Research details.

Headers	Comments
Sector	Enterprises/Industries involved in International Trading
Location	China
Methodology	Structured questionnaire
Sampling technique	Technique of random sampling
Selected respondents	2,000 (1,500)
Period of data collection	October 2020 to December 2020

their data regarding exports and imports. In other words, the data/information of trading is inseparable from internet databases (7, 26, 27). To make appropriate use of resources and as a part of economic globalization, organizations utilize big data. In addition, with an intent to enhance the business and derive profits, enterprises make use of big data (7, 8). Thus, this era is called as the era of big data. Examining data using big data technology is considered scientific, logical, and perfect in nature, when compared with traditional enterprise management (9, 12, 13). To improve the quality of a business, SMEs make use of big data to make an accurate and quick decisions in the need of the hour (7, 27). The literature review shows that the use of big data in the business will enhance the whole process of business, and for this reason, SMEs are considering adopting

TABLE 2 | Variables of the study.

Name of the variable	Variable definition	Items (5-point Likert Scale)
COVID-19 pandemic	This variable helps the researchers to understand the market conditions, analyse the essential needs of the customers across the industries, and propose a new way of remote operations/work leading toward economic globalization	5
Big Data technology	Big Data refers to massive volumes of data, which expands the business with new opportunities and challenges, even at the international level. Adopting innovative technological advancements within the industries will help them to enhance their services to customers, improve supply chain linkage, and strengthen their knowledge of market and trade relationships	5
International trade	Understand the concept of international trade, which will help the researcher to examine the impact of COVID-19 and Big Data on China's International Trade	4
Pressure from international market	Understand the International market, which will help the researcher to examine the impact of COVID-19 and Big Data on China's International Trade. It also helps the researcher to understand the challenges faced by the industries with regard to trading, during the pandemic times and suggest the countermeasures	5



big data to businesses (12). The use of big data technologies will help SMEs in deriving market value. The best way to deal with the challenges in business is to adopt big data in SMEs (9, 12). However, researchers have shifted their focus to big data, on discovering the benefits of big data.

A series of recent studies have indicated that multinational organizations are buying big data. Even startups are purchasing big data technologies to understand the new market, new clients, new business, and so forth. Big data will also help enterprises to cut down on their costs of business and enter the market. Transforming the big data to business applications will cost them real difficulty. Investing capital in big data hardware and

software is high. Few other studies revealed that technology adaptation, financial innovations, and big data are regarded as the strong pillars of enterprises (23). Organizations that use big data can increase their productivity and growth, which will improve the performance of enterprises. It will also help organizations to understand the behavior of the market. There exists a considerable body of literature on the importance of data within companies. Data are regarded as important asset for enterprises. Large industries across the world are exploring different ways to tackle the data, which are usually called big data (26). **Figure 1** shows the COVID-19 cases and deaths recorded during the first wave.

TABLE 3 | Demographic details of the respondents.

Details	Number	Percentage%	Total count
Gender			
Male	950 (M)	64.3%	1,500
Female	550 (F)	36.3%	
Business nature			
Manufacturing	850	55.05%	1,500
Services	650	46.21%	
Establishment year			
<10	242	18.4%	1,500
10–15 years	561	40.31%	
15–20 years	322	22.18%	
>20 years	272	19.61%	
Employee count			
>150	172	13.01%	1,500
25–150	687	49.21%	
<25	536	39.41%	
Revenue			
>10 million	371	27.21%	1,500
5–10 million	582	42.60%	
<5 million	442	32.23%	

Few other studies stressed that enterprises could use big data technology to facilitate trading. Enterprises can come up with different strategies to enhance international trade. As per the international trade theory, economic exchanges between the countries will reflect their competitive spirit in their economic activities (7, 9, 12). Profit being the ultimate aim of any business, enterprises ensure to meet the needs of customers, thus adding value to the business. Efficient and productive business always help the industries to understand the market and improve the commercial value of the products. It will also enrich the scope of the market by providing innovative ideas for the enterprises to operate more successfully. Recent studies have concluded that the present era is popularly known as the era of big data and economic globalization (13). Researchers have come up with different trading models that can increase profit. One such model is to utilize the internet database and then make significant decisions on trading products at the international level. It is also one of the prominent ways to improve the strength of enterprises. Big data also helps enterprises to understand the international market before entering the global market (8). This technology provides good protection to enterprises. Hence, the organizations will be able to participate in international trade and produce additional products. It can therefore be concluded that big data has advantages and disadvantages. From the analysis of the existing literature, the study proposes the following hypotheses:

H1: There is a negative relationship between the COVID-19 pandemic and International Trade.

H2: There is a positive relationship between the COVID-19 pandemic and big data technology.

H3: There is a positive relationship between big data and international trade.

H4: Big data increases the growth and development of enterprises, even during the pandemic.

H5: Technology adaptation and big data technologies will increase the international trade even during the COVID-19 pandemic.

METHODOLOGY

The current study mainly concentrates on examining the impact of COVID-19 and big data on China's international trade. In addition, it also examines the relationship between COVID-19 and international trade; and the COVID-19 pandemic and big data technology; adopting big data technologies from the perspective of international trading. The analysis of the current study has been conducted through secondary literature and primary analysis as well. The study has developed a hypothesis based on the analysis and review of the secondary literature. The formulated hypothesis is tested using a structured questionnaire. Thus, the current study gathers all the required data using a questionnaire and hence the study is descriptive. Using the questionnaire's results, the researcher will evaluate the hypothesis. This method involves describing the objectives, defining the population, selecting the sample, and later interpreting the data and results. The population is a complete set of individuals who are bound together by certain common characteristics. The population is of two types: target and accessible. The target population consists of those whom the researcher wishes to generalize the findings of the study. In the current study, the total population includes enterprises that participate in international trading in China. From the total population, the study derives the required sample. The term sample includes the individuals selected to participate in the study. These selected participants are popularly known as respondents/subjects of research. Sampling methods are of two types: probability/random sampling and non-probability. To carry out the research, this study employs a random sampling method. At times, researchers also tend to use purposive sampling to obtain required data from certain areas of research.

To fulfill the objectives of the study, the study selects a sample consisting of 5,210 enterprises located in China. This study focused on those international trading enterprises in China that were relatively easy to connect using an electronic channel. Prior to the administration of the questionnaire prepared, consent from the enterprises was imitated as the first step. Only after the participant's acknowledgment, the questionnaire link was distributed to the selected sample. Out of 5,210 samples, approximately 4,500 of them acknowledged and agreed to participate in the study. So, in total, 4,500 SMEs sent their prior consent, out of which only 3,000 were considered valid. Based on the analysis of the secondary literature, the researcher prepared a structured questionnaire, which addressed the factors, such as the relationship between COVID-19 and international trade, the COVID-19 pandemic and big data technology, adoption of big data technologies, and challenges in the international trading and its countermeasures from the perspective of international trading. This structured questionnaire will allow the selected

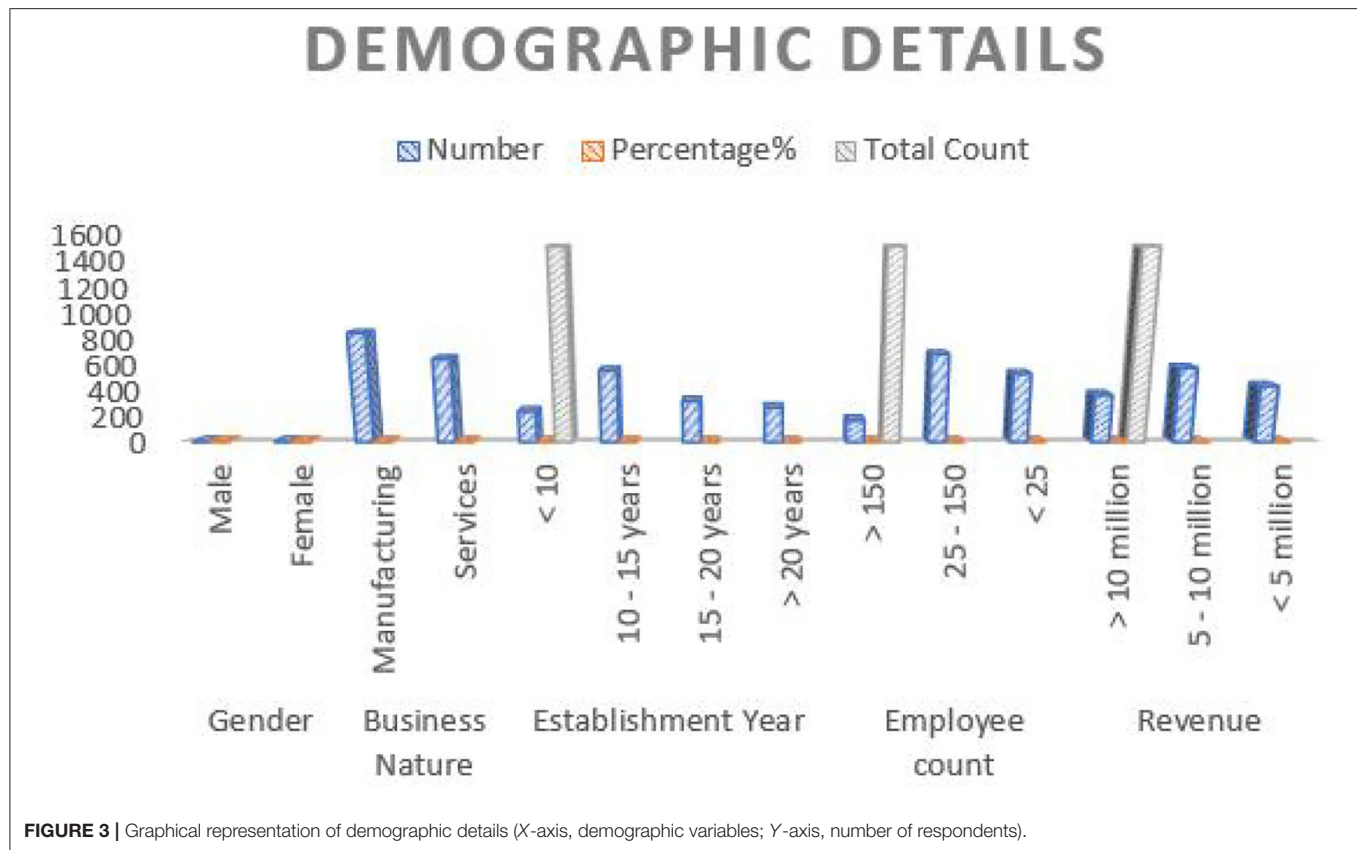


TABLE 4 | Validating the instrument used in the study.

	PD	BD	IT
PD1	0.921		
PD2	0.882		
PD 3	0.945		
PD4	0.891		
PD5	0.820		
BD1		0.991	
BD 2		0.891	
BD 3		0.912	
BD 4		0.890	
IT1			0.893
IT2			0.882
IT3			0.960
IT4			0.921
IT5			0.881

respondents to share their views, opinions, beliefs, attitudes, and values on the research topic. The data were collected from October 2020 to December 2020 and a sample of 3,000 was considered along with their responses. **Table 1** presents the technical details of the research. In total, 2,000 responses were collected back and after the screening process, data of

1,500 respondents were finalized and considered for further analysis. Both primary and secondary data are collected to find out the results. The primary data are collected using the structured questionnaire designed to collect the required data from the participants. The collected data will help the researcher to examine the relationship between COVID-19 and international trade, the COVID-19 pandemic and big data technology, adopting big data technologies, and challenges in the international trading and its countermeasures from the perspective of international trading. The researcher collects the secondary data required for the study from research articles and other journals. Finally, all gathered information was collected and analyzed to answer the research purpose.

The present study identifies different variables, such as big data technology, COVID-19 pandemic, international trade, and pressure from international market along with the measurement model. This model is presented in **Table 2** and its graphical representation is presented in **Figure 2**.

To analyze the data collected, the researcher employs Statistical Package for the Social Science (SPSS) and analysis of moment structure (AMOS) 26.0 version. To study the relationship between the variables identified, the study adopts structural equation modeling (SEM). Furthermore, the selected enterprises/industries will be able to provide accurate and precise information on the questions covered in the questionnaires related to the research topic. As the SEM method is highly resilient and efficient in modern times, the researcher decided

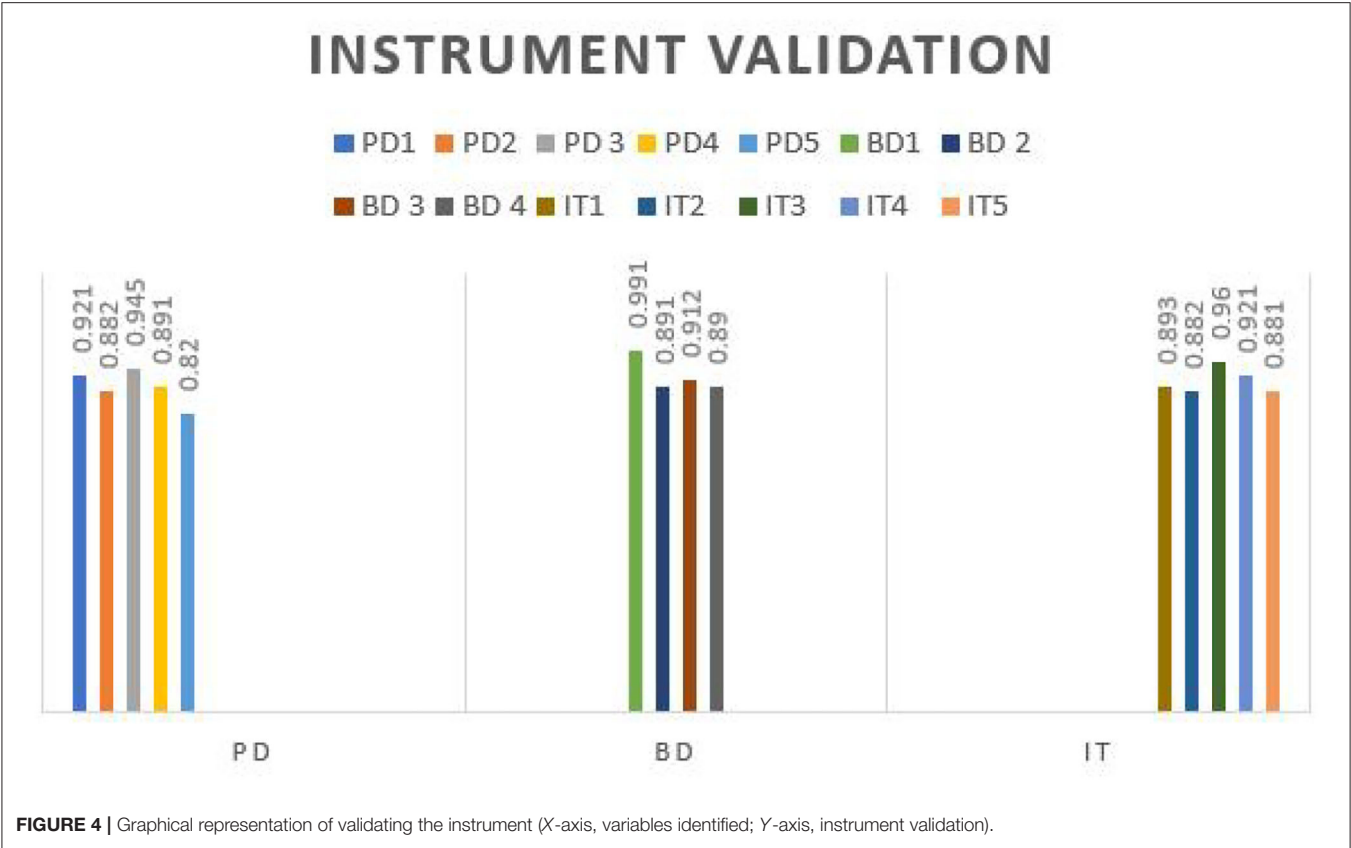


TABLE 5 | Results of hypothesis testing.

Relationships	Path	SD	t-Value	p-Value
H1: There is a negative relationship between COVID-19 pandemic and International Trade	0.171	0.125	4.145	0.002
H2: There is a positive relationship between COVID-19 pandemic and Big Data Technology	0.282	0.084	6.828	0
H3: There is a positive relationship between Big Data and International Trade	0.332	0.087	5.267	0.018
H4: Big Data increases the growth and development of enterprises, even during the pandemic	0.201	0.086	2.432	0.39
H5: Technology adaptation and Big Data technologies will increase the international trade even during the COVID-19 pandemic	0.32	0.09	2.802	0.201

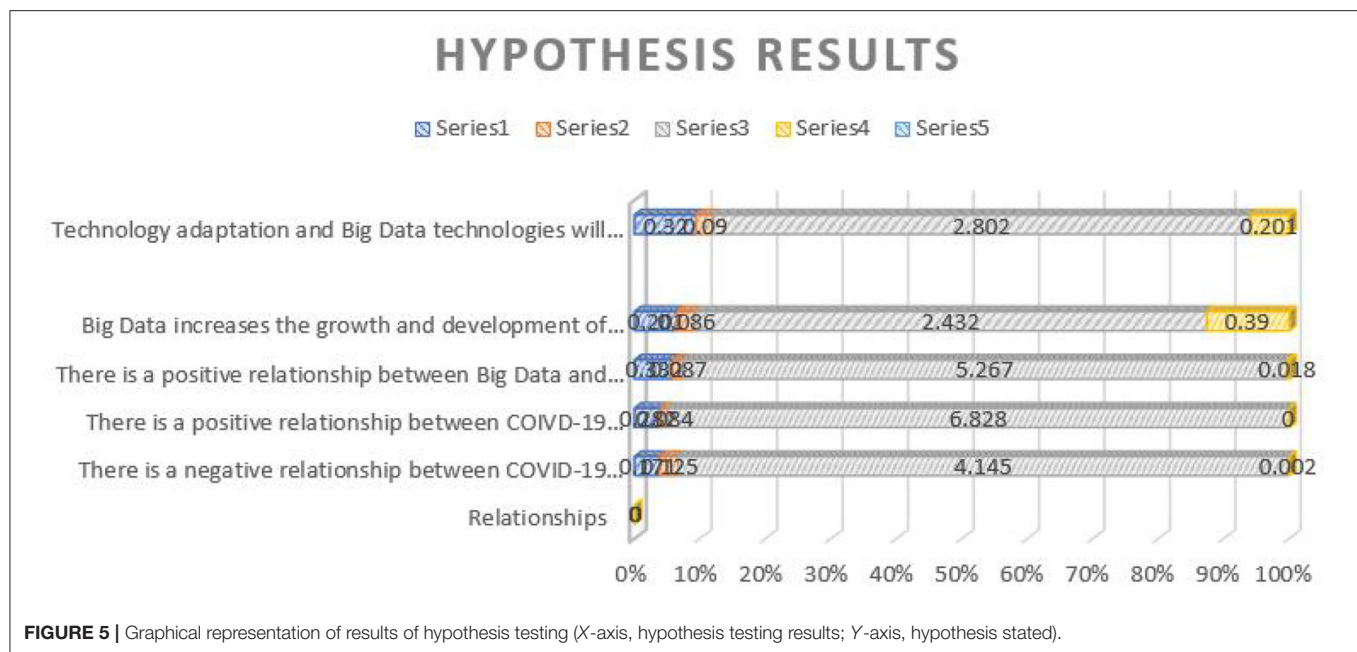
to use the same. This method will help the researcher to examine the relationship between the variables identified by testing the proposed hypothesis. This method also focuses on the appropriateness of the results and hence was taken into consideration.

Although the owners of enterprises were reluctant to share the details of trading, such as their performance during the pandemic, challenges faced during pandemic times to trade the services/products, adopting big data technologies for smooth trading, and their point of view on the international market, from the perspective of international trading sustainability initially, later, they understood the need to evaluate the challenges faced by the enterprises in terms of trading, especially during the pandemic times, which helped the researcher to record the accurate data. Past researchers also tried to measure the impact of COVID-19 and big data on international trading, which were

in line with the opinions of the respondents, marked on a 5-point Likert scale, scaling from extremely poor to extremely good. The study also recorded responses from the participants on innovative ways to manage trading among China's enterprises from the perspective of profit and development. Lastly, the study also recorded the responses of the respondents on adapting to innovative technologies and big data within enterprises that will enhance international trading on a 5-point Likert scale.

RESULTS AND DISCUSSION

The current study confirmed the following findings using artificial intelligence and blockchain technology. Table 3 records the demographic details of the respondents, who participated in the structured questionnaires. Figure 3 provides a graphical representation of demographic details. When analyzing the data



of the enterprises, it was understood that 64.3% of them are men and 36.3% of them are women, spread across industries, such as manufacturing and services, essential products, such as food and medical manufacturing enterprises, units of footwear, leather, textiles, machinery, and transportation services. About 55.05% of the respondents come under the essential products manufacturing units and 46.21% of them belong to service units, such as beauty parlors, book shops, and transportation services. Similarly, 40.31% of the enterprises were established for almost more than 10 years and come in between 15 years, 22.18% of the enterprises were established for more than 15–20 years, 19.61% of the enterprises were established for more than 20 years, and least 18.4% of them were established for less than 10 years. With regard to employee count, 49.21% of them disclosed a high level of engagement in operations, 39.41% disclosed a mediating level of employee engagement, and 13.01% exhibited low levels of employee engagement. Lastly, about the employee revenue, 42.60% of them earned almost 5–10 million in a year, followed by 32.23% (<5 million) and 27.21% (<10 million).

The validation of the instrument used in the study is recorded in **Table 4**. From the table, it can be understood that the skewness test range results suggest that variables identified in the study—big data technology, COVID-19 pandemic, international trade, and pressure from international market are equally distributed. The extreme loading values presented in the table state that the instrument used is highly reliable and valid, which is calculated as 0.7 in terms of implementation. Moreover, the results presented in **Table 4** also confirm the absence of multicollinearity in the data gathered. **Figure 4** presents the graphical representation of validating the instrument used in the study.

The result of the empirical study shows that implementing big data technology within the enterprises will be the best way to manage international trading, during the pandemic

times, as big data plays a crucial role from the perspective of industry sustainability, as the coefficient value seems to be higher than the cut-off value. Similarly, the results associated with variable COVID-19 pandemic also confirmed that they seem to significantly impact the smooth functioning of the trading, due to the financial pressure these industries face in China. It was also found that the international trading market will slow down, especially when advanced technologies are not implemented, which are in line with enterprise sustainability from the perspective of the pandemic. All the identified variables seem to be efficient and hence the results can be considered reliable. The findings of the study also disclosed that there are no reliability and validity issue about the identified constructs.

Moreover, the study identified several challenges, such as facing extreme financial pressure, pressure for the industries or enterprises to explore the international market, the pressure of ordering goods/services, the pressure of transferring goods and services, and others. During the pandemic times, industries faced operating difficulties as there were strict lockdown measures, which turned the lives of people upside down. People have started spending less on durable products than on non-durable products. For these reasons, the economic activities during the pandemic were stringent. Earnings of the workers were less, and hence people were skeptical about spending on non-essential items. Even the transportation services were banned from one place to another as the spread of the disease was rapid. All these factors reduced the export and import of goods/services from one country to another. Hence, it can be stated that the pandemic negatively affected international trading, thereby lowering the economic growth of the country. As a countermeasure, these enterprises can implement big data technologies or advanced ITs, which will help them carry out the operation remotely. Past studies also confirmed that new technologies in the field

of IT were extremely optimistic about the pandemic situation. It was equally important to understand the international market and develop international trade, especially during the pandemic times. Generally speaking, businesses faced a huge decline in their profits when the pandemic hit hard, which also badly impacted international business. In addition, the study presented the results in measurement models, including all the identified various variables. **Table 5** presents the measurement model results of the study, which indicate that there exists a relationship between the constructs—innovative finance, adopting technology within the SMES, and adapting to big data technologies from the perspective of SME sustainability and big data. **Figure 5** represents the results of hypothesis testing.

The study found that the hypothesis proposed in the study has a high impact on enterprises' international trading and sustainability. The results of the study document that there is a negative relationship between the COVID-19 pandemic and international trade; there is a positive relationship between COVID-19 pandemic and big data technology; there is a positive relationship between big data and international trade; big data increases the growth and development of enterprises, even during the pandemic, and technology adaptation and big data technologies will increase the international trade even during the COVID-19 pandemic. In addition, the study found that the enterprises performing international trading in China are high in number and hence the operations of the enterprises should focus on adapting to innovative technology, such as big data to sustain in the international market. Even big data technologies will create new challenges and opportunities for the enterprises in the contemporary world and enhance trading. Furthermore, there is a positive relationship between adopting technology and international trading, which will expose enterprises to new opportunities and challenges. In summary, big data technologies are essential in enterprise sustainability, even though a pandemic has hardly hit the trading industries.

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CONCLUSION

The present article has proposed and tested the relationship between the COVID-19 pandemic and big data on China's international trade. The results of the study indicated that there is a negative relationship between the COVID-19 pandemic and international trade; there is a positive relationship between COVID-19 pandemic and big data technology; there is a positive relationship between big data and international trade; big data increases the growth and development of enterprises, even during the pandemic, and technology adaptation and big data technologies will increase the international trade even during the COVID-19 pandemic. The study also identifies the challenges faced by the industries during pandemic times and thus, as a countermeasure proposed adapting big data technology implementation within the industries to enhance international trade.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

Ethics review and approval/written informed consent was not required as per local legislation and institutional requirements.

AUTHOR CONTRIBUTIONS

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

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COVID-19 Pandemic and SMEs Performance Decline: The Mediating Role of Management Innovation and Organizational Resilience

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It is a major practical problem to find out a pathway for firms to quickly recover from the performance decline in the context of the COVID-19 pandemic and other sudden major crisis in the current academic circles. Based on event system theory and structural adjustment to regain fit model, this paper empirically explores the impact of the COVID-19 pandemic on SMEs performance decline and discusses the management innovation response and organizational resilience mechanism of firms by virtue of the questionnaire survey data of SMEs in Guangdong Science and Technology Park in China. The research results elucidate that the criticality and disruption of the COVID-19 pandemic will not only lead to the SMEs performance decline, but also enable SMEs to carry out management innovation. Moreover, management innovation does not directly curb the SMEs performance decline caused by the COVID-19 pandemic, but indirectly inhibit it by promoting organizational resilience. In other words, the COVID-19 pandemic will indirectly promote organizational resilience through firm management innovation, thereby curbing the SMEs performance decline. A path of management innovation response and organizational resilience to reverse the performance decline can be obtained in the study when SMEs confronting sudden major crisis. Furthermore, the study also expands the application scope of structural adjustment to regain fit model, which provides a useful reference for firm crisis response and sustainable development.

Keywords: COVID-19 pandemic, performance decline, management innovation, organizational resilience, sudden crisis, SMEs

INTRODUCTION

The COVID-19 pandemic (COVID-19) has forced a global blockade and economic shutdown (1), with a significant negative impact on production, operations and sales of firms, resulting in firm performance decline (FPD) (2). Against this background, many a firm all over the world are stuck deeply into the quagmire of the COVID-19 with great crisis and difficulties, and small and medium-sized enterprises (SMEs) were hit especially hard (3), may put SMEs' lives at risk (4), yet quite a few Chinese firms are still able to quickly revitalize from it. Therefore, it is of far-reaching practical significance to analyze the path of rapid resilience of the declining performance of Chinese firms under the background of the COVID-19, which will promote the sustainable development of firms and the healthy development of national economy in the sudden major crisis.

The existing research on the relationship between the COVID-19 and firm performance (*FP*) is mainly based on the analysis of corporate financial data, finding out the COVID-19 has a negative impact on *FP* (4–9) and firm sustainable growth (10). Nevertheless, there is a lack of empirical research on *SMEs*. In addition, some scholars have found that organization redundancy weakens the negative relationship between the COVID-19 and *FP* (5), and R&D investment plays a moderating role in the relationship between the COVID-19 and *FP* (8), customer concentration can relieve the negative impact of the COVID-19 on firm sustainable growth (10). The above studies mainly discuss the moderating function of redundant resources, R&D resources and customer resources from the perspective of resources, but not the mediating mechanism of the COVID-19 affecting *FP*. The existing research has ignored the theoretical premise that the resources can be used effectively to alleviate the chilling impact of the COVID-19 on *FP*. In the early period of the COVID-19, most firms come into a standstill, which brings about the shortage of these resources owned by firms and the difficulty to use them effectively. Under the circumstances, how to get these resources effectively used and back on track has become the top priority as to firms. However, there is short of discussion and research on how to deal with firm management innovation (*FMI*), how to achieve organizational resilience (*OR*) and performance improvement upon the major crisis.

The COVID-19 makes the external market environment more turbulent, which leads to the mismatch between the original organizational structure and the new environment. The mismatch between organizational structure and contingency factors causes a decline in performance, while the matching of the two factors will lead to the increase of performance (11). According to structural adjustment to regain fit model (*SARFIT* model) proposed by Donaldson (11), the change of contingency factors will lead to the adaptive change of organizational structure. Firms adopt new organizational structure to match the new contingency factors, contributing to the resilience of *FP*. Firms have to confront severe economic situation due to the drastic change of firm external environment caused by the COVID-19. Grim economic situation will prompt managers to regard innovation as the right strategy and adjust their management model to the crisis by virtue of a series of management innovation (*MI*) practices (12). *MI* is the invention and implementation of a new management practice, new process, new structure, or new technology to achieve further organizational goals (13). The practice of *MI* under crisis is the adaptive change of firms, and it is the process that firms adjust the mismatch between organizational structure and environmental factors to rematch. As a new practice beneficial to sustainability and performance improvement (14), *MI* offers a solution for companies breaking out of the COVID-19 dilemma and achieving resilience. *MI* is an effective measure in that it not only improves the economic benefit of firms in the short term, but also enhances the competitiveness and development potential in the long term. However, the abrupt outbreak of the COVID-19 has also changed the background of *FMI*. The conventional *MI* that the firm takes the initiative and carries on the *MI* step by step becomes the passive and emergency management

innovation (*EMI*) that the firm carries on suddenly. What's worse, when implementing organizational changes such as new work organization or new knowledge management system, staff need a process of adaptation and learning, which means *MI* does not immediately transform into substantial improvements in innovation performance (15). In such a case of COVID-19, can *EMI* soothe *FPD*? If so, how does it reverse the trend of *FPD*?

With the COVID-19 and other major crisis, the premise of firms meliorating the *FPD* is to resume normal operations. The current business environment is characterized by a high degree of competition, uncertainty and ambiguity. Natural disasters and crisis occur frequently. These changes of the external environment magnify the importance of resilience to the organization (16). Organization resilience (*OR*) means an organization's ability to overcome difficulties, create opportunities and build a successful future by integrating resources from all sides. Resilience helps companies recover faster in the case of interrupted supply chain. The higher the resilience is, the better performance in terms of delivery performance, cost reduction and recovery situation they would be (17). Therefore, this study suggests that *OR* may be an important pathway for firms to reverse the trend of *FPD* caused by the COVID-19. Based on it, this study intends to further explore the following issues: Can *EMI* help firms achieve *OR* with the COVID-19, and then reverse the *FPD* caused by the COVID-19?

Based on the above considerations, this study intends to integrate the event system theory and the *SARFIT* model, constructing a *MI* response and *OR* mechanism model to deal with *FPD* caused by the COVID-19. Moreover, an empirical analysis is carried out by using the questionnaire survey data of firms in Guangdong Science and Technology Park in China. First and foremost, the study explores the impact of the COVID-19 on *FPD* and *MI*. Secondly, it discusses the intermediary conduction mechanism of *MI* and *OR* between the COVID-19 and *FPD*. At last, it pores over the mediating role of *MI* in changing *FPD* through *OR*, which provides some practical enlightenment for firms to carry out *MI* so as to promote *OR* and reverse the tide of *FPD* under the COVID-19 and other crises. The research contributions of this thesis are as follows.

Firstly, this study constructs and validates the input-process-output (*IPO*) mechanism model of firms' *OR* in the context of sudden and major emergency crisis, finding out the path of *MI* response and *OR* when firms want to reverse the *FPD*. At present, there are quite a few research on the application of event system theory. Most of them are qualitative and case studies, while quantitative empirical studies are relatively rare. This paper tries to put forward a theoretical framework of *IPO* about the impact of the COVID-19 on *MI*, *OR* and *FPD*, elaborating the criticality and disruption of the pandemic can promote the *OR*, and finally reverse the trend of *FPD* by enhancing *FMI*. From the perspective of event system theory, this paper reveals the intermediary conduction mechanism of the COVID-19 affecting *FP*, clarifies the path of *MI* and *OR* for firms to deal with sudden major crisis, and enriches the empirical research results of the event system theory as well.

Secondly, this paper extends Donaldson's (11) SARFIT model and finds the double-edged sword effect of the COVID-19. Based on the SARFIT model, this study tries to explain the process of *FPD* and *OR* caused by the COVID-19. It means that the COVID-19 incurs the imbalance between firm organizational structure and external environment, and then *FP* will fall off. While through the adaptive change of *MI*, firms can make them rematch to obtain the *OR*, which can reverse the *FPD* in return. In other words, although the COVID-19 will cause *FPD*, it can also prompt firms to carry on *MI*, then helping them to recover and revitalize the performance. It means that the COVID-19 has a double-edged sword effect. The research findings not only provide theoretical inspiration for firms to turn crisis into opportunity, but also apply the SARFIT model to the research field of firm crisis management, elucidating the phenomenon that firms implement *MI* and obtain *OR* with the sudden major crisis.

Thirdly, this paper digs out that *EMI* will result in the decline of short-term performance, and makes it clear that *OR* plays a mediating role between *MI* and *FPD*. Different from previous studies which have found that *MI* exerts a positive influence over *FP*, this study discovers that *EMI* has a positive effect on *FPD* under the impact of the COVID-19, and it will lead to a *FPD* in short-term. Maybe that's because *EMI* can cause short-term maladjustment, thus it can't bring about immediate and substantial melioration of *FPD*. In the sudden crisis, *MI* can't directly reverse the *FPD*. Only by virtue of *OR* can help firms restore from the *FPD* under the influence of the COVID-19. The findings generate a new insight for the role of *MI*, favorable to further understanding the theoretical black box between *MI* and *FP*, making up the deficiency of the existing research on the relationship between *MI* and *OR*, and enriching the research findings in the related fields of *MI* and *OR*.

The following contents of this article are as follows: the second part is literature review and research hypothesis; the third part is research design, including sample selection and variable description; the fourth part is empirical results and analysis, including reliability and validity test, descriptive statistics, correlation analysis, regression analysis and hypothesis test, and robustness test; The fifth part is the conclusions. The sixth part is the limitation and future research.

LITERATURE REVIEW AND RESEARCH HYPOTHESIS

Literature Review Sudden Crisis and FP

The COVID-19 and other sudden crises will change the external environment on which firms depend and then affect the *FP*. According to literature review, it indicates that some scholars believe that crisis will have a negative impact on *FP*, yet such an influence can be adjusted by relevant factors. Kestens et al. (18) find that the financial crisis show a negative impact on *FP*, and trade credit could adjust the impact of the crisis on it. Ryu et al. (19) discover that natural disasters have a negative effect on organization performance, which could be mitigated by collaborative networks established in response to natural

disasters. Li (5) finds that the COVID-19 has a negative impact on the performance of manufacturing firms, but organization redundancy weakens the negative relationship between the COVID-19 and *FP*.

On the other hand, some scholars hold a different view that crisis and *FP* are uncorrelated or positive correlation. De Freitas et al. (20) discover that there is no correlation between *FP* and other economic crisis. Some scholars believe that the sudden crisis not only bring threats, but also opportunities to firms. For instance, Noth et al. (21) declare that natural disasters have a positive effect on the *FP* since those firms have higher turnover, lower leverage ratio and higher cash flow after undergoing natural disasters.

Sudden Crisis and Firm Response

The abrupt outbreak of financial crisis, natural disasters, public hygiene and other crisis often makes the normal production and operation activities of firms affected or even interrupted. In the turbulent crisis environment, firms will take corresponding measures to adjust their own behavior to alleviate the adverse effects. Previous studies on firm crisis response have mainly focused on crisis interventions, including short-term emergency measures for survival and long-term strategic measures for development. The short-term emergency measures commonly used by firms are mainly such ways of maintaining business liquidity, developing short-term business, increasing income and reducing expenditure (22). Micro, small, and medium-sized firms will adjust workforce use by reducing working hours, arranging alternative jobs and layoffs, and take emergent measures to tackle the economic crisis such as exploiting new customers and markets, reducing costs and production (23). Since the outbreak of the COVID-19, the quarantine policies have restricted the mobility of people, and online telecommuting has become the most common-used measure for firms to deal with the pandemic (24, 25). While off-the-shelf information and communication technologies such as video conferencing can solve physical distance problems in the short and medium term, more advanced information and communication technologies such as virtual reality are more likely to become critical in the long term. The utility of information and communication technology has made business model innovation become a strategy of crisis response for firms (26). Among them, temporary business model adaptation is a short-term emergency measure, while continuous business model adaptation and identification of new value propositions are more in favor of long-term strategy (22).

In addition to getting through the crisis, firms entail a long-term strategic response to turn the crisis into an opportunity if they want to be stronger during crisis. Martin-rios et al. (27) find that service innovation is a long-term strategic adaptation activity adopted by top service firms in the EU during the economic crisis, among which increasing R&D investment, strategic mergers and acquisitions, and recruitment expansion can help firms to maximize the adaptation to crisis, ensure the long-term viability of strategic orientation, and promote the growth of operating profit, sales and market capitalization. It is true that innovation like digital innovation is a significant strategic response to crisis and long-term survival (28). Workflow

digitization is an effective way for firms to overcome their long-term crisis (22). Digitization helps SMEs to cope with public crisis better and improve their performance as well (29). In addition, Martinelli et al. (30) point out that dynamic capabilities that firms reconstruct and utilize resources, perceive and interpret the environment, and learn to integrate knowledge can contribute to improving *OR* of firms in response to natural disasters, among which the ability of resource utilization is more suitable for short-term response, while the ability of resource reconstruction, environmental perception and interpretation are more favorable to long-term action. *OR* is beneficial to help firms turn crisis into safety with the environment of volatility, uncertainty, complexity, and ambiguity (*VUCA*).

Research Hypothesis

The COVID-19 and *FPD*

FPD mainly shows that the actual performance of firms is worse than the expected performance. The expected performance level can be determined as the historical expected performance level based on the historical performance created by the firm capabilities and resources in the course of firm development, or based on the performance produced by other firms in the same industry to define the expected performance level of the industry. The *FPD* will be influenced by many a factor, such as manager's ability, firm resources, external environment and so on. The more uncertain factors they are, the more obvious impact on the *FPD* it will be. When emergency occurs, the entity usually does not prepare an effective response mechanism or procedure (31), so more or less it will cast a bad impact on the entity. The COVID-19 first occurred globally in January 2020 and spread quickly into a global pandemic (32). From the point of view of event system theory, the sudden outbreak of the COVID-19 has the characteristics of event's strength including novelty, disruption and criticality and so on, which will exert a series of influence on firm entities.

During the COVID-19, in order to prevent and control cross-infection and spread, government departments implement measures such as public health pandemic prevention, personnel isolation and travel restrictions, resulting in a sharp decline in population mobility, causing the direct blockade in terms of people, logistics and commodity flow (33). Due to it most people are isolated at home, and the out-of-home consumption activities plummet sharply, which reduce the consumption and demand of products and services, causing the original inventory backlog of firms, the increase of the inventory cost, and the reduction of firm profits. As a result, *FP* becomes lower than the historical level of the same period. At the same time, self-segregation and travel restrictions have less necessity for workforce in the economy sectors and lead to a sharp drop in jobs (34). Therefore, it increases the proportion of unemployed people, directly reduces the income of consumers, weakens the consumption power, and causes the *FPD* accordingly. The stagnant global stock markets is also attributive to the COVID-19 (35), triggering a signal to consumers that the expected business environment is unfavorable, and the uncertainty of consumers' expected income will increase. Such a situation in return affects consumers' confidence, expectations and behaviors, resulting in insufficient

consumer demand, which in return causes *FPD*. The manpower tightness, the shortage of capital and supply chain disruptions caused by the COVID-19 are also the important reasons for it. During the COVID-19, most of the employees are isolated at home, and the firms are unable to resume work and production. Even if those firms that may resume work are also faced with the difficulties of insufficient manpower. And internal business activities fail to be carried out normally so that firms can't meet consumers' demand for products, which leads to *FPD*. Research shows that after the outbreak of crisis, people are inclined to avoid investment and remedy losses by withdrawing investment (36), and the decrease or even interruption of the supply of investment funds will have a negative impact on *FP*. At the same time, in order to avoid the cross-regional spread of the virus during the COVID-19, the geographical borders are blocked, which limits the services area of the logistics and transportation industries, letting firms fall into the plight of insufficient supply of raw materials, reducing the production capacity of the firm, and then leading to *FPD*. Moreover, large-scale shutdown has delayed the delivery of upstream production companies. Compared to large enterprises, SMEs have shorter life, lack preparedness when dealing with unforeseen circumstances (37), lack sufficient cash flow and are more vulnerable to labor shortage, and are affected negatively by the COVID-19 (38), which will lead to *FPD*.

Based on the above analysis, this paper proposes the hypothesis 1: the COVID-19 plays a significant positive role in SMEs *FPD*.

The COVID-19 and *FMI*

As an organism with self-healing function, firms will try to fit in with the changes by innovation when it is impacted by crisis. Existing research shows that SMEs will take measures to deal with the COVID-19, for example, transferring to the virtual space to make employees continue working remotely (38), implementing organization structure innovation (4), and other *MI* measures. *MI* is a new process in which firms bring about a shift in organization strategies, structures, procedures and systems by applying new knowledge and management methods (39). It is an adaptive change made by firms to respond to environmental changes. Environmental factor turns out to be a crucial point for *FMI* (40). Those managers who can perceive the external environment's change better is more sagacious to recognize new problems in time, so as to urge the firms to carry on the *MI* under crisis.

