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The impact of COVID-19 on vulnerable populations

Edited by
Echu Liu, Keith Elder and Caress Alithia Dean

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The impact of COVID-19 on vulnerable populations

Topic editors

Echu Liu — Saint Louis University, United States

Keith Elder — Mississippi College, United States

Caress Alithia Dean — Oakland University, United States

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INSERM U1027 Epidémiologie et analyses en santé publique: Risques, Maladies Chroniques et Handicap, France

*CORRESPONDENCE
Echu Liu
✉ echu.liu@slu.edu

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Editorial: The impact of COVID-19 on vulnerable populations

Echu Liu[1]*, Caress A. Dean[2] and Keith T. Elder[3]

[1]Department of Health Management and Policy, College for Public Health and Social Justice, Saint Louis University, Saint Louis, MO, United States, [2]School of Health Sciences, Oakland University, Rochester, MI, United States, [3]Office of the Provost, Mississippi College, Clinton, MS, United States

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Editorial on the Research Topic
The impact of COVID-19 on vulnerable populations

Introduction

The COVID-19 pandemic has been a harsh reminder of the stark health disparities in our societies. Vulnerable populations, including older adults, women, low-income communities, racial and ethnic minorities, individuals with underlying health conditions, and people without housing, have faced disproportionate challenges during this global health crisis. In this editorial, we examine *The impact of COVID-19 on vulnerable populations* from a public health perspective, highlighting the need for targeted interventions and a more equitable approach to safeguarding public health. The following section lists some critical aspects of the impact and summarizes the findings of the studies on the Research Topic.

The impact of COVID-19 on vulnerable populations

1. Higher Infection and Mortality Rates:

   Vulnerable populations, such as older adults and individuals with underlying health conditions (e.g., diabetes, heart disease, and respiratory illnesses), lower income, or immunocompromised bodies, experienced higher COVID-19 infection, and mortality rates. These groups often have weakened immune systems or pre-existing health conditions that make them more susceptible to severe outcomes if infected. In some settings, women may have been overrepresented in healthcare and frontline jobs, putting them at higher risk of exposure to the virus. They may also have played a significant role in caregiving, professionally and within their own families, potentially increasing their risk of exposure.

   Acevedo-Sánchez et al.'s findings show that age significantly predicted one's probability of being infected with COVID-19 during the first pandemic wave in Mexico. For example, older Mexicans with diabetes, hypertension, or obesity were more likely to be infected than older Mexicans without these health issues. Their study also shows that chronic illness was significantly associated with COVID-19 case mortality rates for the same period. Another critical finding is that female Mexicans with metabolic or cardiovascular diseases had a higher mortality rate due to COVID-19 than their counterparts. The analysis by Gerken et al. demonstrates that age was positively associated with COVID-19 case fatalities, whereas income was negatively associated

with COVID-19 case fatalities in the United States. Wu and Qian reviewed data collected from March 2020 to February 2022 by Canada's Public Health Agency to study the gender difference in infection rate during the peak of the COVID-19 pandemic. Their work shows that women had a steadily higher infection rate than men during the study period. According to the empirical evidence in this research, this gender disparity can be explained by women's higher share of care work during the pandemic. Santa-Ramírez et al. analyzed data collected from 2,889 participants of a 2020 population-based survey conducted in Geneva, concluding that individuals with financial hardship had higher odds of being infected with COVID-19.

2. Health Care Access Disparities:

Access to quality healthcare was a significant challenge for vulnerable populations during the pandemic. For instance, many disabled individuals, a considerable portion of the vulnerable group, rely on public transportation or specialized services for mobility. During the pandemic, lockdowns, reduced services, and safety concerns might limit their ability to access transportation, making it difficult to travel to essential places such as medical appointments. Therefore, their ability to access appropriate healthcare can be negatively impacted. In addition, individuals with underlying health conditions may have been less physically active, particularly outside their homes, due to the fear of contracting the virus. This reduction in physical activity is often associated with adverse health consequences.

Sohn et al. analyzed matched samples from the 2015 to 2020 Korean National Health Insurance's claim records to determine the influence of the pandemic on disabled individuals' healthcare use. The difference-in-differences estimates calculated in this study indicate that the pandemic significantly reduced disabled Koreans' use of medical care and that the degree of decline is positively associated with the severity of the disability. Additionally, this study shows that those with a physical disability experienced the most significant reduction compared to individuals with other disabilities. A qualitative survey by Krczal and Hyll indicates that the COVID-19 pandemic deteriorated the pattern of physical activities of Austrians with cardiovascular diseases in its initial stage. Despite all odds, this pattern did improve as the pandemic progressed.

3. Health Communication Challenges:

Public health communication efforts occasionally struggle to reach vulnerable populations effectively. Language barriers, literacy issues, and limited internet access hindered people's ability to receive accurate information about COVID-19, preventive measures, and vaccination. Significantly, the shift to online health education and virtual healthcare services during the pandemic highlighted the digital divide among vulnerable populations. Lack of access to reliable internet connections, devices, and digital literacy skills also hindered their ability to participate fully in remote activities and access essential information, potentially exacerbating existing inequities and limiting their opportunities for support and engagement. Ritcher and Heidinger's findings suggest that older Austrians in poverty were less likely to use the internet than younger and financially stable Austrians during the pandemic. Wang et al. analyzed the 2020 China Family Panel Studies cross-sectional data. They concluded that the intensity of internet use is associated with the quality of life among chronically ill Chinese during the pandemic.

4. Mental Health and Wellbeing:

The pandemic's toll on mental health has been profound, particularly among vulnerable populations. The stress and anxiety, economic hardships, and social isolation related to the virus have affected these communities disproportionately. However, mental health support and resources may not have been readily available or culturally appropriate, exacerbating the strain on their wellbeing.

Schippers et al.'s findings show that the public health measures adopted to slow the spread of COVID-19 disturbed and reduced the social connections of older adults during the pandemic. This study also shows that the public health measures worsened the pre-existing disparities in the social relationships among racial and ethnic groups. Islam et al. analyzed data from three waves from the US COVID-19 Impact Survey to identify characteristics associated with financial hardship and to evaluate the associations of final difficulty with mental health symptoms among cancer survivors during the pandemic. According to this study, minorities, younger adults, and cancer survivors with low socioeconomic status had a higher chance of financial hardship during the COVID-19 crisis, resulting in anxiety, depression, and hopelessness.

5. Social and Economic Consequences:

The socioeconomic consequences of the pandemic have been particularly devastating for vulnerable populations. Many lost their jobs or faced reduced working hours, leading to financial instability and increased vulnerability to food insecurity, homelessness, and other hardships. Dean et al. analyzed data from three US COVID-19 Impact Survey waves. They found that approximately one-third of the study sample with chronic illness experienced food shortages in the initial phase of the COVID-19 pandemic. The results from this study suggest that chronically ill Americans with lower socioeconomic status, such as those with lower income or less education, have a higher risk of food shortage.

6. Vaccination Inequities:

Vaccine distribution and accessibility have not been equitable, leading to lower vaccination rates in vulnerable communities. Issues such as vaccine hesitancy, limited access to vaccination sites, and mistrust of healthcare systems have contributed to disparities in vaccination coverage. An analysis by Ritcher and Heidinger shows that although older Austrians in poverty were significantly more likely to refuse COVID-19 vaccination, they adhered to other public health measures.

7. Systemic Inequities and Structural Racism:

COVID-19 exposed and amplified systemic inequities and structural racism, perpetuating disparities among vulnerable populations. In some regions, women faced barriers to accessing healthcare, leading to potential negative consequences for women's health during the

pandemic. Moreover, racial and ethnic minorities, indigenous communities, immigrants, and refugees experienced higher infection rates, inadequate healthcare, and discriminatory treatment.

Samanta et al.'s findings suggest that women living in Tamil Nadu, India, had a lower rate of detected cases than men. In 2020, Oliveira Martins et al. surveyed a cohort of 410 households in Amadora Municipality, Lisbon Region in Spain, to examine COVID-19's socioeconomic impact on immigrants, who remain among the most vulnerable and neglected members of many societies. Their statistical analysis shows that the COVID-19 pandemic exacerbated the pre-existing socioeconomic inequalities between immigrants and non-immigrants in the area. Compared to natives, this study found that the likelihood of immigrants in the region losing jobs and being laid off was higher during the pandemic. Furthermore, immigrants' possibility of facing financial hardship, such as difficulties buying food and hygiene products and paying bills, was also higher. Plümecke et al. analyzed Swiss mortality statistics and concluded that non-Swiss citizens had higher death rate increases than Swiss citizens during the first two waves of the pandemic. This finding suggests that the Swiss healthcare system does not protect all citizens equally in a public health crisis like the COVID-19 pandemic. The pandemic has laid bare the urgent need to address the underlying social determinants of health and work and build toward a more equitable society.

Call to action

Addressing *The impact of COVID-19 on vulnerable populations* requires a multifaceted and targeted approach. Governments, healthcare systems, and community organizations must prioritize equitable vaccine distribution, improve access to healthcare services, and ensure culturally sensitive and linguistically appropriate information dissemination. Officials should strengthen social safety nets to support those facing economic hardships, intensify efforts to bridge the digital divide and ensure mental health services are accessible and affordable for everyone. Addressing systemic inequities and racism is crucial for long-term change.

Conclusion

Ultimately, it is essential to approach the pandemic response with an equity lens to ensure that vulnerable populations are not left behind and that public health efforts are inclusive and effective for all segments of society. The COVID-19 pandemic has further exposed the vulnerabilities and disparities experienced by marginalized populations. Schippers et al. demonstrated that the crisis hit vulnerable people hardest. Therefore, we must focus on protecting and supporting vulnerable communities as we navigate the recovery phase and continue to build a more resilient and inclusive society that leaves no one behind by addressing each person's specific challenges and working toward equitable solutions. We can emerge stronger from this crisis and ensure a more equitable future through collective action and commitment to social justice.

Author contributions

EL: Writing—original draft. CD: Writing—review and editing. KE: Writing—review and editing.

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Conflict of interest

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EDITED BY
Echu Liu,
Saint Louis University, United States

REVIEWED BY
Mónica Rodrigues,
University of Coimbra, Portugal
Pedro Candeias,
Universidade de Lisboa, Portugal
Maria Alzira Cavacas,
Egas Moniz Interdisciplinary Research Center, Portugal
Nuno Mendonça,
Universidade Nova de Lisboa, Portugal
David Lopes,
Rua do Instituto Bacteriológico, Portugal, in collaboration with reviewer NM

*CORRESPONDENCE
Maria Rosario O. Martins
mrfom@ihmt.unl.pt

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Are immigrants more vulnerable to the socioeconomic impact of COVID-19? A cross-sectional study in Amadora Municipality, Lisbon metropolitan area

Maria Rosario O. Martins[1]*, Ahmed Nabil Shaaban[1], Ana Abecasis[1], Zelia Muggli[1], Regina Amado[1], Dora Vaz[2], Sara S. Dias[3,4], Antonio C. Silva[5,6] and Ines Fronteira[1]

[1]Global Health and Tropical Medicine (GHTM), Institute of Hygiene and Tropical Medicine (IHMT), NOVA University of Lisbon, Lisbon, Portugal, [2]Amadora Primary Care Health Centers Group, Regional Health Administration of Lisbon and Tagus Valley, Lisbon, Portugal, [3]ciTechCare—Center for Innovative Care and Health Technology, Polytechnic of Leiria, Leiria, Portugal, [4]School of Health Sciences, Polytechnic Institute of Leiria, Leiria, Portugal, [5]Public Health Department, Regional Health Administration of Lisbon and Tagus Valley, Ministry of Health, Lisbon, Portugal, [6]AJPAS—Associação de Intervenção Comunitária, Desenvolvimento Social e de Saúde, Amadora, Portugal

Introduction: Immigrants carry an extra burden of morbidities and mortalities since the beginning of the coronavirus disease 2019 (COVID-19) pandemic. Pre-existing inequalities among immigrants may threaten their economic wellbeing during the pandemic. This study analyzed the socioeconomic impact of COVID-19 on immigrants and natives living in Amadora, Metropolitan Region of Lisbon and the extent to which preexisting inequalities had been exacerbated during the pandemic.

Materials and methods: This cross-sectional study was conducted in Amadora Municipality, Lisbon Region, through phone interviews and using a structured questionnaire. Data collected in July 2020, included information on a cohort of 420 households, of which 51% were immigrants. To evaluate the socioeconomic position and economic wellbeing changes occurring during the pandemic we estimate crude and adjusted odds ratio (OR) and 95% CI, using Portuguese natives as the reference group.

Results: Overall, 287 (70%) participants responded to the questionnaire, of which 47% are immigrants. Preexisting socioeconomic inequalities were exacerbated during the pandemic. Compared with natives, immigrants were more likely to experience job loss, temporary lay-off, and income loss during the COVID-19 pandemic. Immigrants were also more likely to face several kinds of financial hardship during the pandemic, such as difficulties in buying food, hygiene products, and paying bills.

Conclusion: To the best of our knowledge, this study is the first to capture the direct socioeconomic impact of COVID-19 among immigrants and natives in Portugal. It highlights the bidirectional relation between inequalities deeply rooted among immigrants and COVID-19. Socioeconomic inequalities affect local patterns of COVID-19 burden, as confirmed in previous studies, but

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COVID-19 also has an impact on the economic wellbeing of Amadora immigrants during the pandemic. Urgent policies must be implemented to mitigate the economic burden of COVID-19 among immigrants, namely in Amadora, Lisbon Region.

KEYWORDS

COVID-19, immigrants, socioeconomic impact, inequality, vulnerabilities, Lisbon, Portugal

Introduction

Since it was reported in December 2019, the coronavirus disease 2019 (COVID-19) pandemic caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread across the globe, causing more than 490 million infections and about 6 million deaths (1). As the disease spread, immigrants have also been substantially affected by the pandemic in what seems to be a disproportional manner. COVID-19 has exacerbated vulnerabilities among immigrants, which were previously caused by long-standing limited access to healthcare, socioeconomic inequalities, and health disparities (2–5). Since the beginning of the pandemic, these preexisting inequalities have translated into higher morbidity and mortality among immigrants in Europe and the United States (5–8). Explanation of how these pre-existing conditions can affect the spread of COVID-19 among immigrants and the importance of universal and equitable access to healthcare services during and after the COVID-19 crisis has already been clarified elsewhere (4).

In Portugal, from 3 March 2020 to 8 April 2022, more than 3.6 million cases of COVID-19 have been notified with 21,851 COVID-19 deaths (9). As a result of the measures undertaken to mitigate the pandemic, such as partial and total lockdown, the unemployment rate was 8.2% in August 2020, compared to only 6% reported in May of the same year (10). In addition, the contraction in the Portuguese economy was 8.4% in 2020 due to COVID-19 (11). Moreover, the country's once-booming tourism sector, which contributed about 15% to Portugal's gross domestic product in 2018, collapsed in 2020 due to coronavirus (12, 13).

Immigrants in Portugal are less likely to access health services compared to natives (14). In an effort to improve immigrants' access to healthcare, Portugal has temporarily regularized all immigrants, including asylum seekers, who have applied for a residence permit before the declaration of the state of emergency on 18 March 2020 (15). Although this step has been appreciated at a regional and international level, it might not be enough to address preexisting conditions that are deeply rooted among immigrants in Portugal, since it is expected that the financial crisis caused by the COVID-19 pandemic will aggravate the economic situation among immigrant's populations. Lessons learned from the previous financial crisis showed that immigrants are among the first groups to be affected (16–20). Previous research shows that the social and economic consequences of the pandemic are hitting disadvantaged groups harder (21). Also, the existing evidence illustrates that COVID-19 has affected people unequally because of pre-existing unequal living and working conditions, as is the case of migrant populations. However, in this review (21), few studies are related to the EU, and no references can be found related to immigrants in Portugal. The objective of this study is to analyze the socioeconomic impact of COVID-19 on immigrants and natives living in Amadora, Metropolitan Region of Lisbon and the extent to which preexisting inequalities had been exacerbated during the pandemic.