According to event system theory, those events not created by entities, but entailing entities to deal with passively are called passive events. The COVID-19 belongs to a passive event, which has the characteristics of novelty, disruption and criticality, leading to the mismatch between firms and new external environment, and forcing firms to put forward a series of *MI* measures. At first, the novelty of the COVID-19 that it is significant departure from previous public health with its sudden outbreak, high speed and wide range of spread, handling difficulty and long duration. As for the sudden outbreak of the COVID-19, firms lack corresponding management experience for reference, so they need to reformulate new solution to adapt to the current environment. Thereupon, firms will change internal

communication methods, such as communication between employees and departments from offline to online, firm meetings from face-to-face communication to cloud communication like video conference. Companies will also shift their work patterns, moving flexible work arrangements online. More Internet-based remote work and less reliance on personnel gathering do good to maintaining social distancing for employees (41) and helping companies better fit into the outbreak. Secondly, the disruption of the COVID-19 is reflected in the hindrance and disruption of conventional entities activities. The pandemic spread more or less has impact on the economy, including trade reduction, supply shortages, and financial tightening. To alleviate the economic losses caused by the COVID-19, firms will change the traditional mode of offline sales in the entities to online sales model such as video live selling goods, short video marketing, and recommendation by WeChat official accounts. To adapt to the new sales model, firms will change their organization structure, such as the establishment of network marketing department, e-commerce department, and adjust the staff functions in time. Moreover, the criticality of the COVID-19 shows that firms need to give high priority to the pandemic. Since the outbreak of the COVID-19, firms has always put high premium on pandemic prevention and control to reorganize production patterns and take staggered shifts and so on. In addition to maintaining existing operations to ensure business liquidity, companies also explore long-term strategic changes to guarantee firms' viability (20). It shows that the COVID-19 will have a far-reaching impact on firms, may resulting in the mismatch of firms' original structure and external situation. Compared to large enterprises, SMEs are largely affected by external environmental changes (42). To accommodate to the changes in the external environment, SMEs will more likely to combine with the actual situation to achieve *MI* in the aspects of production process, operation modes, organization structures, task and function, management system, etc.

Based on the above analysis, this paper proposes the hypothesis 2: the COVID-19 has a significant positive effect on SMEs *FMI*.

MI and OR

During the pandemic period, due to home quarantine and other pandemic prion measures, it is difficult for firms to carry out business activities as usual, resulting in a mismatch between the original firm organization structure and the new external environment. *MI* stimulates the new knowledge that can change the existing capabilities of firms, making it more adaptable to the changing environment (43), and helping the rematch. *OR*, as a flexible dynamic capability that enables firms to adapt to and recover from unexpected adverse circumstances (44), represents the resilience of firms after its rematch. *OR* includes agility, integrity, and robustness, in which robustness reflects an organization's ability to withstand and recover from adverse conditions, agility measures an organization's ability to act quickly, and integrity reflects the cohesion of an organization's members in the face of adverse circumstances (16).

Innovation is the key factor to promote *OR* in sudden major crisis. Existing studies have found that the COVID-19

causes serious job insecurity and financial worries, affects the mental health of employees, and leads to negative emotions such as anxiety and depression (45). Anxiety, on the other hand, will affect an employee's work efficiency and target progress (46). Firms carry out *MI* by adjusting the task functions and salary structure of employees and using the new way of telecommuting or online and offline combination, which can help employees to adapt to the pandemic better and faster, reduce their negative emotions and economic worries, enhance their adaptability, improve individual resilience and then promote *OR*. The positive emotion of the staff is transmitted in the team through interactive communication, which facilitates collective positive emotional convergence of the team members and helps build team resilience (47). With positive emotions, team members show high cooperative willingness and team cohesion, which can help alleviate the damage and shock on team integrity caused by the COVID-19, thus enhancing team resilience and thus promoting *OR*. During the COVID-19, traditional management systems, work rules and procedures of firms are no longer fully applicable due to the restriction of pandemic prevention policies. Against this background, the establishment of new management systems and optimization of business procedures can enhance firms' adaptability and flexibility in the face of complicated environment, helping withstand risks and promote the robustness of firms. In addition, by means of information and communication technologies to adjust internal and external communication of firms not only facilitates effective communication and collaboration at all levels within firm, but also helps to maintain external social networking relationships, promote linkages between firms and stakeholders and enhance the robustness of their social networks. Furthermore, the flexibility provided by information and communications technology enables firms to rebuild and expand communication networks during disasters, collect resources and establish trans-geospatial working procedures. In this way may it promote *OR* of firms (48). Compared to large enterprises, SMEs are more flexibility. Therefore, when SMEs carry out *MI*, it is easier for them to recover to the normal operating level and obtain *OR*.

Based on the above analysis, this paper proposes hypothesis 3: SMEs *MI* has a significant positive effect on *OR*.

MI, OR and FPD

Existing research shows that the innovation practices adopted by SMEs to face the repercussions of COVID-19 had a positive impact on the performance (4). According to the SARFIT model of Donaldson (11), which has been successfully implemented in multiunit firms' research when subsidiary performance is below aspirations, and found that the subsidiary performance problems trigger structural adaptation in the internal governance mechanisms in pursuit of regaining fit (49). The structural adaptation has a positive impact on the performance of manufacturing SMEs (50). These studies show that the refitting between organizational structure and contingent factors can improve *FP*. The sudden outbreak of the COVID-19 makes firms face the dilemma of production and work stoppage, which leads to the mismatch between the organizational structure and the

external environment. In this situation, firms will adjust their structure through *MI* to adapt to the change of contingency factors in order to regain the match, and then maintain the effective operation of firms and improve *FP*. For example, some Chinese enterprises, such as GREE, have taken actions to the COVID-19, which helps GREE reverse to the *FPD*. In 2020, the first quarter after the COVID-19, GREE's sales revenue decreased sharply by 49.01% year-on-year. In this context, GREE has developed strict and comprehensive prevention and control measures, established an epidemic prevention and control team, used online meetings whenever possible, stipulated that employees are not allowed to gather. Due to the shortage of workers, GREE requires all administrative personnel to enter the production line. Besides, GREE required, trained and guided all offline stores to start live selling, and adopted the management and assessment method of combining offline and online sales for the sales stores. Based on the above *MI* measures and sales organization structure adjustment, in the first half of 2020, GREE's sales revenue was decreased by 28.21% year-on-year, which means that the *FPD* has been reversed. This shows that enterprises' *MI* to deal with the COVID-19 may help to reverse *FPD*.

MI promotes the internal management ability of firms by adjusting the management practice, improving the business process, changing the organizational structure and so on. It can help firms to maintain strategic agility, operational robustness and team integrity under crisis, thus promoting *OR*. The implementation of *MI* can facilitate organizational change, organizational renewal, adaptation and effectiveness (39), and motivate organizational knowledge creation, sharing and application. *Via* knowledge-sharing mechanisms to obtain critical information in the external environment, firms can effectively deploy contingency plans and organize resources to facilitate internal knowledge and information exchange, so that they can better adapt to the changes, enhance *OR* of firms to withstand crisis. Using information and communications technology to achieve remote connections with employees may create a mutual vision for employees to move forward with their leaders about goals, key issues and work progress, which facilitates internal communication and create a shared environment for them to work together from a distance (48). By the telecommuting approach, as well as the adjustment and incentives of salary policies, employees can continue to work in a flexible way and have a positive psychological state under the crisis with less finance and unemployment concerns. Individual resilience allows employees to cope more successfully and effectively with uncertainty, rapid change, and pressure (51), which in return helps firms resume operations well after a crisis. Employees can contribute to *OR* through their positive psychology and communication behaviors (52). A firm's *OR* is supported by the collective resilience of its members, which the firm can leverage to generate higher value (53), enabling firms to adapt their structures more rapidly to environmental change.

OR contributes significantly to firm survival, business continuity and performance improvement. Firstly, resilient firms that can take advantage of their agility and flexibility are able

to change course anytime at a low cost in order to transcend survival and thrive in complex and uncertain situation (53). Firms with agility can quickly and effectively integrate internal and external resources, adapt to situation changes, enhance their crisis response capacity, and effectively reduce the loss of firm resources. Agility significantly affects the product innovation ability of firms, which is conducive to develop new products better and faster (54), and to seize market opportunities, thus gaining an edge of market and improving *FP*. Resilient firms are more likely to increase their economic investment in resource conservation and sustainable production (1). Meanwhile, they can guarantee employees' health and safety, maintain their rights continuously, and enable them to stick to their post despite the crisis, thereby keeping the original organizational functions of firms and ensuring business continuity and organizational system robustness. Systems with robustness can consistently perform their expected functions even with interruptions (55). With the original function, business activities can be carried out as usual, so as to alleviate the impact of the COVID-19 to firms, minimize economic losses. In addition, the stronger the *OR* it is, the more likely firms are to find support and guidance from its resources and social networks when needed (56). Valuable and unique resources like information, knowledge, cooperation, and loyalty are embedded in the relationships established between firms and its major stakeholders. These resource advantages help firms cope with external shocks and bounce back from unexpected crisis during periods of uncertainty and severe volatility (57), which can reverse the trend of *FPD*.

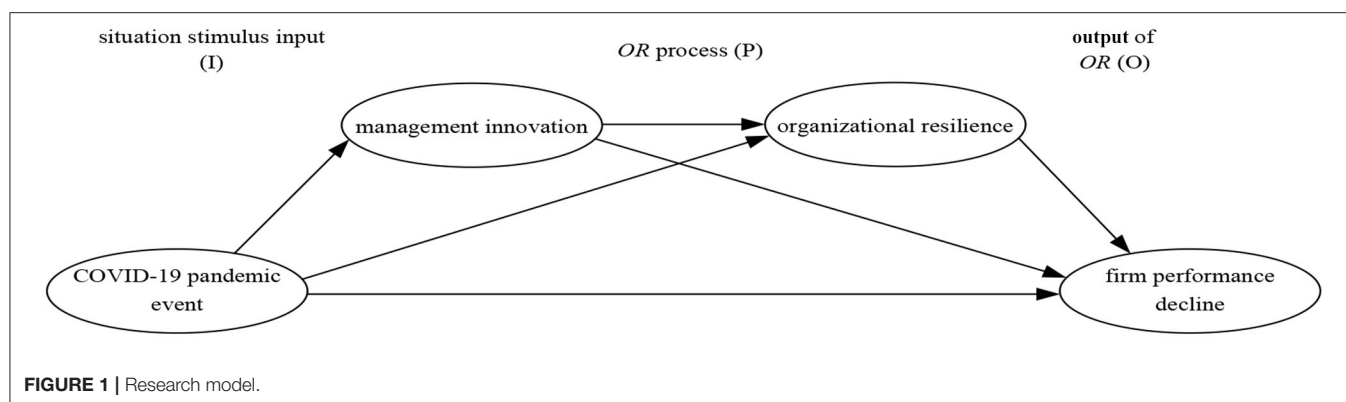
Based on the above analysis, this paper proposes the hypothesis 4: SMEs *MI* can reverse the *FPD* caused by the COVID-19 through *OR*.

To sum up, this paper regards that although the COVID-19 will lead to *FPD*, it will promote *MI* as well. *FMI* can spur *OR* and then reverse *FPD*. Therefore, this paper constructs the *IPO* mechanism of *FMI* response and *OR* under the sudden crisis, and regards the COVID-19 as the situation stimulus input (I), *FMI* response process as the *OR* process (P), and the improvement of performance as the output of *OR* (O). The research model of this paper is shown in **Figure 1**.

RESEARCH DESIGN

Sample Selection

The object of this study is the SMEs from Guangdong Science and Technology Park in China. The survey period is from June 2020 to September 2020, and a total of 206 questionnaires have been collected, excluding five questionnaires with firms' established time over 20 years, 201 questionnaires left. The specific sample distribution is shown in **Table 1**. The sample firms mainly derive from information transmission, software and information technology services, scientific research and technology services. Most of them are SMEs new-established within 8 years with employees <300 and operating income <20 million yuan, and most of them have no overseas business. In a nutshell, the sample covers a wide range of industries with a good representation.

**TABLE 1 |** Characteristics of valid samples.

Variables	Categories	Frequency	Percentage	Variables	Categories	Frequency	Percentage
Enterprise age	Within 8 years	168	83.582%	Industry attributes	Information transmission, software and information technology services	96	47.761%
	9–19 years	33	16.418%		Scientific research and technology services	43	21.393%
Number of employees	<20 employees	136	67.662%		Manufacturing	14	6.965%
	20–299 employees	63	31.343%		Leasing and business services	12	5.970%
	300–999 employees	2	0.995%		Culture, sports and entertainment	11	5.472%
Revenue of the previous year	Revenue <million	127	63.184%	Whether there is overseas business	Wholesale and retail	9	4.478%
	Revenue 3–20 million	59	29.353%		Other industries	16	7.960%
	Revenue 20–40 million	14	6.965%		Export	15	7.463%
	Revenue of more than 40 million	1	0.498%		No export	186	92.537%

Variables Description

The Event's Strength of the COVID-19 Pandemic

The variable is based on the measuring instrument of Morgeson et al. (31), Morgeson (58) and Morgeson et al. (59) under the background of the COVID-19, including three dimensions: novelty, criticality and disruption. The novelty reflects in “there is a clear, known way for my company to respond to the COVID-19 pandemic event” and other three items. The criticality reflects in “the COVID-19 pandemic event is critical for the long-term success of my company’s innovation and development” and other two items. The disruption reflects in “the COVID-19 pandemic event disrupts our company’s value creation and acquisition ability to get its work done” and other three items. The variable is measured by Likert 5-point Scale, ranging from “1 = totally disagree” to “5 = totally agree”. The novelty is the reverse scoring question.

Management Innovation

This variable is mainly adapted from the measurement tool of Vaccaro et al. (60) and combined with the COVID-19 pandemic background. It includes that “rules and procedures within our

organization are renewed during the COVID-19 pandemic” and other five items. The variable is measured by Likert 5-point Scale, ranging from “1 = totally disagree” to “5 = totally agree”.

Organizational Resilience

The variable is based on measurement tool of Kantur et al. (16) with the COVID-19 pandemic background, reflecting in “facing COVID-19 pandemic, our company is successful in generating diverse solutions,” and other eight items. The variable is measured by Likert 5-point Scale, ranging from “1 = totally disagree” to “5 = totally agree.”

Firm Performance Decline

This study measures the *FPD* from the dropping proportion of sales revenue, profit and market share, including “in the first half of 2020, the proportion of our company’s sales revenue decline is expected to be” and other two items. The variable is measured by Likert 6-point Scale, namely “1 = no decline”, “2 = below 20%”, “3 = 20%~29%”, “4 = 30%~39%”, “5 = 40%~49%”, “6 = 50% and above.”

TABLE 2 | Measurement items and the reliability and validity of variables ($N = 201$).

Variable	Dimension	Item	EFA factor loading	CFA factor loading	Total variance explained	CR	Cronbach's α
COVID-19 pandemic event's strength (KMO = 0.867)	Novelty	There is a clear, known way for our company to respond to the COVID-19 pandemic event®	0.901	0.915	30.574%	0.930	0.929
		There is an understandable sequence of steps that can be followed in responding for our company to the COVID-19 pandemic event®	0.921	0.943			
		Our company can rely on established procedures and practices in responding to the COVID-19 pandemic event®	0.898	0.834			
		Our company had rules, procedures, or guidelines to follow when the COVID-19 pandemic event occurred®	0.847	0.809			
	Criticality	The COVID-19 pandemic event is critical for the long-term success of our company's innovation and development	0.703	0.773	58.193%	0.880	0.875
		The COVID-19 pandemic event is of a priority to our company's innovation and development	0.846	0.846			
		COVID-19 pandemic is an important event for our company's innovation and development	0.783	0.903			
	Disruption	The COVID-19 pandemic event disrupts our company's value creation and acquisition ability to get its work done	0.765	0.772	78.686%	0.876	0.872
		The COVID-19 pandemic event causes our company to stop and think about how to respond	0.744	0.799			
		The COVID-19 pandemic event alters our company's normal way of responding	0.861	0.852			
		The COVID-19 pandemic event requires our company to change the way it does its work	0.835	0.773			
		Rules and procedures within our organization are renewed during the COVID-19 pandemic	0.864	0.850			
Management innovation (KMO = 0.865)		Our organization make changes to our employees' tasks and functions during the COVID-19 pandemic	0.863	0.840	72.816%	0.925	0.922
		Our organization implements new management systems during the COVID-19 pandemic	0.886	0.867			
		The policy with regard to salary has been changed during the COVID-19 pandemic	0.787	0.715			
		The intra-and inter-departmental communication structure within our organization is restructured during the COVID-19 pandemic	0.890	0.877			
		our organization continuously alter certain elements of the organizational structure during the COVID-19 pandemic	0.825	0.764			
		Facing COVID-19 pandemic, our company stands straight and preserves its position	0.725	0.679			
		Facing COVID-19 pandemic, our company is successful in generating diverse solutions	0.694	0.643			

(Continued)

TABLE 2 | Continued

Variable	Dimension	Item	EFA factor loading	CFA factor loading	Total variance explained	CR	Cronbach's α
Firm performance decline (KMO = 0.698)		Facing COVID-19 pandemic, our company shows resistance to the end in order not to lose	0.548	0.517	87.390%	0.933	0.927
		Facing COVID-19 pandemic, our company does not give up and continues its path	0.816	0.795			
		Facing COVID-19 pandemic, our company rapidly takes action	0.833	0.830			
		Facing COVID-19 pandemic, our company develops alternatives in order to benefit from negative circumstances	0.756	0.692			
		Facing COVID-19 pandemic, our company is agile in taking required action when needed	0.874	0.856			
		Facing COVID-19 pandemic, our company is a place where all the employees engaged to do what is required from them	0.765	0.698			
		Facing COVID-19 pandemic, our company is successful in acting as a whole with all of its employees	0.830	0.784			
		In the first half of 2020, the proportion of our company's sales revenue decline is expected to be	0.962	0.968			
		In the first half of 2020, the proportion of our company's profit decline is expected to be	0.964	0.983			
		In the first half of 2020, the proportion of our company's market share decline is expected to be	0.875	0.756			

Control Variable

In this study, taking enterprise age, number of employees, revenue of the previous year, industry attributes, and whether there is overseas business as control variables.

In this study, the original measurement scale of the event's strength of the COVID-19, *MI* and *OR* are measured in English. This study adopts the back translation method to translate these English scales into Chinese and back into English. This study also adjusts the measurement items of the COVID-19 pandemic event's strength, *MI* and *OR* according to the COVID-19. Specific measurement items are shown in **Table 2**.

EMPIRICAL RESULTS AND ANALYSIS

Testing of Reliability and Validity and Common Method Bias

Considering that the core scales used in this study are all adapted based on the background of the COVID-19, the study uses exploratory factor analysis (EFA) in order to test the validity and reliability of the adapted scale. As shown in **Table 2**, the KMO value of the COVID-19 event's strength is 0.867, which indicates that the COVID-19 event's strength is suitable for EFA. By the maximum variance method three factors selected, the results show that the items are well clustered into three

dimensions: novelty, criticality and disruption, and the total variance of cumulative interpretation is 78.686%, which indicates that the scale has good validity. The Cronbach's α values of novelty, criticality and disruption of the COVID-19 is 0.929, 0.875, 0.872 respectively, and the composite reliability values are 0.930, 0.880, 0.876 respectively, which shows that the scale has good internal consistency and reliability. The KMO value of the *MI* is 0.865, which indicates it is suitable for EFA. One factor is extracted by using the maximum variance method, and the total variance of cumulative interpretation is 72.816%, showing that the scale has good converge validity. As to *MI*, its Cronbach's α is 0.922 and its combined reliability is 0.925, which reflects that the scale has good internal consistency and reliability. The KMO value of *OR* variable is 0.878, which indicates that the scale is compatible to EFA. One factor is extracted by using the maximum variance method, and the total variance for the cumulative interpretation is 58.625%, evincing that the scale has good converge validity. The Cronbach's α of the *OR* variable is 0.905 and its composite reliability is 0.909, showing that the scale possesses good internal consistency and reliability. The KMO value of *FPD* is 0.698, congruent for EFA. Extracting one factor is through the maximum variance method, and the total variance for the cumulative interpretation is 87.390%, declaring a good converge validity. The Cronbach's α of *FPD* and its combination reliability are 0.927 and 0.933,

respectively, which shows the scale has good internal consistency and reliability.

Based on exploratory factor analysis (EFA), confirmatory factor analysis (CFA) is performed to test the discrimination validity. The results are shown in **Table 3**. It can be seen that the fitting degree of six-factor model ($\chi^2/df = 1.973 < 3$, $RMSEA = 0.070 < 0.08$, CFI , TLI , $IFI > 0.9$, $PCFI > 0.5$) is superior to single-factor, two-factor, three-factor, four-factor and five-factor models, indicating that there is a good distinction between novelty, criticality, disruption of *MI*, *OR* and *FPD*. In addition, the factor loading of CFA ranges from 0.517 to 0.983, all of which are bigger than 0.5, ensuring a good validity. In terms of common method bias test, Harman's single-factor test method used firstly shows that factor 1 accounts for 18.821% of the variance, <40% and not exceeding half of the 70.899% of the total variation, which means the method is feasible. The results of EFA in **Table 3** show that the fitting degree of single-factor model is very poor, which is much lower than that of six-factor model. And the changes of $RMSEA$ and CFI are 0.002, 0.001 respectively after controlling common method factors, the variation is <0.05, which evinces that the common method deviation could be well controlled.

Descriptive Statistics

According to the *FPD* of various industries under the COVID-19, the COVID-19 has the greatest impact on the accommodation and catering, entertainment, education, water environment and public facilities management sectors. And it has a greater impact on agriculture, forestry, animal husbandry and fishery, manufacturing, wholesale and retail trade, and financial industry, while exerts less influence on health and social work, neighborhoods' services, repair and other services.

Specifically, Among the sample firms in the first half of 2020, there are 37 firms whose sales revenue year-on-year decrease is <20%, accounting for 18.4%; There are 17 firms whose sales revenue year-on-year decrease is 20%–29%, accounting for 23.4%. There are 47 firms whose sales revenue year-on-year decrease is between 40% and 9%, accounting for 8.5%; There are 34 firms whose sales revenue year-on-year decrease is above 50%, accounting for 16.9%. There are 41 firms without decline in sales revenue, accounting for 20.4%. In the first half of 2020, there are 40 firms whose profit year-on-year decrease is within 20%, accounting for 19.9%, and 49 firms' profit year-on-year decrease is between 20 and 29%, accounting for 24.4%. There are 25 firms whose profit year-on-year decrease is between 30 and 39%, accounting for 12.4%, and 17 firms whose profit decrease is from 40 to 49%, accounted for 8.5%. There are 33 firms whose sales revenue year-on-year decrease is 50% and above, accounting for 16.4%. There are 37 firms without decline in sales revenue, accounting for 18.4%. In the first half of 2020, there are 68 firms with their market share decrease is <20%, coming in at 33.8%. There are 45 firms whose market share year-on-year decrease is between 20 and 29%, accounting for 22.4%, and there are 27 firms whose market share year-on-year decrease is between 30 and 39%, accounting for 13.4%. There are 12 firms whose market share year-on-year decrease is between 40 to 49%, coming in at 6.0%, and there are 17 firms whose market share year-on-year decrease is 50% and above, accounting for 8.5%. The market

share of 32 firms without decline, accounting for 15.9%. Overall, about 80% of the sample firms experience a decline in sales revenue, profit and market share, while more than 16% of firms have a decline year-on-year in their sales revenue and profits by more than 50%. It elucidates that under the influence of COVID-19, *FP* generally declines and even some firms have a significant decline in performance.

Correlation Analysis

As the results of **Table 4** shows, the novelty mean value of the COVID-19 is 1.901, which is much lower than the criticality ($m = 3.731$) and disruption ($m = 3.586$). It shows that the sample firms have the corresponding methods, procedures, rules and guidelines to deal with the COVID-19.

The mean value of *FPD* of sample firms is 3.093, and the standard deviation is 1.516, which manifests that different firms have different *FPD*. The novelty is negatively correlated with *MI* and *OR*, but not significantly correlated with *FPD*. Criticality and disruption are positively correlated with *MI*, *OR* and *FPD*. The preliminary results show that the novelty of the COVID-19 does not promote the *FMI* and lead to *FPD*, while the criticality and the disruption of the will result in *FPD* but it will enhance *FMI* and then obtain *OR* at the same time.

Regression Analysis and Hypothesis Test

The SPSS 22.0 software and Model 6 in the macro program process are applied for regression analysis (The regression results are shown in **Table 5**). From Model 1, Model 2 and Model 3, it can be concluded that the COVID-19 has a significant negative effect on business *MI* ($\beta = -0.376$, $p < 0.001$), and the criticality ($\beta = 0.406$, $p < 0.001$) and disruption ($\beta = 0.327$, $p < 0.001$) of that have positive effects on business *MI*. The results shows that the criticality and disruption of the COVID-19 could promote *FMI*, while the novelty of the COVID-19 could not. Therefore, the hypothesis 2 gets some support. Model 4, Model 5 and Model 6 shows that there is a significant negative correlation between the novelty of the COVID-19 and *OR* ($\beta = -0.345$, $p < 0.001$). Yet the regression coefficients of the criticality and disruption of the COVID-19 are not significant ($\beta = 0.089$, $p > 0.050$; $\beta = 0.048$, $p > 0.050$). However, in all the three models, *MI* has significant positive effect on *OR* ($\beta = 0.247$, $p < 0.001$; $\beta = 0.323$, $p < 0.001$; $\beta = 0.346$, $p < 0.001$), indicating that the event's strength of the COVID-19 does not directly promote *OR*, but indirectly by promoting *FMI*. Thus, the hypothesis 3 is supported. From Model 7, Model 8 and Model 9, it can be seen that the criticality and disruption of the COVID-19 have significant positive effect on *FPD* ($\beta = 0.591$, $p < 0.001$; $\beta = 0.841$, $p < 0.001$), but the regression coefficient of the novelty of the COVID-19 is not significant ($\beta = 0.056$, $p > 0.050$). The result shows that the criticality and disruption of the COVID-19 could lead to *FPD*, while the novelty of the COVID-19 does not. Hypothesis 1 gets some support.

In addition, Model 7, Model 8 and Model 9 show a significant positive correlation between *MI* and *FPD* ($\beta = 0.714$, $p < 0.001$; $\beta = 0.464$, $p < 0.010$; $\beta = 0.411$, $p < 0.010$), which shows that *EMI* will also lead to the *FPD* when crisis come. However, *OR* has a significant negative

TABLE 3 | Confirmatory factor analysis results ($N = 201$).

Variables	χ^2	df	χ^2 / df	RMSEA	CFI	TLI	IFI	PCFI
6-factor model	710.220	360	1.973	0.070	0.923	0.913	0.924	0.819
6-factor model + common method factor	684.644	337	2.032	0.072	0.924	0.908	0.925	0.767
5-factor model	1,256.175	365	3.442	0.110	0.804	0.782	0.806	0.723
4-factor model	1,477.050	371	3.981	0.122	0.757	0.734	0.759	0.692
3-factor model	2,161.381	374	5.779	0.155	0.608	0.574	0.610	0.560
2-factor model	2,810.093	376	7.474	0.180	0.466	0.423	0.469	0.431
1-factor model	3,248.710	377	8.617	0.195	0.370	0.321	0.374	0.343

6-factor model: novelty, criticality, disruption, MI, OR, FPD. 5-factor model: novelty, criticality, disruption, MI + OR, FPD. 4-factor model: novelty + criticality + disruption, MI, OR, FPD. 3-factor model: novelty + criticality + disruption, MI+OR, FPD. 2-factor model: novelty + criticality + disruption, MI+OR+FPD. 1-factor model: novelty + criticality + disruption + MI + OR + FPD.

TABLE 4 | Means, standard deviations and correlations coefficients ($N = 201$).

	Mean	SD	1	2	3	4	5	6
1 novelty	1.901	0.710	0.877					
2 criticality	3.731	0.795	−0.422***	0.842				
3 disruption	3.586	0.817	−0.234***	0.692***	0.780			
4 MI	3.611	0.754	−0.355***	0.443***	0.375***	0.821		
5 OR	3.774	0.608	−0.507***	0.286***	0.199**	0.435***	0.728	
6 FPD	3.093	1.516	0.026	0.350***	0.498***	0.265***	−0.065	0.908

*** $p < 0.001$.

** $p < 0.010$.

* $p < 0.050$.

The bold part in the table is the AVE square root of each latent variable.

TABLE 5 | Results of hierarchical regression analyses ($N = 201$).

	MI			OR			FPD		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Novelty	−0.376***			−0.345***			0.056		
Criticality		0.406***			0.089			0.591***	
Disruption			0.327***			0.048			0.841***
MI				0.247***	0.323***	0.346***	0.714***	0.464**	0.411**
OR							−0.476*	−0.594***	−0.580***
Enterprise age	0.001	0.0001	0.003	−0.004	−0.0004	0.001	0.003	−0.007	−0.008
Number of employees	0.110	0.048	0.077	0.104	0.064	0.068	−0.0002	−0.012	0.028
Revenue of the previous year	−0.055	0.035	0.054	−0.031	0.029	0.029	−0.467*	−0.425*	−0.338
Dummy variable_Manufacturing	−0.480	−0.346	−0.308	0.165	0.217	0.223	−0.428	−0.319	−0.072
Dummy variable_overseas	0.411*	0.409*	0.309	−0.138	−0.167	−0.191	0.056	0.146	−0.096
Constant	4.256	1.976	2.243	3.463	2.146	2.214	2.893	2.129	1.287
R	0.415	0.479	0.412	0.585	0.465	0.457	0.397	0.482	0.571
R ²	0.173	0.229	0.170	0.342	0.216	0.209	0.158	0.232	0.326
F	6.742***	9.619***	6.597***	14.344***	7.604***	7.281***	4.499***	7.263***	11.631***

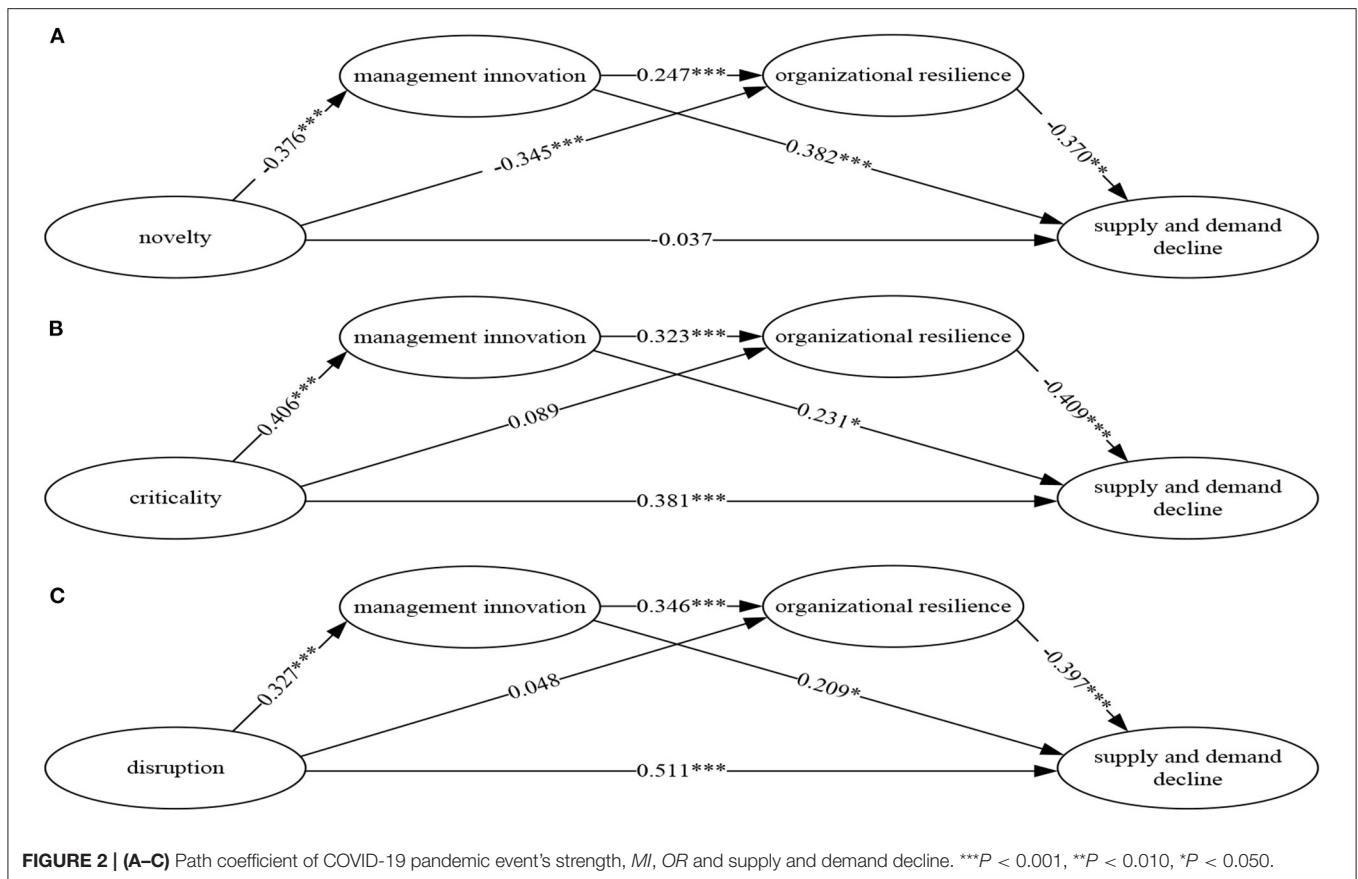
*** $p < 0.001$.

** $p < 0.010$.

* $p < 0.050$.

effect on FPD ($\beta = -0.467$, $p < 0.050$; $\beta = -0.594$, $p < 0.001$; $\beta = -0.580$, $p < 0.001$), which means that OR can reverse the situation of FPD. In summary, EMI cannot

directly improve FPD, but indirectly restrain FPD by promoting OR in the context of the COVID-19. Thus, the hypothesis 4 is supported.



Robustness Test

A robustness test by using supply and demand recession as the variable. Considering that the decline of supply and demand means the decline of performance, this paper uses the supply and demand recession as the substitute variable for robustness test. The supply and demand recession of firms includes four items, the proportion of production capacity decline, order decline rate, the proportion of raw material gap, and employee turnover rate. (The variable, Cronbach's α is 0.845, and the factor loading of the items is 0.732–0.919. The cumulative explained total variance is 68.456%). On this basis, this paper examines the impact of the event's strength of the COVID-19 on MI, OR, and supply and demand recession. The results are shown in **Figure 2**. It shows that the result of regression test is consistent with that of FPD as a dependent variable, which shows that the result of this study has sound robustness.

Based on the above analysis, the research hypotheses 1 and 2 of are partially supported, and hypotheses 3 and 4 are supported.

CONCLUSIONS

Based on the event system theory and SARFIT model, this study constructs a research model covering the COVID-19, MI, OR and FPD and performs a questionnaire survey among SMEs in Guangdong Science and Technology Park in China in the context

of the COVID-19 to empirically explore how SMEs reverse FPD in sudden major crisis. Conclusions are as follows.

Firstly, the criticality and disruption of the COVID-19 will not only lead to FPD, but also encourage FMI. The results of the empirical study show that for the SMEs, the novelty of the COVID-19 is relatively low, and most of the sample firms have the corresponding methods, procedures, rules and guidelines to deal with the COVID-19. Moreover, the novelty of the COVID-19 doesn't cause FPD, and it is not conducive to FMI and OR. But the COVID-19 enjoys relatively high criticality and disruption to the SMEs, which explains that the COVID-19 has the important influence on SMEs, and they need to carry on innovation response. The empirical results further show that the criticality and disruption of the COVID-19 is positively correlated with FPD and MI, which indicates that the criticality and disruption of the COVID-19 will lead to FPD, and prompt SMEs to carry on MI response as well.

Secondly, the event's strength of the COVID-19 does not directly promote OR, but indirectly influences the OR by promoting FMI. The results of the empirical study show that the novelty of the COVID-19 has a negative effect on OR, while the criticality and disruption of the COVID-19 have no significant direct effect on OR. The results show that the event's strength of the COVID-19 could not directly promote OR. However, the event's strength of it will directly affect FMI. The novelty of the COVID-19 has a significant negative impact on FMI, while the

criticality and disruption of the COVID-19 have a significant positive influence on the *MI*, which indicates that the former is not conducive to the *MI* and *OR* of firms, but the latter can prompt SMEs to carry out *MI* to indirectly promote *OR*. The results show that the different characteristics of the event's strength of the COVID-19 have different effects on *MI* and *OR*.

Thirdly, *MI* cannot directly curb *FPD* caused by the COVID-19, but indirectly reverse it by promoting *OR*. As empirical study shows that SMEs carrying out *EMI* in response to major crisis cannot directly restrain *FPD* caused by the COVID-19. On the contrary, the *EMI* is positively correlated with *FPD*, which indicates that *EMI* is not conducive to the improvement of *FP* in the short term. The results declare that *MI* has a significant positive effect on *OR*, while *OR* has a significant negative correlation with *FPD*. In other words, *OR* is the medium transmission mechanism of *MI* to reverse the trend of *FPD*. Only by *OR* can SMEs reverse the *FPD* caused by major crisis such as the COVID-19 to help the business return to normal development.

Based on the above conclusions, this paper puts forward the following suggestions. First and foremost, firms should critically treat major crisis such as the COVID-19 and learn to leap to safety. With current turbulent market environment, sudden crisis are inevitable, managers need to deal with *FPD* at any time, and consider how to achieve sustainable development. This paper finds that although unexpected crisis such as the COVID-19 may give rise to *FPD*, firms can carry out *MI* in response to crisis by exerting their own subjective initiative. In return, it can contribute to *OR* and curb *FPD*. Public emergent crisis like the COVID-19 is hard to predict and inevitable for firms, but it also provides them with the opportunity to reexamine the original organizational system. It can urge managers to improve their firm's current management systems, work procedures and so on, helping them accumulate crisis management experience. Therefore, firms should treat crisis correctly, draw lessons from crisis management, and learn to achieve *OR* to head off a danger through *MI* and other measures.

Secondly, firms should initially take *MI* and other actions to deal with the COVID-19 and other major emergencies. In such a market environment with *VUCU*, firms should take the initiative to effectively cope with crisis. Therefore, they can strengthen the application of digital technology, promote the firm management toward digitalization transformation, and enhance *MI* when firms respond to the sudden crisis. Meanwhile, they can use digital technology for employees to create a digital work platform, providing security for them to work in times of crisis, and to help firms maximize the normal operation. At the same time, they can strengthen the construction of digital infrastructure, improve the internal basic data interfaces for all types of business, open up and connect the corresponding subsystems for all types of business, and promote data sharing and business synergy, enhancing the system agility of firms. Finally, they can enhance firms' ability to predict crisis *via* digital technology to collect and analyze warning data, and establishing a timely response mechanism for crisis response plans so as to help firms mitigate the harm of crisis.

Thirdly, firms should attach importance to enhancing *OR* through digitization and crisis management training. *OR* is the core of firms to deal with sudden crisis and reverse *FPD*. Firms

should pay attention to building *OR* cultivation and promotion mechanism. Moreover, they can use digital technology to build data sharing platform for knowledge and information exchange, which can improve organization communication and work efficiency, and enhance the agility of individual employees and firms as a whole. Furthermore, companies can utilize social media to interact with stakeholders, establish partnerships with mutual benefit and reliance, and enhance the robustness of their networks. The last but not least, they should also value the training and the promotion of leadership crisis management capability, notice the staff and the teams' mental and physical pursue and enhances the staff's organizational commitment and the team cohesive force, strengthening the organizational integrity of firms when confronting crisis.

The COVID-19 is a global public health event, and it is still affecting enterprises in the world today. During the COVID-19, most countries adopted quarantine policies, for example, Japan, South Korea, Germany, Britain, the United States, Australia, etc. For enterprises in these countries and regions, they also suffered from the impact of the COVID-19, they also need to adopt *MI* to deal with the government's quarantine policies, and they also need to pay attention to improving their *OR* to deal with sudden major crises. Therefore, the implications on taking *MI* action and improving *OR* can also be used as a reference for enterprises in other countries.

LIMITATIONS AND FUTURE RESEARCH

Although this paper has made some contributions, there are still some limitations. First, this paper is an empirical study based on SMEs in China. Like most local studies based on a national sample, the selection of research samples has limitations. Therefore, in the future, international research cooperation should be carried out, sample enterprises from more countries should be selected for comparative analysis, and comparative analysis of different types of enterprises should be carried out.

Second, because it is difficult to obtain the first-hand longitudinal survey data at the enterprise level, this paper has the limitation of a single data source. In the future research, it is better to select different sources to obtain multi-stage longitudinal research data, so as to further analyze the dynamic impact of major public health events such as COVID-19 on enterprises and the dynamic response strategies of enterprises, and then more accurately determine the causal relationship between major public health events, enterprises' innovation response and enterprise performance.