Methods

Setting

Amadora is the most densely populated municipality in the country and the fourth most populous city in Portugal; moreover, 10% of its population has a foreign nationality, namely, from Portuguese-speaking countries (Brazil and Lusophone African countries). Census 2011 data suggest that the socioeconomic conditions of the population living in Amadora Municipality are comparable to those of the Metropolitan Region of Lisbon as a whole, except for the educational level, where Amadora is at a disadvantage. Between June and the beginning of August 2020, Amadora remained among the municipalities in Portugal with a higher incidence of SARS-CoV-2 infection and in a situation of contingency (while the remaining country was in a situation of alert). Due to this situation, and while the country was slowly deconfining, in Amadora some restrictions remained (e.g., shops closing by 8 pm, with exception of supermarkets, petrol stations, clinics, pharmacies, and gyms; restrictions on selling alcohol and limitation on social gathering to 10 persons). A special task force was created to deal with this situation that improved in August. Figure 1 shows the

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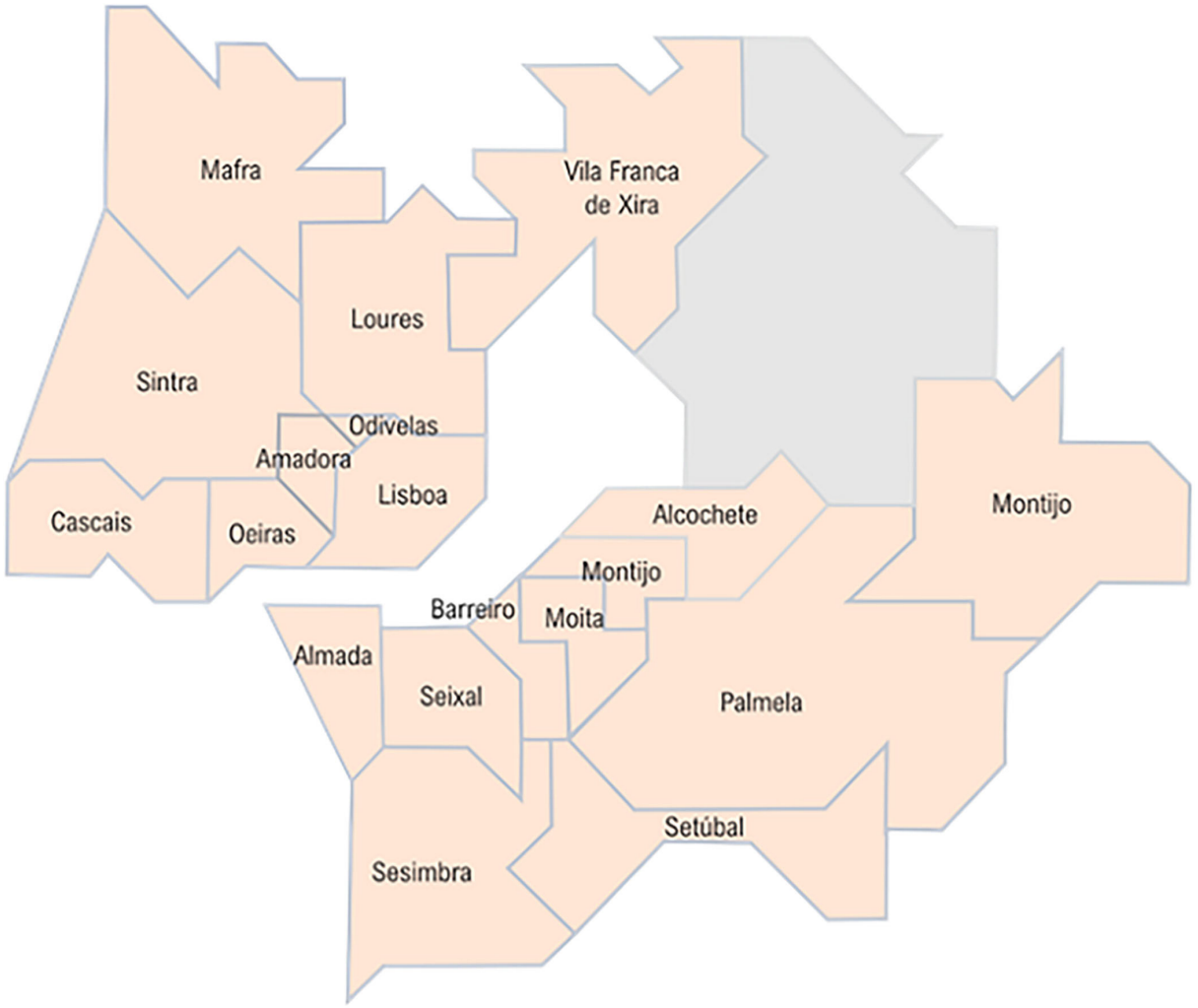

FIGURE 1
Municipalities in Lisbon metropolitan area. Source: EMTA. https://www.emta.com/spip.php?article1405&lang=en.

location of Amadora Municipality with the Metropolitan region of Lisbon.

Design

This study is nested within the prospective cohort study of native and immigrant children and their parents/caregivers living in Amadora, Metropolitan Area of Lisbon, Portugal which started in 2019. In brief, this cohort study collects quantitative data annually coming from 3 different sources: questionnaires (face-to-face and phone interviews), health center administrative data, and hospital records and the whole information is linked in a unique data set. The first data collection corresponded to the baseline assessment and was conducted between June 2019 and the 1st week of March 2020 (before the first case of SARS-CoV-2 infection had been notified in Portugal). At the baseline, we collected information on the socioeconomic and demographic characteristics and migration history of parents/caregivers and children's health outcomes.

Participants were recruited at Amadora health centers during children's consultations. The target population includes all immigrant households with children born in 2015 (starting point of the children's cohort) and the same number of native households with children also born in 2015. Because of the COVID-19 pandemic, we concluded the recruitment 3 months earlier than foreseen, in the 1st week of March 2020, with 420 children/households enrolled with complete data (22). In the present study, the participant is one of the adults living in the household (one of the child's caregivers). At the baseline, about 51% of the 420 adults are immigrants, mainly from Cape Verde, Brazil, Angola, and Guinea-Bissau.

Participants

For the baseline study ($n = 420$), participants were recruited, between June 2019 and the 1st week of March 2020. Two questionnaires were implemented, face-to-face, to collect data on the main socioeconomic and demographic characteristics of the households and migration history (for immigrants).

In July 2020, 4 months after the notification of the first case in Portugal, and during the Amadora partial lockdown (23), we invited adult participants ($n = 420$) to answer a semistructured pilot-tested questionnaire divided into four sections: changes in employment and household income during the COVID-19 pandemic; changes in material deprivation; difficulties during the lockdown; and difficulties in accessing healthcare. Participants were contacted by phone and in absence of a response, a second and a third call were made.

Questionnaire variables

The baseline questionnaire, conducted in 2019 by face-to-face interview, explored sociodemographic, economic, and living conditions and when conducted for immigrants (born outside the EU and living in Amadora) also addressed their history of migration. Demographic variables included sex, age ($\geq$18$<$35 or $\geq$35 years), and place of birth. Variables that measure socioeconomic status included employment status: employed, unemployed, and others (domestic, students, retired, and social integration income); family monthly income, originally measured in five categories was dichotomized into $<$750; $\geq$750 Euros, where 750 represents the lower limit of the median income class. This option was chosen due to the small number of frequencies in cross tables obtained with the original categories and $n = 287$. Occupations are classified according to the Portuguese Classification of Professions adapted from the International Standard Classification of Occupations (ISCO-08), categorized, for the analysis in: high-skilled occupations (managers; professionals; legislators; technicians; and armed forces occupations), and low-skilled and medium-skilled occupations (personal service workers; industrial workers; unqualified workers; and students). The level of education was measured according to the International Standard Classification of Education (ISCED) adopted by the United Nations Educational, Scientific and Cultural Organization (UNESCO), categorized into 3 classes: professional and higher education, secondary education, and less than secondary education (24).

The questionnaire on the socioeconomic impact of COVID-19 was administrated in July 2020 and included, among others, eight variables related to the impact of COVID-19 on participants' economic wellbeing, defined as follows: unemployed because of COVID-19 (no and yes), on layoff because of COVID-19 (no, yes, and not applicable), change in monthly household income due to COVID-19 (increased or remained the same, decreased), falling behind with bills (no and yes), financial difficulties in buying food (no and yes), financial difficulties in buying hygiene products (no and yes), financial difficulties to pay phone and internet (no and yes), and if kids go to school for a meal when schooling was interrupted during lockdown (no and yes).

Statistical analysis

Baseline sociodemographic characteristics (categorical variables) across immigrants and native Portuguese were compared using the x^2-test; associations between social inequalities at the baseline were estimated using logistic regression where natives were the reference class. Logistic regression was also used to compute the odds ratio and CI95% of an immigrant being unemployed due to COVID-19, being on lay-off, having household income change, falling behind with bills, or having financial difficulties, when compared to a native, and adjusting for sex, age, education level, employment status, occupation, and family income. Statistical analyses were conducted with STATA®, version 13 (Stata Corp LP, College Station, Texas, USA) and figures in R version 4.1.

Results

The response rate was 70% ($n = 287$) and did not differ by immigrant status (Natives—born in Portugal, Immigrants—born abroad and outside the EU). A total of 152 (53%) participants were natives, whereas 135 (47%) were immigrants. Table 1 presents the main baseline characteristics, collected during 2019 (before the COVID-19 pandemic), according to immigrant status.

Most of the participants are women as the original cohort study focused on the caregivers and children in the household. No differences in the distribution of sex and age were found between immigrants and natives. However, immigrants were less educated ($p = 0.021$), and had lower monthly family income ($p < 0.001$) when compared to natives. Also, among immigrants, there was a lower proportion of people employed than natives, 64.4 vs. 82.2%, respectively ($p = 0.001$). Immigrants were more concentrated in low-skilled and medium-skilled occupations (personal service workers; industrial workers; unqualified workers) in contrast to natives, 40 vs. 18%, respectively, while natives were more concentrated in high-skilled occupations (managers; professionals; legislatives; and technicians; $p < 0.001$). To evaluate socioeconomic inequalities between immigrants and natives at the baseline, we estimated crude and adjusted odds of having lower education, not being employed, having lower income, and always using natives as reference class.

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TABLE 1 Characteristics of the study sample by immigrant status.

	All ($n = 287$)		Natives ($n = 152$)		Immigrants ($n = 135$)		
	n	(%)	*n*	(%)	*n*	(%)	*p*-value
Sex ($n = 287$)							
Male	32	(11.2)	17	(11.2)	15	(11.1)	
Female	255	(88.8)	135	(88.2)	120	(88.9)	0.984
Age ($n = 287$)							
18–34	138	(48.1)	69	(45.4)	69	(51.1)	
≥35	149	(51.9)	83	(54.6)	66	(48.9)	0.333
Education ($n = 286$)							
Professional and higher education	70	(24.5)	47	(30.9)	23	(17.2)	
Secondary education	106	(37.1)	54	(35.5)	52	(38.8)	
Less than secondary education	110	(38.5)	51	(33.6)	59	(44.0)	0.021
Employment ($n = 287$)							
Employed	212	(73.9)	125	(82.2)	87	(64.4)	
Unemployed and others	75	(26.1)	27	(17.8)	48	(35.6)	0.001
Occupation ($n = 287$)							
High-skilled occupations[a]	202	(70.4)	124	(81.6)	78	(57.8)	
Low and medium skilled occupations[b]	85	(29.6)	28	(18.4)	57	(42.2)	<0.001
Family income ($n = 272$)							
≥750 Euros	167	(61.4)	106	(73.6)	61	(47.7)	
<750 Euros	105	(38.6)	38	(26.4)	67	(52.3)	<0.001

Baseline assessment: 2019. n = 287. Natives—born in Portugal, Immigrants—born abroad and outside the EU.
[a]Managers; professionals; legislatives; technicians; and armed forces occupations.
[b]Personal service workers; industrial workers; unqualified workers; and students.

As can be seen in Figure 2, before the pandemic and adjusting for other factors, immigrants when compared with natives were more likely to not be employed, to have low-skilled occupations and a lower monthly income.

Results from the July 2020 COVID-19 impact survey show that most of the changes in socioeconomic status were unfavorable to immigrants (Table 2). About 27% of them mentioned someone in the household became unemployed due to the COVID-19 pandemic compared to only 9.9% of natives ($p < 0.001$). More than 50% of immigrants were subject to temporary or partial lay-off because of COVID-19 in comparison to 32.2% lay off among natives ($p = 0.001$) and more than two-thirds of immigrants have seen their monthly household income decrease during the pandemic compared to 50% of native ($p < 0.001$).

A higher proportion of immigrants reported financial difficulties in paying bills (40.3%), buying food (31.5%), buying hygiene products (42.5%), and paying for phone and internet (50.4%), when compared to native Portuguese, 23.7, 25.7, 23, and 19.9%, respectively, with differences being significant ($p = 0.003$; $p = 0.024$; and $p < 0.05$). About 10% of immigrants reported sending their children to school to have meals compared to 3% among natives ($p = 0.02$).

Figure 3 presents the effect of the COVID-19 pandemic on participants' economic wellbeing measured by crude and adjusted odds ratio taking natives as the reference class. Adjusting for sex, age, education level, occupation, and family income, immigrants were more likely to be unemployed due to the COVID-19 pandemic (AOR 3.54, 95% CI 1.72–7.30). In addition, immigrants were more likely to be subject to temporary or partial lay-offs because of COVID-19 (AOR 2.10, 95% 1.17–3.76), and to suffer a decrease in their monthly household income due to COVID-19 (AOR 3.21, 95% CI 1.80–5.75). Regarding financial difficulties during the COVID-19 pandemic, immigrants were more likely to fall behind with bills (AOR 1.95, 95% CI 1.09–3.50), to find it difficult to buy hygiene products (AOR 1.95, 95% CI 1.10–3.48), paying phone and internet bills (AOR 3.02, 95% CI 1.65–5.53).

Discussion

This study aimed to examine the socioeconomic impact of COVID-19 on immigrants living in Amadora, Metropolitan Region of Lisbon and the extent to which preexisting inequalities had been exacerbated during the pandemic. First, analyses of variables that measure the participants' socioeconomic

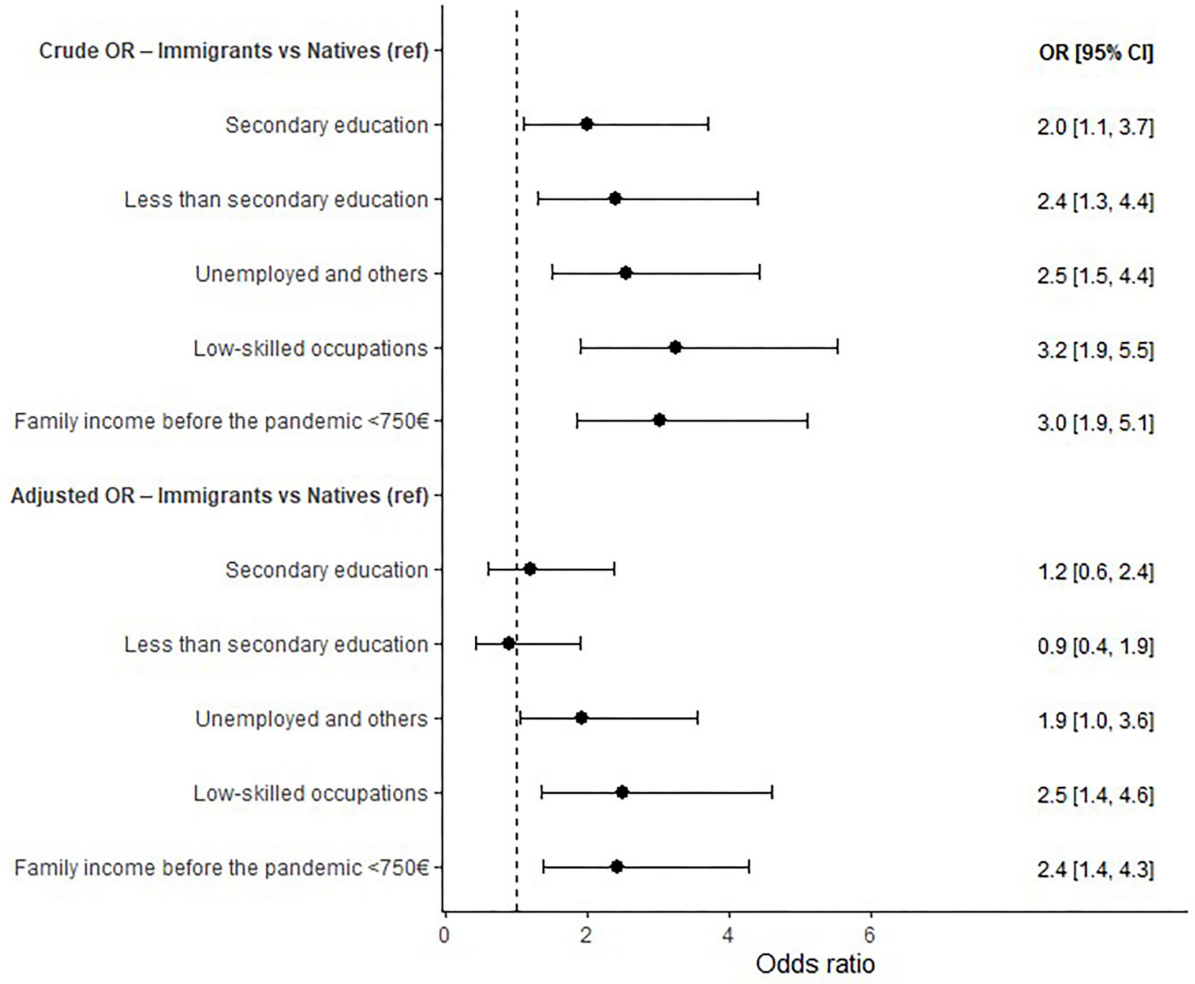

FIGURE 2
Socioeconomic inequalities between immigrants and natives before the pandemic (adjusted OR for sex and age).

position before the pandemic showed preexisting socioeconomic inequalities among immigrants compared to natives. In general, socioeconomic factors have been widely used to assess health in research. For example, better socioeconomic status in terms of higher education, employment, or income may translate to better living conditions, and access to information, and hence better health outcomes (25, 26). The preexisting conditions in our study translate into immigrants being less employed, underpaid, and more likely to have low-skilled occupations compared to natives. Second, our results show disparity in the socioeconomic impact of COVID-19 among immigrants and natives, which translates into an exacerbation of immigrants' lower economic wellbeing during the pandemic. This impact is more evident in immigrants' employment status, monthly income, and financial difficulties during the pandemic. As such, our results indicate that immigrants face other types of inequality besides preexisting socioeconomic and access to health inequalities, being at higher risk to suffer adverse economic outcomes due to COVID-19. These findings are consistent with other studies that found immigrants to suffer from social and economic disparities (27, 28). Moreover, the Portuguese Migration Observatory registered several disparities among immigrants in Portugal with respect to housing, access to healthcare, low wages, and the greatest exposure to social exclusion (29).