Third, how to recover from a major crisis, reverse the *FPD* and carry out sustainable development is a more complex process. With the continuous spread of the COVID-19, in order to cope with the impact of the epidemic, in addition to *MI*, enterprises will also carry out business model innovation and use digital technology for innovation and development. Therefore, future research should further analyze the impact of major public health events on enterprises in terms of the event's time and space, and comprehensively consider the impact mechanism of business model innovation, digital innovation and *MI* on firm performance.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

YL and HC designed the study, collected the data, and revise the full text. YL wrote the introduction, performed the statistical

analyses, discussed the results and wrote the conclusions. HC contributed to the implications. LuW and LuqW wrote the first draft of the literature review research hypothesis. All authors contributed to manuscript revision, read, and approved the submitted version.

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Area Deprivation and COVID-19 Incidence and Mortality in Bavaria, Germany: A Bayesian Geographical Analysis

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Background: Area deprivation has been shown to be associated with various adverse health outcomes including communicable as well as non-communicable diseases. Our objective was to assess potential associations between area deprivation and COVID-19 standardized incidence and mortality ratios in Bavaria over a period of nearly 2 years. Bavaria is the federal state with the highest infection dynamics in Germany and demographically comparable to several other European countries.

Methods: In this retrospective, observational ecological study, we estimated the strength of associations between area deprivation and standardized COVID-19 incidence and mortality ratios (SIR and SMR) in Bavaria, Germany. We used official SARS-CoV-2 reporting data aggregated in monthly periods between March 1, 2020 and December 31, 2021. Area deprivation was assessed using the quintiles of the 2015 version of the Bavarian Index of Multiple Deprivation (BIMD 2015) at district level, analyzing the overall index as well as its single domains.

Results: Deprived districts showed higher SIR and SMR than less deprived districts. Aggregated over the whole period, the SIR increased by 1.04 (95% confidence interval (95% CI): 1.01 to 1.07, $p = 0.002$), and the SMR by 1.11 (95% CI: 1.07 to 1.16, $p < 0.001$) per BIMD quintile. This represents a maximum difference of 41% between districts in the most and least deprived quintiles in the SIR and 110% in the SMR. Looking at individual months revealed clear linear association between the BIMD quintiles and the SIR and SMR in the first, second and last quarter of 2021. In the summers of 2020 and 2021, infection activity was low.

Conclusions: In more deprived areas in Bavaria, Germany, higher incidence and mortality ratios were observed during the COVID-19 pandemic with particularly strong associations during infection waves 3 and 4 in 2020/2021. Only high infection levels reveal the effect of risk factors and socioeconomic inequalities. There may be confounding between the highly deprived areas and border regions in the north

and east of Bavaria, making the relationship between area deprivation and infection burden more complex. Vaccination appeared to balance incidence and mortality rates between the most and least deprived districts. Vaccination makes an important contribution to health equality.

Keywords: COVID-19, area deprivation, standardized incidence ratio, standardized mortality ratio, Bavarian Index of Multiple Deprivation, hierarchical models

INTRODUCTION

COVID-19 (Coronavirus disease 2019), an infectious disease in humans caused by the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), first emerged in December 2019 in China and was declared a pandemic by March 2020 (1). This pandemic caused a significant increase in mortality and led to a heavy burden in healthcare systems worldwide. The search for factors related to COVID-19 outcomes is of great interest for the development of strategies to cope with this disease.

Lack of material and social resources may explain why worse health outcomes are often observed for residents of more deprived areas (2). Area deprivation relates to a large number of adverse health outcomes, e.g., coronary heart disease, type 2 diabetes or cancer (3–6). To analyze those area-level health disparities, deprivation indices are widely used (7–9). These indices include several distinct indicators or rather domains to describe different aspects of area-based lack of resources. Typically, income and employment are key domains of deprivation indices, but other indicators, e.g. educational or environmental aspects, are also considered.

Associations between aspects of COVID-19 and area deprivation have been investigated for several countries, including Germany (10–18). Even though COVID-19 is transmitted by individuals, these studies consistently report that the risk of COVID-19 infections, as well as COVID-19-related mortality, are higher in more deprived than in less deprived areas. However, it has also been found that this relationship could change over time (19, 20).

With regard to COVID-19 it should therefore be of interest to include data over longer time periods to account for temporal variations and to disentangle the associations between different deprivation domains and COVID-19 incidence and mortality.

The very first SARS-CoV-2 outbreak in Germany was reported for the southern federal state of Bavaria (21, 22), which is the largest German state by area and the second largest by population with more than 13 million inhabitants. This exceeds significantly the population size in many European countries. Moreover, Bavaria is one of the wealthiest states in an already economically strong country like Germany.

Infection control measures in Germany differ from state to state. Therefore, it would be appropriate to focus on a specific area with largely uniform control measures like Bavaria.

Several infection waves have occurred since March 2020 and at the time of submission of this paper, Bavaria and Germany are in the transition phase between the fifth and sixth infection wave. To date, Bavaria still lacks a comprehensive analysis on how area

deprivation and the COVID-19 burden relate to each other over the course of the pandemic.

However, it should be considered that geographical patterns of health inequalities already existed before the pandemic. In particular, non-communicable diseases are unequally distributed in the population which could be related to area deprivation (3–6). Such geographical patterns of health inequality may also apply to COVID-19.

We therefore decided to focus on Bavaria to investigate which area-related material and social factors could be associated with COVID-19 infection risk and mortality, and how they interact with approaches chosen to counteract COVID-19 such as vaccination or lockdown. Given pre-existing geographical health patterns, we expected higher COVID-19 infection and mortality rates in more deprived districts. We hypothesized that income, employment and education may be related to COVID-19, as these factors appear to be strongly related to the ability to work from home, to reduce contacts and to reduce mobility. We explore how the effect of the measures taken may interact with area deprivation.

The specific aim of our study is to investigate the association between area deprivation and standardized SARS-CoV-2 incidence and mortality ratios (SIR, SMR) between spring 2020 and winter 2021 at the district level in Bavaria, Germany, and to assess whether area deprivation consistently explains the variability in local population-adjusted COVID-19 incidence and mortality at specific time points and over longer periods.

MATERIALS AND METHODS

Data Source and Structure

The Bavarian Health and Food Safety Authority (Bayerisches Landesamt für Gesundheit und Lebensmittelsicherheit, LGL) is the competent authority in Bavaria for the report of SARS-CoV-2 data and publishes the aggregated data of all local Bavarian health offices (23). We processed the data provided by the LGL at the individual level for the years 2020 and 2021, starting on March 1, 2020, until December 31, 2021, to exclude sporadic infections before March 2020. This period included data from the first to the fourth wave of infection (24): the first wave started in calendar week 10 in 2020 (03/02/2020) in Germany and lasted until 05/17/2020, followed by sustained low rates in the summer period in 2020 between 05/18/2020 and 09/27/2020. The second wave started on 09/28/2020 and lasted until 02/28/2021. The third wave started on 03/01/2021 and went on until 06/13/2021, followed by sustained low rates in 2021 (between 06/14/2021

and 08/01/2021). The fourth wave started on 08/02/2021 and continued until 12/26/2021 (24).

In Germany and Bavaria, incident cases are persons with laboratory-confirmed evidence of SARS-CoV-2 (direct pathogen detection). COVID-19 deaths are defined as death cases related to this infection (25). In practice, it is often difficult to decide to what extent the SARS-CoV-2 infection directly contributed to the death. Both groups, people who died directly from the disease (“death due to COVID-19”) and patients with pre-existing conditions who were infected with SARS-CoV-2 and for whom the cause of death cannot be clearly determined (“death with COVID-19”), are reported as COVID-19-related deaths. We rely on data from the LGL without knowing in detail how the COVID-19-related deaths were identified as such by the health offices/doctors.

While the exact date of death was used for the analysis of mortality, the incidence was analyzed using the reporting dates of the infection, which do not have to coincide with the date of onset of symptoms or the date of the first positive test result. The Bavarian data do not include the date of the first positive test result. We did not perform nowcasting (26) to correct for the reporting delay. For a part of the infections, the date of symptom onset is given. In order to take into account the natural course of the infection, we additionally considered a 14-day delay between infections and deaths (27). For the main analysis, the data were aggregated in monthly periods. Accordingly, the first period of aggregated data (“March 2020”) includes data on infections between 1 March and 31 March 2020 and data on deaths between 15 March and 14 April 2020.

Premature mortality is an important indicator for public health and the effectiveness of health systems (28, 29). Deaths below the age of 65 are considered premature, occurring at an age well-below the average life expectancy and being in many cases preventable. A high percentage of premature deaths is an indication of increased health risks in the population.

Area Deprivation

Area deprivation was assessed at district level (“Kreisebene”) using the Bavarian Index of Multiple Deprivation (BIMD) for the reference year 2015 (BIMD 2015) (30). Bavaria consists of 96 rural and urban administrative districts. Both the BIMD and the area deprivation measure for the whole of Germany, the German Index of Multiple Deprivation (GIMD), were constructed based on the method used in the UK and adapted to the German context (6). Both indices have been shown to be associated with a number of adverse health outcomes in non-communicable diseases, including diabetes and cancer incidence, but also mortality (31–33).

The BIMD consists of seven deprivation domains with different weighting: income (25%, financial poverty of residents), employment (25%, unemployment), education (15%, lack of vocational training), municipal/district revenue (15%, financial situation of the districts), social capital (10%, for lack of social capital), environment (5%, poor quality of the physical environment), and security (5%, accidents and crime rates) (29, 30). In our analysis, we used quintiles of the overall score and the domain-specific scores (“deprivation quintiles”) where

quintile 1 (Q1) includes 20% of the least deprived and quintile 5 (Q5) 20% of the most deprived districts. The BIMD quintiles were calculated using the distribution of districts without taking population size into account. We label the quintiles as follows: least deprived (Q1), less deprived (Q2), moderately deprived (Q3), more deprived (Q4), and most deprived (Q5). During the observation period, we assigned to each district a constant deprivation quintile not changing over time.

Statistical Analyses

We determined SIR and SMR as ratios of observed to expected infection incidence and mortality rates. SIR and SMR are therefore relative risks. We calculated the expected values using indirect standardization to the latest available Bavarian population (from 2020) (34). The Bavarian population is comparable to the European Standard Population 2013 (see **Supplementary Table 1**). For this approach, the population was stratified into 15 age and sex-specific categories (0–4, 5–9, ..., 60–64, 65–74, and 75 years and older). These age categories were available for each district. For each month, the stratum-specific event rates (infection/mortality) for the whole of Bavaria were multiplied by the specific population of the district. Summing over all strata gives the local expected number of events. The locally observed number of events was divided by the locally expected number to obtain the local standardized event ratio. These ratios can therefore change every month. Monthly, they represent the extent of heterogeneity of SIR and SMR in the Bavarian population.

The primary analysis examined the association between area deprivation and SIR and SMR simultaneously using the bivariate version of the Besag-York-Mollie (BYM) model (35–37). This model is referred to as a standard model in geographical epidemiology (38). The BYM model includes both rates as a bivariate endpoint and considers the correlation between them. It is important to include both measures together in the model (i) to increase power in detecting specific associations (39) and because (ii) the strength of correlation between the two measures is a measure of dependence on common, area-level, unmeasured risk factors (40). Another problem in working with spatial data is spatial autocorrelation, which occurs when the values of a variable (e.g., SIR) measured at nearby locations are more similar than the values of the same variable measured at a greater distance (41). The BYM model also takes into account that the relative risks (SIR, SMR) of neighboring districts are correlated and introduces smoothing of extremely large estimates, which are generally caused by few observations in small regional populations. As is often the case, only nearest neighbors (i.e., districts with a common border) are considered for the correlation in the model, while next nearest neighbors are not. Border effects are neglected, i.e., morbidity and mortality in neighboring districts outside Bavaria are not considered. Neighboring German federal states to Bavaria are Baden-Wuerttemberg and Hesse in the west, and Thuringia and Saxony in the north. Neighboring countries are the Czech Republic in the east, Austria in the east and the south, and Switzerland in the south of Bavaria.

The deprivation quintiles were included in the BYM model as an ordinal variable. In a test for linear trend, linear contrast was used for the quintiles centered on their mean ($-2, -1, 0, 1, 2$). In a sensitivity analysis, the BYM model for SIR/SMR using the BIMD was additionally adjusted for the population density for 2020 (“population density in 1,000 inhabitants per square kilometer”). In a complementary analysis, we also examined how area deprivation affects the risk of dying as an infected person using the standardized case fatality ratio (sCFR). The sCFR describes the ratio of the regional variation in mortality to the regional variation in the documented infection process (42). It estimates the relative risk of dying from or with COVID-19 as a documented case. Strong small-scale variability in sCFR suggests a preference for regional over higher-level measures to manage the incidence of infection. The sCFR can be estimated as the ratio of SMR and SIR using the bivariate BYM model (42).

The BYM model uses non-informative a priori distributions according to the default settings of the analysis software (40). We reported the mean estimates averaging over 20,000 replications, including an initial burn-in period of 10,000. Point estimates were reported together with 95% credibility intervals (95% CrI). Statistical significance is claimed if the 95% CrI does not contain the value one. These models are referred to as structured models.

In addition to the Bayesian BYM model, we fitted a frequentist multilevel Poisson model to the data. To determine a marginal effect of the BIMD 2015 on the SIR and the SMR over the entire observation period, multilevel Poisson models were used in which the district and time were random effects and the BIMD or one of the seven domains were fixed effects. These models are fitted using the maximum likelihood method and referred to as unstructured models in this paper. More specifically, these generalized mixed Poisson models include the observed counts as the outcome and the BIMD quintiles as the predictor (fixed effect). The logarithm of the expected counts was included as an offset and time and district as random effects. The observed and expected counts were aggregated beforehand on a monthly basis, using the same data as for the BYM model. The model provides risk ratios (RR) interpreted for BIMD as relative increase in SIR/SMR per one quintile increase in BIMD. In addition, population density was included as a fixed effect for the sensitivity analysis.

For testing statistical significance in the multilevel models, we adopted a hierarchical approach: first, the main effect of the association between BIMD and SIR/SMR was estimated and statistical significance was claimed at a 5% confidence level. If the main effect was found to be statistically significant, analyses were conducted for the seven domains. The p -values for the domains were adjusted using the Bonferroni correction. This hierarchical testing procedure maintains the overall significance level of 5% and minimizes the number of falsely significant results due to multiple testing for the same data. Point estimates are reported together with 95% confidence intervals (95% CI).

Additional exploratory analyses were conducted to examine the relationship between incidence rates (IR) and mortality rates (MR) between the most and least deprived districts (IR_{Q5}/IR_{Q1} and MR_{Q5}/MR_{Q1}) over time.

The analyses were carried out using the software R (Version 3.6.3.) (43) and GeoBUGS (Version 1.2) (40). The unstructured models were estimated using the R function “glmer” of the R package “lme4” (44). The R function “supsmu” was used to smooth weekly incidence and mortality rates to present smoother curves (45). Maps were generated in QGIS 3.10.10 (46).

RESULTS

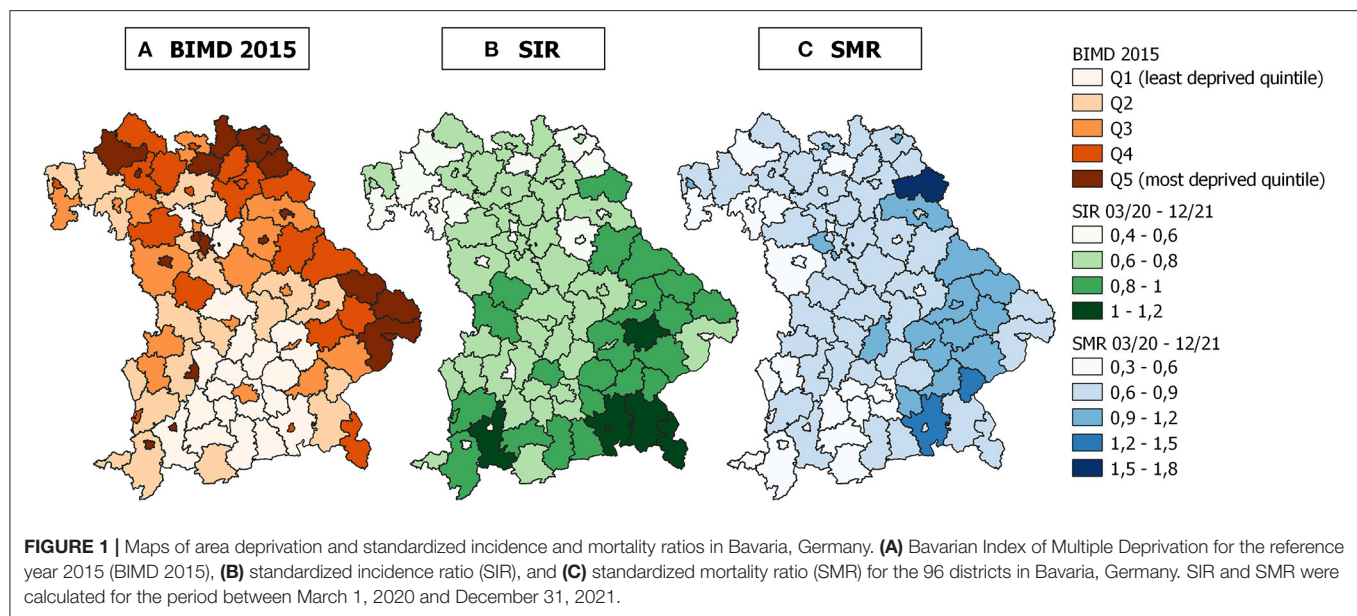
Overview

After excluding all individuals without valid age and/or sex information ($n=10,993$, 0.8% of data), a total of 1,319,456 SARS-CoV-2 infections and 19,571 associated deaths were reported in Bavaria between March 1, 2020 and December 31, 2021. Comparison of daily SARS-CoV-2 incidences and deaths in Bavaria compared to Germany and other selected European countries of similar size to Bavaria are shown in **Supplementary Figures 1, 2**, respectively. In persons under 65 years of age, a total of 1,694 COVID-19-associated deaths were reported (8.5% of all deaths). Infections were evenly distributed between both sexes (males 49.8%), and the median age of those infected was 38 years (interquartile range IQR: 22 to 54 years). Of the fatal COVID-19 cases, 52.2% were males with a median age of 83 years (IQR: 76 to 89 years). The population of the districts varies between 40,842 and 1,488,202 inhabitants, with a median of 117,648 inhabitants. Taking into account the area of the districts, the population density ranges from 66 to 4790 persons per square kilometer (median: 149). Of the 96 districts, 19 (20, 18, 20, and 19) belong to the first (second, third, fourth, and fifth) BIMD 2015 quintile, respectively (**Figure 1A**). As can be seen from **Supplementary Figure 3**, the assignment of districts to BIMD 2015 quintiles looks different for each domain of the BIMD 2015. In addition, **Figures 1B,C** show maps of SIR and SMR of accumulated data over the whole observation period.

Unstructured Analysis of Time-Specific Area Deprivation Effects

Figure 2 shows the weekly reported incidence and SARS-CoV-2-associated mortality rates in the districts belonging to each BIMD 2015 quintile. To indicate the first wave, the graph starts in January 2020 and covers the whole period until December 2021. The incidence rate (IR) curve (**Figure 2A**) thus qualitatively shows the four pandemic waves in Bavaria. The periods of the waves according to the official definition (23) are shown as light gray-shaded areas in **Figure 2** and the initial dates of the lockdowns are indicated as vertical dashed lines.

During the first wave in March/April 2020, the least and more deprived districts (Q1 -purple and Q4 -green) have the highest IR, while the most deprived districts have the lowest rates (Q5 -light green). At the beginning of the second wave in August 2020, moderately deprived districts (Q3 -light blue) show the highest IR, but as the wave progresses, the most deprived districts are the most affected, peaking in October and November 2020. Around Christmas 2020, the districts in Q4 and Q5 show an increase in IR, and these two categories remain the ones with the highest IR until the end of the third wave. At the beginning of the fourth wave in August 2021, districts in Q1 and Q3 show higher



rates. After the rapid increase in pandemic activity in September and October 2021, again the districts in Q4 and Q5 show the highest IR.

In terms of mortality rates (MR, **Figure 2B**), MR generally peak a few weeks after the peak in IR. During the first wave, MR are highest in the districts Q4 and Q1, similar to IR. The second MR peak is observed around Christmas 2020, with MR highest in Q4 and Q5 districts, which is also true for the third and fourth pandemic waves. Up to 2.5-fold relative differences between mortality rates are observed between Q5 and Q1. Premature mortality rates show a similar ranking of districts as mortality rates (see **Supplementary Figure 4**). However, because of the smaller sample size, the curves are not as smooth. In the second and in the third wave, the least deprived districts in Q1 show a nearly constant and very low MR. It is interesting to note that while overall COVID-19 mortality rates decline after the second wave, the magnitude of premature mortality remains about the same.

Figure 2C shows a remarkable ratio for IR and MR between the districts with the highest and lowest deprivation for the first COVID-19 winter. In the period of general vaccination (the first months in 2021), this inequality gets balanced.

Unstructured Analysis of Overall Area Deprivation Effects

The overall strength of the association between area deprivation, as measured by either the BIMD 2015 or its domains, and the SIR/SMR was calculated for the entire study period, adjusting for district and time. The results are shown in **Figure 3** for the BIMD 2015 and in **Table 1** for the BIMD 2015 and its seven domains. For the BIMD 2015, a statistically significant positive association was found with SIR and SMR (SIR = 1.04 (95% CI: 1.01 to 1.07), $p = 0.002$; SMR = 1.11 (95% CI: 1.07 to 1.16), $p < 0.001$, per one quintile increase in the BIMD 2015). The SIR/SMR thus increases with increasing area deprivation.

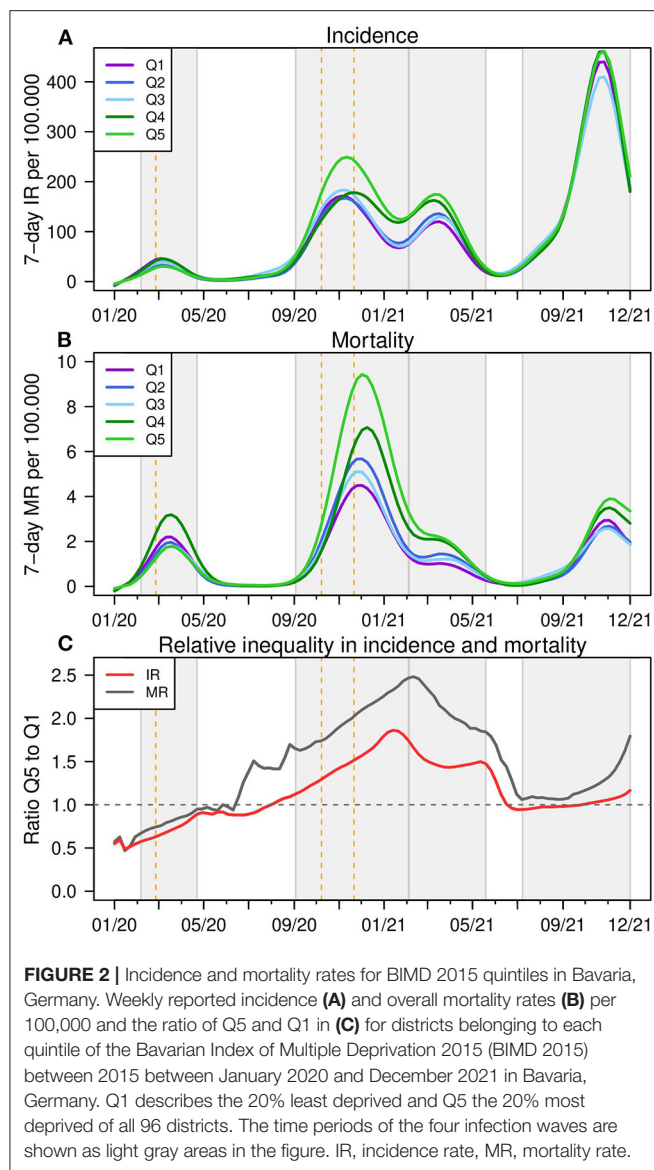
With respect to the single domains, statistically significant positive associations were found for SIR and SMR with income deprivation (SIR = 1.05 (95% CI: 1.02 to 1.08), $p = 0.003$; SMR = 1.11 (95% CI: 1.06 to 1.16), $p < 0.001$ per one quintile increase) and social capital deprivation (SIR = 1.04 (95% CI: 1.02 to 1.07), $p = 0.010$; SMR = 1.11 (95% CI: 1.06 to 1.16), $p < 0.001$ per one quintile increase). Another positive association was found for SMR with employment deprivation (SMR = 1.09 (95% CI: 1.05 to 1.14), $p < 0.001$ per one quintile increase) and a negative association for SIR with environmental deprivation (SIR = 0.95 (95% CI: 0.93 to 0.98), $p = 0.005$).

Table 1 also shows the estimates from a model adjusted for population density. The results are very similar to the results of the models without adjustment for population density, except for educational deprivation, which now shows a positive association with SIR.

Structured Analysis of Time-Specific Area Deprivation Effects

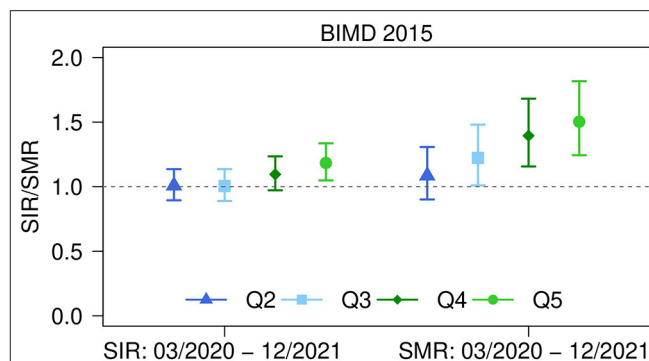
Figure 4 shows the estimates of the BYM model for the bivariate endpoint SIR (A) and SMR (B) over time for each quintile of the BIMD 2015. The point estimate for each quintile is shown along with the 95% CrI, and the value of one ("neither increased nor decreased SIR/SMR") is shown as a dashed line. Note that due to the very low number of deaths in July and August 2020 in Bavaria ($n = 11$ and $n = 18$, respectively), the SMR could not be reliably estimated and is not shown in the figures.

At the beginning of the first wave in March 2020, the SIR are the highest in the least deprived districts and the lowest in the most deprived districts. However, as the first wave progresses, this effect disappears. Between the first and second wave in summer 2020, infection and death counts were low, which is reflected in wide credibility intervals. At the beginning of the second wave, districts from the two least deprived quintiles (Q1 and Q2) appear to have a slightly lower SIR. However, given the uncertainty of



the estimates, no clear conclusion can be drawn from this. In December 2020, in the middle of the second wave, the trend of an increasing SIR with increasing area deprivation becomes statistically significant and remains so until the end of the third wave. The fourth wave begins with the same significant trend of higher incidence ratios in more deprived districts, and at the end of the fourth wave the effect is still present.

Mortality ratios show similar trends compared to incidence rates. In the last month (December 2021), the SIR was 0.93 (95% CrI: 0.83 to 1.07) for the least deprived and 1.11 (95% CrI: 0.98 to 1.28) for the most deprived districts. The corresponding numbers for SMR are 0.76 (95% CrI: 0.58 to 0.98) and 1.39 (95% CrI: 1.05 to 1.78). **Figure 4** also implies that the association between the BIMD 2015 and SIR/SMR is strongly fluctuating over time (tests on time \times BIMD interaction are highly significant with $p < 0.00001$).



In an additional sensitivity analysis we, included population density in the BYM model. The adjusted result is shown in **Supplementary Figure 5**. The results show the effect of the BIMD 2015 independent of population density. The overall impression is that the results remain comparable to the unadjusted model shown in **Figure 4**. Population density is generally higher in city districts than in rural districts. Therefore, the population-adjusted model partially controls for the effects of densely populated cities. In both the unadjusted and population-adjusted models, the linear trend of BIMD remains similar. Population density itself showed a statistically significant positive effect on the SIR mainly in between infection waves. This means that in times of low infection activity (summer 2020 and summer 2021), the SIR was higher in more densely populated districts.

Corresponding analyses for the seven domains of the BIMD 2015 are shown in Additional files 6 to 12. During the first wave, no clear association between income deprivation and SIR/SMR can be observed (**Supplementary Figure 6**). In the second and third waves, higher SIR and SMR are detected in districts with higher income deprivation. At the end of the fourth wave, this effect is also present for both SIR and SMR.

In the second and third wave, the SIR showed higher values in districts with higher employment deprivation (**Supplementary Figure 7**), which occasionally also applied to the SMR in winter 2020/2021. Between these waves, the association did not show any clear direction.

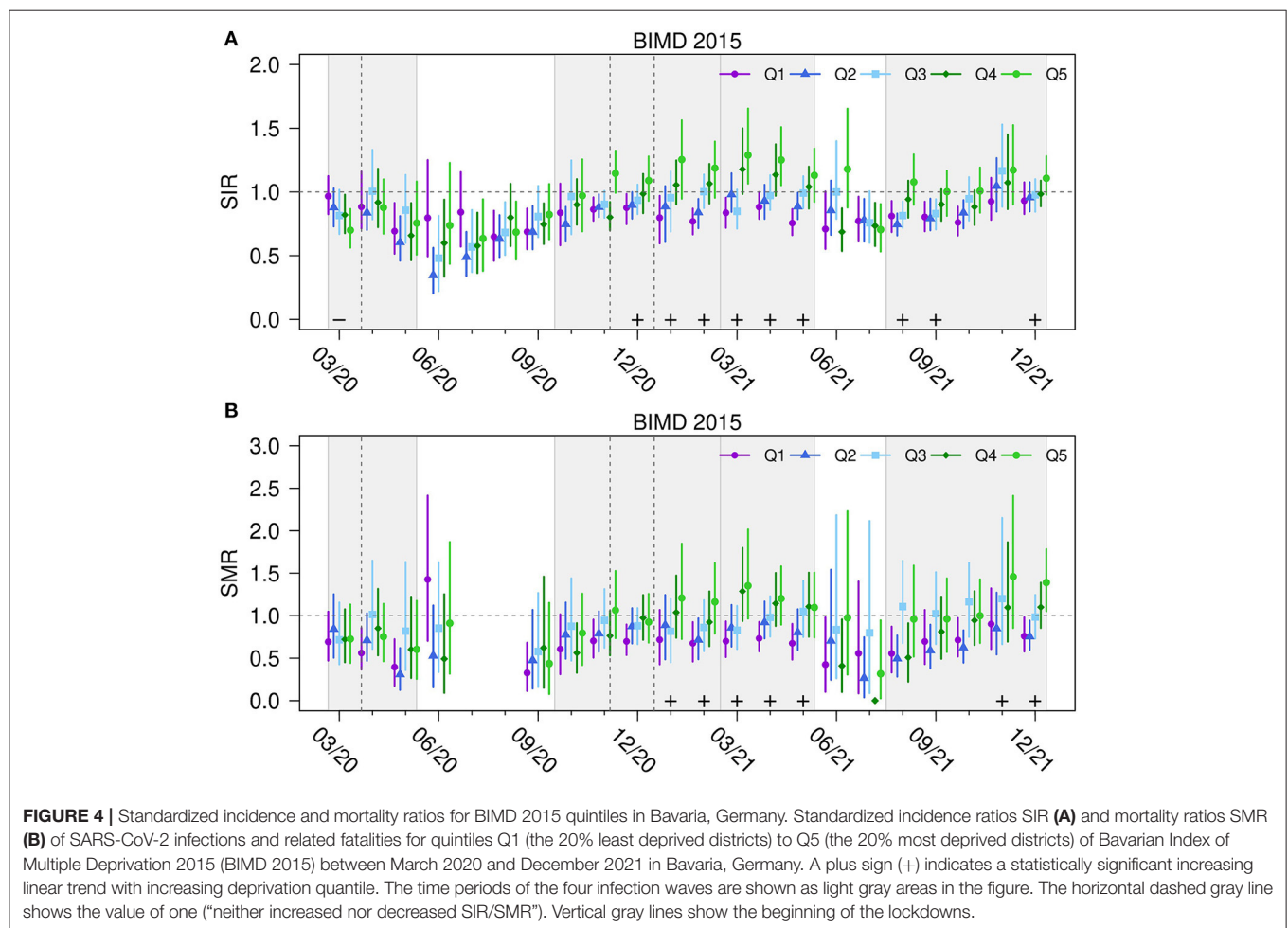
Educational deprivation (**Supplementary Figure 8**) showed a significant positive linear trend with SIR and SMR that started in the second wave and continued until the fourth wave. It appears that the association was significant either at the beginning and/or at the end of the waves.

For the time periods between the waves, there was a negative linear trend between municipal/district revenue deprivation and SIR (**Supplementary Figure 9**), implying that infection ratios are higher in districts with lower municipal/district revenue

TABLE 1 | Strength of associations between area deprivation and standardized incidence and mortality ratios in Bavaria, Germany.

Area deprivation index / domain	Model without population density				Model with population density			
	SIR (95% CI)	p	SMR (95% CI)	p	SIR (95% CI)	p	SMR (95% CI)	p
BIMD 2015	1.04 (1.01, 1.07)	0.002	1.11 (1.07, 1.16)	<0.001	1.05 (1.02, 1.08)	<0.001	1.12 (1.07, 1.17)	<0.001
Income	1.05 (1.02, 1.08)	0.003	1.11 (1.06, 1.16)	<0.001	1.05 (1.02, 1.08)	0.003	1.11 (1.06, 1.16)	<0.001
Employment	1.02 (1.00, 1.05)	0.653	1.09 (1.05, 1.14)	<0.001	1.04 (1.01, 1.08)	0.105	1.12 (1.07, 1.18)	<0.001
Education	1.03 (1.00, 1.06)	0.155	1.06 (1.02, 1.11)	0.056	1.04 (1.01, 1.07)	0.043	1.07 (1.02, 1.12)	0.051
Municipal/district revenue	1.01 (0.99, 1.04)	1	1.05 (1.00, 1.10)	0.402	1.01 (0.98, 1.05)	1	1.07 (1.01, 1.13)	0.091
Social capital	1.04 (1.02, 1.07)	0.010	1.11 (1.06, 1.16)	<0.001	1.04 (1.02, 1.07)	0.009	1.11 (1.06, 1.16)	<0.001
Environment	0.95 (0.93, 0.98)	0.005	1.00 (0.95, 1.04)	1	0.93 (0.90, 0.97)	<0.001	0.98 (0.92, 1.04)	1
Security	1.02 (1.00, 1.05)	0.693	0.99 (0.95, 1.04)	1	1.03 (1.00, 1.06)	0.306	0.99 (0.94, 1.04)	1

SIR, standardized incidence ratio; CI, confidence interval; SMR, standardized mortality ratio. Shown are models without (left) and with adjustment for population density (right). Ratios were calculated accumulating the data between 01/03/2020 and 12/31/2021 and adjusted for district and time. Statistically significant results are printed in bold. P-values for the Bavarian Index of Multiple Deprivation 2015 (BIMD 2015) domains are Bonferroni adjusted for multiple testing. A p-value after adjustment of >1 is coded as 1.



deprivation. During the waves, SIR was occasionally both positively and negatively associated with SIR and SMR.

Social capital deprivation (**Supplementary Figure 10**) was positively associated with SIR at the end of the second wave, and with SIR and SMR

in the third wave and the second half of the fourth wave.

Environmental deprivation (**Supplementary Figure 11**) shows a positive and significant linear trend with SIR, mostly between waves where only small numbers of cases occur. This

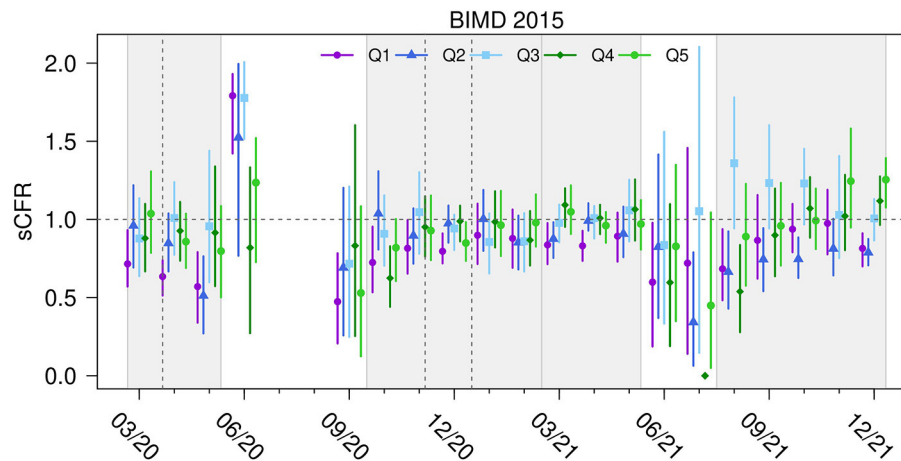


FIGURE 5 | Standardized case fatality ratio for BIMD 2015 quintiles in Bavaria, Germany. Standardized case fatality ratio (sCFR) for COVID-19 for quintiles Q1 (the 20% least deprived districts) to Q5 (the 20% most deprived districts) of Bavarian Index of Multiple Deprivation 2015 (BIMD 2015) between March 2020 and December 2021 in Bavaria, Germany. The time periods of the four infection waves are shown as light gray areas in the figure. The horizontal dashed gray line shows the value of one ("neither increased nor decreased sCFR"). Vertical gray lines show the beginning of the lockdowns.

positive trend changed to a negative trend in the fourth wave, which is also true for the SMR.

Security deprivation (**Supplementary Figure 12**) shows hardly any relevant association with SIR/SMR.

The median correlation (over all time periods) between SIR and SMR in the models with the BIMD 2015 or the domains ranged from 0.74 (for the model with income deprivation, see **Supplementary Figure 6**) and 0.78 (for the models with employment and environmental deprivation, see **Supplementary Figures 7, 11**, respectively). This strong correlation between both endpoints suggests that both SIR and SMR have similar geographical risk patterns.

Standardized Case Fatality Ratio

Figure 5 aggregates the sCFRs monthly across the regions belonging to each BIMD quintile and shows how the area deprivation affects the sCFR at specific time points. There is a general tendency for the least deprived districts to have the lowest sCFR values. The effect is attenuated in the fall and winter of 2020/2021 and seems to be more distinct in the fall and winter of 2021.

DISCUSSION

This study investigated the association between area deprivation and regional SARS-CoV-2-associated incidence and mortality ratios by districts in Bavaria from the first until the fourth pandemic wave between March 2020 and December 2021. Besides the general view on area deprivation, we also studied the relevance of specific domains on COVID-19-related epidemiological outcomes.

We focused on Bavaria as the largest German federal state by area and the second largest by population size with over 13 million inhabitants, being bigger than many other European countries (for example Sweden, Portugal, the Czech Republic or

Greece each have around 10.5 million inhabitants). Bavaria had high infection activity during the COVID-19 pandemic. Infection control measures were uniform in this single federal state, unlike Germany where control measures differ from state to state.

In addition to infection incidences, we examined whether the effects of area-based material and social deprivation were also reflected in mortality. The focus was on standardized ratios (standardized incidence or mortality ratio (SIR/SMR)) taking into account the demographic structure of the regions. We used the Bayesian BYM model, which accounts for the correlation between the two measures. We also used unstructured random effect models for the time-aggregated analysis.

In the unstructured analysis (excluding regional structure and averaging over longer time periods) a positive association was found between the BIMD 2015 and the SIR/SMR. This demonstrates that the COVID-19 burden increases with increasing area deprivation. In relation to the seven area deprivation domains included in the BIMD 2015, income and social capital deprivation were found to be positively associated with incidence and mortality ratios. In addition, a positive association was found between employment deprivation and SMR, while the association between environment deprivation and SIR was negative. These observations are consistent with a corresponding study for Belgium (19).

Our findings are in line with several previous results. The association of area deprivation with the health burden of COVID-19 has been studied in a number of international studies, e. g. in the United Kingdom (10, 47), India (11), Brazil (48), Italy (49), and the United States (12, 13, 50, 51). The study by Bach-Mortensen et al. (10) investigated the association between area deprivation and COVID-19 outbreaks and related deaths among care home residents in England. They found that deaths were more common in the most deprived than in the least deprived areas, while outbreaks in care homes did not vary by area deprivation. Higher social deprivation, quantified using the

Townsend Deprivation Score, was found to be associated with greater risk of dying from COVID-19 in another study from the United Kingdom (47). Study results from India and the United States showed that higher SARS-CoV-2 incidences or odds of infection have been found in more deprived compared to less deprived areas (11–13). Studies from Brazil and Italy concerning case-fatality ratio (CFR) and COVID-19 related deaths found a higher CFR and increased risk of death in people living in regions of highest deprivation (48, 49). Comparing rural and urban environments in the United States, a study from Kitchen and colleagues found a positive relationship between area deprivation and COVID-19 prevalence, which was higher for rural counties, when compared to urban ones (50). A combination of area level deprivation data and individual data from two U.S. municipalities was analyzed in a study by Feehan et al. (51). While higher area deprivation was found to be associated with higher risk of SARS-CoV-2 infection, the authors found that individual-level data accounted for a significant proportion of this association.

Interestingly, our results also show that during the first wave higher SIR and SMR were observed in less deprived districts, whereas this association reversed over time. This finding has also been confirmed in German-wide studies (14, 20). The association between infection incidence and social deprivation during the first wave was investigated by Wachtler et al. and Plümper and Neumayer (14, 20). For this purpose, the German Index of Socioeconomic Deprivation from the Robert Koch Institute, Germany's national Public Health institute, was linked to incidence data (14). However, this index considers only three dimensions of deprivation, whereas the BIMD considers seven domains. Across Germany, higher incidences were observed in less deprived regions at the onset of the pandemic, which was associated with affluent ski vacationers returning with SARS-CoV-2 infection. Over time, this effect disappeared in the generally less deprived south of Germany (federal states of Baden-Württemberg and Bavaria), while higher incidences were observed in other more deprived regions. Similar observations were published by Plümper and Neumayer (20), where the authors concluded that COVID-19 started as a rich man's disease and slowly transformed into a poor man's disease.