In our study, immigrants were more likely to be unemployed, on temporary lay-off, or to have lost income due to COVID-19. These findings are consistent with findings from other studies in which immigrant workers have confronted a disproportionate social and economic impact of the pandemic (21, 30). These findings are not surprising and can be explained for several reasons. First, the previous crisis showed immigrants to be the first affected by financial crises (17, 19, 20). The global financial crisis in 2008 and the following wave in

TABLE 2 Socioeconomic impact of COVID-19 by immigrant status in July 2020, $n = 287$ (natives—born in Portugal, immigrants—born abroad and outside the EU).

	All ($n = 287$)		Natives ($n = 152$)		Immigrants ($n = 135$)		p-value
	N	%	*n*	%	*n*	%	
Someone in the household unemployed because of COVID-19 ($n = 287$)							
No	236	(82.2)	137	(90.1)	99	(73.3)	
Yes	51	(17.8)	15	(9.9)	36	(26.7)	<0.001
On temporary or partial on lay-off because of COVID-19 ($n = 251$)							
No	133	(53.0)	82	(62.6)	51	(42.5)	
Yes	118	(47.0)	49	(37.4)	69	(57.5)	0.001
Household income change ($n = 285$)							
Increased or remained the same	112	(39.3)	75	(49.3)	37	(27.8)	
Decreased	173	(60.7)	77	(50.7)	96	(72.2)	<0.001
Falling behind with bills ($n = 286$)							
No	196	(68.5)	116	(76.3)	80	(59.7)	
Yes	90	(31.5)	36	(23.7)	54	(40.3)	0.003
Financial difficulties in buying food ($n = 286$)							
No	196	(68.5)	113	(74.3)	83	(61.9)	
Yes	90	(31.5)	39	(25.7)	51	(38.1)	0.024
Financial difficulties in buying hygiene products ($n = 286$)							
No	194	(67.8)	117	(77.0)	77	(57.5)	
Yes	92	(32.2)	35	(23.0)	57	(42.5)	<0.001
Financial difficulties to pay phone and internet ($n = 284$)							
No	187	(65.8)	121	(80.1)	66	(49.6)	
Yes	97	(34.2)	30	(19.9)	67	(50.4)	<0.001
Kids go to school for a meal ($n = 266$)							
No	249	(93.6)	131	(97.0)	118	(90.1)	
Yes	17	(6.4)	4	(3.0)	13	(9.9)	0.02

2011, which resulted in a major recession with severe labor market depression, led to a rapid, significant increase in the immigrants' unemployment rate compared to native inhabitants (19). Second, Portugal, in 2020, has been among the most affected by any economic crisis due to COVID-19 compared to other countries (the economy contracted 16.3% in the 1st semester of 2020), given the high contribution of tourism to the Portuguese economy (31). According to the Portuguese Migration Observatory, immigrants are more likely to be employed in underpaid jobs related to the domestic services sector, construction sector, or employed in jobs linked to tourism, such as hotels, cafes, and restaurants (29). During the year 2020, about 45% of Portuguese hotels have temporarily closed or are planning to close due to the impact of the coronavirus pandemic, which kept most visitors away from our tourism-dependent country for over 9 months (32). The Portuguese Hospitality Association (AHP) estimated revenue losses of between €3.2 and €3.6 billion during 2020, and 24.8–46.4 million fewer overnight stays during the same year (33). As these sectors are among the ones strongly hitten by COVID-19 restrictions, immigrants may be the first to suffer from the economic consequences as shown in the precedent crisis, being highly represented in these sectors. For example, during the Portuguese economic recession that started in 2008 and the following financial crisis, occupations with high immigrant concentrations such as construction, accommodation, and restaurant sectors, were severely affected. Accordingly, the difference in unemployment rates between natives and immigrants had widened by 7.8% points in 2010 (34).

Our study found that immigrants living in Amadora, Lisbon Region, are more likely to face financial hardship during the pandemic, and this finding could be alarming for several reasons (35, 36). Inability to provide proper nutrition or hygiene products due to financial difficulties during the pandemic may put immigrants at higher risk of infection, especially when immigrants live in poor environmental conditions (8). In addition, over 25% of immigrants in Portugal live in overcrowded housing (29). Immigrants living in these conditions and unable to afford proper nutrition or hygiene products due to financial hardship will find themselves unable

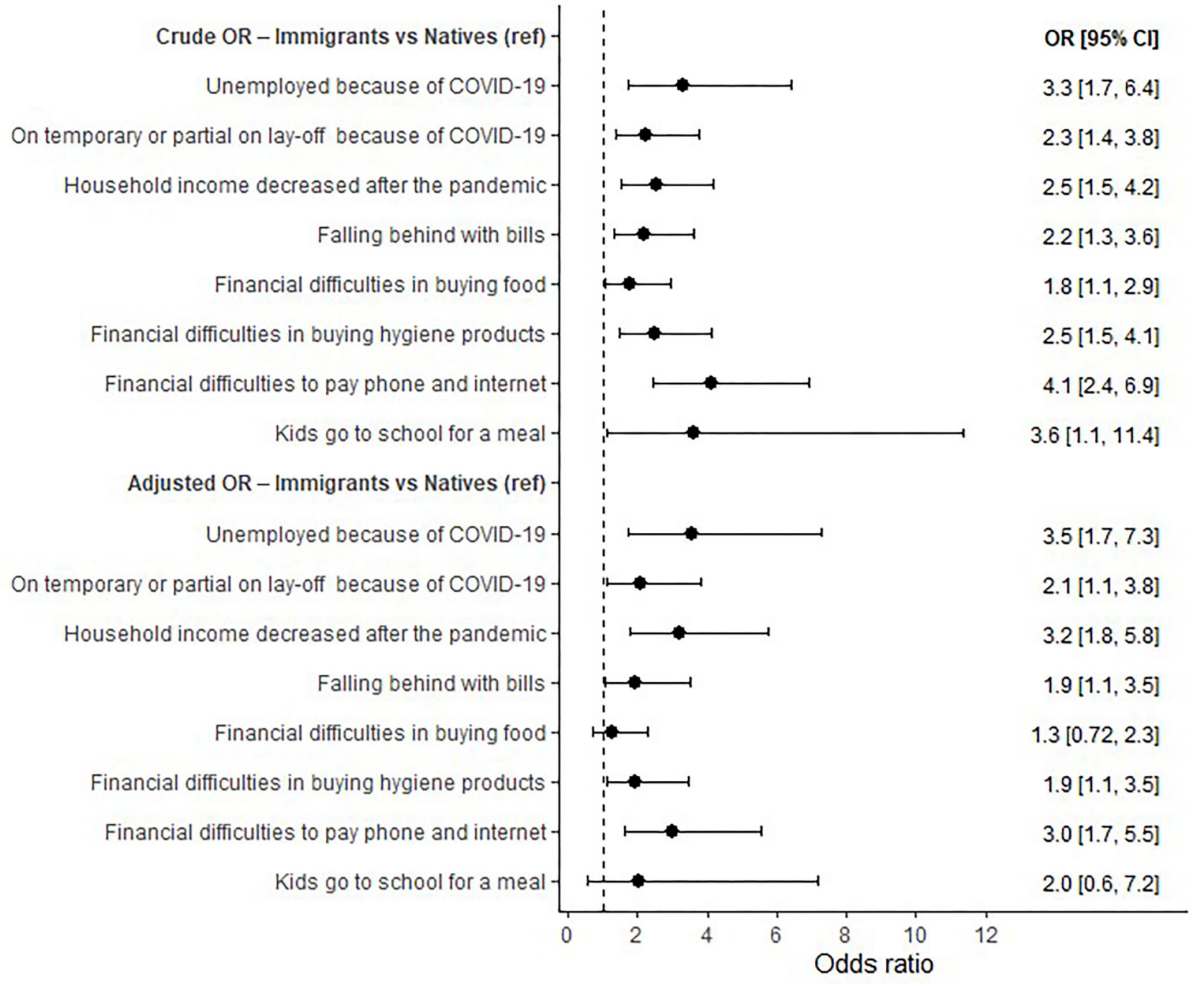

FIGURE 3
The effect of the COVID-19 pandemic on participants' economic wellbeing (immigrants vs. natives).

to follow essential prevention measures that include hand hygiene, social distancing, or proper self-isolation in the case of infection. Conclusions from a UK population study go in the same direction: compared to UK-born white, British, Black, Asian, and Minority Ethnic (BAME) migrants in the United Kingdom were more likely to experience job and income loss during the COVID-19 lockdown (37). Moreover, recent publications for France (38) and the United States (39) reveal an unequal burden of COVID-19 to income, race/ethnicity, and household crowding.

Historically, immigrants and ethnic minorities were among the most affected by infectious diseases during economic crises due to poor living conditions and lack of access to preventive health services and information (40, 41). All these factors can put immigrants at a higher risk of infection, especially in light of their limited ability to afford proper nutrition or hygiene products due to financial limitations (8).

To the best of our knowledge, our study is the first to capture the direct socioeconomic impact of COVID-19 among immigrants and natives in Portugal. It highlights the bidirectional relation between inequalities deeply rooted among immigrants and COVID-19. On the one hand, socioeconomic inequalities affect local patterns of COVID-19 burden, as confirmed in previous studies (2, 4, 6–8, 42, 43). On the other hand, COVID-19 affects the economic wellbeing of immigrants during the pandemic. The importance of our study lies in its ability to reveal that the current pandemic has not only exposed health disparities among immigrants but also exposed the economic vulnerability of this population during the pandemic, which is a result of long-standing structural inequalities. Moreover, our study was able to analyze preexisting socioeconomic conditions among immigrants using data from the first wave of the survey. Since the immigrant households in our study include children, special attention should be paid to

the potential associated effects of this economic downturn on children, such as poor nutrition, overcrowded houses, and lack of access to technologies for online learning and during repeated lockdown periods. As Portugal ensured immigrants' access to healthcare during the pandemic, similar attention should be paid to this population's financial hardship. Inclusive policies that guarantee equal access to social security during the pandemic will be critical to protecting the immigrant population.

This study has some limitations. First, data were collected from an existing cohort study; individuals were recruited before the pandemic in a different context and the impact was measured using two sequential cross-sectional studies. However, considering the difficulty to obtain information and reaching this population during COVID-19 lockdowns, we consider they offer valuable evidence in this research area. Also, we only consider families that have at least one child. Second, we only analyzed a specific point in time (July 2020 lockdown), a period accentuated by a significant economic crisis. We implemented a similar questionnaire in January 2022, during the Omicron wave, and we believe the results will give additional and relevant insights to this study. Finally, our findings described the situation in Amadora Municipality, which cannot be assumed to represent the national reality. However, we are currently expanding the area of our study to include four other Municipalities with different socioeconomic characteristics.

Conclusion

The COVID-19 pandemic that started as a health crisis is rapidly turning into an economic crisis, especially among immigrant populations. This study urges policymakers to take urgent actions to protect immigrants from COVID-19 adverse economic impact and guarantee social equality during this unprecedented crisis.

Our results were already presented at the regional (Regional Health Administration of Lisbon and Tagus Valley) and national level (Portuguese Parliament) and are being incorporated in public health programs, namely, in Amadora. The importance of this study was recognized at the national level, with the gold medal of the 2020 Human Rights Award of the Portuguese Parliament.

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 Health Ethics Committee of the Regional Health Administration of Lisbon and Tagus Valley, Portugal (001/CES/INV/2019 and 9-2020/CES/2020). The patients/participants provided their written informed consent to participate in this study.

Author contributions

MO: conceptualization, methodology, supervision, funding, and original draft. ANS: investigation, data analysis, and original draft. AA, DV, and ACS: methodology and review. ZM and RA: data collection and analysis. SD: methodology and data analysis. IF: methodology, data analysis, data field supervision, and review. 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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Echu Liu,
Saint Louis University, United States

REVIEWED BY
Jitian Sheu,
Chang Gung University, Taiwan
Shih–Chuan Lin,
Tamkang University, Taiwan
Seongwon Choi,
Trinity University, United States
Ahreum Han,
Trinity University, United States
Mei–Ling Tung,
Saint Louis University, United States

*CORRESPONDENCE
Euna Han
eunahan@yonsei.ac.kr

†These authors have contributed equally to this work

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Collateral impact of the COVID–19 pandemic on the use of healthcare resources among people with disabilities

Minjeong Sohn[1†], Heejo Koo[1†], Heekyoung Choi[2], Hyunsan Cho[3,4] and Euna Han[1*]

[1]College of Pharmacy, Department of Pharmacy, Yonsei Institute of Pharmaceutical Sciences, Yonsei University, Incheon, South Korea, [2]Division of Infectious Diseases, Department of Internal Medicine, National Health Insurance Service Ilsan Hospital, Goyang–si, South Korea, [3]Institute of Human Genomic Study, Korea University Ansan Hospital, Ansan–si, South Korea, [4]BK 21 Four R&E Center for Learning Health Systems, Korea University, Seoul, South Korea

Objective: We assessed the collateral impact of the COVID–19 pandemic on healthcare service use among people with disabilities.

Methods: We utilized the COVID–19 database from the Korean National Health Insurance Service claims from 2015 until June 2020. We included 5,850 people with disabilities and matched 5,850 without disabilities among those who were neither tested nor diagnosed with COVID–19. We used a quasi–experimental setting with a COVID–19 outbreak as an external event in a difference–difference estimation with matching controls.

Results: Participants with disabilities recorded a larger decrease in the number of claims for total services (2.1 claims per 5 months) upon the COVID–19 pandemic's onset compared to those without disabilities (1.6 claims), and the difference–in–difference estimates were statistically significant (0.46 claims). The decline was driven by outpatient and emergency visits. The extent of the decline was large for the severe disability group overall. By disability type, those with a physical disability showed a statistically significant decline in the number of claims.

Conclusion: The COVID–19 pandemic has had a collateral impact on people with disabilities' use of healthcare services. Continued assessment is needed regarding whether the collateral impact has been sustained or is following a different path.

KEYWORDS

COVID–19, health services research, epidemiology, disability, healthcare use

Introduction

The novel SARS–CoV–2 and the disease COVID–19 were first reported in late 2019, and the World Health Organization declared COVID–19 a global pandemic on March 11, 2020 (1, 2). The number of confirmed cases worldwide surpassed 1 million on April 2, 2020, 3 months after the first case was detected in central China (3). There were 360 million confirmed cases as of January 2022 (4).

The COVID−19 pandemic has caused collateral damage to the healthcare system in many countries; for example, the use of inpatient services fell by almost one–half after the onset of the pandemic in the United States, not only for elective surgeries but also for acute illnesses, such as stroke, cirrhosis, and myocardial infarction (5–8). The use of necessary services, such as vaccination or cancer treatment, has also declined during the pandemic (9, 10). Non–COVID−19 admissions in the United States declined between 39.5% and 50.0%, being more pronounced in poor and ethnic minority neighborhoods (11). By service type, emergency service use showed the largest decrease, followed by outpatient visits (12, 13). The decline in healthcare use might be due to a lower incidence of disease and a consequent low mortality rate, as in previous economic recessions (14), but it might stem from fear of infection, reduction in access associated with lockdown, and the cancellation of some elective services (12).

Considerable attention has been paid to the collateral influence of the COVID−19 pandemic on various non–COVID health outcomes, such as suicide (15), mortality, and healthcare utilization (16). However, these studies have mostly focused on the general population of a nation or a region. People with disabilities represent approximately 15% of the global population. The COVID−19 pandemic is likely to pose more challenges for people with disabilities than for the general population (17), considering that they may have limited access to information and communication, misconceptions, or administrative difficulties due to disruptions in assistive services (18–21). These challenges may increase in difficulty as people with disabilities are likely to be socioeconomically vulnerable: they are less likely to be employed, be reemployed, and have job security (22); they have weaker social networks (21); and they have lower disposable income due to extra costs associated with their disability (23). Together, these conditions raise concerns about the decrease in healthcare service utilization that might not have been so acute otherwise.

Health disparities—defined as avoidable differences in health status or healthcare (24)—between people with disabilities and the general population are a key public health issue. People with disabilities have reported more physical and mental health issues (25) and lower satisfaction with healthcare services (26). Financial constraints, secondary to the disability itself (27), could also contribute to reduced healthcare service use during the COVID−19 pandemic. This declining healthcare service use could exacerbate health disparities. This study explores whether people with disabilities use healthcare services less overall following the outbreak of COVID−19 and whether any variation exists by disability type and severity. We used a quasi–experimental approach and examined the COVID−19 pandemic onset in an event–study framework; people without disabilities were matched to people with disabilities to establish causality in the average collateral impact of COVID−19 on healthcare utilization among the latter group.