Socioeconomic differences in infection risk during the second wave were investigated in Germany by Hoebe and colleagues (15). Similar to the first wave, a higher incidence rate was found in less deprived regions at the beginning of the second wave. Again, this pattern reversed as the second wave progressed. In the second wave, COVID-19-related mortality and area deprivation were also examined in Germany, with higher mortality rates found among residents of deprived areas (16). In the third wave of infection, higher incidences were observed in socioeconomically disadvantaged regions (17, 18), which was related to the fact that individuals from socioeconomically disadvantaged regions were not able to limit their mobility as much as individuals from less disadvantaged regions due to their occupation (17). The fourth wave showed a similar association of infections and area deprivation as the second wave, despite the vaccination campaign (18). It is worth mentioning that in our study the overall mortality during the third and fourth waves was reduced

compared to the second wave, while no reduction in premature mortality (mortality within persons of an age below 65) was observed. This might be attributable to the vaccination campaign, which was launched on 27/12/2020 in Germany (52). Similar to many other countries, older age groups and the most vulnerable persons were prioritized for the vaccination in Germany. A study by Wollschlaeger et al. (53) in the German federal state of Rhineland-Palatinate found an association between higher vaccination coverage and a decrease in COVID-19 fatalities in the 80+ age group in the 1st months of 2021, supporting our hypothesis. Another study with individual level vaccination data in Bavaria found a high vaccine efficacy in persons over 80 years of age over a similar observation period (54).

In Bavaria, approximately 9% of all COVID-19 attributed deaths were premature deaths, which by definition occur at an age far below the average life expectancy. Unfortunately, the data provided by the LGL did not contain information on personal risk factors or pre-existing medical conditions of the deceased persons. Therefore, the characterization of those who died prematurely remains a task for the future. It should be closely monitored how the number of premature deaths due to/with COVID-19 develops over time, since according to the German health monitoring, premature deaths are avoidable in many cases.

There are several possible reasons for the finding that infection rates increase with increasing area deprivation. People in materially and socially advantaged areas might adhere more to the recommended behavioral changes during the pandemic (55, 56). Such changes include reducing contacts or having better opportunities to work remotely from home, which is still recommended in Germany in spring 2022. As for mortality, the reasons are probably more complex. It is possible that some of the outcomes are related to different prior health burdens (other than COVID-19) in the differently deprived areas. Geographical patterns of health inequalities may also apply to COVID-19 and some unequally distributed chronic diseases may themselves be risk factors for SARS-CoV-2 infection or severe disease course. In Germany, COVID-19 mortality is often assessed only descriptively, and the underlying patterns have not yet been studied in depth. A study from Bavaria investigating the factors related to mortality from COVID-19 in persons over 50 years found SIR to have the greatest effect on the SMR (57).

The district-level BIMD 2015 used in our study was defined for Bavarian districts with varying population sizes (from 40,842 to 1,488,202 inhabitants, median 117,648) and represents a relatively coarse resolution for the deprivation at hand. Individual districts may represent a complex mixture of different settings. However, when using the area-based index, it is assumed that districts are homogeneous within themselves. Therefore, the BIMD 2015 at the district level should be used with caution as a proxy for individual socioeconomic data. A large number of disadvantaged households may account for a few cases, while a few rich households may be responsible for a large number of infections. In terms of aggregated data, the district may have both a high level of deprivation and a high incidence rate, but in fact lower individual socioeconomic deprivation is related to lower incidence. This may carry the risk of ecological bias arising from

the assumption that inferences about individual patterns can be drawn from patterns observed in clusters (groups). However, we had to choose the district level since the COVID-19 data in Germany are aggregated only at this spatial level. To our knowledge, there is only one Germany-wide study to date that has investigated differences in the risk of SARS-CoV-2 infection according to socioeconomic position at the individual level (58). Individual socioeconomic position was measured by education and income. The study found that the odds of SARS-CoV-2 infection were significantly increased in adults with low levels of education compared to adults with high levels of education. In terms of income, the odds of infection were higher in low-income individuals than in high-income individuals, although the result was not statistically significant. The data were collected during the second infection wave. These results are consistent with our study on the dimensions of education and income deprivation. Nevertheless, our study shows that there are other additional factors, such as employment and social capital deprivation, that link deprivation to the regional COVID-19 burden.

This is also true for domains such as income and social capital deprivation. However, educational deprivation also shows a westward trend and is identified as an influential aspect of deprivation in our structured analysis of time-specific regional deprivation effects (see **Supplementary Figure 8**).

In our study, we included population density as a confounding factor, however it did not show much effect on the relationship between area deprivation and SIR/SMR (see **Table 1**).

Finally, we observed that health inequality (expressed as the ratio of IR or MR between the highest and lowest BIMD quintiles) increased during the 2020 fall and winter periods. Vaccination appears to be associated with a balancing of health inequality between the most and least deprived districts. Lockdown periods, on the other hand, appear to be associated with increased or persistent inequality.

We also examined how an area's deprivation level affects the risk of dying if infected (sCFR). Our data support the hypothesis that in districts with low deprivation, sCFR is also generally lower. During the fall and winter of 2020, the SIR and SMR differ between districts with low and high deprivation, but the risk of dying from infection is less pronounced.

We could not correct for vaccination coverage as another confounding factor in a satisfactory manner and therefore had to refrain from including it in our analyses. Vaccination data only contains information on the place of vaccination but not on the place of residence of the vaccinated persons. As many vaccinations have taken place in city districts, people from the surrounding areas were more likely to travel there to get vaccinated.

Ascertainment bias relates to the underreporting of COVID-19 cases. It is very likely that not all infections were officially reported. Testing strategies were a major focus of the Bavarian government, testing opportunities were easily accessible and evenly distributed across the state. However, these testing strategies have changed over time, from free PCR testing for anyone who wanted to be tested to testing only for health professionals with symptoms in early 2022. It is obvious that the reporting rate is not homogeneous over time. Moreover,

continuous serum tests within a representative Bavarian cohort have not been performed. It is also not certain whether the reporting rates estimated in different cohorts at the beginning of the pandemic [as summarized in a meta-analysis (59)] can be transferred to the Bavarian population. When correcting for underreporting, we would assume a constant underreporting rate per month for all of Bavaria. We assume that the variations in the reporting rate would change the relative baseline risk in the BYM model without affecting the relative position of the BIMD 2015 quintiles to each other: The linear trend for the quintiles of BIMD 2015 would remain as shown in the analyses.

Another limitation of this study could be possible confounding of area deprivation and geographical location. It could be that an area bordering Bavaria increases the infection incidence in a Bavarian border district with high deprivation. Border districts may have higher BIMD 2015 values (see **Figure 1A**). This would artificially strengthen the association between BIMD 2015 and SIR. The BYM model only considers the neighborhood effect within Bavaria and neglects any effects outside the region. **Supplementary Figure 3** shows the distribution of the quintiles of deprivation domains across the Bavarian districts. It is easy to see that the BIMD 2015 and some of its domains follow the geographical east and north-east trend. This is also true for domains such as income and social capital deprivation. However, educational deprivation also shows a westward trend and is identified as an influential aspect of deprivation in our structured analysis of time-specific area deprivation effects (see **Supplementary Figure 8**).

Despite potential neighborhood effects that could come from outside the region of interest, we followed a modeling approach that takes into account the spatial structure of the data (BYM) model. In addition, the bivariate version of the model, as used in the present study, takes into account the correlation between the two endpoints, which is important for the simultaneous modeling of SIR and SMR and makes the analysis of potential effects more powerful. A strong correlation of around 0.7–0.8 between SIR and SMR was found for all models, which suggests that both endpoints have similar geographical risk patterns. It was also found that the unstructured model is able to identify the key drivers of the relationship between area deprivation and incidence and mortality rates, even though no such strong spatial correlation pattern could be specified in the model.

In addition, we explored the different dimensions of deprivation, which allowed us to identify which domains might be affected differently by the pandemic. These findings are consistent with those of other studies, but additional associations between social capital deprivation and, to a lesser extent, environmental deprivation, were detected. It is also interesting to note that deprivation effects became effective when pandemic activity was high: when the crisis intensifies, aspects of social equity become even more important.

Even in a particularly wealthy region of an already economically strong country like Germany, COVID-19 affects residents of differently deprived districts in a different manner.

Large differences of up to 41% were found in the SIR and 110% in the SMR between districts in the lowest and highest quintiles, especially in the winter of 2020/2021, suggesting that COVID-19 was a disease that affected disadvantaged areas in the second and third waves. It is also interesting to note that lockdowns have not been able to mitigate the social inequalities associated with deprivation. Therefore, specific strategies need to be explored to successfully control the pandemic in deprived areas.

CONCLUSION

This study reports the results of a retrospective ecological study investigating the relationship between area deprivation and SARS-CoV-2-related burden. It quantifies the influence of regional deprivation on SIR and SMR, which were higher in more deprived than in less deprived areas. Higher levels of income, employment, education and social capital were additionally identified as factors reducing COVID-19 disease burden at the district level. Vaccination appeared to balance incidence and mortality rates between the most and least deprived districts. Under lockdown such a compensation was not observed. Vaccination makes an important contribution to health equality.

DATA AVAILABILITY STATEMENT

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

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ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Medical Faculty of the LMU Munich (No. 21-0213 KB). Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

WM and LS designed the study. KM, UM, and WM acquired the data. WM and UM helped KM with the methodology. KM analyzed the data. KM and WM wrote the first draft of the manuscript. All authors interpreted the data, read, revised, and approved the final manuscript.

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When Lack of Trust in the Government and in Scientists Reinforces Social Inequalities in Vaccination Against COVID-19

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Objective: To assess whether lack of trust in the government and scientists reinforces social and racial inequalities in vaccination practices.

Design: A follow-up of the EpiCov random population-based cohort survey.

Setting: In July 2021, in France.

Participants: Eighty-thousand nine hundred and seventy-one participants aged 18 years and more.

Main Outcome Measures: Adjusted odds ratios of COVID-19 vaccination status (received at least one dose/ intends to get vaccinated/ does not know whether to get vaccinated/refuses vaccination) were assessed using multinomial regressions to test associations with social and trust factors and to study how these two factors interacted with each other.

Results: In all, 72.2% were vaccinated at the time of the survey. The population of unvaccinated people was younger, less educated, had lower incomes, and more often belonged to racially minoritized groups, as compared to vaccinated people. Lack of trust in the government and scientists to curb the spread of the epidemic were the factors most associated with refusing to be vaccinated: OR = 8.86 (7.13 to 11.00) for the government and OR = 9.07 (7.71 to 10.07) for scientists, compared to vaccinated people. Lack of trust was more prevalent among the poorest which consequently reinforced social inequalities in vaccination. The poorest 10% who did not trust the government reached an OR of 16.2 (11.9 to 22.0) for refusing to be vaccinated compared to the richest 10% who did.

Conclusion: There is a need to develop depoliticised outreach programmes targeted at the most socially disadvantaged groups, and to design vaccination strategies conceived with people from different social and racial backgrounds to enable them to make fully informed choices.

Keywords: vaccination, trust, government, scientists, COVID-19, social inequalities

INTRODUCTION

Clinical trials have shown the efficacy of the COVID-19 vaccines on SARS-CoV-2 infections (1). However, vaccination is efficient in combating the spread of the epidemic, as well as in reducing social inequalities in morbidity and mortality, provided that it is affordable and accessible (2, 3). Still, making COVID-19 vaccines available does not necessarily lead to a very large population vaccine coverage, as shown by the percentages of people who are still not vaccinated in Western countries (2), even when these vaccines are free. Recent studies in the UK, in the US and in Norway (4–8) have shown that the most socially disadvantaged and racially minoritized groups are the least vaccinated. In light of their high risk of infection and mortality from COVID-19 (1), it appears all the more important to understand why they are less likely to be reached by COVID-19 vaccination programmes.

Social barriers hampering access to preventive practices, such as social distance from health professionals, geographical distance from health centers, or experiences of discrimination in the health system (9, 10) need to be taken into account to study this particular preventive practice that is vaccination. Preventive health behaviors can also be influenced by institutional trust, which refers to citizens' beliefs that institutions act transparently and fairly, in accordance with the public interest (11). In a context where governments and scientists have taken the lead in managing the pandemic crisis, it is all the more important to analyse vaccination practices along with consideration of the trust that people place in the government (12–15). Many studies have shown that COVID-19 vaccination intentions are related to trust in the government (11, 15–20). One study, in the UK, simultaneously considered trust in the government and in scientists: COVID-19 hesitancy was associated with low trust in scientists and doctors but the correlation was weaker with trust in government (16). Furthermore, conspiracy beliefs and social media use can also predict vaccine hesitancy (21, 22). Three types of mechanisms can explain the link between institutional trust and vaccination. At a first level, people who trust institutions such as the government and science, are more likely to believe in the messages these actors promote in favor of vaccination (23). Secondly, people who lack trust in the government may consider the refusal of vaccination as a political act of resistance (17). Thirdly, people who distrust the government and scientists are more likely to believe information sources that present vaccines as unnecessary or dangerous (24).

Beyond vaccination intentions, there is now a need to clarify whether, and to what extent, lack of trust in institutions, and particularly in the government, has impacted vaccination practices. Because underprivileged social groups are known to be particularly distrustful of the government (25–27), it could be assumed that the government's strong involvement in vaccination programmes and its resulting high degree of politicization are likely to reinforce social inequalities in vaccination. In France as in many countries, the government strongly relied on scientists to justify its epidemic response actions. Studying the impact of trust in the government on vaccination practices therefore also implies taking trust in scientists into account. Vaccination was made available in France, as of mid-January 2021 for people over

75. People over 50 with a COVID-19-related-comorbidity could get vaccinated as of mid-February. The vaccination campaign was then extended to include all individuals over 55 as of mid-April 2021, and any individual aged 18 and over, as of May 12th 2021. The survey took place in July 2021, i.e., at a time when COVID-19 vaccines were free and readily available in France for any individual aged 18 and over. It was just before anti-COVID certifications became compulsory to access certain public spaces and services. Nonetheless, these certifications were then not too restrictive, as they could be obtained with a full vaccination scheme or with a 72-h-negative-test (PCR or antigenic), which were still free and readily available in France at that time. The objectives of this article were (i) to identify social differences in vaccination status and trust in the government and scientists, and (ii) to investigate whether the lack of trust in the government and scientists increased social inequalities in vaccination practices.

PARTICIPANTS AND METHODS

Individuals aged 15 years or older living in France were randomly selected from the FIDELI administrative sampling framework to participate to the EpiCov survey, covering 96.4% of the population, providing postal addresses for all, and e-mail addresses or telephone numbers for 83.0% of them. Differential sampling was used to ensure oversampling of the less densely populated *départements* (i.e., French Administrative Districts), and lower-income categories. Residents in retirement homes were excluded. All selected individuals were contacted by mail, e-mail and text messages, with up to seven reminders. Computer-assisted-web interviews (CAWI) or computer-assisted-telephone interviews (CATI) were offered to a random 20% subsample. The remaining 80% were assigned to CAWI exclusively. All first- and second-round respondents were eligible for the third in July 2021 (28). In this third wave, 85,032 participated in the third wave (79.0% from the second wave and 63.3% from the first one) and served as the basis for this analysis. We focused on people living in metropolitan France and aged 18 and over since vaccination was allowed only for adults at the time of the survey. In all, 80,971 (95.2%) individuals were included in our study.

The survey was approved by the CNIL (French independent administrative authority responsible for data protection) on April 25th 2020 (ref: MLD/MFI/AR205138) and by the “Comité de protection des personnes” (French equivalent of the Research Ethics Committee) on April 24th. The survey also obtained an agreement from the “Comité du Label de la statistique publique,” proving its consistency with statistical quality standards.

Outcome Measures

Vaccination status was classified into four categories: vaccinated (at least one dose); intends to be vaccinated; does not know whether to get vaccinated; refuses vaccination.

Vaccinated people were also asked to give the date of their first injection.

Socio-Demographic Variables

We considered the following variables: age, gender, ethno-racial status (based on migration history), having children, social class

(based on current or most recent occupation), if the respondent was a healthcare professional, standard of living (based on decile of income per household consumption unit) and formal education (defined according to the French hierarchical grid of educational qualifications), the household and the population size of the municipality. The ethno-racial status, used for the first time in France in a COVID survey, distinguished the mainstream population, i.e., people residing in metropolitan France who are neither immigrants nor native to French Overseas Departments (FOD, i.e., Martinique, Guadeloupe, Reunion Island, Guyane and Mayotte), nor descendants of immigrant(s) or native to FOD. For the minority population, a distinction was made between first-generation (immigrants) and second-generation (descendants of immigrants) immigrants, and the country of origin. The term racially minoritized groups refers to immigrants or descendants of immigrants from the Maghreb, Turkey, Asia and sub-saharan African countries (29).

Health Variables

Health variables included the existence of COVID-19 comorbidities (i.e., asthma or other respiratory diseases, high blood pressure or cardiovascular diseases, diabetes, cancer, HIV, mental or psychiatric disability, or BMI > 30 kg/m²) and if the respondent had had a positive COVID-19 test in the past 6 months.

Trust Variables

Specific interest was finally devoted to the level of trust in the government ("To curb the spread of the coronavirus, what is the level of trust you place in the actions undertaken by (i) the government and (ii) by scientists?": Complete trust/Fair amount of trust/Little trust/No trust at all/You do not know).

Statistical Analyses

A first univariate analysis was performed, to compare the distribution of the four vaccination status categories according to social characteristics and trust variables. Then, the cumulative monthly rates of vaccination (from January 31st to June 30th 2021) were stratified by vaccination age categories (18–54/55–74/75+), and assessed according to formal education, standard of living and ethno-racial status.

A multinomial regression was developed to compare the vaccinated people to the others (intend to be vaccinated; do not know whether to get vaccinated; refuse vaccination) and to investigate how non-vaccinated people differed among themselves according to social and trust variables.

We created variables divided into 12 categories crossing a binary variable characterizing the trust variable (Complete trust/Fair amount of trust vs. Little trust/No trust at all/You do not know, labeled as Trust+/Trust-) and formal education or standard of living or ethno-racial status. Six multinomial regressions were then performed, each one adjusted for one combining variable at a time.

Final calibrated weights were calculated to correct for non-response, as detailed elsewhere (28) for the first, second and third waves of the EpiCov survey. Response homogeneity groups were derived from the sampling weight divided by the probability

of response estimated with logit models adjusted for auxiliary variables potentially linked to both the response mechanism and the main variables of interest in the EpiCov survey (age, gender, educational level, and region). The percentages presented are weighted to account for the sampling design with unequal inclusion probabilities due to an oversampling of low-income populations and correction of nonresponse bias.

A *P*-value <0.05 was considered statistically significant for multivariate analyses. Given the sample size, the observed differences were consistently statistically significant. Therefore, no tests are presented for univariable analyses.

Individuals who answered that they did not wish to respond to the question on their vaccination status and/or the date of their first injection were excluded (*n* = 1,93 0.2%). Missing data was rare for all variables (<4%) and was deleted in multivariate analyses (*n* = 7,068 8.7% excluded).

RESULTS

The distribution of the vaccination status in the population is presented in **Table 1**. In all, 72.2% were vaccinated, with at least one injection in July 2021 (71.1% for men vs. 73.3% for women). Less than one respondent out of ten (8.1%) refused to get vaccinated (8.2% of men and 8.1% of women), while one in ten (9.0%) said they intended to get vaccinated (10.7% for men and 9% for women), and a similar proportion did not yet know whether or not they would get vaccinated (10.0% for men and 9.7% for women).

The vaccination rate increased very steadily with age, rising from 54.7% among 18–24-year-olds to 93.2% among 75–84-year-olds, and then falling to 88.2% among those over 85. There were also marked differences in vaccination practices according to social positions. Only 69.8% of people without educational qualifications were vaccinated, compared to 79.2% of those with the highest qualifications. As for the rate of vaccination according to income, it increased regularly from 54.8% among the poorest 10% to 87.6% among the richest 10%. Compared to the mainstream population (74.5%), vaccination uptake was lower only among people belonging to racially minoritized groups, i.e., among first (59.1%) and second-generation immigrants (52.5%) and among people born or whose parents were born in French Overseas Departments (56.2%). Living in a populated area was not associated with being vaccinated, although living in a "priority neighborhood" was (55.4 vs. 73.4%).

Social differences were also found among the unvaccinated: the 10% richest and those with the highest qualifications were more likely to intend to accept vaccination (5.6 and 8.8% respectively) whereas the 10% poorest and people without qualifications were more likely to hesitate (16.9 and 10.9% respectively). Interestingly, racially minoritized first-generation immigrants were among those who least often refused vaccination (7.4%) whereas people from the overseas territories were the most reluctant (14.2%).

The data also showed that social differences were present even before vaccination and that they were maintained or widened over time, especially among the 18–54-year-olds (**Figures 1A–C**).

TABLE 1 | Distribution of the vaccinal status of people aged 18 years or over living in metropolitan France, by socio-demographic characteristics and trust variables.

	Had at least one dose	Intends to get vaccinated	Does not know yet	Refuses to get vaccinated
Total	72.2 (62,418)	9.8 (6,746)	9.8 (6,383)	8.1 (5,231)
Sex				
Men	71.1 (27,879)	10.7 (3,104)	10.0 (2,625)	8.2 (2,116)
Women	73.3 (34,539)	9.0 (3,642)	9.7 (3,758)	8.1 (3,115)
Age				
18–24	54.7 (4,456)	17.2 (1,204)	16.0 (953)	12.1 (712)
25–34	54.1 (5,431)	15.7 (1,281)	15.5 (1,217)	14.7 (1,097)
35–44	60.5 (9,022)	13.6 (1,514)	14.7 (1,526)	11.3 (1,229)
45–54	70.8 (12,360)	10.6 (1,403)	10.5 (1,313)	8.1 (1,064)
55–64	81.7 (13,679)	6.4 (850)	6.5 (888)	5.5 (705)
65–74	89.8 (12,170)	3.8 (404)	3.7 (378)	2.8 (308)
75–84	93.2 (4,449)	2.2 (67)	2.4 (87)	2.2 (80)
85+	88.2 (851)	3.2 (23)	3.3 (21)	5.3 (36)
Social class				
Manual workers	64.8 (6,103)	11.7 (951)	12.8 (988)	10.7 (811)
Self-employed and entrepreneurs	75.9 (3,274)	8.2 (304)	7.8 (281)	8.1 (291)
Senior executive professionals	83.1 (17,783)	6.9 (1,250)	5.6 (968)	4.4 (726)
Middle executive professionals	74.8 (17,322)	8.9 (1,679)	8.6 (1,624)	7.6 (1,363)
Employees	70.6 (13,963)	10.0 (1,676)	10.8 (1,795)	8.6 (1,516)
Students	53.8 (1,891)	19.4 (588)	16.0 (414)	10.9 (268)
Never worked	65.7 (601)	11.0 (94)	12.3 (104)	11.0 (74)
Farmers	77.3 (873)	9.8 (104)	7.2 (85)	5.8 (80)
Missing	608	100	124	102
Formal education				
No diploma	69.8 (2,795)	10.1 (350)	10.9 (405)	9.2 (314)
Primary education	78.5 (5,209)	7.8 (533)	7.8 (479)	5.8 (353)
Vocational secondary	71.8 (11,936)	9.4 (1,178)	9.7 (1,231)	9.0 (1,062)
High school	66.0 (12,140)	12.1 (1,715)	11.6 (1,556)	10.3 (1,409)
High school +2 to 4 years	72.2 (18,679)	9.7 (1,931)	10.4 (1,924)	7.7 (1,510)
High school +5 or more years	79.2 (11,659)	8.8 (1,039)	6.9 (788)	5.0 (583)
Standard of living (in deciles)				
D1	54.8 (3,339)	14.5 (705)	16.9 (745)	13.8 (629)
D2–D3	62.7 (5,939)	12.5 (1,096)	13.6 (1,141)	11.3 (949)
D4–D5	69.9 (8,560)	10.9 (1,229)	10.8 (1,199)	8.4 (987)
D6–D7	75.3 (12,855)	8.5 (1,356)	8.5 (1,305)	7.6 (1,165)
D8–D9	81.9 (18,907)	6.8 (1,474)	6.5 (1,358)	4.9 (974)
D10	87.6 (11,506)	5.6 (641)	3.8 (428)	3.0 (332)
Missing	1,312	245	207	195
Ethno-racial status				
Mainstream population	74.5 (52,430)	9.1 (5,285)	8.6 (4,890)	7.8 (4,203)
Born or parents born in FOD	56.2 (554)	14.0 (112)	15.5 (125)	14.2 (96)
Non-racially minoritized second-generation immigrants	75.6 (3,439)	8.7 (350)	8.5 (327)	7.1 (257)
Racially minoritized second-generation immigrants	52.5 (1,490)	15.5 (342)	19.3 (409)	12.8 (251)
Non-racially minoritized first-generation immigrants	76.3 (2,006)	8.5 (164)	8.2 (138)	7.0 (134)
Racially minoritized first-generation immigrants	59.1 (1,654)	16.4 (377)	17.2 (354)	7.4 (170)
Missing	845	116	140	120
Size of municipality				
Rural area	73.5 (14,519)	9.1 (1,561)	8.9 (1,496)	8.6 (1,408)
>=100,000 inhabitants	72.6 (18,826)	9.3 (1,952)	9.7 (1,983)	8.4 (1,627)
≥100,000 inhabitants	71.7 (17,657)	10.0 (1,954)	10.1 (1,812)	8.1 (1,405)

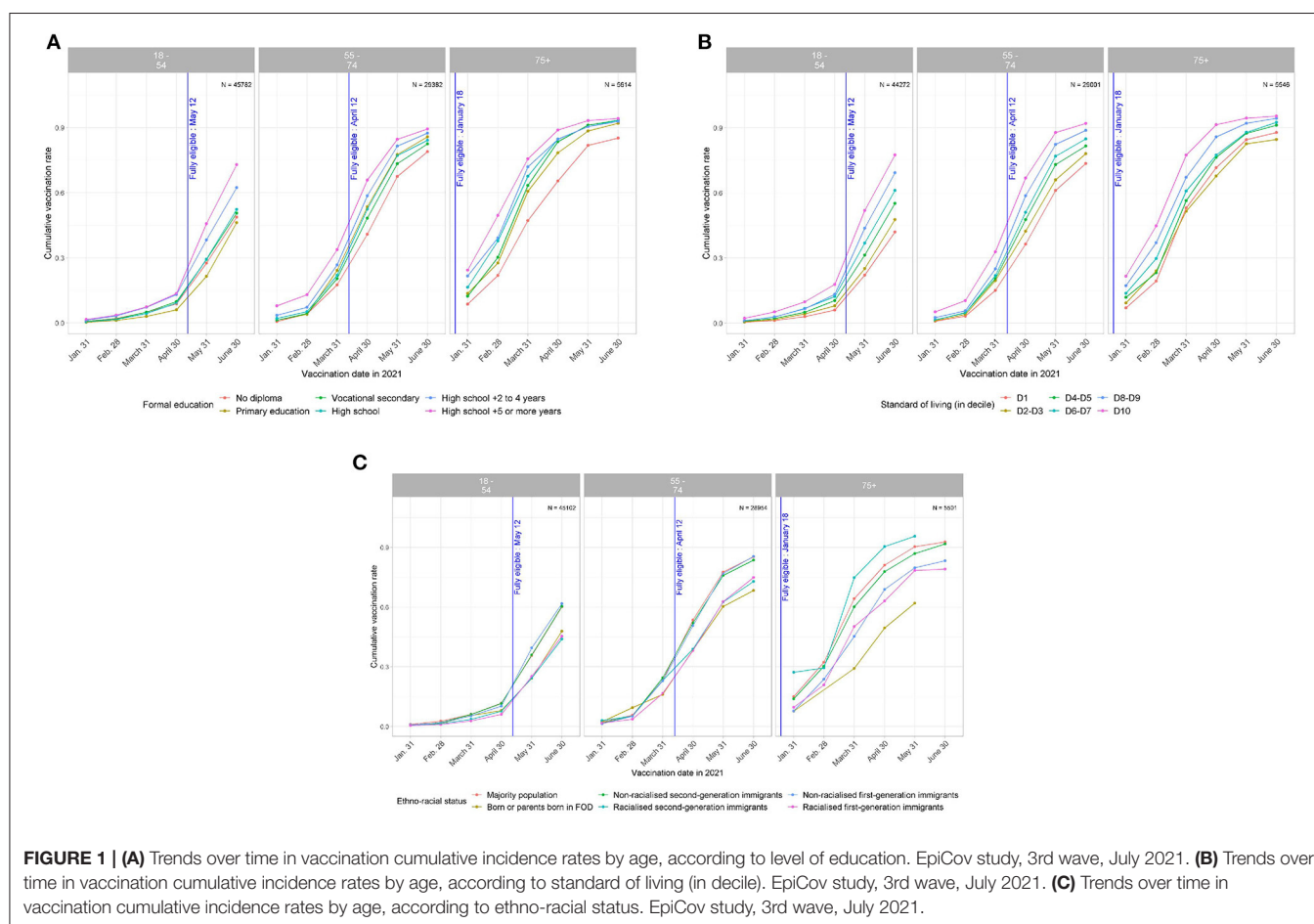
(Continued)

TABLE 1 | Continued

	Had at least one dose	Intends to get vaccinated	Does not know yet	Refuses to get vaccinated
Paris	71.7 (9,214)	11.3 (1,016)	10.6 (841)	6.4 (560)
Missing	2,202	263	251	231
Priority neighborhood				
No	73.4 (60,789)	9.5 (6,358)	9.2 (5,965)	7.8 (4,956)
Yes	55.4 (1,629)	14.2 (388)	18.2 (418)	12.1 (275)
Trust in the government				
Complete trust	85.0 (10,479)	8.3 (719)	4.8 (341)	1.9 (123)
Fair amount of trust	80.5 (30,767)	9.5 (2,903)	7.2 (2,002)	2.8 (760)
Little trust	65.2 (14,388)	11.3 (2,035)	14.2 (2,489)	9.3 (1,681)
No trust at all	51.1 (6,507)	10.1 (1,064)	13.8 (1,486)	25.0 (2,636)
Trust in scientists				
Complete trust	83.5 (26,227)	9.0 (2,153)	5.1 (1,058)	2.3 (479)
Fair amount of trust	70.8 (32,717)	10.5 (3,942)	11.3 (4,043)	7.3 (2,608)
Little trust	45.2 (2,507)	9.7 (467)	19.3 (914)	25.8 (1,225)
No trust at all	34.3 (795)	7.9 (161)	15.9 (319)	41.9 (879)

EpiCov study 3rd wave, July 2021.

Data are presented as % (n), except for missing values where only numbers are reported. Among men, 71.1% had had at least one dose at the time of the survey.



Among these, the gap between the 10% poorest and the 10% richest was 11.9% at the end of April 2021 and it increased to 35.4% by the end of June.

The lack of trust in the government to manage the epidemic crisis was much more pronounced than the lack of trust in the scientists: overall, 15.7% of the respondents trusted the government completely and 17.3% did not trust them at all, while 36.8% of the respondents trusted scientists completely and only 3.9% did not trust them at all (**Supplementary Table 1**). People at the bottom of the social hierarchy showed much less trust in the government. The differences were similar although less pronounced for trust in scientists. Vaccination status varied greatly and regularly according to the degree of trust in the government: from 85.0% of those who trusted the government completely to manage the epidemic were vaccinated to 51.1% of those who did not trust the government at all (**Table 1**).

Multivariate analyses confirmed that those not vaccinated were younger, less educated, had lower incomes and more often belonged to racially minoritized groups than vaccinated people in all three sub-groups, especially those who refused to be vaccinated. Multivariate analyses also showed that people's lack of trust in the government and scientists were the factors that were the most strongly associated with refusing to be vaccinated, compared to vaccinated people with an OR of 8.86 (95%CI: 7.13 to 11.01) for complete lack of trust in the government and an OR of 9.07 (7.71 to 10.7) for complete lack of trust in scientists (**Table 2**).

The data also showed that the richer people were, the stronger the effects of trust in the government were on the decision not to refuse to get vaccinated (**Figure 2; Supplementary Table 2A**). Compared to the richest 10% who trust the government, the poorest 10% who also did reach an OR of 4.44 (3.13 to 6.31) for the decision to refuse to get vaccinated, the poorest 10% who did not trust the government reached an OR of 16.2 (11.9 to 22.0) (**Figure 2; Supplementary Table 2A**). Similar but less marked differences were found according to formal education. Finally, the effect of trust in the government on decreasing refusal to get vaccinated was less pronounced among the racially minoritized first and second generations compared to the mainstream population.

The results were similar but to a lesser extent for mistrust in scientists (**Supplementary Table 2B**).

DISCUSSION

EpiCov is among the largest national socio-epidemiological cohort surveys to be conducted on a random sample of the population, simultaneously considering gender, class and ethno-racial status, health data, and trust of the government and of scientists to analyse social inequalities in vaccination.

We found marked social and ethno-racial inequalities in vaccination, in a context of free access to vaccination and at a time when anti-COVID certifications had not yet been made restrictive. The least educated, those with the lowest incomes, and racially minoritized groups were less likely to have been vaccinated and these differences were maintained or

increased over time. People's lack of trust in the government and scientists to manage the health crisis remained the factor that was the most strongly associated with refusing to get vaccinated. The impact of trust on not refusing to be vaccinated was even more marked among people at the top of the social hierarchy, thus reinforcing social inequalities in vaccination.

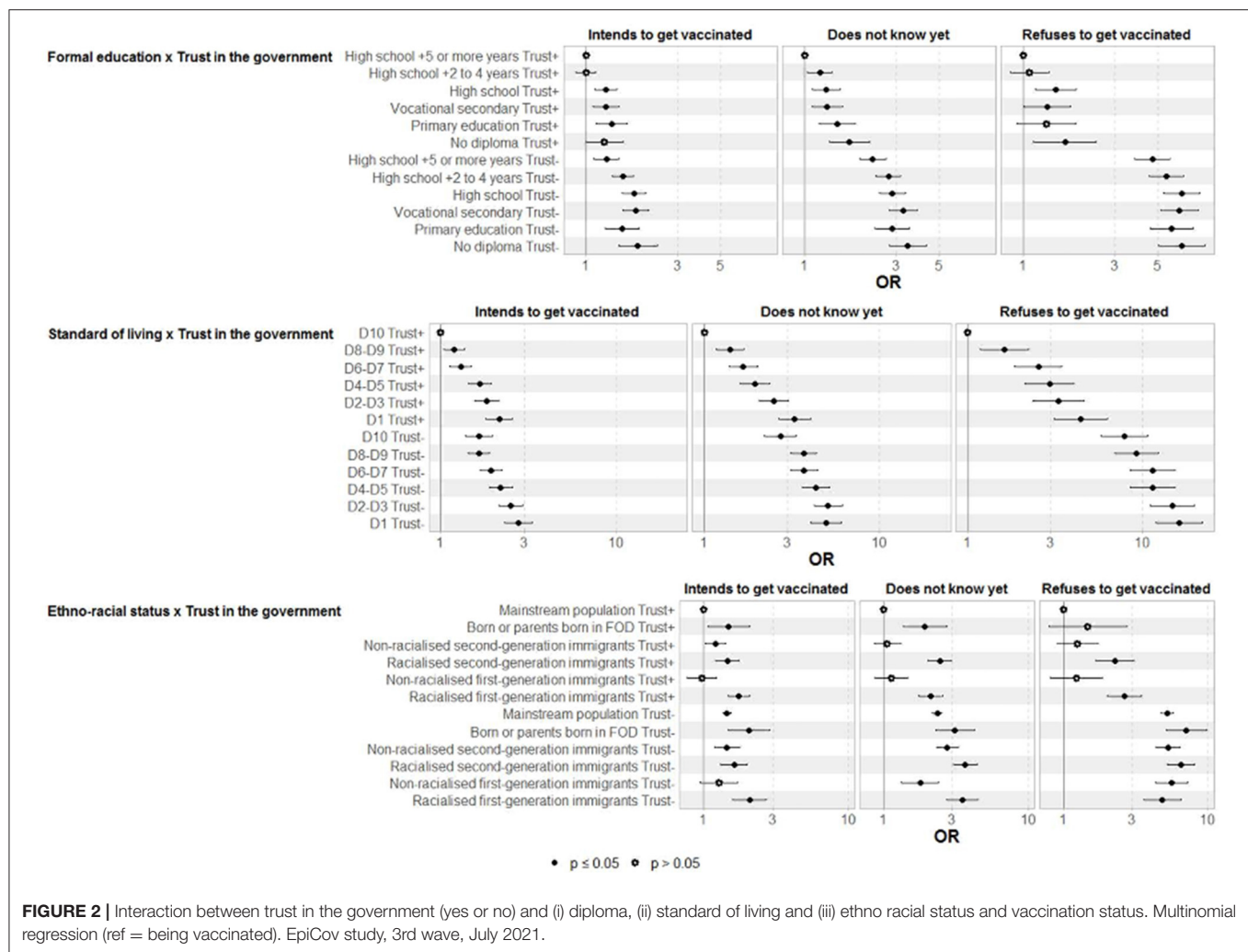
With regard to the social barriers to access to vaccination, we should first of all note that the lower vaccination rates among younger people are likely to be related to a shorter access period. Indeed, data was collected in July 2021, at a time when COVID-19 vaccines were available in France for any individuals aged 18 and over as of May 12th 2021 (12th April for people over 55, and 18th January 2021 for people over 75). Secondly, it is interesting to note that social differences in vaccination practices overlapped with the social distribution of vaccine reluctance observed in France 8 months earlier, except for gender differences (16). Indeed, women were no less likely to be vaccinated than men, although they were more reluctant to get vaccinated in France, as in many countries, before the vaccine was made available to all (30). Faced with the reality/possibility of prevention, one could hypothesize that their gendered reflexes as guardians of the family's health came into play (31). Our results also showed that those with lower levels of education and those belonging to the working class were less likely to be vaccinated, as found in the UK (7). Although many epidemiological studies have shown that the less educated were more reluctant to be vaccinated, they do not explore sociological hypotheses to account for these statistical correlations (32). One could wonder if this does not translate the fact that members of the working classes have a perception of their body and their health that is more distant from medical diagnoses and recommendations than the upper class (33). Racially minoritized groups also appeared to be less likely to be vaccinated, as found in British and US surveys (5, 8, 34, 35). Numerous studies have shown that racially minoritized groups (29, 36) have less confidence in the healthcare system and in caregivers than the mainstream population (37, 38). This lack of trust particularly results from discrimination and mistreatment to which these populations have been exposed when resorting to the public health system (39, 40). A recent study among students in London showed that experiences of racial discrimination increased the likelihood of subsequent COVID-19 vaccine refusal nearly four-fold (5). Barriers other than experiences of discrimination should also be considered, such as the lack of health insurance coverage in countries where vaccination is not free (41). In this respect, it is surprising to note that significant differences were recorded according to income level in the multivariate model, despite vaccination being free in France. While the poorest have the same tendency as others to comply with the use of masks in France (42), they are less likely to be vaccinated. The exclusion of the poorest part of the population from the social contract could lead to a diminished sensitivity toward the national solidarity dimension of vaccination, strongly emphasized in the public discourse on prevention in France. The low rates of vaccination among the most deprived, also found in a US survey (6), probably also relates to the fact that they generally have poor access to healthcare than others for given needs (10).

TABLE 2 | Factors associated with vaccination status (multinomial regression, reference = being vaccinated).

	Intends to get vaccinated		Does not know yet		Refuses to get vaccinated	
	OR	95% CI	OR	95% CI	OR	95% CI
Sex						
Men	—	—	—	—	—	—
Women	0.85	0.80, 0.90	1.02	0.96, 1.09	1.19	1.10, 1.28
Age						
18–24	—	—	—	—	—	—
25–34	1.20	1.06, 1.36	1.34	1.18, 1.52	1.39	1.20, 1.60
35–44	0.83	0.73, 0.93	0.99	0.87, 1.11	0.90	0.78, 1.04
45–54	0.54	0.48, 0.61	0.62	0.55, 0.71	0.58	0.50, 0.67
55–64	0.33	0.29, 0.38	0.47	0.40, 0.54	0.43	0.37, 0.51
65–74	0.20	0.17, 0.24	0.26	0.22, 0.31	0.24	0.20, 0.29
75–84	0.10	0.07, 0.13	0.19	0.15, 0.25	0.20	0.14, 0.27
85+	0.16	0.10, 0.25	0.20	0.13, 0.33	0.47	0.31, 0.72
Formal education						
High school +5 or more years	—	—	—	—	—	—
High school +2 to 4 years	1.08	0.97, 1.19	1.20	1.08, 1.33	1.15	1.01, 1.30
High school	1.31	1.17, 1.46	1.27	1.13, 1.44	1.39	1.21, 1.61
Vocational secondary	1.32	1.16, 1.50	1.39	1.21, 1.58	1.32	1.13, 1.54
Primary education	1.29	1.10, 1.50	1.36	1.15, 1.59	1.25	1.03, 1.51
No diploma	1.32	1.11, 1.58	1.59	1.34, 1.89	1.39	1.13, 1.71
Standard of living (in deciles)						
D1	—	—	—	—	—	—
D2–D3	1.11	1.00, 1.24	1.40	1.24, 1.58	1.28	1.11, 1.48
D4–D5	1.26	1.12, 1.40	1.51	1.33, 1.71	1.66	1.43, 1.92
D6–D7	1.53	1.36, 1.71	1.76	1.55, 2.00	1.69	1.45, 1.97
D8–D9	1.70	1.51, 1.93	2.13	1.86, 2.43	2.12	1.81, 2.48
D10	1.96	1.71, 2.25	2.37	2.05, 2.74	2.47	2.08, 2.93
Ethno-racial status						
Mainstream population	—	—	—	—	—	—
Born or parents born in FOD	1.46	1.16, 1.85	1.55	1.23, 1.96	1.49	1.13, 1.96
Non-racially minoritized second-generation immigrants	1.11	0.98, 1.26	1.14	1.00, 1.30	1.07	0.92, 1.25
Racially minoritized second-generation immigrants	1.31	1.14, 1.51	1.95	1.71, 2.23	1.57	1.33, 1.87
Non-racially minoritized first-generation immigrants	0.94	0.78, 1.13	0.94	0.77, 1.14	1.21	0.98, 1.50
Racially minoritized first-generation immigrants	1.70	1.47, 1.96	1.93	1.65, 2.24	1.58	1.29, 1.94
Trust in the government						
Complete trust	—	—	—	—	—	—
Fair amount of trust	1.18	1.06, 1.31	1.21	1.05, 1.40	1.00	0.80, 1.25
Little trust	1.57	1.40, 1.75	2.48	2.15, 2.87	3.17	2.55, 3.94
Not trust at all	1.79	1.58, 2.03	3.12	2.68, 3.63	8.86	7.13, 11.0
Trust in scientists						
Complete trust	—	—	—	—	—	—
Fair amount of trust	1.17	1.09, 1.25	2.25	2.07, 2.45	2.87	2.55, 3.22
Little trust	1.34	1.18, 1.52	4.08	3.63, 4.58	8.62	7.53, 9.87
Not trust at all	1.22	0.99, 1.51	3.19	2.67, 3.80	9.07	7.71, 10.7

EpiCov study 3rd wave, July 2021.

Also adjusted for social class, healthcare worker, cohabitation status, has children, population size of municipality, priority neighborhood, perceived health status, COVID-19 comorbidities, knows someone who has had a severe form of COVID-19, COVID-19 risk perception, positive test in last 6 months, and date of response to questionnaire.



Our results underline the need to develop outreach strategies targeting the poorest, the least educated, and racially minoritized groups, as recommended by Hanif back in 2020 (43). However, given the preponderant place of vaccine refusal due to lack of trust in the government's and scientists' attempts to curb the spread of the coronavirus, the characteristics of the messenger in vaccination campaigns should also be considered. A recent study compared the relationship between government trust and vaccination coverage in 177 countries, but using pre-pandemic trust scores (44). Studies in the US have shown that non-uptake of vaccination is higher in counties where conservative votes are higher (15, 45). However, in a context where the abstention rates are high (46), especially in France, it seems more relevant to consider the link between trust in the government and individual decision-making about vaccination. We found that lack of trust in the government and in scientists to curb the spread of the epidemic was the strongest predictor for not being vaccinated, even after adjustment on social factors, which were shown to be low confounding factors in a supplementary analysis (data not shown). Nevertheless, the effects of trust were less pronounced for people at the lower end of the social ladder and for racially minoritized groups, with the reinforcement of social inequalities

in vaccination as a consequence. It thus seems preferable for the preventive discourse to come from health agencies in close collaboration with community organizations and social workers (47), without political interference. People's lack of trust in scientists could reflect a strong connivance, in France, between the government and the scientific council. It could also reflect doubts arising from the contradictory injunctions that have been made in the media. Finally, suspicions of scientists colluding with big pharmaceutical companies could also contribute to explaining this lack of trust (48).

It should also be emphasized that the spread of new variants, which has led to a further outbreak of the epidemic in France and in many countries with high vaccination rates, raises questions for many people about the effectiveness of vaccination. New strains, the requirement for boosters, the uncertainty of a possible herd immunity, and the complexity of the scientific and political discourse on COVID-19 vaccines could prompt concerns that groups of people in the population who are more distant from health literacy may no longer embrace the COVID-19 vaccine.

Our analysis nevertheless has some limitations. First, as any national population-based survey, the present study failed to capture highly vulnerable groups such as undocumented

migrants and homeless people, who were particularly affected by the pandemic (49).

Secondly, our analysis was based on a survey conducted in July 2021. Until reaching a plateau in October 2021 (50), vaccination rates continued to rise particularly in connection with the mandatory anti-COVID-19 certification introduced on July 21st 2021 (3, 51). Considering that the least privileged social groups are less impacted by the anti-COVID-19 certification, since they are not likely to routinely access places like restaurants, we could hypothesize that the social inequalities observed are still present today, even if their magnitude is less prominent. In addition, it was interesting to study the social inequalities in vaccination practices before the introduction of the mandatory anti-COVID-19 certification to be able to evaluate its effectiveness afterwards.

The highly structuring effect of trust in the government and scientists remains to be understood in greater detail. The role of the social networks and the contradictory information on COVID-19 vaccination (34) is particularly difficult to grasp in a quantitative survey.

Finally, the issue of social inequalities in vaccination practices is all the more important because the social groups that are the least vaccinated are also those most at risk of contracting COVID-19 (1). Our analyses show that a top-down conception of preventive policies comes up against the social logics that structure vaccination status. There is an urgent need to depoliticise vaccination strategies, and to develop outreach programmes for the most socially disadvantaged groups but also “culturally competent” vaccination campaigns (43) conceived with people from different social and racial backgrounds to enable them to make fully informed choices.

SUMMARY BOXES

What is already known on this topic

Some studies in the UK and in the US have shown that the most socially disadvantaged and racially minoritized groups are the least vaccinated, and that trust in the government was strongly associated with vaccine hesitancy.

What this study adds

We found social and ethnoracial inequalities in vaccination practices, which result from social barriers to engaging in prevention practices. But above all, people's lack of trust in the government and scientists was the factor most strongly associated with refusing to get vaccinated. Nevertheless, the effects of trust on not refusing to get vaccinated were less pronounced for people at the lower end of the social ladder and for those who belong to racially minoritized groups, leading to the reinforcement of social inequalities in vaccination.

How this study might affect research, practice or policy

Our results show the need to develop outreach strategies with no interference of politics, delegated to key-players able to design targeted preventive messages conceived with people from different social and racial backgrounds to enable people to make fully informed choices.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: Data of the study are protected under the protection of health data regulation set by the French National Commission on Informatics and Liberty (Commission Nationale de l'Informatique et des Libertés, CNIL) in line with the European regulations and the Data Protection Act. The data can be available upon reasonable request to the co-principal investigator of the study (nathalie.bajos@inserm.fr). The French law forbids us to provide free access to EPICOV data; access could however be given by the EPICOV steering committee after legal verification of the use of the data. Please, feel free to come back to us should you have any additional questions.

ETHICS STATEMENT

The survey was approved by the CNIL (French Independent Administrative Authority responsible for data protection) on 25 April 2020 (ref: MLD/MFI/AR205138) and by the ‘Comité de protection des personnes’ (French equivalent of the Research Ethics Committee) on 24 April. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

EPICOV STUDY GROUP

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AUTHOR CONTRIBUTIONS

NB and ASp had full access to all the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: NB and ASp. Data acquisition: IPSOS. Data analysis and interpretation: NB, ASp, J-EF, and LS. Drafting of the manuscript: NB, ASp, J-EF, and LS. Critical revision of the manuscript for important intellectual content: all authors. Statistical analysis: ASi. Study supervision: NB and ASp. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpubh.2022.908152/full#supplementary-material>

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Vulnerable populations during COVID-19 response: Health-related quality of life among Chinese population and its influence due to socio-demographic factors and loneliness

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Background: Infection control policy affected people's wellbeing during the COVID-19 pandemic, especially those vulnerable populations. This study aimed to compare the health-related quality of life (HRQoL) of the Hong Kong (HK) Chinese population under the pandemic with the normative profiles and explore its influencing factors, including socio-demographic characteristics, loneliness, and the interaction between them.

Methods: A cross-sectional questionnaire survey (301 online and 202 in-person) was conducted between June and December 2020 among the adult Chinese population during the 2nd wave of COVID-19 in HK. HRQoL was measured by a Hong Kong validated EQ-5D-5L instrument (EQ-5D-5L HK). Loneliness was measured by a single-item question regarding the frequency of the participants reporting feeling lonely and their subjective social status was measured by the MacArthur Scale of Subjective Social Status. A series of Tobit regressions was conducted. The interaction terms between socio-demographics and loneliness were also examined to decide their association with HRQoL.

Results: A total of 503 responses were collected. The level of HRQoL of the respondents was significantly lower than the referred norms profile among the local general population. The findings identified that younger age, single, a higher subjective social status, and a lower level of loneliness were significantly associated with better HRQoL. Moreover, age and marital status were significant moderators in the relationship between loneliness and HRQoL.

Conclusion: The present study found that some population groups face additional vulnerabilities during the pandemic in terms of declined HRQoL. In

addition, reducing loneliness can protect the HRQoL during the pandemic, especially among older people. This article provides useful information for policy-makers to design and promote effective services or provide education to improve the connection of people and recover from the global pandemic.

KEYWORDS

COVID-19 pandemic, health-related quality of life, loneliness, EQ-5D-5L, vulnerable populations

Introduction

Initial cases of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) were detected in Wuhan, China, in December 2019. Since then, ~219 million cases and 4.55 million deaths have been recorded worldwide. Social distancing measures have been launched by the governments to control the spread of the virus. For instance, the Government of the Hong Kong (HK) Special Administrative Region has promptly announced social distancing measures to limit the spread of the virus, such as mandatory wearing of face masks in all public areas, prohibiting large group gatherings, and restricting dine-in hours, closing all leisure facilities, and encouraging work at home.

While such strict measures proved to be effective in containing the spread of the virus, they have also had significant negative consequences on people's daily wellbeing. Health-related quality of life (HRQoL) is a multi-dimensional and interdisciplinary concept that has been used to reflect an individual's subjective evaluation of physical, mental, and social health (1). While there are a lot of studies investigating the HRQoL of COVID patients, survivors, and people with different health conditions specifically, a smaller number of studies have focused on the general population. As an exception, a Japanese study compared the HRQoL of the same cohort in 2017, 2020, and 2021 and found significant declines in HRQoL after the outbreak of the pandemic (2).

Populations with different socio-demographic characteristics may also face different levels of vulnerabilities with regard to the influence of the pandemic on their HRQoL. Some socio-demographic factors have been found to be significantly associated with a lower level of HRQoL, such as older age, female gender, unmarried, and lower socioeconomic status (3–6).

Loneliness is another established factor that can harm people's HRQoL (7, 8). Extensive evidence has suggested that levels of loneliness elevated during COVID-19 (9, 10). Indeed, a study in HK indicated that there were significant increases in loneliness among the older person with multi-morbidity after the onset of COVID-19 (11). However, few studies have examined the relationship between loneliness

and self-reported health-related outcomes during COVID-19 specifically. According to studies conducted before COVID, loneliness can result in a decline in HRQoL. Recently, Liu *et al.* found that in the early stage of COVID, loneliness among young adults was significantly associated with lower self-reported mental health functioning, which is a domain of HRQoL (12).

As mentioned above, socio-demographic factors and loneliness may influence HRQoL during COVID-19, but their combining effects have received little attention. Studies conducted before the pandemic suggested that the influence of loneliness on people's HRQoL varies across socio-demographic characteristics. For instance, a study found that loneliness could predict decreased HRQoL after 3 years in women only (13). A meta-analytic study has also suggested that loneliness is associated with worse HRQoL among women than men (14). Furthermore, a high socio-economic status (SES) may act as a buffer against stress and attenuate the relationship between loneliness and health outcomes (15). On the contrary, those with a lower level of SES may have fewer resources to cope with loneliness, which will further influence their health outcomes. Therefore, some population groups may be even more vulnerable during the pandemic if loneliness is at a high level. Identifying the groups most at risk is critical for public health professionals to launch suitable interventions or programs to help them maintain health and wellbeing during this hard time.

The negative impacts of COVID-19 may differ across regions with different severity of the pandemic, infection control measures, and citizens' responses (16). HK, as one of the few regions that have managed to contain the spread of COVID-19 for a long time, is a unique context to examine the HRQoL of the population. While it is a good thing that HK citizens may have fewer concerns with the risks of being infected due to the relatively successful physical distancing measures, in the meantime, they may have experienced more inconvenience than those from regions with looser social distancing measures. How such a dilemma influences people's HRQoL needs to be investigated.

To address this knowledge gap, this study examined (1) the HRQoL of the HK general population during COVID-19 by EQ-5D-5L HK compared with its population norms obtained

at the pre-pandemic period; (2) the effects of loneliness on HRQoL among the HK population during COVID-19; (3) the effects of socio-demographic factors on HRQoL among the HK population during COVID-19; (4) the interaction effects between different socio-demographic factors and loneliness. This study can help to provide additional evidence on how resources should be allocated among the vulnerable population groups, as well as provide insights on the formulation of suitable policies and responses to improving population health.

Materials and methods

Study design

A cross-sectional survey with a structural questionnaire was conducted between June and December 2020 (the second wave of COVID-19 in HK). There was a rise in case of number in July 2020 to around 100 per day, which reduced to single digits by the end of August. Another wave arrived at the end of November with dozens of cases per day. During this period, the Hong Kong (HK) government launched social distancing measures, such as restricting the number of people dining in restaurants and implementing mask mandates. Due to the social distancing measures and concerns regarding virus spread, most of the questionnaires were filled in *via* online platforms ($n = 301$), with the rest being administrated in person ($n = 202$). Convenience sampling was adopted with the help of NGO partners. Those who were HK residents, aged 18 years or above, and able to understand Chinese were eligible for the survey. An information sheet, including the details of the study, was available at the beginning of the survey. Electronic consent was obtained from the participants and the participants who agreed to join the study filled in the questionnaire on their own electronic devices or with the help of interviewers. Data collected were retrieved from an online platform, and the downloaded database was password protected. Ethical approval was obtained from the Survey and Behavioral Research Ethics Committee of the authors' University (Ref. no: SBRE-19-755). All participants were required to consent to participate after receiving an explanation of the purpose of this study and their rights during participation.

Measurements

HRQoL was measured using the HK Chinese version of the EQ-5D-5L instrument (EQ-5D-5L HK) (17, 18). Developed by the EuroQoL Group, EQ-5D consists of five dimensions to measure HRQoL for clinical and economical assessment: mobility (MO), self-care (SC), usual activities (UA), pain/discomfort (PD), and anxiety/depression (AD). For each dimension, there were five response levels indicating the severity

of the participant's problem, if any: (1) no problem, (2) slight problems, (3) moderate problems, (4) severe problems, and (5) extreme problems. The best health state can be represented by "11111" and the worst can be represented by "55555". The different health states were converted into a utility index ranging from -1 to 1 , where full health is anchored at 1 , death at 0 , and a negative value is obtained when the health state is worse than death, the higher score indicating better HRQoL. In HK, a hybrid model without a constant after feedback module was selected as the final model to derive utility decrements (17, 18). Thus, the size of the coefficients reflects the relative weight placed on different kinds of health problems. For example, if mobility scores level 3 but all other dimensions scored level 2, the utility index by subtracting the coefficients (mobility: 0.1823 ; self-care: 0.0867 ; usual activities: 0.0672 ; pain/discomfort: 0.0756 ; and anxiety/depression: 0.0801) from 1 , giving 0.5081 . The lowest possible estimated value for the health state 55555 was estimated to be -0.8637 for the HK general population. The first population norm profile of HRQoL for Chinese residents aged 18 years and above was derived based on a representative sample (1,014 respondents) in HK using the preference-based value set of EQ-5D-5L HK at the pre-pandemic period. Thus, this norm profile was used in this study as the reference for the comparison of HRQoL between pre- and during the COVID-19 pandemic (19).

Loneliness was measured by a single-item question regarding the frequency with which the participant reported feeling lonely (1 = never, 2 = rarely, 3 = occasional, 4 = often, 5 = always). The single-item loneliness measurement was adopted by large surveys, such as The English Longitudinal Study of Aging (ELSA) (20, 21). A five-point Likert scale to measure the frequency of loneliness has also been widely used in previous studies among the Chinese population (22, 23). Due to the potential underestimation of loneliness level resulting from stigma concern and following the practice adopted by previous studies, the score of loneliness was further categorized into two groups: not lonely (never or rarely felt lonely) vs. lonely (occasional, often, and always felt lonely) (24).

Demographic characteristics included age, gender (female vs. male), religion (yes vs. no), education (<middle school, middle school, >middle school), living arrangement (living alone vs. living with others), and marital status (single vs. married/cohabited vs. divorced/widowed/separated) were also collected. Subjective social status (SSS) was measured by the MacArthur Scale of Subjective Social Status (1 = lowest to 10 = highest), which is a visual instrument to capture participants' sense of social status on a social ladder (25). This scale has been previously adopted in several studies undertaken on the HK population (26, 27). To account for the potential influence of the pandemic situation on participants' HRQoL, we also controlled for the stability of the pandemic on the date of the questionnaire survey collected. During our data collection period (June to December 2020), the government has

adjusted physical distancing measures multiple times for virus control. Due to the rising infection number at the beginning of July 2020, the government tightened physical distancing measures on July 11. It did not loosen them until September 11, when the local infection number reduced to a single digit per day. On November 14, 2020, foreseeing another infection wave, the government tightened the measures again (28–30). Therefore, based on the infection number and the strictness of social distancing measures introduced by the government, we categorized the date of questionnaire survey collection into “stable” (before July 11, 2020; between September 11 and November 14, 2020) and “unstable” (July 12 to September 10, 2020; after November 14, 2020).

Statistical analysis

The index score of EQ-5D-5L was calculated using the established HK value set (17, 18), and the norms profile for the general HK adult population was used for comparing the differences in the COVID-19 pandemic (19). Descriptive summary statistics were estimated for the mean index score, and percentage of people reporting any problem on each EQ-5D-5L dimension. Due to the non-normally distribution of EQ-5D-5L index score, univariate analyses, including Mann-Whitney U-tests, Kruskal-Wallis tests, and Spearman's correlations, were conducted to investigate the differences between participants with different demographic characteristics. Mann-Whitney U-tests and Kruskal-Wallis tests were used to compare group differences of socio-demographic variables in HRQoL, while Spearman's correlations were applied to examine the association between continuous socio-demographic variables (age and subjective social status) and the EQ-5D-5L score.

To explore the factors influencing the EQ-5D-5L index score, a Tobit regression model was adopted, which was considered appropriate for analysis due to the censored nature and the skewed distribution of the index score. Studies have shown in the ceiling effect of EQ-5D-5L that most respondents will report a perfect health state according to this instrument, which cannot differentiate respondents reporting perfect health. Therefore, the data should be interpreted to be censored to 1 and will generate a biased coefficient with conventional linear regression models (19). In the current sample, 200/533 (37.52%) participants score the highest score of 1 in our sample. To make the sample more comparable with the profile of the general HK adult population, the sample data were weighted based on gender and age using the 2020 HK census data as a reference. The regression was conducted among the weighted sample to examine the estimates among a sample that is closer to the HK general population. The independent variables included socio-demographic characteristics (including age, gender, marital status, education, religiosity, living arrangement, and SSS)

and loneliness. The format of the questionnaire (face-to-face vs. online) and the stability of the pandemic during the data collection period was controlled in the model. The interaction effects between each socio-demographic variable and loneliness were then examined by adding an interaction term into the regression model. To avoid multicollinearity, all the continuous variables in the interaction term were centered. Akaike information criterion (AIC) and the Bayesian information Criterion (BIC) were computed to indicate the model fit, with smaller values indicating good model fits (31). Data were then analyzed using R version 4.0.3. Any $P < 0.05$ values were regarded as statistically significant.

While a Tobit regression model has been frequently adopted by many studies examining factors influencing EQ-5D-5L due to its advantage in dealing with censored data (19, 32), the estimates in the Tobit model may be biased if the assumption of normality is violated (33). To check the robustness of the Tobit estimates, based on suggestions from previous studies, we conducted another two types of regression models as a sensitivity analysis: (1) a two-part model and (2) a generalized linear model. A two-part model consists of a logistic regression model with the binary outcomes (full health vs. non-full health) as the dependent variable and an ordinary least squares (OLS) model with the scores of non-full health as the dependent variable (34, 35). Including two parts in the model can mitigate the ceiling effect of the EQ-5D-5L score (34, 35). Generalized linear models allow for non-normal distribution. Gamma distribution of the EQ-5D-5L scores in the current sample was detected based on the Cullen and Frey graph (36). Moreover, because GLM with Gamma distribution requires a positive value of the dependent variable, we transformed the EQ-5D-5L score to a disutility score (1-EQ-5D-5L) as the dependent variable, the same as previous studies did (37, 38).

Results

Demographics

A total of 503 valid responses among the general HK adult population were collected. The profile of the present sample has younger age and a larger proportion of females than the general HK population, with the age of the respondents ranging from 18 to 89, with an average of 42.0 (SD = 21.9) (2020 HK population: 44.8). A total of 74.2% of participants were females (2020 HK population: 54.4%), while 41.4% of the participants were younger than 24 years old (2020 HK population: 10.1%). A total of 57.3% of the participants were single and 9.2% of them were widowed, divorced, or separated. A total of 62.6% of participants obtained an education level higher than an associate degree and 57.5% of them were non-religious. Only 8.0% of participants reported living alone. On a scale of 1–10, the average score of subjective social status was 5.37 (SD = 1.60). A total of

TABLE 1 Sample characteristics and EQ-5D-5L HK index score ($N = 503$).

Variables	Sample characteristics	EQ-5D-5L HK index score					EQ-5D-5L HK index score by socio-demographics	
		<i>N</i> (%) / mean \pm SD	Mean \pm SD	min	1st quartile	Median	3rd quartile	Unweighted <i>p</i> -value
Age	42.0 \pm 21.9	0.862 \pm 0.209	–	–	–	–	0.000*** a	0.002** a
Marriage status								
Married/co-living	169 (33.6%)	0.829 \pm 0.252	–0.865	0.773	0.924	1.000	0.000*** b	0.000*** b
Single	288 (57.3%)	0.919 \pm 0.112	–0.251	0.856	0.920	1.000		
Widowed/divorced/separated	46 (9.1%)	0.829 \pm 0.201	0.139	0.784	0.924	0.931		
Education level								
<Middle school	22 (4.4%)	0.818 \pm 0.187	0.444	0.664	0.922	1.000	0.036* b	0.064 b
Middle school/diploma/advanced diploma	166 (33.0%)	0.847 \pm 0.228	–0.865	0.815	0.924	1.000		
Associate degree/degree/master/doctoral	315 (62.6%)	0.902 \pm 0.153	–0.625	0.844	0.920	1.000		
Gender								
Male	130 (25.8%)	0.851 \pm 0.269	–0.865	0.844	0.920	1.000	0.354 c	0.191 c
Female	373 (74.2%)	0.891 \pm 0.143	–0.251	0.844	0.924	1.000		
Religion								
No	289 (57.5%)	0.900 \pm 0.151	–0.416	0.844	0.920	1.000	0.034* c	0.135 c
Yes	214 (42.5%)	0.854 \pm 0.220	–0.865	0.844	0.920	1.000		
Living alone								
No	40 (8.0%)	0.888 \pm 0.170	–0.652	0.775	0.844	0.924	0.003** c	0.001** c
Yes	463 (92.0%)	0.788 \pm 0.292	–0.865	0.844	0.920	1.000		
Subjective social status	5.37 \pm 1.60	0.862 \pm 0.209	–	–	–	–	0.001** a	0.000*** a
Loneliness								
Not lonely	219 (43.5%)	0.901 \pm 0.175	–0.652	0.860	0.924	1.000	0.000*** c	0.000*** c
Lonely	284 (56.5%)	0.864 \pm 0.190	–0.865	0.844	0.920	1.000		
Questionnaire format								
Online	301 (59.8%)	0.890 \pm 0.173	–0.652	0.844	0.920	1.000	0.901 c	0.050 c
Face-to-face	202 (40.2%)	0.866 \pm 0.200	–0.865	0.844	0.924	1.000		
Stability of the pandemic								
Unstable	139 (27.6%)	0.843 \pm 0.221	–0.652	0.830	0.920	1.000	0.000***c	0.004** c
Stable	364 (72.4%)	0.894 \pm 0.167	–0.865	0.844	0.924	1.000		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.^aSpearman's Correlation.^bKruskal-Wallis test.^cMann-Whitney U -tests.

43.5% of participants were categorized as “not lonely” with the rest being “lonely”. Details are shown in [Table 1](#).

HRQoL during COVID-19 pandemic

The average EQ-5D-5L index score of the respondents was 0.862 (SD = 0.209), which was significantly lower than the norms profile ($M = 0.915$, $SD = 0.128$, $P < 0.001$) before the pandemic (19). [Figure 1](#) shows the percentages of participants in the current sample and in the normative profile who reported having problems in the five domains of EQ-5D-5L. While 89.3, 96.2, and 92.5% of the participants reported no problems in mobility, self-care, and usual activities, only 56.1 and 52.7% reported no problems in pain/discomfort and anxiety/depression, respectively. In the normative profile, the most prevalently reported problem was pain/discomfort, while in the current sample, it was anxiety/depression that most participants reported having problems with. A total of 74.0% reported no problems with anxiety/depression, while the percentage was reduced to 52.9% in the current sample.

Factors associated with EQ-5D-5L index scores

The EQ-5D-5L index scores by demographic information are also shown in [Table 1](#). There were no significant differences in EQ-5D-5L index scores between the online and the in-person collected respondents ($P = 0.050$). Participants who participated in the survey during the stable months of the pandemic reported significantly higher scores in EQ-5D-5L ($P = 0.004$). In addition, after weighing the sample, there were no significant differences among participants of different gender, education, and religion (P s = 0.191; 0.164; 0.135). Participants who were single and living together with others reported significantly higher EQ-5D-5L index scores than those who were married/co-living or widowed/divorced/separated ($P < 0.001$), and solo-living ($P = 0.001$), respectively. A younger age ($P = 0.002$) and a higher SSS ($P < 0.001$) were also related to higher EQ-5D-5L indices. Participants in the “not lonely” group also reported a significantly higher EQ-5D-5L index score than those in the “lonely” group ($P < 0.001$).

As shown in [Table 2](#), an older age was associated with lower EQ-5D-5L index score ($P = 0.001$). Single participants reported a 0.080-unit higher EQ-5D-5L index score than married/co-living participants [95% CI = (0.005, 0.156), $P = 0.037$]. One-unit increase in SSS was significantly associated with 0.028-unit increase in EQ-5D-5L index [95% CI = (0.012, 0.045), $P < 0.001$]. Lonely participants report a 0.152-unit lower EQ-5D-5L index score than lonely participants [95% CI = (−0.206, −0.098), $P < 0.001$]. The formats of the questionnaire and the

stability of the pandemic had no significant associations with the EQ-5D-5L index score after controlling for all other variables.

Interactions between socio-demographic characteristics and loneliness

Interaction terms were also added to the regression model to examine the interaction between socio-demographic characteristics and loneliness in influencing the participants' EQ-5D-5L index scores ([Table 3](#)). Among all the socio-demographic characteristics, the interaction effects of loneliness with age or marital status on HRQoL were significant (as shown in Models 1 and 2, respectively). Adding interaction terms into the model improved the model fits (smaller values of AIC and BIC) compared to the baseline model to explain the impact on HRQoL.

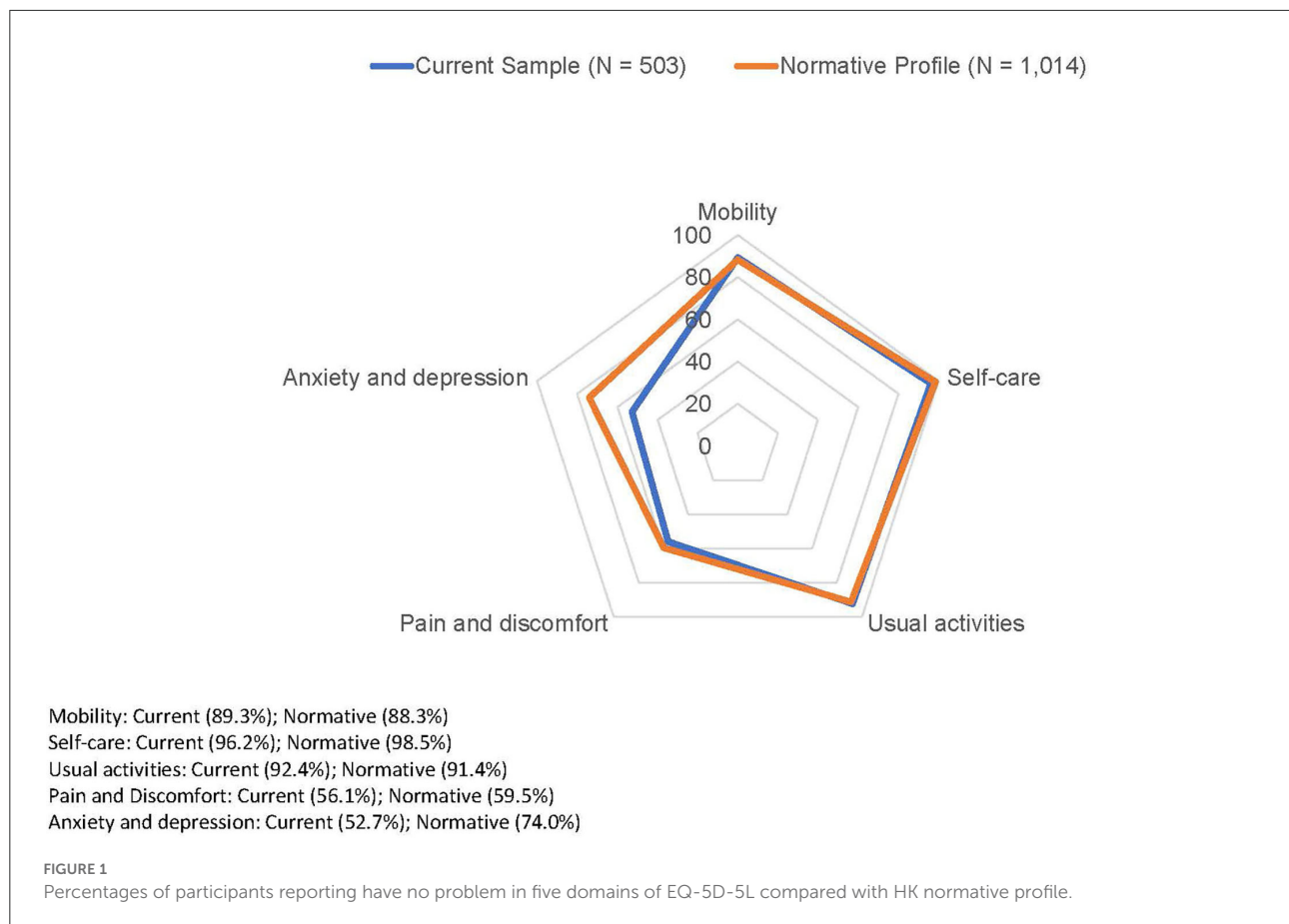
The interaction impacts of loneliness with age or marital status on HRQoL are plotted in [Figure 2](#) for ease of interpretation. In Model 1, the age differences in HRQoL differed by loneliness level. While both the younger and the older participants were at a similarly high level of loneliness, the age advantages of younger people in HRQoL were more apparent under the pandemic. When they both reported “not lonely”, older adults may not necessarily report a lower level of EQ-5D-5L score than younger people, indicating that older people may have some resilience in maintaining HRQoL. For the interaction effects between marital status and loneliness (Model 2), married or cohabited participants reported a lower level of HRQoL than single participants if they reported loneliness.

Sensitivity analysis

We conducted two-part models and GLMs as sensitivity analysis, which showed similar findings to the Tobit models mentioned above. As shown in [Tables 4, 5](#), in the logistic regression models of the two-parts model, being lonely was significantly associated with a lower likelihood of reporting full health. Participants who were single, lived together with others, and had a higher SSS were more likely to report full health. In the OLS models, age and marital status were significant moderators between loneliness and the utility score. Similar findings were also reported in the GLM models.

Discussion

The present study examined the shift in HRQoL of the general HK adult population during the COVID-19 pandemic



using the local validated EQ-5D-5L HK instrument. The EQ-5D-5L index score of the respondents was significantly lower than the referred population norms profile in HK. However, problems related to anxiety/depression were found to be more prevalent during the pandemic than pre-pandemic. The findings revealed that people with a higher level of loneliness tended to report lower HRQoL. In terms of the effect of socio-demographic factors on HRQoL, the findings indicated that people who were single or had a higher level of subjective social status tended to report higher HRQoL.

The COVID-19 pandemic has posed extra challenges to the personal, social, and professional lives of people of all ages. It also disturbed people's regular daily routines, such as attending community activities, seeking medical consultation, and meeting with families and friends, which will have detrimental effects on their physical and mental health. The significant decline of EQ-5D-5L index scores during the pandemic from the 2016 HK norm is consistent with some studies from other countries that the HRQoL of the general population was lower than the norms, such as in Portugal (39) during COVID-19. However, it was inconsistent with a previous study conducted in mainland China, which reported that the HRQoL

of people in the examined city did not change much during the pandemic (5). Another study in Vietnam also did not find a significant difference between the pandemic EQ-5D-5L index and the normal scores (40). Such inconsistencies may be due to the different conditions of COVID-19 in different cities (5).

Socio-demographics and HRQoL

Older age was significantly associated with a lower EQ-5D-5L index score after controlling of other variables. The findings are consistent with previous studies showing age as a risk factor of decreased HRQoL during COVID-19 (5). Possible explanations include that older people are more frequent users of the public healthcare system, community services, and other formal and informal caregiving. Such services have been greatly disrupted during the pandemic, which may influence their physical and mental health.

Subjective social status is a protective factor of HRQoL during COVID-19. This is consistent with previous research about the impacts of social positioning on one's health

TABLE 2 Tobit regression analyses of factors associated with EQ-5D-5L HK index scores.

Variables	Estimate (B)	95% CI		Pr (> z)
		Lower limit (LL)	Upper limit (UL)	
Age	−0.004**	−0.006	−0.002	0.001
Male (ref: female)	−0.037	−0.091	0.016	0.174
Education				
Middle school/diploma/advanced diploma (ref: <middle school)	0.020	−0.122	0.163	0.779
Associate degree/degree/master/doctoral (ref: <middle school)	0.034	−0.097	0.165	0.609
Marriage status				
Single (ref: married/co-living)	0.080*	0.005	0.156	0.037
Widowed/divorced/separated (ref: married/co-living)	0.027	−0.058	0.112	0.531
Religious (ref: non-religious)	−0.038	−0.088	0.013	0.148
Living with others (ref: living alone)	0.071	−0.022	0.163	0.136
Subjective social status	0.028***	0.012	0.045	0.001
Lonely (ref: not lonely)	−0.152***	−0.206	−0.098	0.000
Online survey (ref: face-to-face)	−0.046	−0.117	0.026	0.210
Pandemic (ref: stable)	−0.053	−0.117	0.012	0.108
AIC		306.636		
BIC		365.722		
Log likelihood		−139.317		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

(41, 42). COVID-19 has accentuated the correlation between social disparity and health disparity (43, 44). People with higher socioeconomic status may experience less financial pressure due to the disruption of economic activities amid COVID-19. On the other hand, they have more resilience in conducting activities beneficial for their health under the condition of social distancing. A qualitative study previously undertaken among a local population in HK (45) suggested that socially disadvantaged people have suffered more from the economic and financial impacts of the COVID-19 pandemic; and they tend to have limited access to personal protective equipment, such as face masks, hand rub, and other disinfecting products. Work-from-home suggestions from the government also hardly applied to groups, whose jobs were usually unable to be completed at home. Poor housing conditions also exacerbated their vulnerability to disease infection due to overcrowding of families.

It is a bit surprising that compared to married/co-living couples, single participants were more likely to report a higher level of HRQoL and better health status on mobility and pain/discomfort. Tentative explanations include that continuous home office has increased the possibility of interpersonal conflict. Based on the vulnerability-stress-adaptation model, Pietromonaco & Overall suggested that

COVID-19 caused external stress and may result in harmful dyadic processes and decreased quality of romantic relationship (46). Another study adopting a nationally representative sample of American adults also revealed escalated partner conflicts during COVID-19 (47). Similarly, a study in mainland China has found that married participants reported a greater decline in emotional wellbeing during COVID-19 than their non-married counterparts (48). For those married, COVID-19 may have caused some family separation that may pose more adverse effects on married couples than single persons.

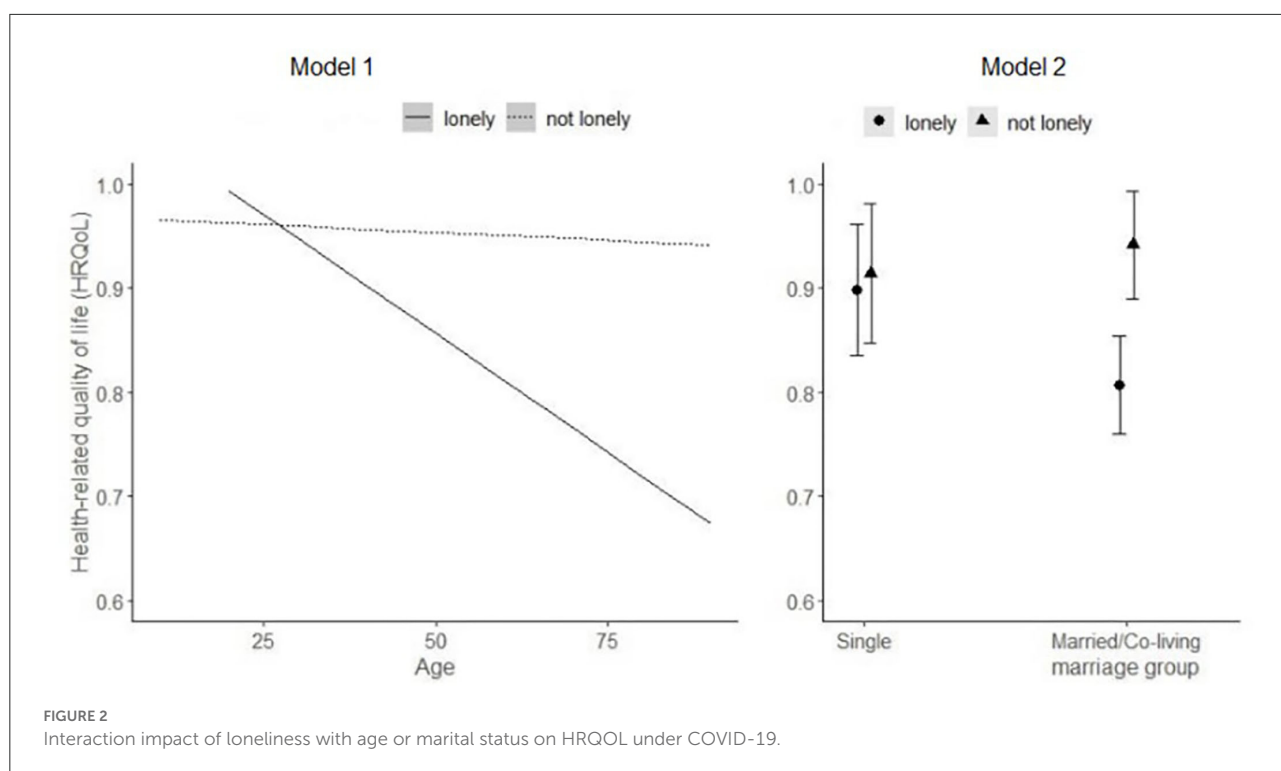
Loneliness and HRQoL

The findings also revealed that loneliness was a strong predictor of HRQoL. Loneliness indicates a self-perceived insufficiency of social and emotional support. Loneliness, as a source of chronic stress, may cause pathologic hypervigilance and a dysfunctional immune system, which can further harm one's physical and mental health (49). Our finding is consistent with well-established empirical evidence indicating the concurrence of loneliness and a variety of health problems, such as depression, anxiety, cardiovascular diseases, hypertension, and chronic pain (7, 49–51).

TABLE 3 Tobit regression analyses of factors associated with EQ-5D-5L HK index scores with interaction terms.

Variables	Model 1				Model 2			
	Estimate (B)	95% CI		Pr (> z)	Estimate (B)	95% CI		Pr (> z)
		LL	UL			LL	UL	
Age	−0.002***	−0.005	0.001	0.179	−0.004***	−0.007	−0.002	0.000
Male (ref: female)	−0.037	−0.090	0.015	0.165	−0.038	−0.091	0.015	0.163
Education								
Middle school/diploma/advanced diploma (ref: <middle school)	0.023	−0.118	0.164	0.753	0.024	−0.118	0.165	0.743
Associate degree/degree/master/doctoral (ref: <middle school)	0.040	−0.089	0.170	0.543	0.039	−0.092	0.170	0.559
Marital status								
Single (ref: married/co-living)	0.081*	0.007	0.156	0.032	−0.005	−0.113	0.102	0.924
Widowed/divorced/separated (ref: married/co-living)	0.018	−0.066	0.102	0.670	0.059	−0.086	0.204	0.424
Religious (ref: non-religious)	−0.038	−0.088	0.012	0.136	−0.040	−0.091	0.010	0.120
Living with others (ref: living alone)	0.054	−0.039	0.146	0.256	0.066	−0.027	0.158	0.167
Subjective social status	0.028***	0.012	0.045	0.001	0.027**	0.010	0.044	0.002
Online survey (ref: face-to-face)	−0.045	−0.116	0.025	0.204	−0.042	−0.113	0.029	0.249
Pandemic	−0.047	−0.110	0.017	0.149	−0.049	−0.113	0.015	0.130
Lonely (ref: not lonely)	0.035	−0.118	0.188	0.655	−0.187	−0.255	−0.120	0.000
Age*lonely	−0.004*	−0.007	−0.001	0.011				
Marital status*lonely								
Single (ref: married/co-living)* lonely					0.119*	0.005	0.234	0.041
Widowed/divorced/separated (ref: married/co-living)*lonely					−0.039	−0.215	0.137	0.663
AIC		301.949				305.659		
BIC		365.257				373.188		
Log likelihood		−135.974				−136.829		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.