Materials and methods

Study sample

We analyzed data from the South Korean National Health Insurance Service (NHIS) COVID−19 database (DB), a retrospective cohort that includes all COVID−19 patients and their matched controls. The NHIS is the only public health insurer to have all Koreans as compulsory beneficiaries and every healthcare provider as a mandatory participant. The NHIS claims data include both enrollees' insurance qualification information and insurance claims from healthcare providers. Disability type and severity are included in the qualification information. In response to the COVID−19 pandemic, the Korean government publicly released the COVID−19 DB, which includes healthcare utilization data for 2020, covering medical claims from January 1, 2015, to July 31, 2020; this is the only publicly available dataset with healthcare use information from the COVID−19 pandemic period. The first diagnosis of COVID−19 in South Korea was made on January 8, 2020, so we considered 2020 as post–COVID−19 and all years up to 2019 as pre–COVID−19. Because the NHIS COVID−19 data were only compiled until July 2020, we used the 5–month data (from February to June) in each year from 2015 to 2020 for comparison.

The NHIS COVID−19 DB includes patients who were diagnosed with COVID−19 from January 1 to June 4, 2020, those who were tested for COVID−19 but not diagnosed; and those who were randomly selected to match the COVID−19 patients using a ratio of 1:15, matching by sex, age, and residential region. This study excluded COVID−19 patients and those tested for COVID−19 infection, noting that these groups might differ from the general population. The Korean government released a National Code of Conduct in March 2020 and ordered a mandatory quarantine for all confirmed cases and their close contacts, with the former being secluded in designated public hospitals with no out–of–pocket expenses (28). Therefore, we excluded the confirmed and tested cases in the study given that the healthcare use for the confirmed and test cases in the COVID−19 DB cannot be generalized, and our interest is to assess the collateral impact of the COVID−19 not the direct outcome of it.

Figure 1 presents the process of sample selection from the NHIS COVID−19 DB. Among the 351,377 individuals in the NHIS COVID DB, we identified those neither diagnosed nor tested for COVID−19 (n = 121,050) and classified them as disabled (n = 6,642) or nondisabled (n = 114,408). We matched the disabled and non-disabled groups using a 1:1 ratio, employing a propensity score matching method with age group, gender, and Charlson comorbidity index (CCI) as matching variables. Age was measured in 10–year intervals ranging from 0–9 years to 80 years or older. The CCI is a widely used composite indicator for comorbidities ranging between 0 (no

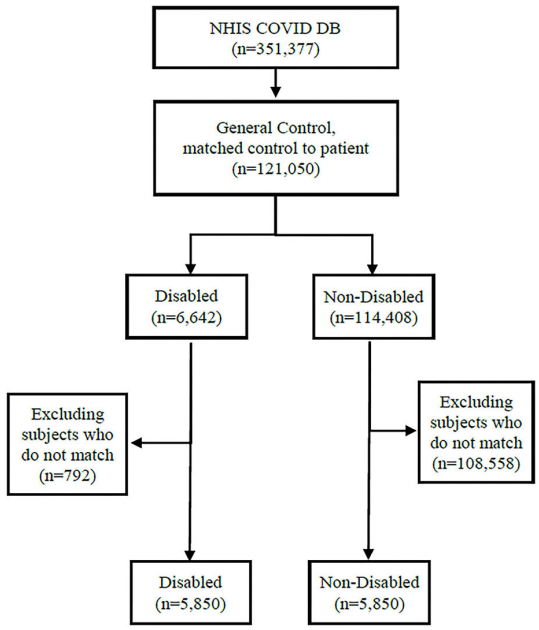

FIGURE 1
Sample selection flow.

comorbidity overall) and 16 (the highest level of comorbidity) for 19 diseases, each of which is weighted from 1 to 6 by severity (29). We grouped the combined CCI scores into 0, 1, 2, and 3 or higher for this study. We used 2019 as the index year for the CCI calculation. After the matching process, data from 5,850 participants with disabilities and 5,850 participants without disabilities remained for the analysis.

Measures

The key independent variables were disability status, type, and severity. People with disabilities are required to register their physician's diagnosis with local governmental bodies to receive social welfare benefits (30). The insurance qualification database in the NHIS uses these registration data to compile disability information regarding type and severity, which is updated annually. We classified disabilities into the following categories: visual disability, hearing disability, physical disability, and others (including disability involving brain lesions; speech disability; intellectual disability; mental disorder; autistic disorder; kidney, cardiac, respiratory, or hepatic dysfunction; facial disfigurement; intestinal or urinary fistular; and epilepsy). We also used a binary classification for the presence of any disability. Disability severity is defined by the Enforcement Decree of the Act on Welfare of Persons with Disabilities, which has included two levels (mild or severe) since July 1, 2019, and included six levels (1 = most severe to 6 = most mild) before that point (31). For data from years before 2019, we collapsed grades 1–3 into the severe group and grades 4–6 into the mild group.

The outcome variables were total healthcare utilization and utilization by service type, including inpatient, outpatient, and emergency services in the insurance claims. Healthcare service utilization was measured as the total number of claims and total medical expenditures.

The covariates included qualification type, residential region, and income level. A linear variable corresponding to each year was controlled as the time trend. The qualification of health insurance was provided as insured as an employee, self–employed, and medical aid. The qualification information is a proxy for occupational status in this study. The residence was categorized into five regions.

Analysis

We estimated a random–effects model in a difference–in–difference (DID) framework to assess COVID−19's impact on healthcare service utilization by disability status. This DID framework allowed us to compare COVID−19's effects on the dependent variables for the treatment group (people with disabilities) and the control group (people without disabilities), respectively, by controlling background changes in outcomes that occur with time (32). We used the following equation for the estimation:

$$Y_{it} = \beta_0 + \beta_1 Disabled_i + \beta_2 Post_{it} + Disabled_i \times Post_{it} + \beta_4 X_{it} + \beta_5 Time_t + u_i + \varepsilon_{it}$$

where i and t indicate each participant and each year, respectively. Y represents a series of dependent variables: healthcare utilization (medical expenditures and the number of claims) overall and by service type. If a specific service type was not used for a given observation, then the dependent variables were coded as zero. *Disabled* and *Post* are dummy variables denoting people with disabilities and the post–COVID−19 outbreak, respectively. *Time* is a linear variable that represents years, with 1 indicating the year 2015. X is a vector for the aforementioned confounding variables. u_i is a constant error component for each participant.

$\beta_2 + \beta_3$ represents marginal changes in Y after the COVID−19 outbreak among people with disabilities compared to pre–outbreak. β_2 represents the marginal change in Y after the COVID−19 outbreak among people without disabilities compared to pre–outbreak. Therefore, β_3 is the DID estimate for the incremental change of Y after the COVID−19 outbreak among people with disabilities when the difference in Y between pre– and post–outbreak among people without disabilities is controlled.

We also estimated the DID after classifying disabilities as severe or mild as well as by disability type to assess variation in the COVID−19 outbreak's collateral impact by disability profile. All data extraction and statistical analyses were performed using SAS (version 9.4) and STATA (version 17).

Results

Table 1 shows the study participants' general characteristics. Almost two–thirds of participants with a disability (64.6%) had a mild disability. Physical disabilities accounted for approximately half (44.1%) of total disabilities. More than half of all participants (i.e., both groups) were aged 60 or older. There were more than four times as many medical aid recipients among participants with disabilities (18.9%) compared to those without disabilities (4.6%) (Table 1).

Figure 2 shows the unadjusted yearly trend of healthcare service utilization between 2015 and 2020 for participants with disabilities compared to controls. There was a decline of approximately 10% in the total number of claims during the COVID−19 pandemic compared to the previous 5 years. Further examination by service type indicated that this decline at the beginning of the COVID−19 pandemic occurred mainly with respect to outpatient and emergency services, whereas the level of inpatient service utilization remained stable. There were also nearly parallel trends concerning total healthcare service utilization between participants with disabilities and the corresponding controls before the COVID−19 outbreak, which supports the DID framework's validity.

Dividing participants with disabilities into two groups by severity also uncovered an immediate decline in the number of claims at the beginning of the COVID−19 pandemic, with a larger decline for those with a mild disability compared to those with a severe disability. However, for emergency services, a sharper decrease was found among patients with severe disabilities than those with mild disabilities (Supplementary Figure 1). The yearly trends in healthcare service use by disability type also showed an approximately 10% decline in the number of claims for total, outpatient, and emergency services upon the outbreak across all disability types (Supplementary Figure 2).

Table 2 shows the results of the multivariate random–effects event analysis. To increase the analyses' efficiency within the sample, we estimated the average DID specifications for the aggregated pre–pandemic years. Participants with disabilities were estimated to have a larger decline in total healthcare service use (number of claims) upon the COVID−19 pandemic's onset compared to those without disabilities (2.1 vs. 1.6 claims per 5 months, respectively), and the difference–in–difference (0.46 claims) was statistically significant. Analyses by service type confirmed that this decline in the number of claims was driven by outpatient and emergency service use, as the DID estimate for each showed decreases of 0.56 and 0.01 claims per 5 months, respectively. Participants with disabilities also had a larger decline in medical expenditures after the outbreak compared to those without disabilities with respect to outpatient services (by KRW 69,224 and 39,501, respectively; 1 USD is approximately KRW 1,200) and emergency services (by KRW 42,102 and 39,061, respectively); however, the difference–in–differences in medical expenditures were not statistically significant for either service type.

Table 3 shows the estimation results in relation to disability severity. Overall, participants with severe disabilities were

TABLE 1 Summary statistics.

Total	People without disabilities *N* (%)	People with disabilities *N* (%)
	5,850 (100.00)	**5,850 (100.00)**
Severity of disability		
Severe	–	2,070 (35.4)
Mild	–	3,780 (64.6)
Disability type		
Physical	–	2,579 (44.1)
Visual	–	580 (9.9)
Hearing	–	947 (16.2)
Other	–	1,744 (29.8)
Gender		
Male	2,903 (49.6)	2,773 (47.4)
Female	2,947 (50.4)	3,077 (52.6)
Age group (years)		
0∼9	14 (0.2)	14 (0.2)
10∼19	44 (0.8)	44 (0.8)
20∼29	433 (7.4)	435 (7.4)
30∼39	218 (3.7)	221 (3.8)
40∼49	397 (6.8)	405 (6.9)
50∼59	1,094 (18.7)	1,112 (19.0)
60∼69	1,703 (29.1)	1,459 (24.9)
70∼79	1,291 (22.1)	1,197 (20.5)
80 or older	656 (11.2)	963 (16.5)
Charlson comorbidity index		
0	3,421 (58.5)	3,466 (59.3)
1	1,280 (21.9)	1,475 (25.2)
2	753 (12.8)	610 (10.4)
3 or higher	396 (6.8)	299 (5.1)
Qualification		
Self–employed	1,659 (28.4)	1,379 (23.6)
Salaried	3,920 (67.0)	3,361 (57.4)
Medical aid	271 (4.6)	1,110 (18.9)
Region		
Seoul	315 (5.4)	259 (4.4)
Kyunggi	3,840 (65.6)	3,850 (65.8)
Daegu	304 (5.2)	262 (4.5)
Kyungbook	872 (14.9)	940 (16.1)
Other	519 (8.9)	539 (9.2)

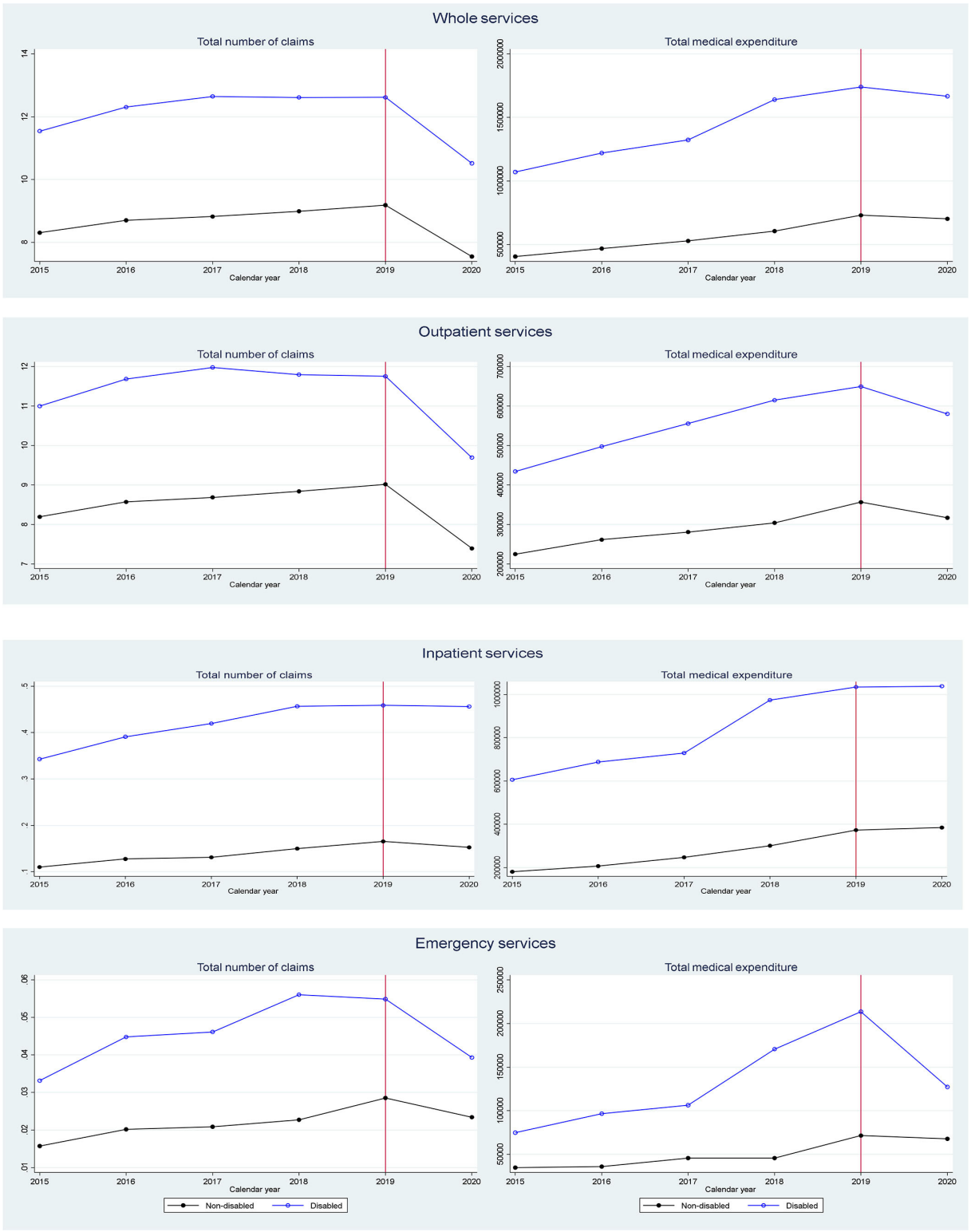

FIGURE 2
Average healthcare utilization trend for 5 months of each year pre- and post-outbreak of COVID-19.

TABLE 2 Multivariate random–effects regression of the incremental change in healthcare service utilization in the early COVID−19 pandemic compared to pre–pandemic for people with disabilities, controlling for the parallel difference among people without disabilities[d].

Service type	Expenditure[a] ($N = 11,700$)		*P*–value	Number of claims[a] ($N = 11,700$)		*P*–value
	b	(Standard error)		b	(Standard error)	
Total[b]						
COVID−19 onset	−28,074	(46,796)	0.54	**−1.6357**	**(0.1220)**	<0.00
Disability	**861,515**	**(67,474)**	<0.00	**2.7963**	**(0.2431)**	<0.00
Disability × COVID−19 onset	−45,109	(66,179)	0.49	**−0.4643**	**(0.1725)**	0.00
Change between pre– and post–COVID−19 among nondisabled	−28,074	(46,796)	0.54	**−1.6357**	**(0.1220)**	<0.00
Change between pre– and post–COVID−19 among disabled	−73,183	(46,385)	0.11	**−2.1000**	**(0.1320)**	<0.00
Outpatient[b,c]						
COVID−19 onset	**−39,501**	**(13,665)**	0.00	**−1.8152**	**(0.1195)**	<0.00
Disability	**277,607**	**(30,157)**	<0.00	**2.5311**	**(0.1976)**	<0.00
Disability × COVID−19 onset	−29,723	(19,326)	0.12	**−0.5612**	**(0.1494)**	0.00
Change between pre– and post–COVID−19 among nondisabled before	**−39,501**	**(13,665)**	0.00	**−1.8152**	**(0.1195)**	<0.00
Change between pre– and post–COVID−19 among disabled	**−69,224**	**(13,085)**	<0.00	**−2.3764**	**(0.1185)**	<0.00
Inpatient[b,c]						
COVID−19 onset	11,427	(44,383)	0.79	−0.0128	(0.0148)	0.38
Disability	**557,402**	**(59,677)**	<0.00	**0.2143**	**(0.0216)**	<0.00
Disability × COVID−19 onset	−7,660	(62,767)	0.90	0.0104	(0.0210)	0.62
Change between pre– and post–COVID−19 among nondisabled before	11,427	(44,383)	0.79	−0.0128	(0.0168)	0.38
Change between pre– and post–COVID−19 among disabled	3,767	(44,834)	0.93	−0.0023	(0.0148)	0.87
Emergency[b,c]						
COVID−19 onset	**−39,061**	**(19,463)**	0.04	−0.0051	(0.0044)	0.24
Disability	**53,257**	**(8,063)**	<0.00	**0.0245**	**(0.0054)**	<0.00
Disability × COVID−19 onset	−3,041	(21,780)	0.88	**−0.0104**	**(0.0067)**	0.09
Change between pre– and post–COVID−19 among nondisabled before	**−39,061**	**(19,463)**	0.04	−0.0051	(0.0064)	0.24
Change between pre– and post–COVID−19 among disabled	**−42,102**	**(19,435)**	0.03	**−0.0155**	**(0.0044)**	0.00

[a]Number of individuals with disabilities and 1:1 matched control.
[b]Controlled for gender, age group, residential region, insurance qualification, and Charlson comorbidity index.
[c]For each service type, no corresponding service use was coded as zero.
[d]Statistically significant results at the 5% level are presented in bold.
[e]The covariates included qualification type, residential region, and income level. A linear variable corresponding to each year was controlled as the time trend.
[f]During the study period (January 1, 2015–July 31, 2020), USD 1 was equivalent to KRW between 1,065.67 and 1,210.80.

estimated to have a larger decrease in healthcare service utilization compared to those with mild disabilities. Among participants with severe disabilities, total medical expenditures upon the onset of the COVID−19 pandemic were estimated to decline by KRW 91,534 for 5 months relative to the pre–COVID−19 period, controlling for the corresponding difference among participants without disabilities. Total medical expenditure for emergency services was also estimated to decline following the outbreak, with decreases being larger for those with severe disability relative to those with mild disability: KRW 132,054 vs. 61,340 for emergency services, respectively.

There were different healthcare service utilization outcomes by disability severity in terms of the number of claims. Participants with mild disabilities showed a decline in the number of claims for total and outpatient services (by 0.6383 and 0.6066 per 5 months per year, respectively) compared to the pre–COVID−19 period, controlling for the corresponding difference among those without disabilities. For emergency services, only participants with severe disabilities had a lower number of claims (by 0.0371 per 5 months per year) compared to the pre–COVID−19 period, controlling for the corresponding difference among those without disabilities (Table 3, right panel).

Finally, participants with physical disabilities showed a significantly different change in the number of claims compared to those with other disabilities. Participants with physical disabilities showed a decline in the number of claims for total and outpatient services (by 0.5785 and 0.5541 per 5 months per year, respectively) upon the onset of the pandemic, controlling for the pre–post difference among those without disabilities (Table 4).

TABLE 3 Multivariate random effect regression of the incremental change in healthcare service utilization in early COVID−19 pandemic compared to pre−pandemic period for people with mild and severe disabilities compared to those without disabilities[d].

Service type	Expenditures[a] ($N = 11,700$)	*P*–value	Number of claims[a] ($N = 11,700$)	*P*–value
	b (Standard Error)		b (Standard Error)	
Total[b]				
Severe disability × COVID−19 onset	**−91,534**	0.02	**−0.6066**	0.02
	(42,552)		**(0.2631)**	
Mild disability × COVID−19 onset	−74,692	0.17	**−0.6383**	0.00
	(46,510)		**(0.2147)**	
Inpatient services[b,c]				
Severe disability × COVID−19 onset	−56,745	0.53	0.0009	0.97
	(91,096)		(0.0314)	
Mild disability × COVID−19 onset	−66,926	0.36	−0.0242	0.34
	(74,335)		(0.0256)	
Outpatient services[b,c]				
Severe disability × COVID−19 onset	−33,542	0.17	−0.3728	0.14
	(29,508)		(0.2575)	
Mild disability × COVID−19 onset	**−27,631**	0.08	**−0.6006**	0.00
	(15,789)		**(0.2101)**	
Emergency visit[b,c]				
Severe disability × COVID−19 onset	**−132,054**	0.00	**−0.0371**	<0.00
	(44,606)		**(0.0086)**	
Mild disability × COVID−19 onset	**−61,340**	0.09	−0.0074	0.29
	(36,398)		(0.0070)	

[a]Number of individuals with disabilities and 1:1 matched control.
[b]Controlled for gender, age group, residential region, insurance qualification, and Charlson comorbidity index.
[c]For each service type, no corresponding service use was coded as zero.
[d]Statistically significant results at the 5% level are presented in bold.
[e]The covariates included qualification type, residential region, and income level. A linear variable corresponding to each year was controlled as the time trend.

Discussion

The study revealed significantly larger decreases in healthcare service use overall and for outpatient and emergency services, particularly upon the onset of the COVID−19 outbreak among people with disabilities compared to those without disabilities. The study further showed that the severe disability group had a larger decline in medical expenditures compared to the mild disability group, with these declines being driven by emergency service use. The number of claims was estimated to decline for overall and outpatient services in the mild disability group but emergency services in the severe disability group.

Although our findings do not account for the underlying mechanisms driving such differences, they at least highlight the need for continuous scrutiny. People with disabilities confront more challenges in situations such as the COVID−19 pandemic. For example, non-transparent masks hinder communication for people with hearing disabilities (19). Studies have also reported substantial interruption of medical follow–up and rehabilitation during the lockdown for people with physical disabilities (33). Healthcare service disruption during the COVID−19 epidemic among people with disabilities and such disruption for chronic health conditions was also reported even in a sample with relatively higher socioeconomic status in the United States (34). Other than these administrative issues related to the pandemic, people with disabilities are more vulnerable to COVID−19 given their socioeconomic characteristics (35), which may impede the timely use of healthcare services. Social distancing during the pandemic has also led to restricted access to social welfare assistance for people with disabilities, which in turn may have reduced their utilization of routine healthcare services (17). People with disabilities are consequently likely to face increased marginalization in both routine and preventive care amid the pandemic. Thus, COVID−19's collateral impact on overall healthcare utilization could be stronger among people with disabilities. The decrease in the use of emergency services among people with severe disabilities could imply an interruption in healthcare services for those who require them most. Simultaneously, people with even mild disabilities must still be

TABLE 4 Multivariate random−effects regression of the incremental change in healthcare service utilization in early COVID−19 pandemic compared to pre−pandemic period by disability type[d].

Disability subgroup	Expenditures		*P*−value	Number of claims		*P*−value
	b	(Standard error)		b	(Standard error)	
Physical disability[a,b,c] ($N = 5,158$)						
Total						
Disabled × COVID−19 onset	−28,261	(80,643)	0.72	**−0.5785**	**(0.2535)**	0.02
Inpatient						
Disabled × COVID−19 onset	−4,276	(74,688)	0.95	−0.0248	(0.0258)	0.33
Outpatient						
Disabled × COVID−19 onset	−24,041	(22,011)	0.27	**−0.5541**	**(0.2497)**	0.02
Emergency						
Disabled × COVID−19 onset	−15,550	(37,404)	0.67	−0.0031	(0.0087)	0.72
Visual disability[a,b,c] (N = 1,160)						
Total						
Disabled × COVID−19 onset	−103,720	(182,940)	0.57	0.0810	(0.5401)	0.88
Inpatient						
Disabled × COVID−19 onset	−63,603	(168,167)	0.70	0.0275	(0.0371)	0.45
Outpatient						
Disabled × COVID−19 onset	−40,369	(51,711)	0.43	0.0517	(0.5368)	0.92
Emergency						
Disabled × COVID−19 onset	−62,009	(61,400)	0.31	−0.0069	(0.0152)	0.65
Hearing disability[a,b,c] ($N = 1,894$)						
Total						
Disabled × COVID−19 onset	67,211	(149,744)	0.65	−0.3062	(0.4203)	0.46
Inpatient						
Disabled × COVID−19 onset	81,942	(143,871)	0.56	0.0063	(0.0464)	0.89
Outpatient						
Disabled × COVID−19 onset	−14,731	(31,113)	0.63	−0.3126	(0.4150)	0.45
Emergency						
Disabled × COVID−19 onset	−39,244	(69,719)	0.57	0.0105	(0.0139)	0.44
Other disabilities[a,b,c] ($N = 3,488$)						
Total						
Disabled × COVID−19 onset	−111,523	(157,208)	0.47	−0.5625	(0.3314)	0.08
Inpatient						
Disabled × COVID−19 onset	−42,713	(151,267)	0.77	0.0590	(0.0522)	0.25
Outpatient						
Disabled × COVID−19 onset	−42,726	(50,597)	0.39	−0.4931	(0.3195)	0.12
Emergency						
Disabled × COVID−19 onset	−2,140	(57,589)	0.97	**−0.0338**	**(0.0138)**	0.01

[a]Number of individuals with each disability type and 1:1 matched control.
[b]Controlled for gender, age group, residential region, insurance qualification, and Charlson comorbidity index.
[c]For each service type, no corresponding service use was coded as zero.
[d]Statistically significant results at the 5% level are presented in bold.
[e]The covariates included qualification type, residential region, and income level. A linear variable corresponding to each year was controlled as the time trend.

considered in public strategies to protect this demographic in social crises such as the COVID−19 outbreak (20, 21).

We estimated that the incremental decrease in the number of claims for overall healthcare services upon the onset of the COVID−19 pandemic was statistically significant among people with physical disabilities. There has been relatively few research on COVID−19's effect on people with disabilities (not to mention in terms of disability type) despite the significant attention paid to COVID−19's overall collateral impact (18). For example, a cross−sectional study including many US HMO patients reported that intellectual disability was the greatest risk factor for COVID−19 diagnosis and

mortality (36). Two other studies investigating people with intellectual or developmental disabilities reported similar results regarding the COVID−19 fatality (37, 38). With people with disabilities' increased overall vulnerability during the pandemic, studies have also reported that certain disabled populations, such as those with visual or hearing impairments, may be less susceptible than others requiring routine medical follow–up and rehabilitation, such as those with physical or neurological disabilities (18, 39). Studies have suggested potential problems among people with hearing or visual impairments (40–43), although some studies do not provide supportive empirical evidence (42, 43). These arguments highlight the urgent need for data–informed strategies that address the heterogeneity in COVID−19's collateral impact due to disability characteristics. Researchers should pay close attention to people with disabilities when assessing any interruption of healthcare use during the pandemic, and more specific interventions targeting people with disabilities are required.

We acknowledge that this study has several limitations. First, some information is not present in insurance claims data because these data are originally collected administratively for reimbursement purposes. For example, in place of socioeconomic status, we were forced to substitute health insurance premium level, which is approximately proportionate to household incomes and assets, and qualification information for occupational status. We also note that the unit of analysis is claims per person rather than individual visits. Second, outpatient drug costs are not available in the COVID−19 DB. Third, we extracted the disabled and non-disabled groups from those who were neither tested for nor diagnosed with COVID−19 in the database. Nevertheless, this was the only database available in South Korea that included insurance claims during the COVID−19 outbreak.

Despite some caveats, this study has several merits. A recent study in Korea estimated that people with disabilities had higher risks of major adverse outcomes from COVID−19, including admission to the intensive care unit, invasive ventilation, and mortality (44). However, the researchers focused on confirmed COVID−19 patients to assess clinical outcomes among people with disabilities. Our study expands the investigation into the pandemic's spillover effect on people with disabilities in terms of healthcare service utilization. First, the national representativeness of the data is indisputable. We explored insurance claims data from the NHIS, to which every citizen in Korea is a mandatory subscriber and every medical provider is an obligatory participant. Second, the use of a quasi–experimental setting that exploited COVID−19 onset in an event–study framework is another merit of our study. We established the pandemic's causality by controlling for parallel pre–pandemic healthcare service use with a matched non–disabled group. Third, we identified heterogeneity in the pandemic's collateral effects in terms of disability severity and type. Additionally, we explored not only total healthcare service use but also use by service type.

Given the data's limited availability, we assessed only the immediate impact of the COVID−19 outbreak on healthcare service utilization. Whether this short–term impact will be sustained or follow a different path should be assessed further after the additional accumulation of data. Additionally, long–term studies should use more specific service characteristics for assessment—including preventive healthcare or targeted services, such as rehabilitation or assistive care—to enable more purposeful responses to similar future shocks for people with disabilities. Future studies also need to assess whether there are variations in the collateral impact of the COVID−19 pandemic on people with disabilities by socioeconomic or demographic characteristics as well as other disability profiles such as disability duration or types uninvestigated in this study.

Our findings have important implications for people with disabilities and the continuity of their care. People with disabilities used healthcare services (outpatient and emergency services, particularly) less frequently during the early stages of the COVID-19 pandemic relative to people without disabilities. Whether such declines stem from exacerbated access disparities during the COVID−19 outbreak and newly created disparities in health outcomes should be assessed in future work.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://nhiss.nhis.or.kr/bd/ab/bdaba000eng.do;jsessionid=EdTiA5aI1e1JP24bLXzVxDO7AasuZvIoWYvEa1306FNRmmHU75Yx2DamU4FI8L4U.primrose2_servlet_engine10.

Ethics statement

The studies involving human participants were reviewed and approved by Yonsei Institute Review Board (7001988– 202010–HR−1005–01E). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

EH conceptualized the study, designed methodology, and prepared original draft. MS wrote original draft. HK curated data, wrote original draft preparation and contributed visualization of the results. HC and HyC reviewed and revised the manuscript. 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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.922043/full#supplementary-material

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Zhaohui Su,
Southeast University, China

REVIEWED BY
Tiantian Zhang,
Fudan University, China
Shudi Li,
University of Texas Health Science Center at Houston, United States

*CORRESPONDENCE
Cary Wu
carywu@yorku.ca
Yue Qian
yue.qian@ubc.ca

†These authors have contributed equally to this work

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The gender peak effect: Women are most vulnerable to infections during COVID-19 peaks

Cary Wu [1*†] and Yue Qian [2*†]

[1]Department of Sociology, Faculty of Liberal Arts and Professional Studies, York University, Toronto, ON, Canada, [2]Department of Sociology, Faculty of Arts, University of British Columbia, Vancouver, BC, Canada

In this article, we describe a gender peak effect that women's relative share in COVID-19 infections increases when there is a sharp increase in cases, and it reaches the highest level during peak times in each wave of the COVID-19 outbreak. We demonstrate this gender peak effect by analyzing detailed, sex-disaggregated Public Health Agency of Canada (PHAC) data. The data include 1,045,998 men and women who were confirmed cases of COVID-19 from March 2020 to February 2022. We show that women's relative share in COVID-19 infections always increases and reaches the level exceeding men's share when we see a sharp peak in case number. We further show that women's higher share in care work (e.g., captured by occupation and age variables) largely explains their elevated infections during COVID-19 peaks. Effective public health interventions during infectious disease outbreaks must recognize this potential gender peak effect and take appropriate measures to curb women's health vulnerabilities.

KEYWORDS

gender, COVID-19 peaks, care work, Canada, infection

Introduction

Success in public health requires effective and equitable responses to disease outbreaks. A fundamental key to achieving such responses lies in pinpointing how people are unequally affected (1). In particular, women and men often fare differently in disease outbreaks. This is due to both biological sex features and socially constructed gendered responsibilities (2). The present COVID-19 pandemic is no exception (1, 3). A consistent pattern documented in almost all countries with sex-disaggregated data is that, if infected with COVID-19, men experience a higher risk of severe illness and death, compared with similarly-aged women (3–9). Scholars suggest that men's higher severity and mortality of COVID-19 are more likely due to biological sex differences (e.g., sex-based immune responses), although gender differences in health behaviors (e.g., smoking) and pre-existing conditions (e.g., diabetes, hypertension) could also play an important role (1, 3, 4, 8, 10).

By contrast, research on the overall difference in COVID-19 infections between men and women has reported mixed findings (5, 8, 9, 11–13). Still, two specific empirical findings seem consistent. First, differences in infection rates are age-dependent: women show higher infection rates than men in prime working ages but the reverse is true

in young or retirement ages (14). Second, women's higher representation in health- and care-related occupations explains a large portion of the differences in infection rates between women and men (5, 14). These findings suggest that the differences in susceptibility to COVID-19 infection between men and women are primarily a result of gendered work-family responsibilities that place women at the forefront of the pandemic (1, 3, 5).

Two years into the COVID-19 pandemic, there have been ebbs and flows of cases, but little is known about how gendered health impacts vary over the course of the pandemic. In this study, we seek to demonstrate that gender differences in infection rates are also time-dependent. Most notably, when there is a sharp increase in COVID-19 cases, women's infection rate increases disproportionately to exceed that of men.

There are two main reasons why women are most vulnerable to infection during COVID-19 peaks. First, given the infectious nature of COVID-19, women's predominant roles as caregivers within families and as frontline health care and community workers expose them to a high risk of infection (1, 3, 5). In the workforce of almost all countries, women represent the majority of frontline workers in health care and other essential high-contact jobs (2, 15). At home, women shoulder the majority of care work, including caring for not only children but also sick family members (3, 16). Caregiving demands from families and workplaces are likely intensified during COVID-19 peaks, thereby leading to a greater infection risk for women than for men.

Second, disease outbreaks, especially during peak times, often exacerbate pre-existing gender inequalities, which in turn exposes women to a high risk of infection (17). Pre-existing gender inequalities include, for example, women's disadvantage relative to men in access to support services, health care, medical treatments, and economic opportunities, which are often amplified during disruptive times when resources are much scarcer (18). Pre-existing occupational gender segregation and insufficient financial resources may compel women essential workers to continue performing on-site, high-contact jobs (15), which places them at elevated risk of infection especially when COVID-19 cases are rapidly rising. On the policy level, women's underrepresentation in leadership positions means that they wield little influence over the decision-making on outbreak responses (1, 19). As a result, women's needs are largely unmet (18), leaving them more vulnerable than men in times of peaked turbulence.

Taken together, we expect that, across major waves of outbreak in the pandemic, the share of women in COVID-19 infections increases as the number of confirmed cases rises, and it likely peaks when case number peaks. Further, we expect that women's higher share in care work largely explains their elevated infections during peak times.