Interaction of socio-demographics and loneliness

The negative association between loneliness and HRQoL was more apparent among older people. It also indicates that reducing loneliness may be more rewarding for the HRQoL of older people in particular. At a lower level of loneliness, younger people's advantages in HRQoL decreased, which is consistent with previous literature regarding older people's resilience and favorable emotional regulation under adverse situations. It aligns with the socio-emotional selectivity theory (SST), indicating that older people tend to spend more energy on positive experiences rather than negative ones (52); while younger people tend to have more social and outdoor lives than other older age groups, the detrimental effects of social distancing may hit them more strongly than the older people. Indeed, it is common for younger people to report more mental health problems than the older population. A recent study conducted among American adults aged 18–76 found that the age advantages were sustained during COVID-19 (52). Such findings were also seen among samples from other countries, such as Canada (53). Other studies have also confirmed the greater risk of younger people suffering from mental health issues (54, 55); a global online survey collected data from 63 countries in the world and also found that younger people reported more mental health problems, including stress, depression, and anxiety, than middle-aged and

older-aged population during COVID-19 (55). Marital status and loneliness also interacted with each other to influence HRQoL. Being married but at the same time feeling lonely may indicate separation or conflicts between partners, which will negatively influence their HRQoL.

Limitation

This study possesses a few limitations. First, the data were cross-sectional data, and therefore no causal relationship can be drawn. Future studies should adopt a longitudinal or experimental approach to examine the factors influencing people's HRQoL. Moreover, the sample may be biased and not generalizable to the whole population. For instance, more than half of the participants were those who had access to the Internet for the online survey. Although we have controlled the collection in the regression, there may still be unobserved bias related to social desirability in the face-to-face samples. The sample was collected over a 6-months period, and the fluctuations in the COVID-19 situation may influence the respondents' responses to the questions. Second, it is noteworthy that the norms scores were generated in 2016. The differences between the scores collected in this study and the norms may be due to COVID-19, but it is also possible that the lower score is due to the continuous effects of the social and political unrest in HK (56, 57). Third, we used a single-item question to measure loneliness,

TABLE 4 Two-part models of factors associated with EQ-5D-5L HK index scores.

Predictors	Logistic regression				OLS			
	OR (95% CI)	<i>p</i>	B (95% CI)	<i>p</i>	B (95% CI)	<i>p</i>	B(95% CI)	<i>p</i>
Age	0.985 (0.965, 1.005)	0.137	−0.003** (−0.006, −0.001)	0.008	−0.006*** (−0.008, −0.003)	<0.001	−0.004** (−0.006, −0.001)	0.003
Male (ref: female)	1.179 (0.762, 1.823)	0.459	0.036 (−0.017, 0.088)	0.183	0.037 (−0.014, 0.088)	0.158	0.037 (−0.015, 0.090)	0.16
Education								
Middle school/diploma/advanced diploma (ref: <middle school)	1.094 (0.323, 4.027)	0.887	0.019 (−0.119, 0.157)	0.787	0.012 (−0.122, 0.146)	0.865	0.016 (−0.121, 0.153)	0.823
Associate degree/degree/master/doctoral (ref: <middle school)	1.225 (0.393, 4.230)	0.734	0.015 (−0.111, 0.141)	0.814	0.017 (−0.105, 0.140)	0.784	0.015 (−0.111, 0.140)	0.82
Marital status								
Single (ref: married/co-living)	1.962* (1.509, 3.670)	0.033	0.024 (−0.061, 0.110)	0.576	0.039 (−0.045, 0.123)	0.361	−0.087 (−0.214, 0.041)	0.183
Widowed/divorced/separated (ref: married/co-living)	0.731 (0.319, 1.592)	0.442	0.045 (−0.036, 0.126)	0.276	0.031 (−0.048, 0.110)	0.444	0.054 (−0.096, 0.204)	0.480
Religious (ref: non-religious)	0.705 (0.462, 1.072)	0.103	−0.004 (−0.055, 0.046)	0.865	−0.01 (−0.059, 0.040)	0.699	−0.009 (−0.059, 0.042)	0.74
Living with others (ref: living alone)	2.727* (1.096, 7.626)	0.04	0.013 (−0.071, 0.097)	0.759	−0.007 (−0.090, 0.075)	0.858	0.009 (−0.075, 0.093)	0.829
Subjective social status	1.297*** (1.126, 1.502)	<0.001	0.012 (−0.005, 0.029)	0.157	0.011 (−0.005, 0.027)	0.176	0.010 (−0.007, 0.027)	0.241
Lonely (ref: not lonely)	0.403*** (0.263, 0.614)	<0.001	−0.100*** (−0.154, −0.045)	<0.001	0.213** (0.058, 0.367)	0.007	−0.143*** (−0.213, 0.074)	<0.001
Online survey (ref: face-to-face)	0.603 (0.345, 1.047)	0.073	−0.001 (−0.074, 0.071)	0.973	0.004 (−0.066, 0.075)	0.91	0.006 (−0.066, 0.078)	0.871
Pandemic	0.649 (0.384, 1.093)	0.104	−0.021 (−0.081, 0.039)	0.495	−0.013 (−0.072, 0.046)	0.659	−0.017 (−0.077, 0.044)	0.589
Age*lonely					−0.006*** (−0.009, −0.003)	<0.001		
Marital status*lonely								
Single (ref: married/co-living)*lonely							0.144* (0.019, 0.270)	0.024
Widowed/divorced/separated (ref: married/co-living)*lonely							−0.007 (−0.180, 0.165)	0.933
Observations	503		318		318		318	
R2 Tjur	0.112		0.118/0.083		0.167/0.131		0.133/0.093	
AIC	508.625		125.265		109.108		123.719	

p* < 0.05, *p* < 0.01, ****p* < 0.001.

TABLE 5 Generalized linear models of factors associated with EQ-5D-5L HK index scores.

Predictors	Generalized linear models (disutility score)					
	B (95% CI)	p	B (95% CI)	p	B (95% CI)	p
Age	0.003** (0.001, 0.004)	0.002	0.000 (−0.001, 0.002)	0.641	0.003** (0.001, 0.004)	0.001
Male (ref: female)	0.027 (−0.009, 0.064)	0.141	0.027 (−0.008, 0.063)	0.134	0.028 (−0.008, 0.065)	0.124
Education						
Middle school/diploma/advanced diploma (ref: <middle school)	−0.014 (−0.114, 0.087)	0.791	−0.019 (−0.117, 0.080)	0.711	−0.019 (−0.118, 0.080)	0.704
Associate degree/degree/master/doctoral (ref: <middle school)	−0.019 (−0.112, 0.073)	0.682	−0.028 (−0.119, 0.063)	0.545	−0.024 (−0.116, 0.069)	0.615
Marital status	−0.045 (−0.097, 0.006)	0.085	−0.045 (−0.096, 0.005)	0.080	0.030 (−0.040, 0.100)	0.398
Single (ref: married/co-living)						
Widowed/divorced/separated (ref: married/co-living)	−0.021 (−0.080, 0.039)	0.494	−0.011 (−0.069, 0.047)	0.707	−0.037 (−0.132, 0.057)	0.439
Religious (ref: non-religious)	0.023 (−0.012, 0.058)	0.191	0.023 (−0.011, 0.058)	0.180	0.025 (−0.009, 0.060)	0.152
Living with others (ref: living alone)	−0.037 (−0.103, 0.029)	0.268	−0.016 (−0.082, 0.049)	0.623	−0.034 (−0.100, 0.032)	0.311
Subjective social status	−0.013* (−0.025, −0.002)	0.022	−0.014* (−0.025, −0.003)	0.016	−0.013* (−0.024, −0.001)	0.028
Lonely (ref: not lonely)	0.094*** (0.058, 0.130)	<0.001	−0.112* (−0.211, −0.012)	0.029	0.133*** (0.087, 0.180)	<0.001
Online survey (ref: face-to-face)	0.012 (−0.036, 0.060)	0.629	0.014 (−0.034, 0.061)	0.573	0.010 (−0.038, 0.058)	0.676
Pandemic	0.038 (−0.006, 0.082)	0.088	0.031 (−0.012, 0.074)	0.158	0.035 (−0.009, 0.078)	0.120
Age*lonely			0.004*** (0.002, 0.006)	<0.001		
Marital status*lonely						
Single (ref: married/co-living)*lonely					−0.115** (−0.191, −0.040)	0.003
Widowed/divorced/separated (ref: married/co-living)*lonely					−0.016 (−0.103, 0.136)	0.787
Observations	503		503		503	
AIC	−206.653		−222.927		−212.601	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

which may not be able to capture different dimensions of loneliness, namely social and emotional loneliness. Fourth, this study did not measure the potential mediators between the socio-demographics, loneliness, and HRQoL, so that we cannot detect potential mechanisms between these variables. Fifth, the study sample was generated based on the non-institutional HK population, excluding those older adults who lived in residential care facilities. The care home residents may feel more alone and have poorer HRQoL due to the COVID-19 pandemic.

Implications

The present study offers some implications for practice and policies during the COVID-19 pandemic. While COVID-19 has widespread negative effects on the health status of all populations, it also has the potential to intensify the social

and health disparities. Although HK has so far succeeded in controlling the spread of the virus, the government should put more resources toward safeguarding socially disadvantaged groups who have fewer resources themselves to mitigate the adverse effects of COVID-19 in their careers, everyday lives, and health management.

Loneliness is another important issue because of the ongoing global pandemic and related social distance measures. While there are increasing instances of both family separation and considerably reduced amounts of friends and family gatherings, more mental health supports could be provided *via* phone, video-conferencing, or other telehealth channels. For instance, while long-term care facilities have been prohibited from visiting due to pandemic restrictions, the loneliness level of long-term care residents should be explored regarding their social needs and mental health. It is noteworthy that older people may not be the only group suffering from loneliness, and the younger adults

cannot be assumed to experience a better condition only due to their skills in navigating online. All age groups are exposed to the risks of experiencing loneliness, with consequential outcomes in health and wellbeing. Appropriate and timely services or education should be developed and rolled out to meet the specific needs of people of all age groups for the connection.

Conclusion

This study is among the first to report health-related quality of life (HRQoL) in the HK general population and identified several factors associated with HRQoL, including both demographic and psychosocial characteristics—loneliness during the COVID-19 pandemic, using the local validated EQ-5D-5L (EQ-5D-5L HK) instrument. It calls for future studies to look into the challenges faced and resilience needed by people from different backgrounds to cope with a wide range of difficulties during COVID-19. It also sets out potential implications for practitioners and policymakers to provide effective support or services and related education to help people recover from the global pandemic.

Data availability statement

The dataset is available from the corresponding author on reasonable request.

Ethics statement

The studies involving human participants were reviewed and approved by Survey and Behavioural Research Ethics Committee of the Chinese University of Hong Kong. The patients/participants provided their written informed consent to participate in this study.

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Author contributions

ELYW and EKY conceived the study design. JL and PSYY performed the analysis. JL, SY, and AWLC prepared a preliminary draft of the manuscript. All authors discussed the results and contributed to the final manuscript.

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Conflict of interest

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

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Health economic burden of COVID-19 in Saudi Arabia

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Background: The coronavirus disease 2019 (COVID-19) pandemic has added a massive economic burden on health care systems worldwide. Saudi Arabia is one of the numerous countries that have been economically affected by this pandemic. The objective of this study was to provide real-world data on the health economic burden of COVID-19 on the Saudi health sector and assess the direct medical costs associated with the management of COVID-19.

Methods: A retrospective cohort study was conducted based on data collected from patients hospitalized with COVID-19 across 10 institutions in eight different regions in Saudi Arabia. The study calculated the direct medical costs of all cases during the study period by using SAS statistical analysis software. These costs included costs directly related to medical services, such as the health care treatment, hospital stays, laboratory investigations, treatment, outcome, and other related care.

Results: A total of 5,286 adult patients admitted with COVID-19 during the study period were included in the study. The average age of the patients was 54 years, and the majority were male (79%). Among the COVID-19 patients hospitalized in a general ward, the median hospital length of stay was 5.5 days (mean: 9.18 days), while the ICU stay was 4.2 days (mean: 7.94 days). The total medical costs for general ward and ICU patients were US\$ 38,895 and US\$ 24,207,296.9, respectively. The total laboratory investigations ranked as the highest-cost services US\$ 588,975 followed by treatment US\$ 3,886,509.8. Overall, the total cost of all medical services for patients hospitalized with COVID-19 was US\$ 51,572,393.4.

Conclusion: This national study found that COVID-19 was not only a serious concern for patients but also a serious economic burden on the health care system in Saudi Arabia.

KEYWORDS

burden of COVID-19, Saudi Arabia, direct cost, total cost, pandemic

Key points

- The nursing costs and length of stay were lower in the ICU than in the general ward.
- The costs of hospitalization in general medical wards were less than those of admission to the ICU.
- These cost data will be valuable for researchers evaluating the COVID-19 pandemic's economic burden in Saudi Arabia and assessing the possible implications of prevention and treatment initiatives.

Introduction

Coronavirus disease 2019 (COVID-19) is a respiratory infection caused by a virus called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which originated in Wuhan, Hubei Province, China, in December 2019 (1, 2). COVID-19 was confirmed as a pandemic virus-related infection by the World Health Organization (WHO) in March 2020 (3).

Following the WHO pronouncement, countries worldwide, including the Kingdom of Saudi Arabia (KSA), began focusing on pandemic response plans to combat the spread of the virus. Since the first Saudi Arabian case of COVID-19 was confirmed on March 2nd, 2020, the KSA has implemented many measures to combat the spread of the disease (4).

Based on the general authority for statistics, the KSA is home to 35 million people, the majority of whom live in cities (84%) and the country experienced severe pressure on urban hospitals during the peak of the epidemic (5). The Ministry of Health (MoH) of Saudi Arabia oversees most health care operations and services in the kingdom and has played a key role in offering health care services, including preventive, therapeutic, and rehabilitation (6, 7). The government has endeavored to strengthen the health system and accelerate a health care transition by developing Public Private Participation (PPP) health care models, with the goal of increasing private sector engagement in overall health care spending to 35% by the year 2020 (8). In 2018, the MoH provided 58.3% of all hospitals and 59.1% of all beds in the nation (9).

Saudi Arabia has announced a 32 million USD intervention to help economic sectors impacted by COVID-19. The debt ceiling was increased from 30 to 50% of GDP, while fiscal debt was foreseen to increase from 6.4 to 9% of GDP (10).

A major concern regarding the COVID-19 pandemic is the high-cost burden on health care systems. There have been few economic studies on COVID-19 in Saudi Arabia, especially those that calculated the direct cost for each medication and service provided during hospitalization. However, these studies have some limitations of having studying only one site, less sample size and using differences research methods. A study by Khan et al. calculated the direct medical costs associated with the treatment of COVID-19 patients in Saudi Arabia (11). Based on the degree of care and length of stay, the total direct medical costs per patient were estimated. The total direct medical expenditure per patient hospitalized in the general medical ward (GMW) for moderate-to-severe symptoms was (US\$ 11,388). In contrast, intensive care unit (ICU) patients generated an ~3 fold cost increase (e.g., US\$21,178.5). Surprisingly, the overall cost of care for patients on mechanical ventilators (MVs) was slightly lower than that for patients admitted to the GMW but not on MVs. This difference was mostly due to patients on MVs having a much shorter period of survival and higher mortality rate, which resulted in a shorter length of stay (LOS) and, subsequently, a lower overall cost per patient (12).

According to projections, the total direct medical cost in the United States has ranged from US\$ 163.4 billion to US\$ 654.0 billion over the course of the pandemic (13). In Sweden, the total direct medical cost has been projected to reach US\$ 2 billion (14).

There is a scarcity of data on the direct medical costs of COVID-19 worldwide. Therefore, this study was conducted to present evidence-based statistics on COVID-19's health economic burden on the Saudi health care system. The study aims to provide real-world data on the health economic burden of COVID-19 on the Saudi health sector and assess the direct medical costs associated with the management of COVID-19.

Methods

All the clinical research globally has focused on containing transmission and reducing mortality and morbidity associated with COVID-19 pandemic. The pandemic has hugely impacted the economy and stressed healthcare systems worldwide. We aimed in our study to calculate the direct cost of the pandemic in the health sector in Saudi Arabia.

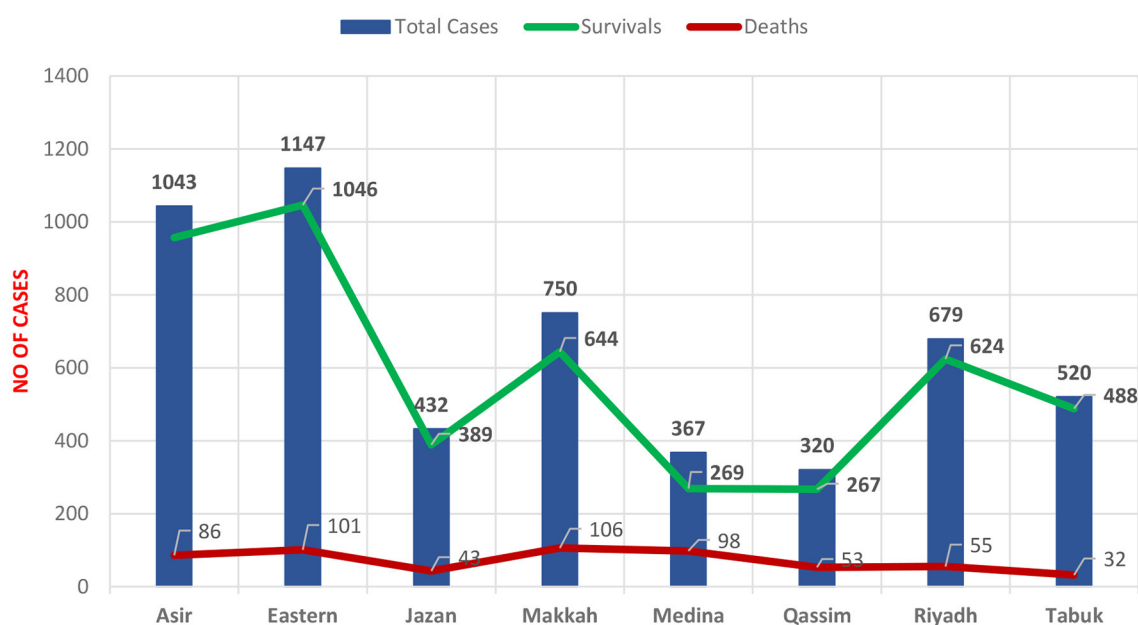


FIGURE 1
Distributions rate of hospitalized patients diagnosed with COVID-19 among Saudi regions, Mar 2020-Jan 2021.

Study design and data source

A retrospective cohort study was conducted based on data collected on patients hospitalized with COVID-19 at 10 governmental institutions selected by the ministry of health as references and centers for treating coronavirus in eight regions in Saudi Arabia. We have tried to cover as much as we can from the hospitals who have high number of COVID-19 cases in Saudi Arabia which are represented in the included cities in this study. The study period started on March 1st, 2020, and ended on January 30th, 2021. The patients included in this study were individuals who were hospitalized and followed until discharge or in-hospital death or those whose final follow-up event occurred at the latest on January 30th, 2021.

The study calculated the economic costs of all cases from the beginning of March to the end of January 2021 using the micro-cost method. The costs included in the study were the direct medical costs, i.e., the costs directly related to medical services, such as health care services, hospital stays, laboratory investigations, treatment, outcomes, and other related care.

The following variables were collected from patient medical records and anonymously entered into a web-based electronic form. When possible, the patient data included demographics characteristics (e.g., age, gender, marital status, and geographic region). Medical information (e.g., comorbidities, length of hospital stay, length of

intensive care unit or isolation room or general ward stay) was also collected. Furthermore, the direct medical care costs were collected, including laboratory and diagnostic test costs [e.g., complete blood count (CBC), liver and cardiac enzymes, renal functions, biochemistry, swabs, cultures, chest X-rays, and computerized tomography (CT) scans], treatment costs including medications (e.g., antivirals, antimalaria, biologics, antibiotics, immunoglobulin, anticoagulants, and plasma), supportive therapy (e.g., mechanical ventilation and pneumatic compression devices), hospital stay (including room fees; intravenous sets and fluids in isolation rooms, intensive care units, and general wards; and cost of care provided by physicians and nurses).

The ministry of health is responsible for providing a management guideline on COVID-19 treatment to be followed by all hospitals that treat patients with COVID-19. Therefore, there is a specific standard to treat these patients.

All medications were obtained from the National Unified Procurement Company pricing list for medications that are available according to the Ministry of Health (antivirals, antimalarial drugs, biologics, antibiotics, immunoglobulin, and anticoagulants). In addition, other medical costs, such as hospitalization fees [including for general wards and intensive care units (ICUs)] and fees for physician consultations and nurse care, laboratory tests, diagnostics tests, and all supportive therapies (mechanical ventilation, intravenous fluids, and

TABLE 1 Basic characteristics of patients hospitalized with COVID-19.

Variables	Relationship with death and discharge				Total	
	Discharge (N = 4,712)		Death (N = 574)		N = 5286	%
	N	%	N	%		
Groups of age (years)						
18–29	241	4.56	15	0.28	256	4.89
30–44	1,190	22.51	102	1.93	1,292	24.44
45–64	2,091	39.56	252	4.77	2,343	44.32
≥ 65	1,146	21.68	202	3.82	1,348	25.50
Gender						
Male	3,688	69.77	493	9.33	4,181	79.1
Female	1,028	19.45	81	1.53	1,109	20.98
Smoking	1,727	32.67	283	5.35	2,010	38.02
Supporting therapy						
Mechanical ventilation	1,554	29.4	218	4.12	1,772	33.52
Cuffs of pneumatic compression devices	230	4.35	2	0.04	232	4.39
Comorbidities	2,940	55.62	496	9.4	3,436	65
Hypertension	1,527	28.89	198	3.74	1,725	32.6
Diabetes mellitus	1,388	26.26	253	4.79	1,641	31.04
Heart disease	328	6.21	116	2.19	444	8.4
Asthma	233	4.41	22	0.41	255	4.82
Cancer	33	0.62	46	0.87	79	1.5
Kidney disease	112	2.12	23	0.44	135	2.56
Obese	183	3.46	23	0.44	206	3.89
Anemia	75	1.42	2	0.04	77	1.46
Benign prostatic hyperplasia	54	1.02	12	0.23	66	1.25
Ischemic stroke	52	0.98	30	0.57	82	1.55
Epilepsy	47	0.89	17	0.32	64	1.21
Autoimmune disease	31	0.59	3	0.06	34	0.63

pneumatic compression devices), were obtained from the Ministry of Health.

Excluded costs

Personal protective equipment (e.g., N95 masks, gowns, protective eyewear), oxygen, plasma therapy, over-the-counter medicines, and the burden-increasing cost of comorbid diseases.

Statistical analyses

The data are presented using descriptive statistics (mean, frequencies, and percentages). All analyses were conducted using statistical analysis software (SAS®; version 9.4, SAS Institute Inc., Cary, NC, USA).

This study was ethically approved by the Central Institutional Review Board at ministry of health, Riyadh (Registration Number 20-56 E).

Results

Epidemiological findings

A total of 5,286 adult patients admitted with COVID-19 during the period March 2020 to January 2021 were included in the study. As shown in [Figure 1](#), the Eastern region of Saudi Arabia had the highest rate of admitted COVID-19 patients (21.69%), followed by Asir (19.73%). The lowest rates were found for the Al-Qassim region and Medina region.

The patients' baseline demographic and general characteristics are shown in [Table 1](#). The age of the participants ranged from 18 years to more than 65 years, whereby males comprised the majority of the study population (79%). The largest proportion of patients consisted of those aged 45–65 years (~44.32%), followed by patients over 65 years (25.50%).

Approximately 89.14% of the patients were discharged from the hospital, whereas 10.85% died. The mortality rate was higher among males (85.88%) than among females (14.12%) ([Table 1](#)).

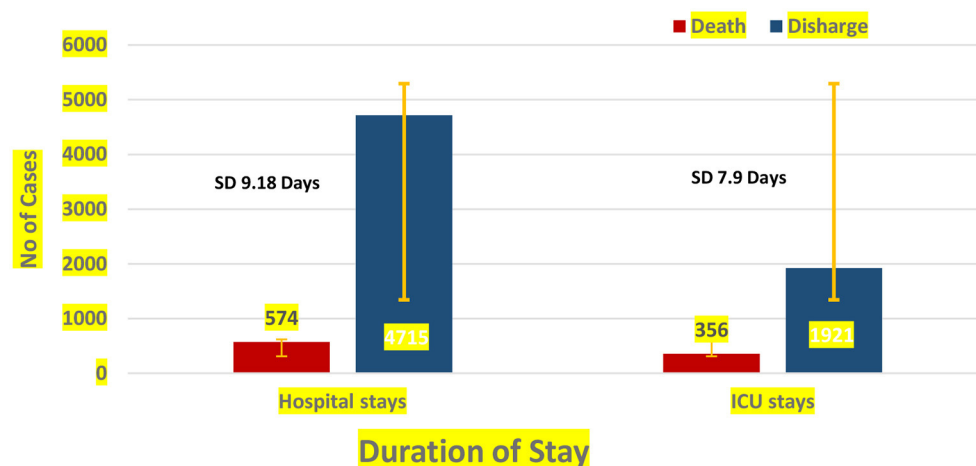


FIGURE 2
Hospital and ICU stay among discharged and non-surviving of hospitalized patients diagnosed with COVID-19.

Among the COVID-19 patients hospitalized in general wards, the median hospital length of stay (LOS) was 5.5 days (mean: 9.18 days), while the median ICU stay was 4.26 days (mean: 7.94 days) (Figure 2).

The number of patients admitted to the ICU (41.90%) compared to the general ward stay. 33.52% of those patients staying in the ICU used mechanical ventilation and 78.40% of those patients had comorbidities. The most common drug provided to patients was dexamethasone (44.82%), followed by favipiravir (39.29%) and hydroxychloroquine (26.63%). All patients were given more than one prophylactic antibiotic, and ceftriaxone was the most prescribed antibiotic (92.87%), followed by azithromycin (64.55%).

The total cost of general ward, isolation room and ICU stays was (US\$ 3,889,551.7), (US\$ 4,675,869.9), and (US\$ 24,207,296.9), respectively, including room fees and intravenous sets and fluids (Table 2). Additionally, nursing care costs amounted to (US\$ 3,235,858.4), (US\$ 1,944,775.9) for general-ward care and (US\$ 1,291,082.5) for ICU care. The total physician consultation cost (US\$ 3,235,954.4) (was divided into ICU (US\$ 1,291,178.5) and general-ward as well as isolation room (US\$ 1,944,775.9) costs.

Among the total hospital service costs, total laboratory investigations ranked the highest (US\$ 5,889,751.2), followed by medications (US\$ 3,886,509.83) (Table 2; Figure 3).

Additionally, the highest costs among the laboratory investigations were PCR testing (US\$ 1,549,333.3), followed by cardiac enzymes investigations (US\$ 1,111,309.6), while the majority of radiology service costs was for CT scans (US\$ 334,697.4) (Table 2; Figure 3).

Among the total ICU service costs, total ICU laboratory investigations ranked the highest (US\$ 2,078,814.09), followed by anticoagulant prophylaxis, including mechanical and

anticoagulation drugs (US\$ 1,756,263.2), and ICU medications (US\$ 1,295,333.3) (Figure 4).

Interferon beta-1 was the highest-cost medication among the treatment options (US\$ 1,672,411.9), followed by tocilizumab (US\$ 709,639.4) and then antibiotics (US\$ 568,654.73). The other cost of each service, is presented in Table 2 in detail.

In contrast, the total cost of patients who died due to COVID-19 was (US\$ 17,188,542.7) (mean: US\$ 4,068.31\$), while that of patients who recovered was (US\$ 34,377,085.31) (mean: US\$ 6,740.3) (Table 3). Overall, the total cost of all medical services for patients hospitalized with COVID-19 was (US\$ 51,565,627.95) (mean: US\$ 11,816.13) (Table 2).

Discussion

Worldwide, health care systems have faced substantial difficulty in terms of resource consumption and expense management as a result of the COVID-19 outbreak. Governments and hospitals have been compelled to make challenging budget allocation decisions. For decision-making, empirical evidence is critical. To make accurate judgments, decision-makers could benefit from economic studies on COVID-19 medical treatment. This study contributes to a better understanding of medical care procedures and resource use. To the best of our knowledge, there have been only a few economic studies on COVID-19. However, we believe that our study provides more detailed information than other studies, as we calculated the cost for each item and service.

While differences in research methods, demographics, health-care costs, and other factors make it difficult to compare studies, particularly studies from different countries, several researchers have investigated the burden of health services on

TABLE 2 The direct medical cost of hospital services for hospitalized patients diagnosed with COVID-19.

	Total USD	Median [IQR] USD	Mean [SD] USD
Hospital stays	32,859,943	815.508	7,224.4
ICU stays	24,207,296.9	11,029.41	7,969
General ward stays	3,899,904	721.92	982.5
Isolation room stays	4,675,869	173.8	1,572.6
Total physician consultations	3,235,954.4	494.65	530.7
Total physician consultations -ICU	1,291,178.5	721.92	425.01
Total physician consultations–Ward & isolation	1,944,775.9	360.96	491.27
Total nursing care	3,235,858.4	474.59	463.35
ICU -Nursing care	1,291,082.5	588.23	425.94
Ward & isolation -Nursing care	1,949,775.9	360.96	491.28
Mechanical ventilation	1,953,262	362.66	705.48
Cuff of pneumatic compression device	6,528.07	25.4	5.4
Laboratory investigations	5,889,751.2	89.6	95.3
CBC	149,031	51.34	18.2
Liver enzymes	433,369	80.46	49.41
Cardiac enzymes	1,111,309.6	64.17	280.5
Renal functions	706,866.3	42.78	115.8
Biochemistry	435,593.6	128.34	64.4
D-dimer	441,540.1	149.73	124.5
Swabs	488,235.3	90.64	15.6
Cultures	263,163.6	127.27	76.57
Antibiotic sensitivity test	387,005.3	71.9	112.6
Radiology services	531,631	173.8	122.2
Chest X-rays	196,042.8	36.4	17.7
CT scans	334,697.4	294.11	134.9
PCR	1,549,333.3	280.75	49.49
Medications	3,886,509.83	723.38	425.13
Lopinavir/ritonavir	18,260.19	12.63	8.63
Favipiravir	202,049.2	44.92	51.87
Interferon beta-1	1,672,411.9	758.22	798.97
Hydroxychloroquine	4,144.38	1.87	1.39
Tocilizumab	709,639.4	527.91	349.4
Anticoagulants	179,694.3	871.6	18.12
Antibiotics	568,654.73	2400.3	49.56
Immunoglobulin	45,228.61	315.8	72.96
Antifungals	488,729	74.9	173.2
Total cost	51,709,653	4,453.243	11,849.14

CBC, Complete blood count; ICU, Intensive care unit; PCR, polymerase chain reaction.

the health care system. All studies have found that the burden on the health care system in the form of resource use and expenses has been substantial (15–18).

This study determined that the total cost of 5,286 patients treated in different units for COVID-19 was (US\$ 51,508,726.60). Based on this outcome, the average cost per

patient was determined to be \approx (US\$ 10,182.5). The cost per patient has been reported to be 3,045 USD in the United States, (US\$ 6,827) in China, (US\$ 12,637.42) in Latin America, (US\$ 2,192) in children aged 0–19 in Korea, (US\$ 4,633.43) in India and (£ 4,847) pounds sterling in the United Kingdom (13, 15, 16, 19, 20). These differences may be attributable to differing

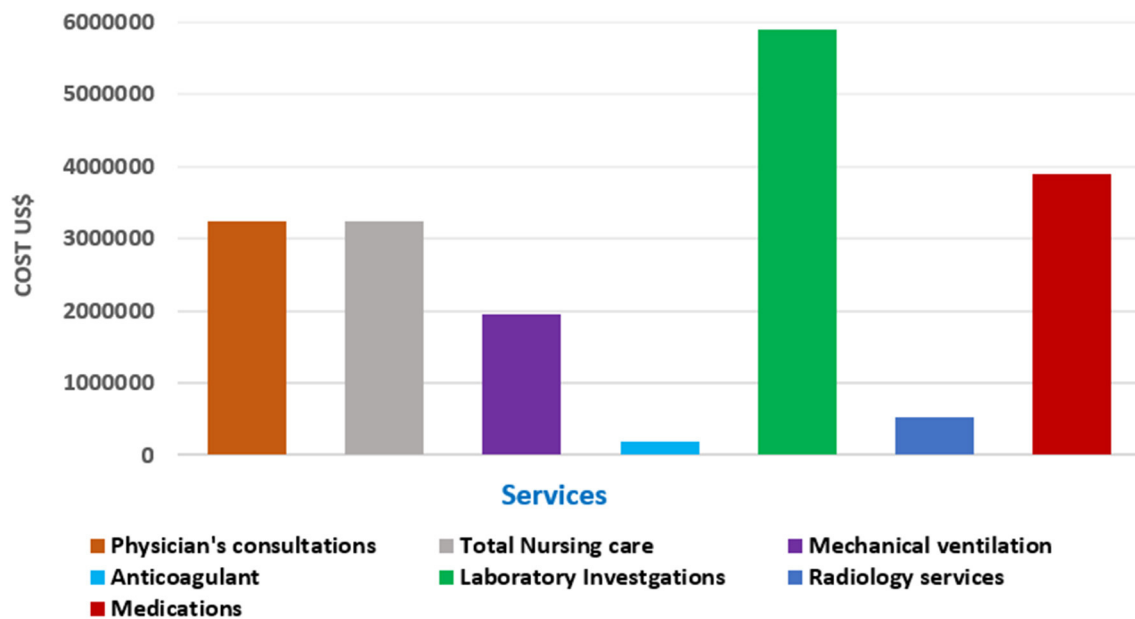


FIGURE 3
Distribution of total hospital costs for hospitalized patients diagnosed with COVID-19.

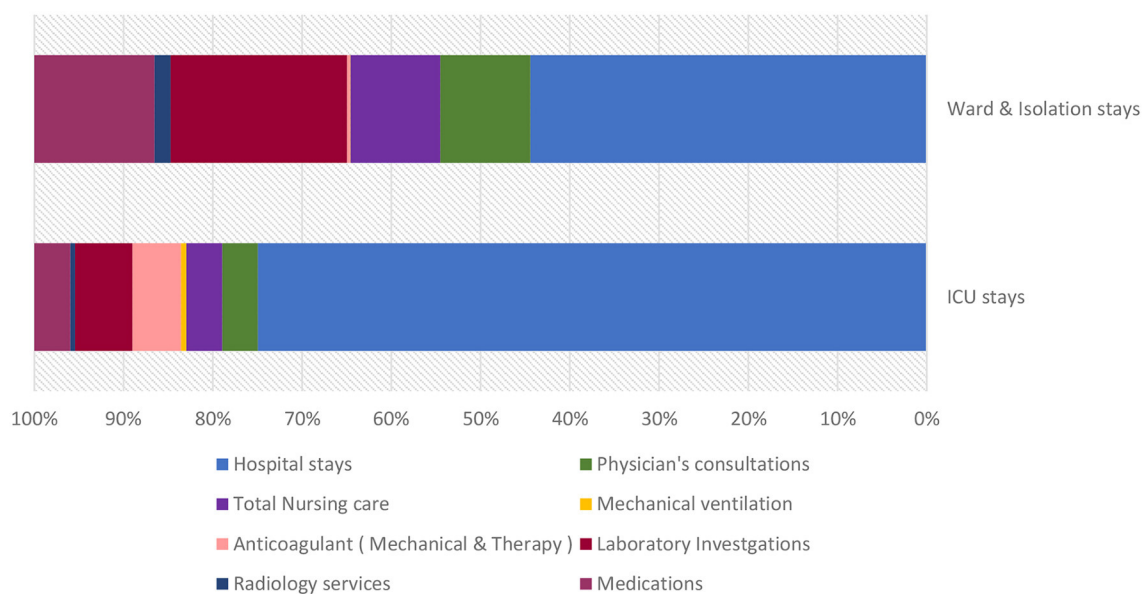


FIGURE 4
Distribution of total hospital costs according to locations for hospitalized patients diagnosed with COVID-19.

treatment regimens, preferences among health professionals, health care resource consumption rates, and medical equipment pricing levels from country to country.

In this study, it was observed that nursing costs and length of stay were lower in the ICU than in the general ward. This finding might be due to ICU patients having a much shorter period of

survival and a higher risk of mortality, which frequently resulted in a shorter LOS and eventually death. However, because of the increased cost of health care resource utilization, the overall cost per patient in the ICU was substantially higher than that in the general ward. This observation is consistent with the findings of Rae et al. (12).

TABLE 3 The direct medical cost of hospital services for hospitalized patients diagnosed with COVID-19 and outcomes.

	Death USD	Discharge USD
Total Cost	17,188,542.7	34,377,085.3
Mean [SD]	4,068.30	6,740.30

Moreover, in hospitalized patients in Turkey, the mean LOS was 8.0 days for patients hospitalized in general wards vs. 14.8 days for patients hospitalized in ICUs. This finding is consistent with our study with respect to general-wards stays and significantly less than twice the LOS in the ICU (21).

Moreover, our results found that the total ICU cost was (US\$ 32,291,912.426) (average cost \approx US\$ 14,532.9), whereas the total general ward cost was (US\$ 19,279,848.4) (average cost \approx US\$ 6,128.37), findings consistent with the results of a study by Khan et al. These findings reveal that the expense of medical care increases as the severity of the patient's condition increases. However, the costs of hospitalization in general medical wards were less than those of admission to the ICU (US\$ 11,387.86) and (US\$ 21,279.2), respectively (11). Notably, the Khan et al. study did not include detailed cost calculations and the total cost of all study populations. Additionally, they investigated fewer study populations. Moreover, ICU hospitalizations had the highest average daily cost, according to a study that only examined the direct medical costs of COVID-19 in South Africa (22). The increase in the cost of critical care may be due to most cases being severe with poor progression and (78.4%) involving comorbidities; most such cases required mechanical ventilation (78.4%) or expensive medications, such as tocilizumab, interferon beta-1 (according to the recommendations of the COVID-19 protocol from the MOH), or systemic antifungal medications.

Our study found that for most of the full hospital service costs, the hospital stay included room fees as well as cost of intravenous sets and fluids in isolation rooms, intensive care units, and general wards (63.55%), followed by laboratory investigations. The latter represented the highest cost (11.42%), while PCR tests were the most expensive among the laboratory tests (26.31%). A study conducted in Greece similarly founding the highest costs for RT-PCR tests and hospitalization (23).

A Turkish study on 163 patients admitted to the ICU found that the largest share of ICU costs was associated with procedural packages (72%), followed by medication costs (12.8%). In our study, we found that the highest costs for patient care were associated with ICU stays, including procedural packages (75%) and laboratory investigations (6.44%), followed by anticoagulant

prophylaxis, including mechanical and medications (5.44), and then treatment (4%) (21).

The Ministry of Health in Saudi Arabia has released protocols to manage incidences despite the significant increases in morbidity and mortality from COVID-19 while considering drug treatment strategies for inpatients in addition to supporting medical resources and the limited use of medications, especially antibiotics. Our study found that antibiotics were the most commonly used medications in managing infections associated with COVID-19. The prescription of antibiotics peaked during the chaotic early days of the pandemic, when physicians did not know much about the virus and prescribed broad-spectrum antibiotics, which are very costly. Additionally, a number of medications were initially thought to be beneficial against COVID-19, such as favipiravir and hydroxychloroquine. However, studies have proven that these medications have no effect against COVID-19 (24). These developments represent additional reasons for the high cost of treating COVID-19 patients. In contrast, several expensive medications (e.g., remdesivir) were not utilized in high quantities during the study period, which might have lowered the treatment cost.

Subsequently, the ministry has issued an updated therapeutic protocol based on global evidence regarding the effectiveness and safety of the medications noted above. As all countries of the world have adopted similar guidelines, the consumption of these medicines has increased. However, the COVID-19 epidemic has caused significant supply chain disruptions and pricing increases for local raw materials, which have disproportionately impacted smaller markets and increased the costs of medications in markets with increased consumption (25). In Denmark, price increases for versions of 10 medications averaged 71.6 percent. The increases averaged 43 and 37% in the Netherlands and Sweden, respectively. Price increases up to 49% were observed in the United Kingdom, primarily for azithromycin. This burden has also affected the Saudi market (25).

The expenses of medical treatment for COVID-19 are not only a concern for hospitals. The expense of COVID-19 is placing a strain on a number of government agencies. Regardless whether care is provided in private hospitals, the Ministry of Health covers all costs (6). Medical expenditures are increasing in line with the severity of cases, placing greater strain on health care systems. Therefore, this research may be of assistance to all governing bodies in planning activities and making choices in connection with the pandemic because it continues to affect all countries and because the study is specific to Saudi Arabia. Additionally, it could help in planning for any future pandemic or other outbreak of communicable and noncommunicable disease.