Methods

We use detailed Public Health Agency of Canada (PHAC) data on confirmed cases of COVID-19. The current dataset (Release date: 11-02-2022) records a total of 1,048,575 people in Canada who tested positive for COVID-19 from 15 January of 2020 to 8 February of 2022. The dataset is a subset of the total counts reported by the health authorities across Canada since it only accounts for those where a detailed case report was provided by the provincial or territorial jurisdiction to the PHAC. The data include information on each confirmed case's episode time (week and year) and demographic characteristics such as gender, occupation, and age group. The 1,048,575 cases consist of 500,526 men (47.7%), 545,472 women (52.2%), and 2,577 case with gender "not stated" (0.25%). Our analyses in this article only include confirmed cases of women and men. Population estimates from Statistics Canada report that the resident population of Canada was 38,246,108 including 18,238,276 women (50.3%) and 19,007,832 men (49.7%), as of September 2021 (Statistics Canada 2021). Table 1 provides the summary statistics of key variables, overall and by gender groups.

Results

Figure 1 visualizes the gender distribution of COVID-19 infections by age group (Figure 1A) and occupation (Figure 1B). Two empirical patterns are clear. First, gender differences in infections are age-dependent. Among the prime working-age population (20–59 years), women account for a higher share of confirmed COVID-19 cases (i.e., infections) than men, whereas the reverse is true in younger age groups (0–19 years) and older age groups (60–69 years). Women's higher share in the age group of 80 or older is likely due to their longer life expectancy (14). Second, gender differences in infections change across occupational categories. The share of women in confirmed cases is much higher among health care workers, school or daycare workers/attendees, and long-term care residents, whereas in "other" and "not stated" occupational categories, women and men share equal representation. These patterns are consistent with previous research (14).

To provide further support that working-age women are particularly vulnerable, Figure 2 compares the share of women among COVID-19 cases and the share of women among the general population across age groups. Among the young age group (0–19), the share of women among COVID-19 cases is identical to the share of women among the general population. This changes among the prime working-age groups (20–59 years): the share of women is about 4–5 percent point higher among the COVID-19 cases than among the general population. In older age groups (60–79 years), the share of women among infected cases becomes 2–3 percent point lower than the share

TABLE 1 Summary statistics of key variables in analysis overall and by gender groups.

	Overall ($n = 1,048,575$)	Men ($n = 500,526$)	Women ($n = 545,472$)
Episode year			
2020	0.211	0.213	0.209
2021	0.593	0.611	0.577
2022	0.193	0.172	0.211
Not stated	0.003	0.003	0.003
Region			
Atlantic	0.011	0.011	0.011
Quebec	0.285	0.277	0.294
Ontario and Nunavut	0.350	0.351	0.347
Prairies the Northwest Territories	0.245	0.250	0.241
British Columbia and Yukon	0.109	0.112	0.106
Age group			
0 to 19 years	0.203	0.216	0.191
20 to 29 years	0.195	0.193	0.197
30 to 39 years	0.175	0.171	0.179
40 to 49 years	0.150	0.144	0.156
50 to 59 years	0.123	0.124	0.121
60 to 69 years	0.074	0.079	0.069
70 to 79 years	0.038	0.040	0.036
80 years or older	0.042	0.033	0.051
Not stated	0.001	0.001	0.000
Occupation			
Health care worker	0.061	0.025	0.093
School or daycare worker/attendee	0.010	0.004	0.016
Long term care resident	0.007	0.005	0.008
Other	0.512	0.542	0.486
Not stated	0.410	0.423	0.397
Hospitalization status			
Hospitalized and in intensive care unit	0.007	0.009	0.005
Hospitalized, but not in intensive care unit	0.034	0.036	0.031
Not hospitalized	0.645	0.643	0.649
Not stated/Unknown	0.314	0.311	0.314
Death			
Yes	0.011	0.012	0.010
No	0.932	0.937	0.927
Not stated	0.057	0.051	0.062

among the general population. Again, women's higher share in the age group of 80 or older is likely due to their longer life expectancy.

Finally, Figure 3 depicts the number of confirmed COVID-19 cases (blue line), the percentage of women in the overall confirmed cases (orange line), and the percentage of women in confirmed cases among care workers (including health care workers and school or daycare workers/attendees; gray line) as well as among non-care workers (amber line), from March 2020 (2020 week 8) to February 2022 (2022 week 4). Since the COVID-19 pandemic started in March 2020, Canada has been hit by five major waves including, roughly, the first wave from March to July 2020 (peaks in April 2020), the second wave from August 2020 to February 2021 (peaks in January 2021), the third wave from March to July 2021 (peaks April 2021), the fourth wave from August to November 2021 (peaks in September 2021), and the most recent fifth wave from December 2021 to February 2022 (peaks in January 2022). Clearly, the

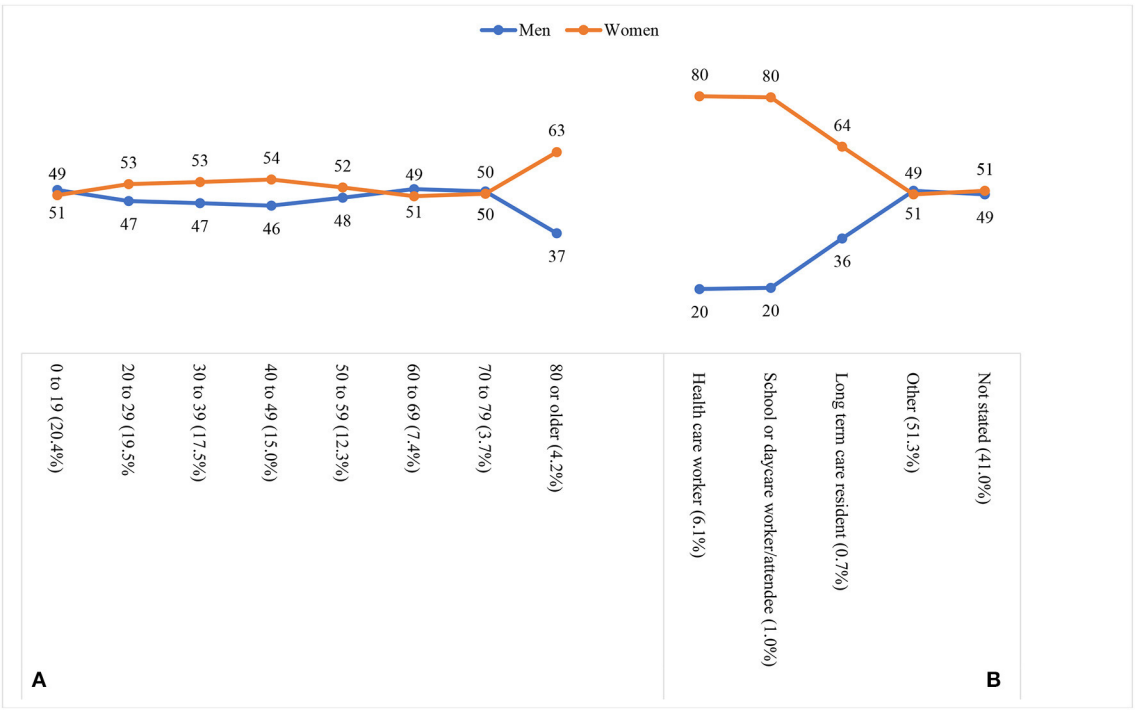

FIGURE 1
Gender distribution of COVID-19 infections by age group **(A)** and occupation **(B)**. The share of cases in each age group or occupation is indicated by the percentage in parentheses.

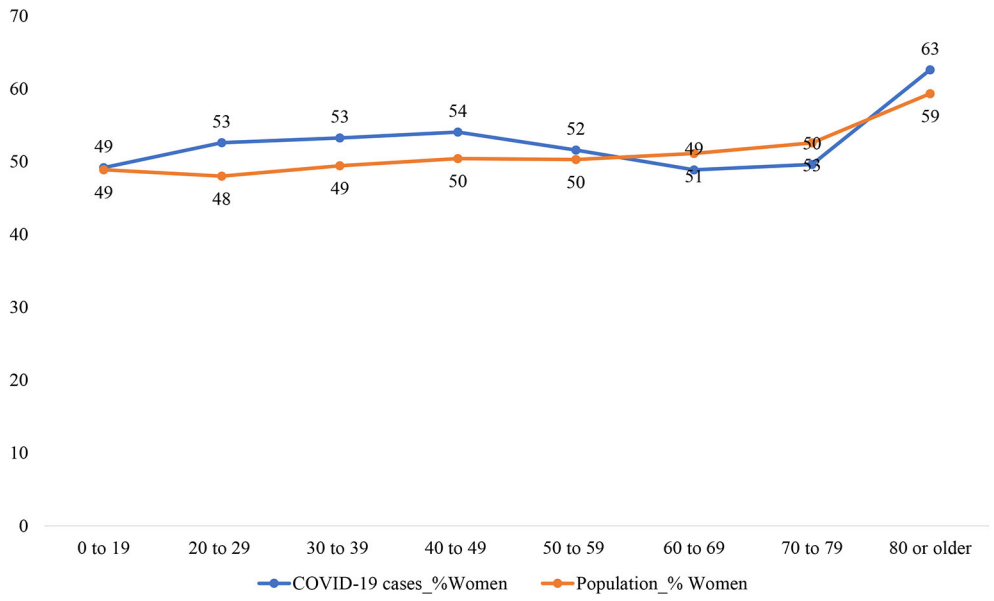

FIGURE 2
Comparing the share of women among COVID-19 cases and among the general population. The share of women among the general population is estimated using data from Statistics Canada (2021): doi: 10.25318/1710000501-eng.

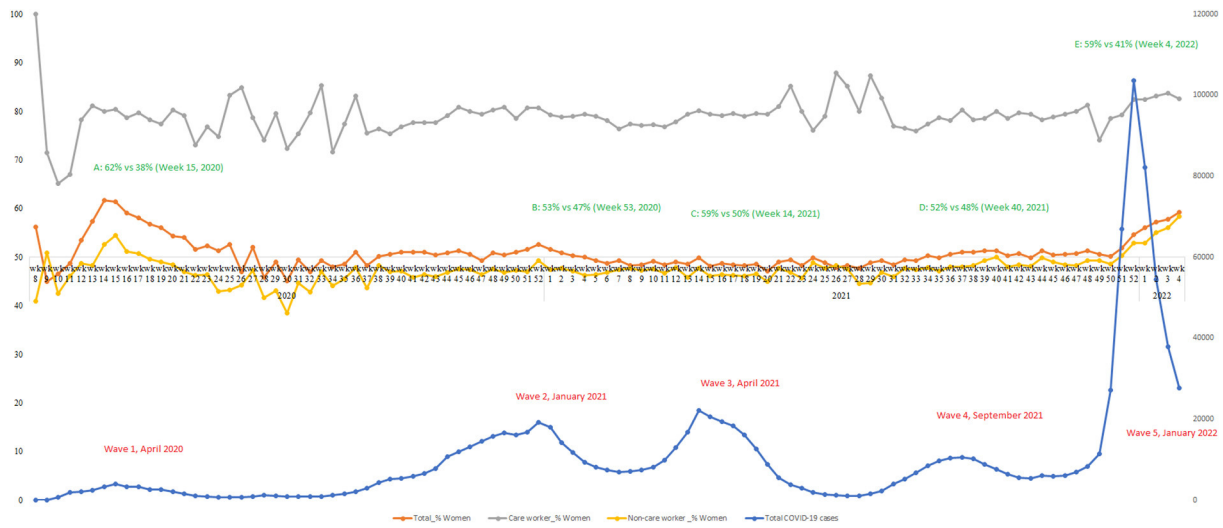

FIGURE 3
Gender trajectories of relative COVID-19 infections in Canada, 2020–2022.

share of women in COVID-19 infections (orange line) always showed an increase as the number of confirmed cases increased in each wave, and women's infections relative to men peaked (i.e., A–E) during each wave's peak time. One concern is that the gender pattern could come from the gender difference in vaccination rate. Our data do not include information about vaccination status for each individual. However, data from Government of Canada website on vaccination coverage show that overall women have higher vaccination rates than men. This is especially true among working age groups.

Further, to demonstrate that women's higher share in care work can largely explain women's elevated infections during peak times, we separate and compare the changes in the percentage of women in infections among care workers (gray line) and non-care workers (amber line). Among infections in care workers, women accounted for the vast majority of cases (80%). The high percentage of women in infections among care workers was relatively stable during COVID-19 peaks, and it showed more fluctuations when the number of total cases was relatively low. Among infections in non-care workers, women's share was mostly lower than men's over the course of the pandemic (reference line y-axis = 50%). Still, we see clearly that women's share often reached the highest point during COVID-19 peaks in each wave. These findings illustrate that women's higher share in care work (including work in health care and schools or daycare centers) largely explains women's elevated infections during peak times of the COVID-19 outbreak.

Taken together, our analysis yields two major findings. First, we show that the female-to-male infection ratio has always been higher during COVID-19 peaks as compared to non-peak times. Second, we show that women's higher representation in care work is likely the cause for the gender peak effect. It is important to note that our conclusion is based on our analysis of the *longitudinal* patterns in gender difference in infections, rather on gender difference in infections *per se*. In other words, we compare changes in gender difference in infections during COVID-19 peaks and non-peak times. Many factors could create gender differences in infection rate. But these factors are unlikely to change during a short period, and therefore they are not the cause for the time-dependent gender patterns. For this reason, we have argued that the time-dependent gender patterns are likely a result of women's higher representation in care work that makes women, working-age women in particular, especially vulnerable to infections during COVID-19 peaks.

Discussions and public health implications

Infectious diseases that can be transmitted through human contact are occurring more often now than ever. Recent outbreaks include the 2002–2004 SARS, the 2013–2016 Ebola, the 2015 Zika virus, and the ongoing COVID-19 pandemic. Underlying the emergence of these outbreaks are global changes such as population growth, urbanization, climate change, and the increase in international travel and human connectivity (20). These changing global dynamics likely make future outbreaks even more lethal. For this reason, the World Economic Forum's 2020 Global Risks Report has listed infectious diseases as one of the top 10 risks in terms of impact for the next decade (21).

A key lesson from these outbreaks is that success in global public health requires responding to disease outbreaks effectively and equitably (17). Because of biological sex differences and societal gender inequalities, scholars have called

for attention to understanding and responding to the gendered impacts of COVID-19 outbreaks since the very beginning of the pandemic (1). Previous research on gender differences in COVID-19 infections has focused on the role of age and occupation in shaping gendered patterns of infections (5, 14). Despite the evolving nature of infectious disease outbreaks, few studies have considered the time dimension of gendered health impacts over the course of the pandemic, a gap that we have filled in this study.

In this study, we have shown that gender differences in infections during COVID-19 outbreaks are time-dependent. When there is a sharp peak in COVID-19 cases, the share of women in COVID-19 infections always increases to a level exceeding the share of men. We have also revealed that women's higher share in care work largely explains their elevated infections during peak times. These findings suggest that women's predominant roles as caregivers in families and workforces expose them to a high risk of infection during COVID-19 peaks. Pre-existing gender inequalities in financial resources, access to health care, and decision-making power in the policy realms may further disadvantage women in times of rising infections (18).

Our finding calls for attention to the particular vulnerability that women experience during the peak times of COVID-19 and potentially future infectious disease outbreaks. When understanding differences in susceptibility to disease infection across segments of the population, time is a critical dimension because disease outbreaks usually last an extended period and different new variants likely emerge to increase the spread of the virus. When a disease outbreak occurs, researchers and policymakers should monitor how gender disparities change at different stages of the outbreak, and design response policies accordingly. Including gender and sex dimensions in public responses will help not only ensure effective and equitable responses but also minimize the chances that disease outbreaks reproduce or exacerbate gender inequalities (1, 18, 22).

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: https://www150.statcan.gc.ca/n1/en/catalogue/13260003.

Author contributions

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

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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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EDITED BY
Caress Alithia Dean,
Oakland University, United States

REVIEWED BY
Adarsh Srivastav,
Chhatrapati Shahu Ji Maharaj University, India
Alpo Juhani Vuorio,
University of Helsinki, Finland

*CORRESPONDENCE
Eva Krczal
eva.krczal@donau-uni.ac.at

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COVID-19 triggered a physically active lifestyle of people with cardiovascular diseases: Results of a small Austrian qualitative study

Eva Krczal* and Walter Hyll

Department for Economy and Health, University for Continuing Education Krems, Krems, Austria

Objective: This paper explores physical activity patterns and compensation strategies of people with cardiovascular diseases. The aim is to provide insights into the factors and their relationships that may affect physical activity levels positively or negatively during the pandemic.

Methods: We adopted a qualitative approach with 35 participants who were purposively sampled from different provinces in Austria, including rural and urban areas. Semi-structured interviews were conducted during the second COVID-19 wave in autumn/winter 2020 and the fourth wave in autumn/winter 2021. Content analysis was applied to explore physical activity patterns, the perceived impact of the pandemic on physical activity as well as strategies adopted by participants to maintain physically active during the pandemic waves.

Results: Results show encouraging signs of a recovery or even increase in physical activity during the pandemic waves. The main drivers for maintaining or even increasing physical activity were intrinsic motivation and self-determined motivation relating to the pursue of individual health goals. Furthermore, analysis suggests a reinforcing effect of exercising in green natural areas by decreasing perception of effort and increasing motivation. There was also one group who experienced difficulties in adapting physical activity behaviors. Study participants who were used to exercise indoors struggled to replace accustomed activity patterns with alternatives that were not impacted by lockdown restrictions.