This study has several strengths and limitations. Three limitations are as follows. (1) Because the data were collected

from patient medical records, certain information was unavailable, such as the frequencies of laboratory and radiology services. Also, since there are some populations are not represented in the study like pregnant women, we do not believe the study is represented the whole COVID-19 population in Saudi Arabia. (2) We could not determine the costs for personal protective equipment (e.g., N95 masks, gowns, protective eyewear), oxygen, plasma therapy, and over-the-counter medicines, or for the burden of comorbid disease. (3) There was a difference in COVID-19 incidence among the different regions. This could be due to the difference in following the precautions (i.e., wearing masks, social distance, and others) between the regions and population density in some regions due to religious reasons in Mecca and Medina, such as Alhaj and Umrah, or main cities like Riyadh.

However, the study has the advantage of being the first—to the best of our knowledge—to include a high number of patients and detailed cost information per item and service. Additionally, this study's findings represent unique insight into the Ministry of Health Hospital's economic burden while providing care for COVID-19-infected individuals in Saudi Arabia. These cost data will be valuable for future researchers evaluating the COVID-19 pandemic's increasing health care economic burden in Saudi Arabia and the implementation of cost-effective models to assess the possible implications of COVID-19 prevention and treatment initiatives.

Conclusion

This national study found that COVID-19 was not only a serious concern for patients but also a serious economic burden on the health care system in Saudi Arabia. This economic burden has affected all types of direct cost within the nation's health institutions. The results of this study should be used to better allocate costs in future planning for pandemics or outbreaks of other diseases.

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Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Ministry of Health, Central Institutional Review Board, Saudi Arabia. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

Study conception and design: KA, HA-m, AAl, and TA. Data collection: HA, FA, MAt, MK, DA, NA, ZA, AK, SA, AAl, and MAI. Analysis and interpretation of results: KA, MK, AAl, and TA. Draft manuscript preparation: KA, HA-m, HA, AAl, and TA. All authors reviewed the results and approved the final version 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.

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Participatory development and implementation of inclusive digital health communication on COVID-19 with homeless people

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Introduction: People experiencing homelessness (PEH) are disproportionately affected by the COVID-19 pandemic. The realities of their daily lives have been given little consideration in the pandemic response. They are not represented in existing health information campaigns, and many are structurally excluded from digital information. The project aimed to develop inclusive COVID-19-information material to strengthen infection prevention and control of PEH.

Material and methods: In a participatory process, PEH were involved in the planning, production, and evaluation of poster and video information material on COVID-19. Various stakeholders were consulted for external supervision. Service providers all over Germany were informed about the material that could be ordered free of charge. For the evaluation, semi-structured interviews with homeless service providers and PEH were conducted, and the online views of the videos were measured.

Results: Sixteen PEH participated actively in the project. Two COVID-19-information videos were launched in 5 languages in February 2021. Posters promoting vaccination against COVID-19 were produced in 9 languages. As of May 2022, the videos have been viewed more than 2,000 times. A total of 163 service providers for PEH and public institutions received the posters, thereof 72 upon request. Twelve service providers and 8 PEH participated in the evaluation. They pointed out the lack of targeted information material for PEH. The consideration of the concerns and the diverse representation of PEH was perceived as particularly important. Most of the service providers were unable to show the videos due to technical and spatial limitations. Digital challenges for PEH, like the lack of and maintenance of a smart phone, became apparent.

Conclusion: The cooperation of research, practice and the community were key factors for the realization of this project. Strong links to the community and the involvement of relevant stakeholders are indispensable when working

with PEH. Exclusion from digital information is an increasingly important component of the structural marginalization of PEH. Digital inclusion for PEH and service providers can help to counteract social and health inequalities. The lessons learned through this project can contribute to strengthen participation of PEH and to consider their perspectives in future health communication strategies.

KEYWORDS

homeless, participatory research (PR), poverty and inequality, health communication, digital gap, SARS-CoV-2, COVID-19

Introduction

People experiencing homelessness (PEH) are disproportionately affected by the COVID-19 pandemic. Precarious living conditions on the street, in encampments and cramped shelters, limited access to hygienic supplies and prevention measures, stigmatization, marginalization from social, political and economic resources as well as exclusion from health services result in high rates of underlying health conditions and a high risk of SARS-CoV-2-infection (1–3). The prevalence among homeless individuals may be similar to that found in the general population, however, the increased risk of outbreaks with high infections rates has to be considered (4). Also, social determinants and pre-existing health conditions place PEH at higher risk of severe COVID-19 infection (5, 6). However, studies to properly assess the outcome of SARS-CoV-2 infection in PEH are still required (3).

Since the beginning of the COVID-19 pandemic, the need to consider the living conditions of PEH when implementing measures of infection control and prevention (IPC) has been addressed by the German national working group on homelessness services (Bundesarbeitsgemeinschaft Wohnungslosenhilfe, BAG W) (7). In July 2021, the Robert Koch Institute, the national public health institute in Germany, published targeted recommendations for COVID-19 in the context of homelessness that were developed together with experts from the field (8). Many good practice solutions were implemented locally to protect PEH during the pandemic, such as provision of adequate isolation and quarantine options addressing possible complex needs of PEH, 24/7 accommodation with single rooms, regular voluntary universal testing for SARS-CoV-2, and mobile vaccination campaigns (9, 10). However, in many places, isolation, access to vaccination and testing as well as targeted information remained a challenge. This is particularly critical because it is known from past respiratory viral outbreaks that these control measures are crucial in managing epidemics or pandemics (11). In our opinion, PEH in Germany are to date not sufficiently addressed in the pandemic response including information campaigns.

With the onset of the pandemic, digitalization was discussed more publicly than before as it affected everyone to a substantial

extent. Being digitalized took on a new relevance, as it was, for example, a prerequisite for the digital EU certificate, which allowed unrestricted access to public buildings, use of transport and freedom to travel between international borders (12). Multiple problems faced by PEH result from their precarious socioeconomic situation which also affects the ability to maintain a digital device and to have access to internet-based services (13). Digital inequalities result in further social exclusion as it limits career opportunities, represents a barrier to maintaining social and service-related contacts, causes financial hardship and are a determinant of health (14–16). At the same time, digitalization can be an opportunity for better social inclusion (14, 17).

In a previous COVID-19 project among PEH, we identified the necessity to address language barriers, to include digital information formats, and to use participatory approaches considering homeless people's needs and life situation (9). This follow-up project aimed a participatory development of inclusive health communication on COVID-19 to strengthen options for IPC for PEH. We describe the development, implementation, and evaluation of targeted digital as well as non-digital (hybrid) health communication material (videos and posters).

Materials and methods

This project was conducted over a period of 11 months, from October 2020 to August 2021 in Berlin, Germany. According to the principle that in participatory projects participants should benefit directly from the research process (18), the perspective of PEH represented the basis for all project steps, and all PEH had decision-making power and were paid for their work effort.

Study team and recruitment of community partners

The study was initiated and supervised by two experts from the fields of medicine and public health. The study team (Figure 1) also included a clinician, a health scientist,



FIGURE 1

Presentation of study team with expertise and responsibilities, including people experiencing homelessness as community partners and various stakeholders.

two social workers, two student assistants and a professional communications designer. Four of the team members had long-term work experience with PEH. The PEH who participated as community partners were actively involved in the planning, production, evaluation and decision-making processes. They were the protagonists with one main actor for the videos and 12 further actors for portraits (vignettes) in the videos and posters. Three PEH had reservations to be filmed or photographed, and were involved in translations, sound recordings or evaluation rounds. Community partners were recruited in a social facility for PEH operated by the Berliner Stadtmission in Berlin. The facility included a 24/7 shelter, a medical outpatient clinic and a clothing store, where people could easily be approached during the day and in the waiting areas. Some members of the study team were already known to the PEH from their (voluntary) work at this facility, which formed the trust base to

approach people directly. We showed a short film clip (mood board) to the PEH in order to introduce them to the project. The communication designer created the clip especially for recruitment purposes. Inclusion criteria were age above 18 years, current or previous homelessness and written informed consent. We aimed at partnering with PEH from different age groups, genders, (dis-)abilities, languages and country of origin to reflect the diverse image of PEH in Berlin and to create material that is easier to identify with.

We consulted the following stakeholders for external supervision: the German national working group on homelessness services (BAG W), a self-organization (Selbstvertretung wohnungsloser Menschen e. V.), the coordination group for homeless shelters in Berlin (Koordinierungsstelle Berliner Kältehilfe), the Robert Koch Institute as well as staff of the Berliner Stadtmission (Figure 1).

Videos

Scripts in German language were created for two videos with general information about COVID-19 and SARS-CoV-2 testing. Expertise of the medical specialists and social workers and the experience of the community partners were combined to gain a better understanding of the health, personal needs and coping strategies of PEH during the pandemic. The scripts were edited in a multi-step revision process. After they were shared with and adapted by all stakeholders, the main protagonist translated them to a simple and clear language. Native speakers translated the scripts into four other languages that were identified in the previous project we performed (9). Quality control was performed by professional translators. The main actor speaks German in the videos. Three PEH and one professional actor have dubbed the clips into Russian, Polish, Romanian and English.

Posters

Information posters with precise key messages on access to vaccination were developed and provided in a digital and printed version to support the public COVID-19 vaccination campaign for PEH that started in Berlin in March 2021. To identify main questions or concerns of PEH regarding vaccinations, we consulted PEH and staff of service providers, as well as our stakeholders.

Participation and participatory decision making

The shooting locations were chosen together with the protagonists. The aim was to find locations that would create a pleasant working environment and at the same time provide images that PEH could identify with and which would not reproduce stereotypes. For the whole process, the individual needs of the protagonists were considered. This included for example a transport service if needed, food and drinks, as well as access to barrier-free sanitary facilities at all locations.

The selection and editing of the video material and photo motifs took place during several feedback rounds with community partners. The videos were watched together several times on a screen in the common room of the homeless shelter. Attending community partners and other PEH were asked for their opinion and criticism, e.g., about the content and the locations. Stakeholders who were not directly involved in the production were also asked for feedback.

Dissemination of the information material

On April 2021, a website was created in order to provide open access to the videos and posters, as well as to provide further information about the project (19). Furthermore, the material was disseminated through various social media channels (Twitter, Facebook and Instagram of the participating institutions). The printed posters were sent to all homeless service providers that were part of the Kältehilfe Network in Berlin (shelters, soup kitchens, warm rooms, medical facilities for people without health insurance and counseling centers). The German national working group on homelessness services informed service providers all over Germany through their network about the project and the offer to order the posters free of charge.

Evaluation and data analysis

All institutions that received material were listed. A telephone survey with randomly selected homeless service providers who had received the printed posters was conducted. Recruitment for the survey took place *via* email. After written informed consent, a semi-structured telephone interview ([Supplementary Interview Guideline 1](#)) was conducted for 15 min addressing the practical implementation and perception of the posters and the videos.

A social worker interviewed PEH in two shelters of the Berliner Stadtmission to determine how the material was perceived by PEH. Participants were randomly approached during the service hours of the shelters. After written informed consent, a semi-structured interview ([Supplementary Interview Guideline 2](#)) was conducted for 20 min.

The data analysis was based on written notes taken during the qualitative phone interviews and face to face interviews. A systematic qualitative content analysis was undertaken (20). After reviewing the data material, it was coded by an inductive procedure and summarized in categories.

Furthermore, the usage of the project website with the number of video views was measured.

Ethics

This study was approved by the Ethics Committee of the Charité – Universitätsmedizin Berlin (No.: EA2/168/21). All PEH who contributed to the implementation of the project were paid for their work. The study was explained to PEH in the preferred language, and written informed consent was provided for participation. The scope and time frame of the project were transparently communicated, as well as the possibility to withdraw participation at any point of the project without

repercussions. As PEH are a particularly vulnerable group, privacy, data security and a familiar atmosphere (to avoid any discomfort) were taken into careful consideration during the interviews.

Results

Participatory production

Sixteen PEH participated actively in the production of the information material. All participants were experiencing homelessness at the time of the study. Ten protagonists were recruited in the 24/7 shelter, 3 in the clothing store and 3 were recruited in the streets during the shooting days. Four of the participants were women and 12 were men, aged between 25 and 75 years from 6 countries speaking 8 different languages, two of them were in a wheelchair.

We produced two multilingual COVID-19 information videos under the slogan “We keep Corona off the streets”. The protagonist changed some parts of the script for a better understanding. For example, regarding information about the opioid substitution programme in the quarantine facility,

“substitution is provided” was replaced by “you can stay there, also if you consume”. The 5-day shooting of the videos took place at 15 locations.

The videos were produced with 13 protagonists. Six protagonists chose spots on the grounds of the Berliner Stadtmission or in the near vicinity as shooting locations, while 7 chose spots around the main railway station, a nearby park and public places.

The first video clip (duration 3 min 13 s) contained general information about COVID-19 ([Supplementary Video S1](#)). It explained the transmission modes of SARS-CoV-2, symptoms, increased risk of infection among PEH and strategies for self-protection (hygiene measures). The second video clip (duration 1 min 14 s) contained details about COVID-19 testing and the proceeding after a positive test result for PEH who lack the possibility of self-isolation at home ([Supplementary Video S2](#)). Thus, the video talks about the possibility of isolation in quarantine accommodations that consider the needs of PEH in a sensitive way.

In the second step, we designed multilingual posters with seven different motifs ([Figures 2, 3](#)) (19). With two versions, we have covered a total of nine languages identified as most relevant



FIGURE 2
Multilingual poster disseminated digitally and in print to support the public COVID-19 vaccination campaign for people experiencing homelessness (one out of seven different motifs).



FIGURE 3
Multilingual poster disseminated digitally and in print to support the public COVID-19 vaccination campaign for people experiencing homelessness, which also addresses drug use (one out of seven different motifs).

in a previous local project (9):

- 1st language version: German, Polish, English, Farsi, Russian
- 2nd language version: German, Romanian, Bulgarian, Arabic, French

Out of the 13 protagonists in the videos, three participated in the production of the posters. Two more were recruited in the 24/7 shelter. Portraits were taken on two shooting days. The main questions or uncertainties about the SARS-CoV-2 vaccination among PEH were identified through discussions with our community partners and staff of homeless service providers. These were having access to vaccination without a permanent address, documents or health insurance, as well as implications of drug use. Accordingly, the posters were designed with the slogan “*You can get vaccinated. Even with no fixed address, no health insurance, no documents. Get informed in the social or health care services you know*”. In another poster version

we included the sentence “*Even if you use drugs*”. The posters that address drug use do not contain portraits of PEH to avoid stigmatization (Figure 3). As a result of the feedback rounds, the hybrid nature of the posters was extended by including a QR-code linking the poster with the project website.

Dissemination

The videos were launched on February 11, 2021 during a hybrid (online and in presence) event. It was screened in the homeless shelter of Berliner Stadtmission under COVID-19 hygiene measures to allow community partners without internet access or mobile devices to participate. Over 100 participants joined online from various fields such as homeless services, politics, research and community.

By May 2022, a total of 1,754 posters were sent to 163 institutions and facilities in 53 cities within Germany (Figure 4; Supplementary Table S1). Whereas a set of posters

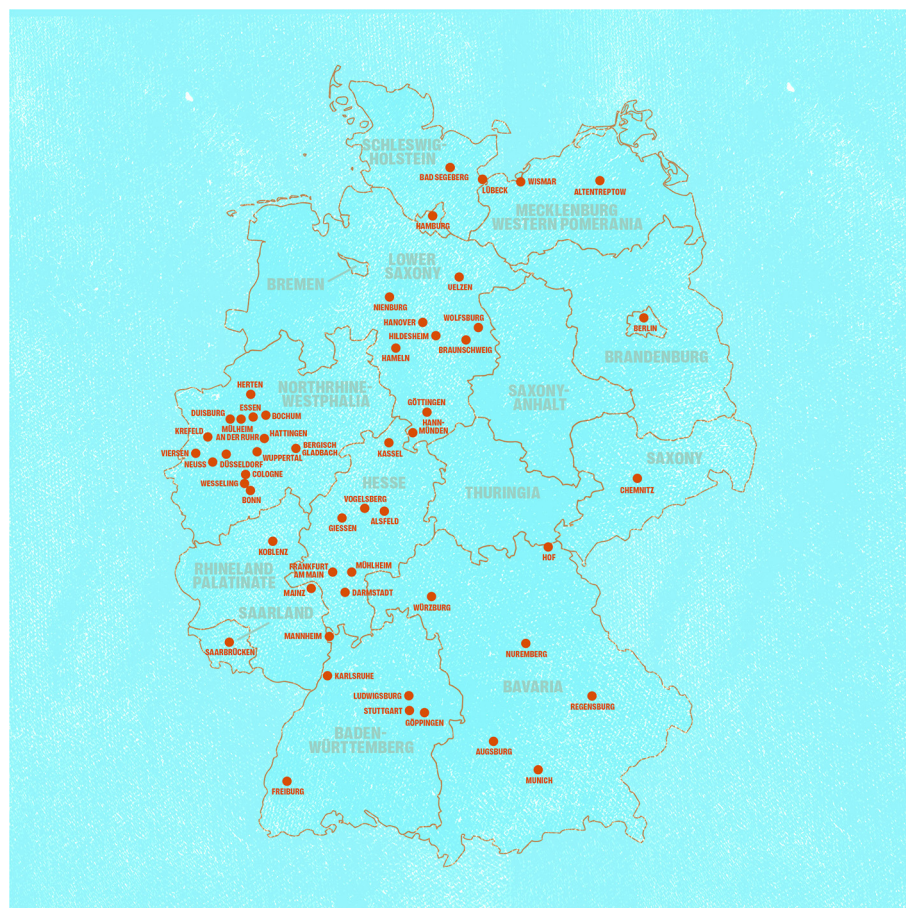


FIGURE 4

Map of Germany showing the cities where institution received the printed posters without or with request. From February 2021 until May 2022, a total of 1,754 posters were sent to 163 institutions in 53 cities.

TABLE 1 Evaluation of the videos and posters according to semi-structured telephone interviews with 12 institutions.

	Achievements	Challenges	Recommendations
1. Feedback on the material (posters and videos) in general	<p>Information reached the stakeholders <i>via</i> different ways:</p> <ul style="list-style-type: none"> • Berlin Kältehilfe list (5) • online search (2) • homeless service providers (2) • source unknown (3) <p>Diverse and barrier-free (analog, hybrid, and digital) material was appreciated (12)</p> <p>Brochures and flyers continue to be popular in respondents' workplace. Regardless of the type of materials, importance was placed on:</p> <ul style="list-style-type: none"> • a simple, clear, and concise message • purposeful design • multilingualism 	<p>Lack of targeted information material on health topics in general</p>	<p>To reach a larger population, materials should be distributed <i>via</i> diverse ways (e.g., mailing lists)</p> <p>Use diverse information modalities and combination of those to reach heterogeneous group (2)</p> <p>Need of similarly tailored information material on diverse (health) topics for daily work with PEH such as: personal hygiene (e.g., showering facilities) (2), preventive medical check-ups (2), medical care options also for people without health insurance or documents (2), scabies treatment, low-threshold psychiatric services, hepatitis (2), sexually transmitted infections, standard vaccinations, counseling on health insurance, safer drug use, tuberculosis, HIV, cancer prevention, and access to health services in general</p>
2. Feedback on the vaccination posters concerning use and benefits ^a	<p>All interview partners used the posters in locations for PEH (12)</p> <p>Positive aspects that were mentioned:</p> <ul style="list-style-type: none"> • appropriate for the counseling context • multilingualism (4) • professional design (2) • diversity-sensitive (2) • simple and clear language, suitable for functional illiterates • accepting drug policy (2) • opened the conversation on vaccination and enabled further counseling (7) • initiated conversation about taboo topics (e.g., drug consumption) (3) • enabled PEH to inform themselves 'quietly' in their preferred language (5) • informed PEH that they had the right to receive vaccinations 	<p>It was perceived as suboptimal that posters did not contain specific information on local vaccination campaign (e.g., timing and places) (2)</p> <p>People have scanned the QR code to the homepage in the false assumption that they can make an appointment for vaccination (3)</p> <p>Posters were removed several times (without obvious vandalism) (2)</p>	<p>The QR-Code could link to further information on vaccinations and facilitate appointments for vaccination. Distinct local information on vaccination programmes was added directly on the posters (2)</p> <p>The following aspects could be considered in the posters:</p> <ul style="list-style-type: none"> • poster version for those who are undecided about vaccination (with a link to a hotline or low-threshold counseling) • clear reasons/arguments pro vaccination • clarification about fake news and vaccination myths • more diversity for example in terms of women <p>Posters can be placed in different locations such as:</p> <ul style="list-style-type: none"> • outpatient clinic buses • shelters (3) • consulting sites (2) • restrooms (2) • train stations (2) • community welfare centers (2) • soup kitchens (2)
3. Feedback on the videos concerning use and benefits ^b	<p>Videos were utilized in the counseling context</p>	<p><i>"I watched the general video and thought it was great. So it's even more unfortunate that I immediately asked myself, how are we going to use this in our service because it's not actually feasible."</i></p>	

(Continued)

TABLE 1 (Continued)

	Achievements	Challenges	Recommendations
		Reasons for not using the videos: <ul style="list-style-type: none"> • lack of time • lack of staff • lack of equipment (screens, accessible PCs or tablets, loudspeakers) (5) • rooms are often too crowded and restless (2) PEH who have a smartphone might have only limited mobile data available, which makes streaming of videos difficult (2)	
4. Opinions about the use of posters for health information	Getting predesigned material is helpful Posters can initiate the conversation on specific topics Posters are a mean to spread important information in an unobtrusive way	The institutions do not have the resources to design information materials themselves Excessive information material in the facilities is overwhelming	Health-information posters should have concise information content PEH sometimes lack the conversation with people in everyday life. Social workers or medical staff can be confidants, especially when no other social network is available (2) <i>“Individual personal contact is irreplaceable”</i>
5. Digitalization in general	PEH that are from a younger generation attach more importance to owning a smartphone and have a greater affinity for digital media Digital material as an opportunity to reach PEH, also people experiencing hidden homelessness Helpful in counseling contexts (5)	Gap in digitalization on both sides, within the institutions and among PEH (8) Lack of appropriate equipment. Personnel, space and financial capacities are limited therefore videos could not be screened (8) Reasons why PEH are excluded from digitalization: <ul style="list-style-type: none"> • expenses implied • difficult in recharging the phone / digital devices • loss of device • stolen device due to lack of access to safe storage • when a smartphone is available, the volume of mobile data is limited and used sparingly 	Audible material can be helpful for visually impaired people Situations and contexts in which digitalization can be useful <ul style="list-style-type: none"> • questionnaires • (anonymous) online counseling • interpreter service (via video call)

The answers were structured in categories commenting on achievements, challenges, and recommendations. In the case of multiple mentions of a specific aspect, the number of mentions is given in brackets.

^aAll 12 participants were familiar with the posters before the interview.

^bSix out of 12 participants were familiar with the videos before the interview.

was automatically sent out to all 91 institutions that were part of the Berlin Kältehilfe list, the others (72) received the material upon request. The institutions included facilities for PEH such as clothing facilities, day care centers, consulting services, hygiene facilities, medical facilities and night shelters (146), facilities for drug users (9), facilities for refugees (2) and municipalities and public facilities such as a library and public authorities (6). The distribution period lasted from February 2021 until May 2022. The dissemination *via* the social media channel of the Charité – Universitätsmedizin Berlin took place in February 2021. Between February 8, 2021 and May 31, 2022, the videos have been viewed 2,064 times *via* the project

website. We registered peaks in the numbers of requests of the posters at the beginning of the vaccination campaigns in spring 2021 and then again in winter 2021. At that time, the booster vaccinations started, the night shelters opened for winter season, and the institutions were informed about the material by email.

Evaluation

Out of 20 homeless service providers that were invited to the evaluation, 12 agreed to participate in a telephone interview

TABLE 2 Evaluation of the videos and posters according to semi-structured interviews with 8 people experiencing homelessness (PEH).

	Positive aspects	Negative aspects	Recommendations
1. General feedback on the posters and videos	Peer-approach is great Videos and posters were both well accepted (2) Visualized information was seen as beneficial, particularly for illiterates (3)		Use written media, such as newspapers, for distribution, as they are used as a source of information (3) Videos are more helpful because they are visually and aurally appealing (3)
2. Where did PEH see the posters? ^a	Homeless facility (2) Homeless shelter Outpatient clinic Restroom Railway station		Posters could be placed in - public transport - churches - public information boards
3. Design of the vaccination posters	Participants liked the posters (7), because: • statements perceived as clear and visible (4) • variety of languages used • people feel addressed/can identify (5) Positive aspects on the choice of motifs: • underprivileged people are the protagonists • individual portraits (2) • variety of motifs (2)	Motifs with PEH or urban motifs do not appeal to everyone because it can remind people of their own harsh realities (2) Excessive text Unsuited for illiterates (3)	The following aspects could be considered in the posters: • also depict drug consumers • utilize city landmarks for identification (2) • portray more women • portray disabilities more obviously • use of one language per poster is clearer • show more positive motives, for example nature
4. Use and benefits of the vaccination posters	Informative (5) Inspiration to think/speak about vaccination/COVID-19, but no influence on the decision to get vaccinated (3)	Not useful Risk of going unnoticed	
5. Design of the videos ^b	The videos were appreciated (8) and perceived as: • concise (3) • easy to understand (5) People felt addressed (4) and could identify: • with the protagonists (2) • with the speaker (4) • with the diversity of protagonists • due to the realistic representation <i>"It's the reality"</i>		Suggestions to improve the videos: • voice could be livelier • to depict individuals who take drugs • to provides Turkish and Arabic translation • key messages conveyed at the beginning of the videos
6. Use and benefits of the videos	Perception of videos being an effective mean for health information distribution for those who possess a mobile phone (4) The information about the possibility of getting vaccinated even without health insurance and in case of drug use was perceived as particularly useful		Distribution of flat rates to the PEH during the pandemic (7)
7. Other information/questions that came up during the interviews	Test site refused rapid antigen testing due to lack of identification Question if the isolation ward is still in place COVID-19 vaccination was well tolerated despite drug use		

The answers were structured in categories commenting on positive and negative aspects as well as recommendations. In the case of multiple mentions of a specific aspect, the number of mentions is given in brackets.

^aThree of the 8 participants had seen the posters before.

^bNone of the participants had seen the videos before the interview.

which were conducted by two of our study team members in August 2021. At the same time, another team member interviewed 8 PEH on 2 days in front of a shelter and in a day center. All were experiencing homelessness at the time of the study. Out of the notes that were taken during the interviews, thirteen categories of different topics were identified (Tables 1, 2). Not all categories were addressed by everyone. There was a general appreciation of how the information was presented in terms of acceptability and sensitivity toward the targeted population.

All service providers approved that the posters were widely used for the vaccination campaigns. All 3 respondents who knew the videos considered them helpful for providing targeted information and allowing PEH to feel addressed directly. However, the streaming of the videos in the services was reported to be difficult due to lack of digital devices. Only 1 institution reported to have used the videos within the counseling context. Eight out of 12 service providers pointed out the digital challenges for PEH, e.g., owning and maintaining a mobile or smart phone, and the lacking digital infrastructure in services for PEH. It was acknowledged that digital tools and offers can be a chance to provide better health and social care for PEH, also those living in hidden homelessness. All respondents spoke about the lack of targeted information material for PEH in general. It was suggested to address a wide range of further topics with targeted digital information material.

Out of 8 PEH, 3 had seen the posters in relevant facilities of homelessness services in Berlin. None had seen the videos before. Participants appreciated that PEH were protagonists of the videos and posters, but even more diversity would have been appreciated. They could identify with the material and pointed out that mentioning consuming drugs and alcohol was crucial. It was reported that the posters encouraged PEH to think about a vaccination. Precise information on vaccination offers in the respective locations would have been helpful. Both, dissemination of information through posters and videos was appreciated. It was pointed out, that visually and auditorily appealing videos could be suitable especially for illiterate people. Respondents appreciated the idea of disseminating information *via* videos. One person addressed the digital gap, saying that it was only useful if you had the convenience of owning a digital device.

Discussion

The participatory approach involves all levels of knowledge

A key factor for the realization of the videos and posters was the set-up of an interdisciplinary team together with community partners and thus bridging the gap between research, practice and community. Of particular significance were good contacts

of the study team with homeless service providers and PEH. Furthermore, it was crucial to involve various local and national stakeholders right from the beginning of the project for advice, support and distribution of the materials. The participatory approach enables active generation of knowledge together with practice and communities (21). Accordingly, we addressed hierarchies transparently and valued PEH's own life experiences as equivalent to knowledge from professionals within the fields of social work and public health.

A challenge was to deal with poverty and precarious living conditions in a sensitive way. Poverty was neither to be tabooed nor trivialized. The goal was to show a realistic picture of the social system and living environment of PEH without reproducing stereotypes or exposing people. The image and portrayal of homelessness in times of the pandemic was therefore to be determined primarily by the community partners themselves. The main protagonist decided to participate by stating *"I think I'm someone people accept"*. In front of the camera, most PEH placed emphasis on a proud attitude showing an active and upright posture.

For the evaluation, 8 PEH and 12 service providers were interviewed. They acknowledged the sensitive implementation of the project. The consideration of the concerns and the diverse presentation of PEH was perceived as particularly important.

In this manuscript we have chosen the term "people experiencing homelessness" because it presents homelessness as one aspect among others and is less generalizing than the term "homeless people".

Participation and its limitations

To enable participation according to the needs of the community partners, work conditions were defined and arranged together. For example, the main protagonist's condition for participation was the assurance of permanent access to barrier-free sanitary facilities. He knew from personal experience that this would be a main challenge, especially during the pandemic when sanitary facilities were even less available for PEH. This highlights one of the fundamental problems that people living in the streets face on a daily basis.

For some people there were barriers that made participation difficult or impossible such as hidden homelessness, illegalization, and precarious employment. We have tried to enable safe participation for them as well. For some, a solution was to participate by dubbing the videos, translating the scripts or by attending the feedback sessions. Others chose to not participate altogether. Our impression was that it has been easier for people to participate if there was pre-existing contact with project staff or other PEH who had already taken part. In regard to the evaluation, we found it easier to find interview partners in the day center which provided a safe setting for the

interview compared to the recruitment in front of the shelter where the interviews were performed outdoors. It is crucial to be aware of and respect the right to non-participation.

We did not collect socio demographic data from the PEH who participated in the production and evaluation of the materials. All were experiencing homelessness at the time of the study. Some had shelter available. Similar to varying infection risks, differences in the participation and responses between sheltered and unsheltered individuals are possible, but this could be not further analyzed in this study (22).

Impact of the information material

Despite the mainly positive feedback in the evaluation, the impact of the videos could only be verified to a limited extent. Most of the homeless service providers were unable to show the videos on their premises, due to technical and spatial limitations. The videos and posters were widely distributed *via* social media and email lists. It remains unclear to what extent they reached the actual target group. However, considering the important role that social media has in shaping people's state of information and attitudes toward public health interventions such as vaccination campaigns, efforts should be increased to utilize these means of communication (23). The posters seem to have been particularly useful for the vaccination campaign according to the feedback of service providers and the number of poster-orders throughout Germany. Addressing the specific questions and concerns of PEH—e.g., having access to vaccination without a permanent address, documents or health insurance, as well as implications of drug use—may be one approach to increase vaccination coverage (24, 25).

The type of institutions that ordered the posters reflect the broad range of services that address the complex needs of PEH (26). Among them were services targeting people without official documents (e.g., passport, citizenship, health insurance), people living in poverty, people using drugs, as well as services exclusively provided for women. The way how people are approached as well as the information that is provided must be tailored to PEH's situation and needs. The videos and posters of this project demonstrate a step into this direction.

A concise point that was emphasized by staff in homeless service providers is that no information material can replace personal contact and face-to-face conversation. Relationships to social workers and medical staff remain essential—especially when people are in precarious situations, access to information is difficult and social contacts are limited.

Limitations of the information material

In the evaluation, it was critically mentioned that the material provided only general information without any details

on how to get access to vaccinations. As the provision of tests and vaccinations were locally organized in various different ways, specific information could not be integrated into the material. Some institutions therefore added distinct information for the local context directly on the posters.

The material intended to encourage testing and vaccination. One of the statements was that both is possible despite alcohol, other substance usage, and without official documents. Although this information was in line with official regulations, we could not guarantee appropriate implementation. In fact, reports from homeless service providers and PEH showed that people lacking identification documents had difficulties accessing public COVID-19 test and vaccination centers (27).

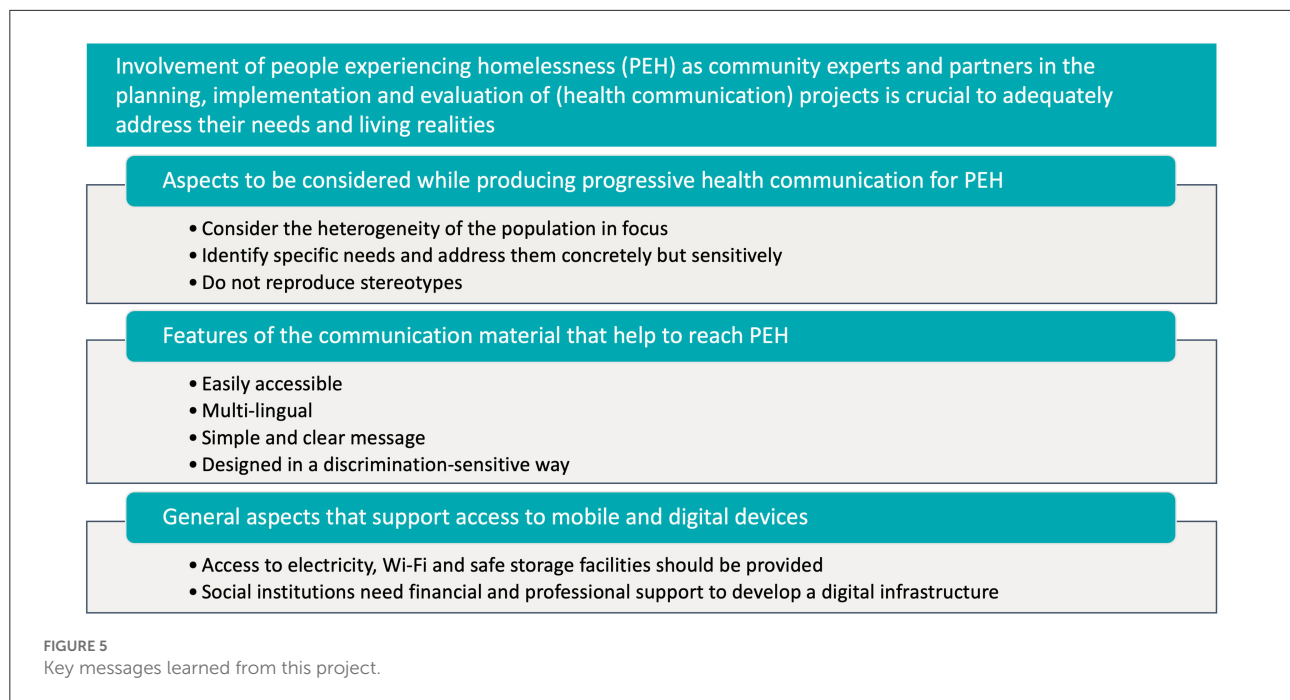
The material also stated that people with positive test results would be cared for according to their needs. However, it was frequently reported to us that quarantine and isolation capacities for PEH were insufficient, and that substitution or medical care was only partially offered.

Benefit and challenges of digital inclusion among PEH

During the pandemic, interpersonal contact became limited and digitalization crucial. Most of the population has been able to continuously access updated information about the pandemic, whereas many PEH were excluded from this information flow due to technical and socio-economic reasons that make it difficult to acquire or maintain digital devices. Even with an internet-enabled device, access to information remains difficult with a lack of free Wi-Fi and a limited access to electricity. When fighting a pandemic, it is important to reach all people in society equally, albeit through different channels and in different languages. To ensure this, digitalization has to be facilitated for social and health institutions as well as for PEH (17, 28).

The digital gap also had to be considered in the planning and implementation of our project. Our community partners without mobile- or smartphones were visited personally by our study team for recruitment and further collaboration. People who were temporarily sheltered in a 24/7 facility were easier to locate than people living on the streets. Creative and individual ways had to be identified to stay in contact with all community partners, regardless of their housing or digital situation. This shows the daily challenges of PEH without digital access, that also affects the interaction with friends and relatives, employers, social and medical service providers as well as with public institutions.

However, it has to be noted that PEH are not per se excluded from digitalization. A considerable number of PEH manage to



purchase and maintain a mobile phone or smartphone and find ways of charging it and accessing internet.

Progressive health communication

There was a wide range of institutions that ordered the elaborated posters, including a library, facilities for people who use drugs as well as different facilities for specific populations. This demonstrates that PEH can and need to be reached in different ways that consider their complex needs and situations including hidden homelessness. Particularly with a group in which digitalization is highly variable, hybrid material enables analog and digital use simultaneously. For personal contact with medical professionals or social workers, the integration of digital formats such as (anonymous) online counseling should also be considered.

Recommendations

Valuable lessons were learned through the project, that can help to strengthen participation of PEH and to consider their perspectives in health communication strategies (Figure 5).

Engaging marginalized populations as community experts and partners in the planning, implementation and evaluation of projects is crucial to adequately grasp their situation and needs. Strong links to the community, trust and the

involvement of relevant stakeholders are indispensable when working with PEH.

Progressive health communication in terms of hybrid information material (analog and digital) considers the heterogeneity of the target group, identifies the specific needs and addresses them concretely but sensitively, without stereotypes. The material should be readily accessible, multi-lingual with a simple and clear message, addressing taboo topics while being designed in a discrimination-sensitive way. In this project people were addressed in their various spoken languages, including minority languages and a clear and simple language for functional illiterates. The experiences and feedback of peers and communities must be included in the development of information material.

Access to mobile and digital devices positively impacts the daily lives and health of PEH. Sustained use of the devices requires access to electricity and Wi-Fi as well as safe storage facilities. Social institutions should receive financial and professional support to develop a digital infrastructure and have it available for its users. Exclusion from (digital) information, on the other hand, is a major factor in the structural marginalization of PEH. Closing the digital gap can be a contribution to counteracting social and health inequalities.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of the Charité – Universitätsmedizin Berlin (No.: EA2/168/21). The patients/participants provided their written informed consent to participate in this study. 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

AS: conceptualization, methodology, investigation, and writing original draft. NS: conceptualization, methodology, and scientific advice. TL, TH, MH, and MW: methodology, investigation, and formal analysis. GE and JS: scientific advice and supervision. AL: project administration, conceptualization, and supervision. All authors: writing—review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fpubh.2022.1042677/full#supplementary-material>

SUPPLEMENTARY VIDEO 1

General information about COVID-19 (<https://player.vimeo.com/video/510624249>).

SUPPLEMENTARY VIDEO 2

COVID-19: testing and quarantine (<https://player.vimeo.com/video/510655463>).

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Substantial increase in perceived benefits over harms of COVID-19 outbreak but persistent socioeconomic disparities: Comparison of two cross-sectional surveys in Hong Kong from 2020 to 2021

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Background: We have reported both perceived benefits and harms of the COVID-19 outbreak and their socioeconomic disparities amid the pandemic in Hong Kong. We further investigated whether such perceptions and disparities had changed after 10 months.

Methods: Under the Hong Kong Jockey Club SMART Family-Link Project, we conducted two cross-sectional surveys online on perceived personal and family benefits and harms of the COVID-19 outbreak in Hong Kong adults in May 2020 (after Wave 2 was under control; $N = 4,891$) and in February and March 2021 (after Wave 4 was under control; $N = 6,013$). We collected sociodemographic information, including sex, age, education, household income, and housing. Using multivariate models of analysis of covariance (MANCOVA), we compared perceived benefits and harms and socioeconomic disparities between the two surveys.

Results: Adjusting for sex and age, the prevalence of 17 out of 18 perceived personal and family benefits of COVID-19 outbreak increased ($P_s < 0.001$). Six of 11 perceived personal and family harms decreased ($P_s < 0.001$) and 4 increased ($P_s < 0.001$). The total number of perceived personal and family benefits increased substantially ($P_s < 0.001$), whereas that of perceived personal harms decreased ($P = 0.01$) and family harms remained stable ($P > 0.05$). Socioeconomic disparities, however, persisted—more perceived benefits in those with higher socioeconomic status ($P_s < 0.001$) and more perceived harms in those with lower ($P_s \leq 0.005$).

Conclusion: We have first reported that perceived personal and family benefits of the COVID-19 outbreak increased substantially over 10 months amid the pandemic, while perceived personal and family harms were lower and stable, respectively. Socioeconomic disparities of the perceived benefits and harms persisted, which need to be monitored and addressed urgently.

KEYWORDS

COVID-19, perceived benefits, perceived harms, socioeconomic disparities, cross-sectional study

Introduction

The coronavirus disease 2019 (COVID-19) poses one of the greatest global public health crises in recent history. Apart from its dire effects on physical health, depression and anxiety have also surged amid the pandemic globally (1). The Organization for Economic Co-operation and Development (OECD) unemployment rate increased by 3% points, reaching 8.8% at the onset of the crisis (2). However, the pandemic may have some unintended benefits. With the stringent public health measures, cold and flu cases plummeted worldwide (3, 4). Information and communications technology has made work-from-home possible, particularly for professionals, in developed countries (5). In addition to reducing risks of infection, such work-from-home arrangements could also benefit workers' health and well-being as well as their family and interpersonal relationships (6).

In Hong Kong, we have reported the mental health crisis early amid the COVID-19 pandemic (7) and factors associated with mental health symptoms (8). The levels of probable depression and anxiety declined further into the pandemic (9), and seasonal flu had also subsided abruptly (10). Despite the economic slowdown in general, logistics related sectors, such as those providing postal and courier services, have seen business increased by over 30% (11).