Conclusions: This study provides novel qualitative evidence on the effect of COVID-19 lockdowns on physical activity patterns of people with cardiovascular diseases. Public health interventions to enhance a physically active lifestyle during and beyond the COVID-19 pandemic are recommended to target moderate outdoor exercising and enhance adaptive capacities of people with cardiovascular diseases.

KEYWORDS

physical activity (exercise), cardiovascular diseases, COVID-19, lockdown, coping strategies, outdoor exercise, intrinsic motivation

Introduction

Since the onset of the SARS-CoV-2 pandemic, first reported in December 2019, political decision makers worldwide have adopted unprecedented measures to limit people's exposure to the virus and contain the spread of the disease (1). On the one hand, Public Health measures like social distancing, staying at home and the closing of cultural and sports facilities had been adopted to break the transmission of the virus. On the other hand, the same type of interventions negatively affected people's mental and physical health. During the lockdown phases, the population has developed a lifestyle characterized by lack of mobility, unhealthy diet, increased depression, loneliness, and psychological distress (2–6). Recent reviews indicate a decrease in physical activity and an increase in sedentary behavior across different populations during the lockdowns (7–9). It is not surprising that people who exercise in their free time are less likely to do so, for example, because of the closure of gyms. Limited physical activity, however, has the potential to increase the risk of many severe and disabling disorders (10). A reduction in physical activity and modified eating habits increase insulin resistance, total body fat, abdominal fat, and inflammatory cytokines, which in turn increase the risk of multiple chronic disease (11).

This paper addresses the question, how lockdowns affected physical activity patterns of people who need to exercise for health reasons, namely cardiovascular disease (CVD) patients. Physical inactivity represents an established risk factor for developing cardiovascular diseases and may have detrimental effects on those already affected (12–16). For CVD patients it is therefore essential for their disease management to practice physical activity on a regular basis. Since preexisting cardiovascular diseases increase the risk of experiencing severe COVID-19 complications (17), CVD patients represent a highly vulnerable group in consideration of the pandemic. Consequently, they were advised to take extra social-distancing measures. Vulnerable individuals were expected to be highly cautious during the pandemic to avoid a potential contact with the virus, thus limiting their opportunities for physical activities further. In addition, assuming that contacts to their physician or physiotherapist declined, the constant monitoring of adherence of stipulated exercise programs was interrupted.

Few studies exist, that focus on the impact of the pandemic on CVD patients' physical activity levels during the first *lockdown* waves. These studies show a decline in physical activity of CVD patients (18–23). There is one study suggesting that most study participants maintained or even increased their normal physical intensity during the first lockdown in UK (24). This study included stroke and heart disease patients in the sample. Yet, there is scarce evidence on the physical activity patterns of CVD patients over a longer time span including the *post-lockdown* period. One longitudinal study assessed changes in physical activity and sedentary behavior in Dutch CVD patients across the various phases of the COVID-19 lockdown between April and July 2020 (25). According to the authors, even when COVID-19 lockdown restrictions were gradually lifted, physical activity levels did not significantly change. Also, a US study on the physical activity patterns of CVD patients from two large cities confirmed a decline in physical activity during the first lockdown in spring 2020, which did not fully recover until October 2020 (26).

In this study, we, focus on a longer time span including the second/fourth waves on the one hand and, point to a maintenance or even an improvement in the physical activity level of CVD patients on the other hand. In an exploratory approach people with CVD were interviewed about their health behavior and physical activity patterns. Interviews were conducted during the successive waves of the pandemic in autumn/winter 2020/21 and autumn/winter 2021/22. Most study participants reported that they were able to maintain or even improve their physical activity level during the waves of the pandemic. These findings raise interest in the factors that influence physical activity patterns and adaptive capacities. We contribute to the existing literature in several ways. First, we provide additional evidence on the effects of a lockdown on physical activity of CVD patients up to January 2022. Second, the study is pointing to a recovery of physical activity levels during the course of the pandemic. Third, we outline determinants that may influence physical activity patterns as well as compensation strategies to restore physical activity levels throughout the pandemic.

A deeper understanding of the motives and experiences of people with CVD, when maintaining or adjusting their physical activity patterns throughout the pandemic, contributes to designing adequate public health interventions. These are necessary to enhance a physically active lifestyle during and beyond the COVID-19 pandemic.

Materials and methods

Data collection

The present research was part of a qualitative study exploring participants' perceptions on the impact of the pandemic on their lifestyles as well as their strategies to manage their disease and maintain a healthy lifestyle throughout the pandemic. During the interviews, physical activity emerged as a major concern for study participants. Therefore, this paper focuses on the physical activity patterns of study participants, the perceived impact of the pandemic on physical activity as well as strategies to maintain physical activity during the pandemic waves. A qualitative approach was adopted to explore perceptions, challenges

Abbreviations: CVD, Cardiovascular Diseases; SDT, Self-Determination Theory.

and experiences from the perspective of participants and to provide insights into the complex relationships that may cause an increase or decrease of physical activity during the pandemic (27).

Selection criteria were set in advance. Participants were chosen along three dimensions: gender, age, and residence (urban or rural areas). The criteria are depicted in Table 1. The aim was to find a participant for each combination, which was almost achieved. Eligible participants were persons 40 years or over with cardiovascular diseases [diagnosed with heart failure or coronary heart disease, received bypass surgery, stent or cardioverter-defibrillator (ICD) implantation]. Exclusion criteria were incapacity to give informed consent and incapacity to articulate answers to interview questions without the help of others. The sampling strategy relied on a combination of convenience and purposive sampling (28). The initial strategy was to recruit participants by distributing an invitation to participate at the interviews at general practitioners' or specialists' practices and self-help groups in the field of heart failure. This strategy did not produce any response from eligible persons. Therefore, participants were recruited using existing personal contacts by research assistants working in health and social care. That is, participants stem from conveniently available sources. All persons, who were addressed personally, agreed to participate in the study and attended the interviews. Semi-structured interviews were conducted with 35 persons, who received health services in different provinces of Austria and from different care providers. Further, study participants differed in their perceived impairment of physical performance due to their disease or other comorbidities. As outlined above, purposive sampling was applied to account for diversity among study participants, to obtain relevant and diversified data relating to the research topic and to mitigate challenges of limited representativeness resulting from a convenience sample (28). Interviews were conducted by mutual agreement between interviewer and interviewee face-to-face in compliance with the applicable COVID-19 safety regulations or via zoom. Study participants were recruited during the pandemic waves in autumn/winter 2020/21 and 2021/22. Eleven interviews were conducted during the second wave between 2020-11-24 and 2021-02-05, another 24 interviews took place between 2021-10-27 and 2022-01-10 during the so-called "lockdowns light" in Austria. The study has been approved by the Ethics Commission of the University for Continuing Education, Krems (No. EK GZ17/2021-2024).

Interviews followed an interview schedule asking pre-defined questions, whereby modifications of questions or the introduction of new ones made room for unexpected and promising themes that emerged during the interviews. The interview schedule is provided in the Supplementary Table 1. At the end of the interview, socio-demographic data of study participants were collected with a short questionnaire. For a better contextualization of the physical activity patterns, study participants were asked to rate their perceived physical impairment due to the perceived burden of disease or other comorbidities following the New York Heart Association (NYHA) Classification (29).

Interviews were audio-recorded, anonymized and transcribed verbatim with annotations, which accounted for pauses, intonations, and nonverbal expressions of study participants to enrich answers with non-verbal information (30). All study participants provided written informed consent.

Analysis

Content analysis was applied to produce a systematic and comprehensive overview of the data set based on participants' statements concerning physical activity patterns, the influence of the pandemic on them, and experiences when maintaining physical activity during the pandemic (31). Content analysis was used to explore, for example, how often certain strategies were mentioned and what these strategies were (31). Specifically, interviews were analyzed according to the content structuring qualitative content analysis (32). This method follows a structured process for arranging and analyzing interview data. The analytic procedure started with getting familiarized with the data by reading through transcripts, highlighting important text segments, writing memos, and case summaries. One third of transcripts was analyzed in this initial step by two researchers separately. Following initial text analysis, thematic main categories were developed, which formed the basis for structuring interview data. Three main categories were defined deductively based on the research question ("*Physical activity patterns*," "*Impact of the pandemic on physical activity patterns*," "*Strategies to maintain physical activity*"). In addition, another two main categories inductively derived from themes that emerged from the transcripts ("*Motivation for physical activity*," "*Influencing factors*"). After the main categories and their descriptions have been developed, all data were coded along the main categories by two researchers independently. Coding of data involved assigning meaningful text segments to correspondent thematic main categories. Whenever text passages included different themes, multiple coding was applied (32). Coding of transcripts was aided by the qualitative data analysis software MAXQDA version 20 (www.maxqda.de/). After all data were coded along the main categories, sub-categories were inductively developed for a more refined structuring of the data set. The development of sub-categories involved compiling all text segments coded within the same main category to get an overview of relevant themes. Sub-categories were then defined according to central topics that emerged from the text. For the further course of analysis, definitions for sub-categories were formulated and supplemented with sample quotes. Next, all transcripts were

TABLE 1 Selection matrix.

	Age				
	40–49	**50–59**	**60–69**	**70–79**	**80+**
Residence					
Big city (100,000+ residents)		f VK3	f JC3 m KS1 m KS3 m KS4 m PJ3	m HB2 m HB3 f JC1 f PP2 m PP1 m PP3	f HB1 m PP4
Small town (3,000–99,000 residents)		f JC4 m KS2 m PJ2	f VK1		m JC2
Rural area (<3,000 residents)	f EL2 f EL3	f EL1 m EL6 f EL7 m EL9 f EL11	m HB4 f EL10 m PJ4 m VK2	m EL4 m EL5 m EL8 m VK4	f PJ1

f, female; m, male. Eligibility criteria: age 40+, cardiovascular disease diagnosed before the pandemic, heart failure or coronary heart disease or bypass surgery, stent or cardioverter-defibrillator (ICD) implantation. Exclusion criteria: incapacity to give informed consent, incapacity to articulate answers to interview questions without the help of others.

coded once again along sub-categories. In an iterative process, coding was refined through review and further analysis. This procedure involved the creation of new sub-codes or the re-evaluation and re-definition of existing sub-codes. For example, Organismic Integration Theory (33), a sub-theory of Self-Determination Theory (SDT), emerged as a promising theoretical background to explain participants' motivation to maintain physical activity. Therefore, sub-codes on motivational factors have been reorganized following the Organismic Integration Theory.

Finally, the coded text segments were analyzed along the main categories to reach an overview of themes that emerged from the strategies and experiences of study participants regarding physical activity during the pandemic. In addition, possible connections between main categories and sub-categories were analyzed to explore complex relationships between main themes emerging from the data.

Results

Sample characteristics

Socio-demographic data of study participants are presented in Table 2. Study participants were living on average about 11 years (mean 11.06, *SD* 9.45) with their disease. Three participants were living with heart failure since birth or early childhood (not included in calculation of mean years of disease). Most study participants were male (63%), between 60 and 79 years old (56%), and lived in a partnership (83%). During the interviews, study participants indicated that they were embedded in a social network receiving support from their partner, family members, or friends during the pandemic. Analyses of transcripts revealed that participants displayed a good self-management of their disease (measuring blood pressure and weight daily or at least weakly, regular medical check-ups as advised by their physician or specialist, awareness of the importance of physical activity, and nutritional intake). Study participants mentioned that they attended regular physical therapy before the lockdowns (HB1, HB3, JC1), others outlined that they received exercise education during their rehabilitation stays before the pandemic (EL5, HB3, PJ1, PH4). Another group noted that they have learned physical exercises from regular attending group courses or a personal trainer (EL6, EL7, PJ3).

Main categories

Qualitative content analysis yielded five main categories: "*Motivation for physical activity*," "*Physical activity patterns*," "*Impact of the pandemic on physical activity patterns*," "*Strategies to maintain physical activity*," and "*Influencing factors*." Table 3 displays these main categories, sub-categories, and the number of corresponding quotes. For example, seven quotes refer to intrinsic motivation as a driver for participating in physical activity. A description of main and sub-categories as well as sample quotes are provided in Supplementary Table 2.

TABLE 2 Participant characteristics.

Characteristic	Categories	$N = 35$
Gender	Female	13 (37%)
	Male	22 (63%)
Age	40–49	2 (6%)
	50–59	9 (26%)
	60–69	10 (28%)
	70–79	10 (28%)
	80+	4 (12%)
Employment status	Employed	9 (26%)
	Partial retirement	2 (6%)
	Retired	24 (68%)
Relationship status	Single	6 (17%)
	Partnership	29 (83%)
Residence	Big city	14 (40%)
	Small Town	5 (14%)
	Rural area	16 (46%)
relationship status	Single	6 (17%)
	Partnership	29 (83%)
Perceived physical impairment (NYHA-Classification)	I (none)	7 (20%)
	II (mild)	7 (20%)
	III (moderate)	15 (43%)
	IV (severe)	6 (17%)

TABLE 3 Main codes, sub-codes, and frequency of physical activity patterns during the pandemic.

Main codes and sub-codes	Frequency
1. Motivation for physical activity	**52**
1.1 Intrinsic motivation	7
1.2 Integrated regulation	6
1.3 Identified regulation	32
1.4 Introjected regulation	1
1.5 External regulation	2
1.6 Amotivation	4
2. Physical activity patterns	**47**
2.1 Moderate outdoor exercise	11
2.2 Moderate to vigorous indoor exercise	10
2.3 Moderate to vigorous exercising at home	7
2.4 Leisure behavior	19
3. Impact of the pandemic on physical activity patterns	**93**
3.1 Continuation of moderate physical activity with no	13
restrictions	20
3.2 Cessation/reduction of moderate to vigorous physical exercise	18
3.3 Continuation of leisure behavior with no/minor restrictions	42
3.4 Cessation/reduction/modification of leisure behavior	
4. Strategies to maintain physical activity	**80**
4.1 Integration of walking into daily routine	12
4.2 Integration of moderate exercising at home into daily routine	25
4.3 Increase in outdoor leisure activities	19
4.4 Increase in moderate outdoor exercise	4
4.5 Introduction/increase of moderate to vigorous outdoor	2
exercise	8
4.6 Replacement indoor exercise by moderate outdoor exercise	3
4.7 Replacement indoor exercise by moderate to vigorous exercise	8
4.8 Resuming physical exercise due to release of measures	
5. Influencing factors	**55**
5.1 Physical impairment	22
5.2 Time of the year	5
5.3 Availability of time	9
5.4 Partner, friends	7
5.5 Availability of garden/proximity to green natural areas	12

Motivation for physical activity

Analysis of transcripts revealed that participants were motivated for engaging in physical activity mostly for self-determined reasons. Engagement in physical activity to achieve desired health outcomes emerged clearly as the most frequently cited and emphasized motive among study participants. This attitude relates to "*Identified regulation*," a moderate form of self-determined external motivation (34). Being physically active was believed to be an essential part of participants' disease-management supporting them to remain healthy. In particular, regular practice was considered important to strengthen the heart muscle or to boost the immune system. Other motives for engaging in physical activity related to a change in lifestyle after a heart attack or to strengthen physical fitness after an operation. For some study participants, being physically active was considered a promising strategy to cope with the pandemic:

> *"And I'm sure if I hadn't done that before, I wouldn't have survived. So, if I had just been sitting around and stuff." [HB2: 50–50]*

Next, analysis of transcripts revealed expressions relating to *"Intrinsic motivation"* (31) among certain study participants. Being physically active was associated with feelings of pleasure, enjoyment, and fun. One participant explained:

> *"And that did me a lot of good, because you feel better afterwards." [EL2: 103–103]*

Some study participants indicated that they have incorporated physical activity in their personal value and belief system by emphasizing that they considered themselves as physically active persons. Motives relate to the *"Integrated regulation"* dimension, the most self-determined form of external motivation (34). One participant claimed:

> *"I am physically even better off than the so-called healthy people, because I have done sports every day. Always. Before, after, and during Corona." [KS3: 10–10]*

It appeared that only a few study participants were physically active for extraneous motives. Two study participants made a comment that their physician advised them to exercise regularly, which belongs to the *"External regulation"* dimension of external motivation (34).

In summary, it was apparent that most study participants were motivated to be physically active for self-determined reasons.

Physical activity patterns

Different physical activity patterns were driven by study participants' individual preferences and perceived physical impairments. Table 4 provides descriptions and examples of physical activity patterns that emerged from the analysis. One group preferred moderate outdoor exercise, for example hiking or biking. Another group favored moderate to vigorous indoor exercise, such as training in a fitness club. Other study participants reported moderate to vigorous exercising at home.

For some participants, going out for a walk represented an essential component of their physical activity program. Furthermore, some participants considered leisure behavior like going shopping, doing housework, or gardening as vital part of their daily physical activities.

From the text analysis it became apparent that the reported intensity and duration of physical exercise was subject to individual framing and perceived physical impairment. For example, exercising 30 min gymnastics in the morning was considered either the prime component of daily exercising for one study participant with major physical restrictions or one element, among other daily activities, for another study participant with minor restrictions.

Impact of the pandemic on physical activity patterns

Insights gained from the analysis showed that study participants experienced the impact of the pandemic on their physical activity patterns in different ways. Those study participants who were used to exercise outdoors stated that they didn't feel much difference during the pandemic because they had the same possibilities to be physically active compared to pre-COVID-19 times. One study participant explained:

> *"I don't go to fitness studios anyway. I move in the great outdoors. I go for walks and hikes." [PJ4: 37–37]*

Another study participant pointed out that he used to exercise with a private personal trainer, and they continued training throughout the pandemic. Physiotherapy and rehabilitation on the contrary, were reported to be canceled at least during the first lockdown.