The impact of COVID-19 showed remarkable socioeconomic disparities. Across the globe, lower socioeconomic status is linked to less frequent COVID-19 testing, more positive tests, and more hospitalization and deaths (12–16). Amid the COVID-19 pandemic, people of lower socioeconomic status or those who reported greater economic hardship showed higher depression, anxiety and stress and lower psychological well-being (17–20). Relatedly, low-paying jobs also saw a much larger decrease in paid work hours during the pandemic than high-paying jobs (2). In addition, workers with higher qualifications and those who worked in larger firms were more able to work from home (5). Consistent with these findings, we found that Hong Kong people with higher socioeconomic status reported more perceived benefits, whereas those with lower socioeconomic status reported more

perceived harms from the COVID-19 outbreak (21). Our search of PubMed using the keywords “benefits” and “harms” and “socioeconomic” and “COVID-19” up to 5 June 2022 yielded seven reports (excluding our own) that investigated both potential benefits and harms of COVID-19 (6, 22–27). However, these reports were based largely on qualitative data or casual observations; none directly compared both perceived benefits and harms and their socioeconomic disparities between early and later waves of outbreak amid the pandemic.

Perception of the COVID-19 pandemic could change over time. As mass vaccination programme is made available, more and more people are protected against serious consequences of COVID-19 (28, 29). People could also become emotionally adapted to the pandemic (9, 30) through cognitive reappraisal where adverse events are seen as positive challenges rather than merely threats (31). However, socioeconomic disparities could persist despite changes in the perception of the pandemic. Flexible work arrangements remain largely irrelevant to manual workers; grassroot families are still less capable to cope with lowering income; cross-infections are still more likely in crowded homes. People's happiness and well-being are linked to their socioeconomic status relative to others as well as their absolute status (32). Such social comparison may affect various domains in life, breeding various forms of socioeconomic disparities (16, 33, 34), especially in Hong Kong, where income inequality is among the highest in the world (35).

We previously published on both perceived benefits and harms of the COVID-19 outbreak and their socioeconomic disparities amid the pandemic. The data were derived from our FamCov1 population survey on Hong Kong adults when Wave 2 was under control in May 2020 (21, 36, 37). At that time, the prevalence of perceived benefits was lower than that of perceived harms, but no other reports were available for comparison. The pandemic then continued with the more serious Wave 3 (July–August 2020) and subsequently a more prolonged Wave 4 (November 2020–March 2021; Figure 1). From February to March 2021, after Wave 4 was under control, we conducted a second population survey (FamCov2) to re-assess the perceived benefits and harms and to measure changes. In the present paper, we compared the perceived benefits and harms of the

COVID-19 outbreak and their relations with socioeconomic status in the two surveys (i.e., across these two time points) on Hong Kong adults.

Subjects and methods

Samples and procedures

The data were collected from two surveys, FamCov1 and FamCov2, under the Hong Kong Jockey Club SMART Family-Link Project. Details of FamCov1 were described previously (21, 36, 37). Briefly, FamCov1 was a population-based cross-sectional online survey conducted from 26–31 May 2020. The participants were Hong Kong Chinese residents aged 18 years or above. The target respondents were given information on the purpose of the survey, with emphasis on confidentiality. The questionnaire (in Chinese) was developed by our project team. The Hong Kong Public Opinion Research Institute (HKPORI), a well-known local survey agency, was commissioned to conduct the survey. The online questionnaire was anonymous and self-administered. HKPORI reviewed the questionnaire, tested it in a pilot survey and found no problems. All data were collected on the e-platform. A total of 70,984 invitation emails were sent by HKPORI to its probability—and non-probability-based—panels; 20,103 emails were opened and 4,944 participants responded. Because our target population was Hong Kong adults having at least one family member, we excluded those having no family members ($n = 30$) and having more than 30% missing values ($n = 23$), leaving 4,891 participants who provided useable data.

FamCov2 was the second population-based cross-sectional survey conducted from 22 February to 23 March 2021. The questionnaire (in Chinese) was developed by our project team, based on that of FamCov1. The methods were similar to those of FamCov1. Briefly, email invitation was sent to 95,705 adults with valid email addresses from the panel. 48,825 (51.0%) invitation emails were opened, and 6,013 respondents (12.3% of 48,825) successfully completed the survey. Both surveys were designed to include as many respondents as possible within a short period at low cost.

Ethics approval was obtained from the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (IRB reference no.: UW20-238).

Measures

Perceived personal and family benefits and harms of COVID-19 outbreak were assessed, with the questions, “What benefits or harms have the COVID-19 outbreak brought to you/your family?”, each followed by a list of putative perceived benefits and harms of COVID-19 based on literature review and team discussion. The present analysis was on data of common items (answer options: yes/no) used in both FamCov1

and FamCov2, which were 10 perceived personal benefits, 8 perceived family benefits, 5 perceived personal harms, and 6 perceived family harms (Table 2). These items were categorized into three domains: (a) physical, (b) psychological, and (c) social. Based on participants’ responses of yes or no (1/0) on each item, we summed the “yes” responses to obtain the total scores for perceived personal benefits (10 items, score range 0–10), perceived family benefits (8 items, score range 0–8), perceived personal harms (5 items, score range 0–5), and perceived family harms (6 items, score range 0–6).

Sociodemographic information was obtained, including sex, age, educational attainment, household monthly income, and housing type. Sociodemographic variables were coded as follows: age into six groups (18–24, 25–34, 35–44, 45–54, and 55–64, 65 years or above), education into two groups (secondary or lower, tertiary), household income into three groups (HKD 19,999 or below, HKD 20,000–39,999, HKD 40,000 or above; US\$1 = HK\$7.8), and housing into two groups (rented, owned). A socioeconomic status (SES) score ranged 0–3 was calculated by summing scores from education (0 = secondary or lower, 1 = tertiary), household monthly income per person (0 = below or equal to median, 1 = above median), and housing (0 = rented, 1 = owned). An SES score of zero was labeled as “very low”, 1 as “low”, 2 as “medium”, and 3 as “high”. We have previously used this classification of socioeconomic status and showed that it was positively associated with perceived benefits and negatively associated with perceived harms (21).

Statistical analysis

All statistical analyses were conducted with IBM SPSS v. 28 and $P < 0.05$ was considered statistically significant. To improve the representativeness of the sample, all data were weighted using random iterative method (RIM) weighting based on sex, age, and education distribution of the Hong Kong general adult population in 2020 (38). Descriptive statistics were used for the sociodemographic characteristics of the participants. Chi-squared tests were used to examine sociodemographic differences across the two surveys and Cohen’s W (0.10, small; 0.30, medium; 0.50, large) were used to estimate the effect sizes of these differences.

A multivariate model of analysis of covariance (MANCOVA) was used to estimate the weighted prevalence and 95% confidence intervals of each item of perceived benefits and harms. The effects of sex and age were adjusted for by entering these variables as covariates. All individual perceived benefits and harms items were entered as the dependent variables and the time of the surveys (FamCov2 and FamCov1) was entered as an independent variable. Prevalence ratios (PRs) were calculated by dividing the prevalence of each item obtained in FamCov2 by the prevalence of the same item in FamCov1. Statistical effect sizes were estimated using partial eta squared (0.01, small; 0.06, medium; 0.14, large).

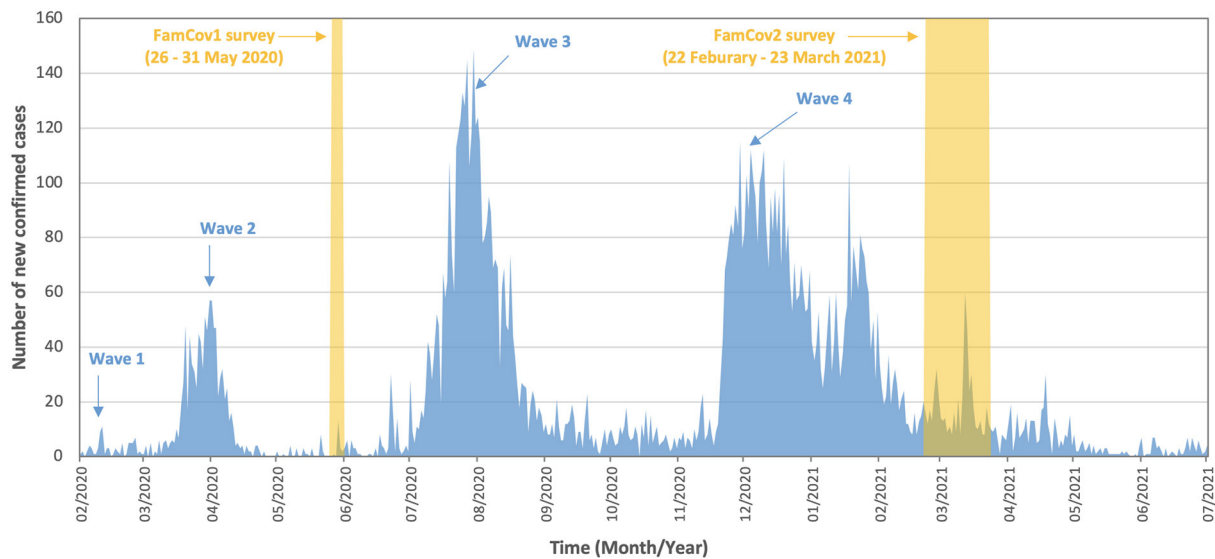


FIGURE 1

Number of new confirmed cases of COVID-19 from February 2020 to July 2021 in Hong Kong. The highlighted periods show the time period during which data of FamCov1 and FamCov2 surveys were collected. Wave 5 started in Jan 2022 with a peak of 56,827 cases (almost all Omicron BA.2) on 3 March 2022, and reduced to 234 cases on 16 May 2022.

MANCOVA was used to test and provide the estimated marginal means (with 95% confidence intervals) of the total number of perceived personal benefits, perceived family benefits, perceived personal harms, and perceived family harms. Each of these four total scores were entered as dependent variables in the model. The time of the surveys (FamCov2 and FamCov1) as well as the SES scores (0–3) were entered as independent variables. The effects of sex and age were adjusted for by entering these variables as covariates.

Results

Participants' characteristics in FamCov1 and FamCov2

From May 26 to 31, 2020, FamCov1 survey collected usable data from 4,891 adults. From February 22 to March 23, 2021, FamCov2 survey collected usable data from 6,013 adults. Table 1 shows, after weighting, similar percentages of women (52.9% in FamCov1 and 52.0% in FamCov2). FamCov1 included greater percentages of participants aged 45–54 and 55–64 years, greater percentage with tertiary education, greater percentage with no income and with higher monthly household income of HK\$30,000 or above, and greater percentage living in owned housing than FamCov2. The differences, though statistically significant, were of very small or small effect size. FamCov1 had a lower percentage (15.1% vs. 22.5%) of participants with very low socioeconomic status, but a higher percentage (34.0% vs. 29.1%) with medium socioeconomic status than FamCov2.

The differences in SES were statistically significant, with small effect size.

Change in prevalence of individual perceived benefits and harms from FamCov1 to FamCov2

Table 2 shows that all but one (17 out of 18) perceived benefits showed significant increase in prevalence from FamCov1 to FamCov2. The largest increases were increased rest time, increased personal time, improved personal hygiene, reduced cold and flu, and increased anti-epidemic knowledge, and increased family time and increased family hygiene. Out of 11 perceived harms, 6 showed significant decreases and 4 showed significant increases, all with small effect size, except for the largest increase in decreased family time with medium effect size.

Socioeconomic disparities in the total number of perceived benefits and harms in FamCov1 and FamCov2

Table 3 and Figure 2 show that the total number of perceived personal and family benefits significantly increased greatly (by almost 2-fold) from FamCov1 to FamCov2 (from 0.85 to 2.83 and 0.62 to 1.68, respectively; all $P < 0.001$), and increased with higher socioeconomic status (in both surveys all P for trend $<$

TABLE 1 Sociodemographic characteristics of participants of FamCov1 (May 2020) and FamCov2 (March 2021) surveys.

Variables	FamCov1		FamCov2		Cohen's	
	Unweighted <i>n</i> (%)	Weighted <i>n</i> (%)	Unweighted <i>n</i> (%)	Weighted <i>n</i> (%)	W (weighted)	P (weighted)
Sex						
Male	2,138 (43.7)	2,302 (47.1)	3,001 (50.2)	2,866 (48.0)	0.01	0.35
Female	2,753 (56.3)	2,589 (52.9)	2,973 (49.8)	3,108 (52.0)		
Age						
18–24	219 (4.5)	372 (7.6)	488 (8.2)	529 (8.9)	0.16	<0.001
25–34	1,090 (22.3)	658 (13.5)	1,306 (21.9)	932 (15.6)		
35–44	1,359 (27.8)	877 (17.9)	1,418 (23.7)	1,028 (17.2)		
45–54	1,204 (24.6)	1,076 (22.0)	1,343 (22.5)	1,112 (18.6)		
55–64	809 (16.5)	1,119 (22.9)	1,067 (17.9)	1,202 (20.1)		
65 or above	210 (4.3)	788 (16.1)	352 (5.9)	1,170 (19.6)		
Education						
Secondary or below	659 (13.6)	3,021 (62.2)	1,098 (18.5)	3,847 (64.9)	0.03	0.004
Tertiary	4,199 (86.4)	1,837 (37.8)	4,830 (81.5)	2,083 (35.1)		
Household income (HK\$ monthly)						
No income	303 (6.8)	451 (10.1)	243 (4.7)	412 (7.8)	0.13	<0.001
9,999 or below	123 (2.8)	246 (5.5)	176 (3.4)	331 (6.2)		
10,000–19,999	363 (8.2)	700 (15.7)	551 (10.6)	935 (17.6)		
20,000–29,999	507 (11.4)	734 (16.4)	679 (13.1)	970 (18.3)		
30,000–39,999	576 (12.9)	687 (15.4)	691 (13.3)	749 (14.1)		
40,000 or above	2,579 (57.9)	1,651 (36.9)	2,849 (54.9)	1,903 (35.9)		
Housing type						
Rented	1,603 (33.9)	1,732 (36.3)	2,205 (37.0)	2,385 (40.0)	0.04	<0.001
Owned	3,120 (63.8)	3,040 (63.7)	3,758 (63.0)	3,580 (60.0)		
Socioeconomic status						
Very low	134 (3.2)	627 (15.1)	322 (6.2)	1,188 (22.5)	0.17	<0.001
Low	656 (15.7)	1,416 (34.1)	1,022 (19.8)	1,768 (33.5)		
Medium	1,497 (35.8)	1,409 (34.0)	1,915 (37.0)	1,539 (29.1)		
High	1,891 (45.3)	689 (16.8)	1,912 (37.0)	786 (14.9)		

Missing data were excluded. US\$1 = HK\$7.8. Socioeconomic status was defined by a composite score of education, household monthly income per person, and housing, analyzed as very low (0), low (1), medium (2) and high (3). Weighting was applied based on the distribution of sex, age, and education in the 2020 Hong Kong population. Cohen's W for effect size (difference between 2 surveys): 0.10, small; 0.30, medium; 0.50, large.

0.001). The magnitude (slope) of such socioeconomic disparities in FamCov1 and FamCov2 was similar (P for interactions = 0.69 and 0.08, respectively). For perceived personal harms, the total number significantly but slightly decreased (by 7%) from 1.14 in FamCov1 to 1.06 in FamCov2 ($P = 0.01$), with a significant linear trend in FamCov2 (P for trend = 0.005) but not in FamCov1 (P for trend = 0.25; P for interaction < 0.001). As for perceived family harms, in both surveys, the total numbers were similar and decreased with higher socioeconomic status (all P for trend < 0.001). Such socioeconomic disparities were greater in FamCov2, as shown by the greater decrease (from 1.48 to 0.75) in FamCov2 than that in FamCov1 (from 1.19 to 1.24 to 1.08 and 0.87; P for interaction = 0.001).

Discussion

We have first reported that the prevalence of perceived benefits, both personal and family, of the COVID-19 outbreak substantially increased over a period of about 10 months (from May 2020 [FamCov1] to February and March 2021 [FamCov2]), the prevalence of perceived harms showed no substantial decrease, and socioeconomic disparities in both the total number of perceived personal and family benefits and the total number perceived personal and family harms. People of higher socioeconomic status reported more perceived benefits, whereas those of lower socioeconomic status reported more perceived harms. Despite the substantial increase in the total number of perceived personal and family benefits from

TABLE 2 Sex- and age-adjusted weighted prevalence (95% confidence intervals) of perceived benefits and harms in FamCov1 (May 2020) and FamCov2 (March 2021) surveys.

Variables	FamCov1	FamCov2	Prevalence ratio (PR) (FamCov2/ FamCov1)	Partial eta squared	P
	Prevalence (95% CI)	Prevalence (95% CI)			
Perceived personal benefits					
Physical					
Improved overall health	8.4 (7.3, 9.4)	17.9 (16.9, 18.8)	2.1	0.019	<0.001
Improved personal hygiene	18.6 (17.1, 20.0)	56.9 (55.6, 58.1)	3.1	0.149	<0.001
Reduced cold and flu	10.5 (9.1, 11.9)	51.3 (50.2, 52.5)	4.8	0.184	<0.001
Increased anti-epidemic knowledge	19.8 (18.3, 21.3)	56.9 (55.6, 58.1)	2.9	0.139	<0.001
Psychological					
Decreased negative emotions	1.9 (1.5, 2.4)	2.2 (1.8, 2.6)	1.2	0.000	0.46
Increased positive emotions	4.1 (3.3, 4.8)	6.3 (5.7, 6.9)	1.5	0.002	<0.001
Increased adversity coping capability	10.9 (9.7, 12.1)	20.7 (19.7, 21.7)	1.9	0.017	<0.001
Social					
Increased work/study efficiency	4.7 (3.9, 5.4)	6.9 (6.2, 7.5)	1.5	0.002	<0.001
Increased rest time	0.4 (−0.7, 1.4)	25.6 (24.7, 26.5)	64.0	0.124	<0.001
Increased personal time	0.5 (−0.6, 1.6)	27.8 (26.8, 28.7)	55.6	0.135	<0.001
Perceived family benefits					
Physical					
Improved family health	10.1 (8.9, 11.3)	24.4 (23.3, 25.4)	2.4	0.034	<0.001
Improved family hygiene	16.8 (15.4, 18.2)	49.9 (48.7, 51.2)	3.0	0.118	<0.001
Psychological					
Decreased family negative emotions	1.9 (1.4, 2.4)	3.3 (2.9, 3.8)	1.7	0.002	<0.001
Increased family positive emotions	5.4 (4.6, 6.2)	8.0 (7.3, 8.7)	1.5	0.003	<0.001
Increased family happiness	3.9 (3.2, 4.6)	5.6 (5.0, 6.2)	1.4	0.002	<0.001
Increased family harmony	7.0 (6.2, 7.9)	9.1 (8.3, 9.8)	1.3	0.001	<0.001
Increased family adversity coping capability	9.8 (8.6, 10.9)	19.7 (18.7, 20.7)	2.0	0.019	<0.001
Social					
Increased family time	0.7 (−0.6, 1.9)	51.3 (50.3, 52.4)	73.3	0.304	<0.001
Perceived personal harms					
Physical					
Delays in doctor consultation	9.9 (8.9, 11.0)	14.0 (13.1, 15.0)	1.4	0.004	<0.001
Psychological					
Caused depression	14.0 (13.0, 15.1)	11.3 (10.4, 12.2)	0.8	0.002	<0.001
Caused anxiety	33.5 (32.0, 34.9)	24.1 (22.8, 25.3)	0.7	0.011	<0.001
Increased negative emotions	43.3 (41.7, 44.8)	39.7 (38.3, 41.0)	0.9	0.001	0.001
Social					
Decreased work/study efficiency	15.8 (14.6, 17.0)	19.2 (18.2, 20.2)	1.2	0.002	<0.001
Perceived family harms					
Psychological					
Increased family negative emotions	32.6 (31.2, 33.9)	18.6 (17.4, 19.8)	0.6	0.026	<0.001
Decreased family happiness	18.7 (17.5, 19.9)	15.4 (14.3, 16.4)	0.8	0.002	<0.001
Decreased family harmony	12.0 (11.0, 13.1)	12.3 (11.4, 13.2)	1.0	0.000	0.68
Social					
Increased family conflicts	13.1 (12.0, 14.3)	18.9 (17.9, 19.9)	1.4	0.006	<0.001
Decreased family income	38.6 (37.0, 40.1)	35.1 (33.8, 36.4)	0.9	0.001	<0.001
Decreased family time	0.3 (−0.7, 1.4)	24.3 (23.4, 25.2)	81.0	0.120	<0.001

Missing data were excluded. Weighting was applied based on the distribution of sex, age, and education in the 2020 Hong Kong population. A multivariate model of analysis of covariance with sex and age entered as covariates were used for significance testing. Partial eta squared for effect size (difference between 2 surveys): 0.01, small; 0.06, medium; 0.14, large.

TABLE 3 Weighted sex- and age-adjusted estimated marginal means (95% confidence intervals) and the multivariate model of analysis of covariance for the total number of perceived personal benefits, family benefits, personal harms, and family harms in FamCov1 (May 2020) and FamCov2 (March 2021) surveys.

Variables	Survey (Time)	Overall	Socioeconomic status (SES)				P for linear trend	P for interaction
			Very low	Low	Medium	High		
Personal benefits	FamCov2 (March 2020)	2.83	2.39	2.75	3.00	3.20	<0.001	0.69
		(2.77, 2.90)	(2.29, 2.50)	(2.66, 2.83)	(2.89, 3.10)	(3.01, 3.39)		
	FamCov1 (May 2021)	0.85	0.34	0.79	0.96	1.29	<0.001	
		(0.77, 0.92)	(0.18, 0.49)	(0.69, 0.90)	(0.86, 1.07)	(1.10, 1.49)		
	Difference	1.99	2.05	1.95	2.03	1.9		
	(95% CI for difference)	(1.89, 2.08)	(1.87, 2.24)	(1.82, 2.09)	(1.88, 2.18)	(1.63, 2.18)		
Family benefits	FamCov2 (March 2020)	1.68	1.39	1.52	1.82	1.98	<0.001	0.08
		(1.63, 1.73)	(1.30, 1.47)	(1.45, 1.59)	(1.74, 1.91)	(1.83, 2.14)		
	FamCov1 (May 2021)	0.62	0.26	0.53	0.64	1.03	<0.001	
		(0.56, 0.67)	(0.14, 0.39)	(0.45, 0.62)	(0.55, 0.73)	(0.87, 1.19)		
	Difference	1.06	1.12	0.99	1.18	0.95		
	(95% CI for difference)	(0.98, 1.14)	(0.97, 1.27)	(0.88, 1.10)	(1.06, 1.30)	(0.73, 1.18)		
Personal harms	FamCov2 (March 2020)	1.06	1.19	1.02	1.05	0.97	0.005	<0.001
		(1.01, 1.10)	(1.12, 1.26)	(0.96, 1.08)	(0.98, 1.12)	(0.84, 1.10)		
	FamCov1 (May 2021)	1.14	1.08	1.31	1.07	1.08	0.249	
		(1.09, 1.19)	(0.98, 1.18)	(1.24, 1.38)	(1.00, 1.14)	(0.95, 1.21)		
	Difference	−0.08	0.11	−0.29	−0.02	−0.11		
	(95% CI for difference)	(−0.14, −0.02)	(−0.02, 0.23)	(−0.38, −0.21)	(−0.12, 0.07)	(−0.29, 0.07)		
Family harms	FamCov2 (March 2020)	1.16	1.48	1.32	1.06	0.75	<0.001	0.001
		(1.11, 1.20)	(1.41, 1.56)	(1.26, 1.38)	(0.99, 1.14)	(0.62, 0.89)		
	FamCov1 (May 2021)	1.10	1.19	1.24	1.08	0.87	<0.001	
		(1.04, 1.15)	(1.08, 1.30)	(1.16, 1.31)	(1.00, 1.16)	(0.73, 1.01)		
	Difference	0.06	0.29	0.08	−0.02	−0.12		
	(95% CI for difference)	(−0.01, 0.13)	(0.16, 0.43)	(−0.02, 0.18)	(−0.13, 0.09)	(−0.31, 0.08)		
	P for difference	0.10	<0.001	0.11	0.74	0.10		

Missing data were excluded. Sex and age were entered as covariates. Socioeconomic status was defined by a composite score of education, household monthly income per person, and housing, analyzed as very low (0), low (1), medium (2) and high (3). Weighting was applied based on the distribution of sex, age, and education in the 2020 Hong Kong population.

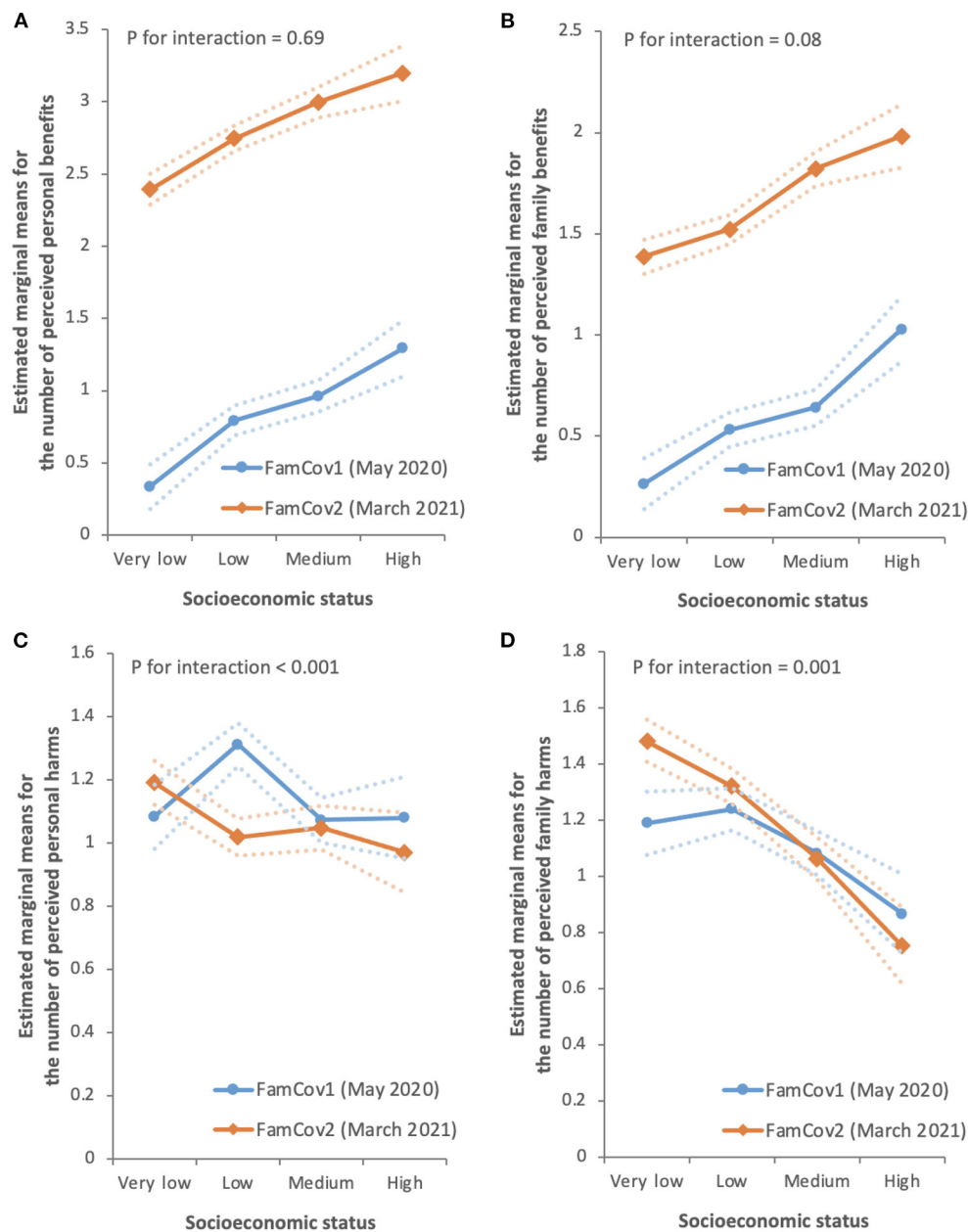


FIGURE 2

Sex- and age-adjusted estimated marginal means for the number of perceived personal benefits (A), family benefits (B), personal harms (C), and family harms (D) by socioeconomic status (SES) for each survey. The error bands indicate the upper and lower bounds of the 95% confidence intervals. Socioeconomic status was defined by a composite score of education, household monthly income per person, and housing, analyzed as very low (0), low (1), medium (2) and high (3). Weighting was applied based on the distribution of sex, age, and education in the 2020 Hong Kong population.

FamCov1 to FamCov2, the socioeconomic disparities persisted over time.

Remarkably, the substantial increase in the total number of perceived personal and family benefits over time occurred without any notable improvements in the COVID-19 situation in Hong Kong. In fact, Figure 1 shows that the daily number of confirmed cases was greater before FamCov2

than before FamCov1. Thus, the large unexpected increase in the total number of perceived benefits was unlikely due to improving outbreak control and socioeconomic environment in Hong Kong.

It is plausible that people's perception of the COVID-19 pandemic and related problems had changed over time. Previous studies showed that a small, non-zero amount of past life

adversity was associated with higher life satisfaction and appreciation of positive events in the present (39–41). We have reported earlier about fear, anxiety, and depression during early COVID-19 outbreaks in Hong Kong (7, 8, 36). Subsequent successful control of each outbreak through government policies and community collective efforts with low infection, severe COVID-19 disease and death rates might have led to increased confidence and self-efficacy in the population. Hong Kong had almost 100% voluntary masking, which became mandatory in July 2020 after 6 months from the beginning of Wave 1. Also, Hong Kong has no lockdown so far, which means people's freedom of movement and related livelihood are not severely limited, as they wear a mask in public places. Experience from coping and overcoming adversity might have helped people to better build resilience and appreciate some new or small pleasures in life amid the evolving pandemic. However, reports on these were lacking. One mechanism by which positive outcomes occur after negative experience could be cognitive reappraisal, a type of emotional regulation strategy where people perceived a stressful situation as not just a negative threat but rather a positive challenge (42). Cognitive reappraisal has been shown to be associated with reduced perceived stress and anxiety symptoms in isolated people amid COVID-19 in Hong Kong (31). Research to increase perceived benefits by designing and testing cognitive reappraisal interventions for improving mental health and well-being of the general population is warranted.

We found the greatest increase in perceived personal and family benefits in the physical and social aspects related to the pandemic. Particularly, under the physical category, improved personal hygiene, reduced cold and flu, increased anti-epidemic knowledge, and improved personal and family hygiene all showed the largest increases. For the social category, increased rest time, increased personal and family time also showed large increases. Most other perceived benefits under the psychological category, such as those concerning emotions and adversity coping capability all showed only modest increases. These suggest that physical and social benefits were not proportionately accompanied by emotional benefits in most people, as the pandemic is so strongly linked to negative feelings or affect. Special actions such as counseling and psychosocial support are needed to tackle emotional problems in those who are most vulnerable. On the other hand, the prevalence of increased personal and family adversity coping capability after Waves 1 and 2 (in FamCov1) which doubled after Waves 3 and 4 (in FamCov2) could be mainly due to the greater increases in perceived physical and social benefits, as adversity coping capability indicates self-efficacy rather than emotion.

In contrast to the many great increases in perceived benefits in FamCov2 from small prevalence in FamCov1, we found that prevalence of perceived harms in FamCov1 were much higher, and perceived harms of COVID-19 outbreak changed in mixed directions and with no substantial decreases. This pattern

suggests that increase in perceived benefits do not necessarily reduce perceived harms. This is expected as the pandemic was evolving, control measures were still stringent, and the threat of COVID-19 infection, isolation and quarantine, and severe illness, and the severe restrictions of cross boarder travels, were still on-going. Wave 4 was just brought under control during FamCov2 and most other countries continued to have serious outbreaks. Whether perceived harms (which remained stable) and perceived benefits (which had increased) would change further, with the much more serious Wave 5 outbreak started in Hong Kong in February–March 2022 and appeared under control in April–May 2022, should be further studied.

For individual items, the two specific items which showed the greatest change were the harms of decreased family time (from 0.3 to 24.3%) and the benefits of increased family time (0.7–51.3%). Such apparently conflicting results of increased harms and benefits in the same surveys could be due to opposite consequence from the same social distancing measures on people of different socioeconomic status. Those with more socioeconomic resources or adversity coping capability were more likely to benefit from work-from-home and school closure and enjoy more quality family time than those who were underprivileged. Further research on such disparities is warranted.

Of interest, our results showed that both the perceived harms items on depression and anxiety decreased significantly. This corroborates the results of a previous longitudinal observation cohort study in England that the levels of depression and anxiety declined over time during the COVID-19 pandemic (30), as well as that of a study using repeated cross-sectional surveys in Hong Kong which reported declines in both probable depression and anxiety from February to August 2020 (9). The above results collectively suggest that some people had adapted to the adverse situation amid the COVID-19 pandemic over time.

A particularly interesting finding of our study was that the socioeconomic disparities in the perceived personal and family benefits of COVID-19 outbreak persisted despite a substantial increase in total numbers of perceived benefits over time. It has been reported previously that the COVID-19 pandemic affected the worldwide population with significant socioeconomic disparities (12–16). Socioeconomic differences have been observed in various domains, such as income, happiness, behavior, and health (32–34, 43, 44). It has been hypothesized that two comparative processes determine subjective well-being as it relates to socioeconomic status: (1) comparison to one's recent past experience, and (2) social comparison between individuals (32, 33). According to this framework, the initial waves of COVID-19 undermined one's health and well-being more strongly because the comparison was made with an earlier normal period where the larger environment was relatively safe and secure. The discrepancy between the current experience (the initial waves of outbreak) and recent past experience (a relatively low infection risk environment) created an unexpected shock. However, as the

pandemic continued, the past experience (the initial waves of outbreak) against which the later experience (subsequent waves of outbreak) was compared with would make the latter seem less surprising or shocking. Thus, people would further adapt to the “new normal” situation and regain a sense of health and well-being amid the pandemic especially when a more serious outbreak had been controlled.

While we found an overall improvement in perceived benefits with time, their socioeconomic inequalities persisted. The latest available Gini coefficient of Hong Kong based on original household income was 0.539 in 2016, increased from 0.518 in 1996 and 0.533 in 2006. The coefficients were amongst the highest in the world. The increased socioeconomic disparities in Hong Kong as a whole suggests that any benefits and adaptation that had occurred were primarily due to the repeated experiences with COVID-19 outbreaks, but not so much from a substantial improvement in the disparities in individuals' socioeconomic situations. Further, the present data indicated that the linear trends of the socioeconomic gradients for perceived harms were more pronounced in FamCov2 than in FamCov1. Thus, in terms of perceived harms, socioeconomic disparities had modestly increased over time in the present study. Our results suggest that socioeconomic disparities in the harms of COVID-19 might continue to expand as the pandemic continued and forewarn that Hong Kong's Gini coefficient would get worse. Interventions to reduce disparities related to COVID-19 and beyond are urgently needed and future changes should be monitored and studied.

Two methodological issues should be addressed. First, the list of items in the two surveys were similar but not identical. New and modified items were used in FamCov2 in response to the evolving pandemic, and corresponding public health measures. However, comparisons were only made for common items across both surveys. Another methodological issue concerns with the validity of the tools used to measure perceived benefits and harms. We have previously reported that people who selected a greater total number of perceived benefits reported higher levels of happiness and decreased drinking during the COVID-19 pandemic, whereas those who selected a greater total number of perceived harms reported lower happiness and increased drinking (37). In previous (21) and present results, we also found that socioeconomic status was positively related to perceived benefits but negatively related to perceived harms. Thus, there is some evidence of convergent validity with our measures of perceived benefits and harms. However, further work is needed to provided other forms of validity, including those that discriminate between personal and family benefits and harms.

The present study had some other limitations. First, perceived benefits and harms were self-reported and might be subject to errors. However, objective measures of harms and benefits are impracticable amid the pandemic. Second, to minimize the length of the questionnaire, we did not ask

about the intensity of the benefits and harms and the details of each benefit/harm. Third, as the present data were collected from two cross-sectional surveys separated by an interval of 10 months, and the participants were different, whether the temporal changes and socioeconomic disparities could apply to the same individuals over time is uncertain. Prospective follow-up studies on the same cohort would be needed to measure changes in individuals and the predictive factors. Fourth, although the differences in sociodemographic characteristics of the participants in the two surveys were statistically significant because of the large sample size, the effect size of the differences were quite small. Because in both surveys, we aimed to collect data from as many respondents as possible within a short period so that the results would not be affected by sudden increase of COVID-19 cases during the data collection period, the response rates were low, and the generalizability of our results might have been limited.

In conclusion, we have first reported substantial increases in perceived personal and family benefits over harms of the COVID-19 outbreak in the adult population over 10 months amid the COVID-19 pandemic, and despite such large increases in perceived personal and family benefits, their socioeconomic disparities remained unchanged. Further, although the perceived harms of the COVID-19 outbreak remained quite stable overall, their socioeconomic disparities modestly increased. Urgent interventions are needed to address the unequal impacts of COVID-19 on individuals and families of different socioeconomic status and to reduce socioeconomic disparities. We recommend that more COVID-19 relief efforts should be directed to people of lower socioeconomic status, and that public health education as well as mental health support should be provided at the community level. Various harms and benefits and their socioeconomic disparities in the general population amid the COVID-19 pandemic need to be monitored regularly and addressed urgently.

Data availability statement

The dataset presented in this article is not readily available because the sharing of data to third parties was not mentioned in the subjects' consent. Requests to access the dataset can be directed to the corresponding author/s.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics approval was obtained from the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (IRB reference no.: UW20-238). The patients/participants provided their written informed consent to participate in this study.

Author contributions

Conceptualization and project administration: HL, TL, SH, and MW. Methodology: TL, AL, SH, and MW. Validation, formal analysis, and data curation: HL and WG. Investigation and writing—original draft preparation: HL and TL. Resources, supervision, and funding acquisition: TL, SH, and MW. Writing—review and editing: HL, TL, WG, SS, AL, SH, and MW. Visualization: HL, TL, and SH. All authors contributed to the article and approved the submitted version.

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The need for COVID-19 clinical trials in LMICs

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KEYWORDS

COVID-19, dexamethasone, clinical trials, Lebanon, low- and middle-income countries (LMIC)

Since the outbreak of the COVID-19 pandemic, the disease has spread worldwide with more than 603 million confirmed cases and with a death toll surpassing 648 million as of 6 September, 2022.¹ Now in its third year, the pandemic is far from finished as the virus continues to claim victims and seize lives. Despite vaccine development and success, potential emergence of SARS-CoV-2 vaccine-resistant variants as well as waning of vaccine-induced immunity, may compromise the impact of vaccines and thus necessitate the need for therapeutics that can control the disease and save lives alongside vaccines.

Early in the pandemic, dexamethasone was proposed as a potential treatment for patients with severe and critical COVID-19 as it suppresses the “cytokine storm” induced by SARS-CoV-2. Given the large number of clinical studies supporting the use of dexamethasone in COVID-19 patients, the most robust evidence came from the Randomized Evaluation of COVID-19 Therapy (RECOVERY) trial conducted by researchers at Oxford University. Low dose dexamethasone (6 mg once daily) has been proven to reduce the 28-day mortality rate for COVID-19 patients on either invasive mechanical ventilation or oxygen therapy (1). On April 8, 2021, the UK National Institute for Health and Care Excellence (NICE) recommended oral or intravenous administration of low dose of dexamethasone to severe or critically ill COVID-19 patients needing supplementary oxygen.² Similarly, dexamethasone use has also been recommended by the Infectious Diseases Society of America (IDSA) (2), the US National Institutes of Health (NIH)³ and the WHO⁴ for hospitalized patients with COVID-19 requiring oxygen therapy. It is worth noting that these therapeutic recommendations were based on evidence acquired from clinical trials conducted in high-income countries and subsequently extrapolated to treatment of COVID-19 patients in low- and middle-income countries (LMIC) (1, 3). Despite the large number of trials for effective

1 WHO Coronavirus Disease (COVID-19) Dashboard. Available online at: <https://covid19.who.int/> (accessed November 12, 2020).

2 Overview | COVID-19 Rapid Guideline: Managing COVID-19. NICE Guidance. Available online at: <https://www.nice.org.uk/guidance/ng191> (accessed September 7, 2022).

3 COVID-19 Treatment Guidelines 2. Available online at: <https://www.covid19treatmentguidelines.nih.gov/> (accessed May 28, 2021).

4 Corticosteroids for COVID-19. Available online at: Available online at: <https://www.who.int/publications/i/item/WHO-2019-nCoV-Corticosteroids-2020.1> (accessed September 7, 2022).

treatment for COVID-19, only a very small portion has been conducted in LMICs (4), which is very essential as outcomes from patients in LMICs could differ due to genetic variations among SARS-CoV-2 strains and other host and healthcare system factors specific to the LMIC settings. The inter-individual variability in dexamethasone response has been reported at the genomic and transcriptomic levels. At the DNA level, SNPs in genes such as NR3C1, NR3C2, and ABCB1 have been linked to an altered dexamethasone metabolism (5). Moreover, dexamethasone induces significant changes in the transcriptome of treated individuals. Therefore, there is a need to conduct dexamethasone clinical trials on different populations, especially those residing in LMICs.

For COVID-19 patients in LMICs such as Lebanon, cost and availability of treatment is very essential. Lebanon is a country facing unprecedented economic crisis that is pushing the country's healthcare system to the brink and creating disastrous medicine shortages. Therefore, for Lebanon, having an effective treatment such as dexamethasone, which is at the same time inexpensive, is highly significant.

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

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