Also, those study participants, who were used to practice regularly at home, continued their exercise as usual. One study participant emphasized:

> *"Exercises and I do all that myself... I did all that and I still do it exactly the same today." [PJ1: 69–71]*

Gardening or hobbies in green natural areas like collecting mushrooms in the forest represent typical leisure activities, which were not perceived to be affected by lockdown restrictions:

> *"And that [gardening] was actually a continuous activity that has remained. Nothing has changed." [KS4: 132–132]*

Another theme, that emerged from the interviews, was the cessation or reduction of moderate to vigorous indoor exercise. Due to lockdown restrictions, public sport facilities and fitness clubs had to close several times depending on current infection rates. Even when fitness clubs or rehabilitative facilities reopened after the lockdowns, there was some reluctance to resume exercising, because certain study participants, considering themselves as high-risk persons, preferred to limit potential contact with the virus.

In contrast, outdoor sporting facilities were allowed to reopen soon after the first lockdown in March 2020. Study participants who, for example, were used to practice golf could resume their physical activities after a few weeks. Another study participant mentioned that she could resume individual physiotherapy after 6 weeks following the announcement of the first lockdown.

Finally, the impact of the pandemic situation on leisure activities, that involved walking, was discussed during the interviews. The continuation or reduction of routine activities like going shopping was perceived to impact daily steps. Especially, study participants, who were used to go out frequently for entertainment, experienced radical changes in leisure activities with the closing of restaurants, pubs and cultural events. Consequently, they reported a reduction of daily movements. One study participant reflected:

> *"One becomes somehow, something like pensionistic.... you don't move out, you don't have the social, active life. The exhibitions were all canceled, all the activities, going abroad and so on, that was all gone. My whole leisure life was completely stopped." [VK2: 59-59]*

TABLE 4 Description and examples of physical activity patterns derived from content analysis.

Physical activity patterns	Description and examples
Moderate outdoor exercise	Moderate forms of outdoor exercise: powerwalking, hiking, biking, golf, archery, skiing
Moderate to vigorous indoor exercise	Moderate to vigorous forms of exercise using indoor sport facilities: group fitness, exercising in a fitness club, swimming, team sport, aerobics
Moderate to vigorous exercising at home	Moderate to vigorous forms of exercising at home: gymnastics at home, TV-led exercise programs, Cardio-training at home
Leisure behavior	Walking and other leisure behavior: going shopping, housekeeping, gardening

In summary, experiences on the impact of the lockdown restrictions related to accustomed physical activity patterns. Study participants, who were used to indoor sport and going out for entertainment, appeared to be discouraged by continued lockdown restrictions, while study participants, who were used doing outdoor exercises or who possessed a garden, claimed to be hardly affected by restrictions. Some individuals from this group even expressed positive associations with the pandemic situation, which offered to them opportunities for relaxation, recreation, and creativity.

Strategies to maintain physical activity

Study participants adopted different approaches aiming to remain active during the pandemic. One strategy that emerged from the transcripts was the integration of regular exercise into daily routine, thus increasing the frequency (and duration) of physical activity. Going out for a walk and walking instead of using public transport became a preferred mode for leaving home, getting out, and practicing physical activity.

> *"And just go for a walk a lot.... we've really been walking since Corona, now the second lockdown, three, four kilometers every day. Even when it is already dark, we go our rounds." [EL1: 47–47]*
>
> *"And I walked five or six kilometers every day, in an hour or an hour and a half. That's actually how it all started. Although I have actually walked before, powerwalking you have to say, I just walked more." [EL11: 3–3]*

Next, study participants engaged in regular exercising at home using home training equipment or performing exercises they have learned from their therapist or from group training:

> *"Because I have had a lot to do with physiotherapists in the last three years. And I've actually picked up quite a lot from them that I can use for myself when I have a pain. In addition, I have always been pretty well briefed by the sports union, (…) which you can actually perform yourself. And a lot has been actually stuck." [EL7: 49–49]*

Other study participants attended TV or online-training programs. However, it appeared from the transcripts that exercising at home was considered a poor alternative for group training, because study participants missed the group feeling:

> *"And the first shock is then again: ah, now we can't go again. And then you try to do something at home. (...) You already do your exercises, but the key is always to go somewhere and exercise together in a group." [EL6: 117–117]*

> *"During the lockdowns, the fitness clubs also offered online-Zumba and then you jump around in front of your laptop in the kitchen and feel relatively stupid. The main problem is that these sports have to be fun, otherwise I don't do them permanently. For example, Zumba depends a lot on having a nice group and a good trainer. And of course, the group experience is gone when I'm jumping around in front of the computer. No, the motivation is much more difficult." [VK3: 61–6].*

Another strategy that emerged was the replacement of indoor activities by outdoor activities. The most favorite outdoor activities were moderate activities like hiking and biking.

> *"It was actually a compensation. What would you have done? As I said, you used to go to the gym, two or three times. It was actually the morning occupation. And then I just went out for a walk almost every day." [HB4: 32–32]*

Fewer participants engaged in moderate to vigorous outdoor exercising. One participant reported regular training in an outdoor parcour, another one reported to have intensified regular outdoor cardio training. Other replacement strategies included swimming in the lake instead of using the public swimming pool or chopping wood instead of training in the gym.

In summary, there were encouraging signs amongst most study participants to adopt a proactive approach in maintaining physical exercising during the pandemic waves.

Influencing factors

Transcripts contained descriptions of influencing factors which acted either as facilitators or barriers to physical activity.

The availability of a garden or the proximity to green natural areas facilitated engagement in outdoor activities. In fact, the availability of a garden emerged as a welcome opportunity to be physically active in a private and safe environment:

> *"Well, because of the garden, the possibility to move and to do something useful is quite big … I didn't do anything in a gym before and I didn't do anything after, so this is all happening at home. There have been no restrictions at all." [KS1: 46–46]*

Also living close to green natural areas encouraged study participants to be physically active.

> *"And actually, I started walking and I didn't go into the town or anything like that, only out in the fields and into the meadows." [EL11: 3–3]*

For some study participants the time of the year played an important role for their motivation to exercise:

> *"At the first lockdown, you have to remember that the weather was different. You had beautiful days there. Those days have lasted longer. (...) Everyone was looking forward to being outside. Many people went outside. Now, the second lockdown is like this: at four o'clock it's dark. And in my opinion, people will become more depressed now. Because it's dark, it's cold." [EL2: 11–11]*

Availability of time emerged as enabler for practicing physical activity. Many study participants were already retired. They had the timely resources to organize their daily activities. Others had more time available because they were classified as high-risk persons and could stay at home for sickness leave. A few participants noted that they had home office arrangements with reduced working times. Home office arrangements allowed a better time management for integrating physical exercises into daily routines.

The social network (partner, family, friends) appeared to act in both ways, either encouraging or limiting physical activity. The accompaniment of a partner, friends, or a dog seemed to motivate study participants to engage in regular exercising. On the other hand, a partner who is not willing or able to practice may reduce physical activity. Study participants outlined that family members or partners did the shopping. On the one hand, this was a measure to limit possible exposure to the virus, on the other hand, it was reducing daily steps.

Cross-category analysis

Analysis of main categories is supplemented by an exploration of the relationships between categories to provide a more contextualized and comprehensive picture of the impact of the pandemic on physical activity patterns. Cross-category analysis revealed interconnections and interactions between main categories in different ways. Apart from the connection between "*Physical activity patterns*" and "*Impact of the pandemic on physical activity patterns*" the most obvious connections that emerged from analysis are presented in this section.

For a better contextualization of those relationships, study participants were grouped into three categories: One group reporting a perceived increase in physical activity during lockdowns, a second group claiming to have maintained their level of physical activity, and a third group who felt that their physical activity had decreased. We exclude seven participants from this analysis, because, due to external factors, an adjustment of the activities was not at their discretion. One participant reported an increase in physical activity due to his recent rehabilitation stay. Five participants reported a decrease in physical activity due to an injury, comorbidity, or aggravation of disease. Another participant made the point that his physical activity was not impacted by the pandemic because he was never much engaged in physical activity before, during and after the pandemic. Table 5 summarizes changes in physical activity patterns as well as motivational factors indicated by participants.

Cross-category analysis between "Motivational factors" and "Strategies to maintain physical activity"

The first group represents six study participants (21%) who claimed to have increased their physical activity by increasing frequency and duration of walking and/or moderate outdoor exercises (see Table 5). These individuals pointed out that they were already engaged in walking and moderate outdoor activities before the pandemic and continued or even increased exercising throughout the pandemic.

> *"I just look forward to walking every day in the morning or afternoon, for me personally (...), I have to say that I have been moving more, quite simply. And that I just enjoy it." [EL11: 233–233]*

Similar connections have emerged from the analysis of the second group, composed of fourteen study participants (50%), indicating that they maintained their level of physical activity (see Table 5). Seven participants continued with outdoor leisure activities like walking or gardening and moderate exercising outdoors or at home, because these activity patterns were not

TABLE 5 Changes in physical activity and motivational factors.

	Motivational factors				$n = 28$
	Intrinic motivation	**Integrated regulation**	**Identified regulation**	**Not reported**	
Changes in physical activity patterns					
Increase in physical activity					**6 (21%)**
Increase in walking	1		1		2 (7%)
Increase in outdoor exercising	2		2		4 (14%)
No changes					**14 (50%)**
Continued as usual			4	3	7 (25%)
Indoor exercising replaced by outdoor exercising	1	4	2		7 (25%)
Reduction of physical activity					**8 (29%)**
Regular exercising at home but less walking			3		3 (11%)
Less indoor exercising			1	3	4 (14%)
Less walking				1	1 (4%)

Percent refer to total number of participants.

affected by lockdown restrictions. The other seven participants replaced indoor exercising by longer and more frequent outdoor leisure activities (walking, gardening) and/or moderate to vigorous exercising outdoors or at home (for example, replacing group training by online-training at home). These individuals reported to be frequently engaged in different physical activities.

Insights from the analysis of the first and the second group revealed intrinsic motives, thus indicating a relationship between "*Motivational factors*" and "*Strategies to maintain physical activity*," specifically between "*Intrinsic motivation*," "*Integrated regulation*," and "*Increase in outdoor leisure activities*" as well as "*Increase in moderate outdoor exercise.*".

Cross-category analysis between "Availability of garden/proximity to green natural areas" and "Impact of the pandemic on physical activity patterns"

Analysis of the second group revealed another interaction, namely between the influencing factor "*Availability of a garden/proximity to green natural areas*" and "*Impact of pandemic on physical activity patterns*." Eleven participants (out of 14) from this group were living in rural areas or possessed a garden or a second home in rural areas. Study participants noted that having an own garden enabled them to pass lockdowns without major restrictions. Similarly, study participants living close to green natural areas noted that it was easy for them to continue or even increase outdoor activities:

> *"With sport and with fresh air the first lockdown went pretty well." [EL6: 7–7]*

The third group consists of eight study participants (29%) indicating that their level of physical activity has decreased (see Table 5). One group of three participants noted that they continued with regular moderate exercising but noticed a decrease in general movements (going shopping, going out). Two of those lived in an apartment in a big city. Another group of four study participants indicated a reduction in physical activity due to a decrease in moderate to vigorous exercising. These were all individuals accustomed to indoor training and explained that they did not find adequate alternatives during the lockdowns. Three of them were living in urban areas, two in an apartment. Finally, one person mentioned a reduction of general movements (less going out) until vaccination was received. Also, this participant lived in a big city.

Insights from the third group reveal that "*Moderate to vigorous indoor exercise*" and "*Availability of garden/proximity to green natural areas*" was highly connected to "*Cessation/reduction of moderate to vigorous physical exercise.*" Participants who lived in urban areas and were used to exercise indoors struggled to find adequate outdoor alternatives during the lockdowns:

> *"I did much less sport, because apart from going for a walk you couldn't do anything at the beginning and I don't like going for a walk very much, I'm more of a swimmer or fitness club exerciser, Zumba, and we finally brought ourselves to do something, and we went out for a walk or a small bike ride almost every day." [VK3: 9–9]*

For these participants the closure of sport facilities appeared to produce feelings of frustration or helplessness:

> *"Before Corona I went swimming regularly and then that was no longer possible, because now of course I couldn't go through with it. I just slacked off and now I'm still waiting. Until they unlock." [JC3: 58–58]*

In the further course of the pandemic waves in autumn/winter 2020 and 2021 this frustration was nurtured by insecurity deriving from continued closings and reopening's:

> *"Everything was then actually over from March 15 and of course also the uncertainty, who is still open then and what do you really get then, so the uncertainty and the disappointment together." [KS4: 20–20]*

The relation to motivational factors remains unclear in this group. Four individuals (out of eight) did not emphasize their motivation for physical exercise during the interview, the other four, among them those who continued regular exercising at home, expressed motives relating to Identified regulation (see Table 5).

Discussion and limitations

This paper explored how the pandemic waves in 2020 and 2021 affected physical activity patterns of people with CVD. Previous research outlined a general trend of reduced physical activity due to COVID-19 lockdown restrictions for CVD patients as well as other populations. This evidence is related to the effect of the first lockdown in spring 2020. Findings of Vetrovsky et al. suggest a 16% decrease in step counts of heart failure patients during COVID-19 quarantine (18). Compared to the present study, they focus on a short time period, namely on the first 3 weeks after the first quarantine in the Czech republic. Another study by Fagih et al. also reported a significant decline of 27% in physical activity during the lockdown periods between February and April 2020 due to the pandemic (19). Similar results have been shown by Sassone et al., who analyzed how the first forced 40 day in-home confinement in Italy affected physical activity of patients with automatic implantable cardioverter-defibrillators. They find a 25% decline in physical activity after the lockdown began (20). Due to the short time span long run effects are not mapped.

Our results point out that behavior might change again in the long run such that physical activity levels recover. When analyzing transcripts, it became apparent that during and after the first pandemic wave, most study participants developed coping strategies and were able to adapt to pandemic circumstances. Findings of this study display encouraging signs pointing to a recovery of physical activity over the long run. Most participants in our study (71%) reported that they managed to maintain or even increase pre-COVID-19 physical activity levels. Specifically, 21% of study participants claimed to have increased physical activity and 50% of participants indicated that they have maintained their level of physical activity.

Our findings are supported by emerging evidence from longitudinal studies, suggesting a gradual recovery of physical activity levels following the time span after the first lockdown. In line with previous research, Lu et al. reported that physical activity has reduced among patients with pre-existing cardiac diseases during the first lockdown (26). Their findings further suggest that physical activity decreased the most during the first 3 weeks of the emergency quarantine order, and then started to slowly increase. Yet, in their study patients did not return to pre-restrictions levels till early October 2020.

Findings from other studies suggest that certain populations were more successful in maintaining physical activity levels than others. Rogers et al. assessed the impact of the first lockdown on physical activity behavior of adults with serious health problems or self-perception of high risk from COVID-19 (24). In line with the results of our study, most participants (75%) maintained or even increased their normal physical activity intensity. One UK study outlined that older people were more likely to maintain and recover their physical activity levels compared to younger counterparts (35). These results are supported by a US nationwide Coping Study conducted during the first pandemic wave between April and May 2020 (36). Insights from this US study highlight the resilience of older adults to cope with adverse consequences of the pandemic. Our findings support the idea that certain populations, in this case individuals who are aware of the need to exercise for health reasons, are more resilient to the impact of the pandemic than others by developing adaptive skills to cope with the unique pandemic situation.

Our results clearly show that the most successful group (regarding coping strategies) were those who have integrated walking or moderate outdoor activities into daily routine. This is not surprising, because activities like walking, biking, or hiking were not affected by lockdown restrictions, as long as they were practiced alone, or with a person from the same household. The findings are supported by a study from New Zealand reporting that moderate active individuals were more likely to maintain or even increase the intensity of physical activity during and after the first lockdown (37).

It is important to note that previous research assessing the impact of the pandemic on physical activity of people with CVD is lacking information on factors that may affect a change in behavior. This study presents refined findings, providing a deeper understanding of the reasons why certain individuals were more successful in recovering physical activity than others.

For example, van Bakel et al. conducted an online questionnaire for patients with CVD to assess physical activity before and during the first lockdown restrictions (April 2020) in the Netherlands (22). They find that moderate-to-vigorous

physical activity increased mainly due to an increase in time spent walking and doing odd jobs, while time spent exercising declined. There is no information, whether the decrease in exercising is the result of closure of sport facilities. In a follow up study van Bakel et al. show that overall moderate-to-vigorous physical activity did not change between April 2020 and July 2020 (25). The effect of reopening of sport facilities remains unclear.

Our findings suggest that adaptive capacities depend on existing physical activity patterns. This would be in line with the Theory of Planned Behavior (38). According to this theory, health behavior is determined by personal beliefs, attitudes, expectations, self-efficacy, and intentions of individuals. Thereby, people are more likely to adopt certain behaviors when they feel confident to be able to perform them (38). Insights from our analysis show that those participants, who were already engaged in outdoor activities or training at home prior to the pandemic, more easily compensated gym visits or group trainings by increasing outdoor or home exercising. That is, they were already used to perform those activities. In contrast, participants, who were used to exercise only indoors, struggled to adapt their physical activity routine during the pandemic. These findings suggest that they might lack confidence in engaging in novel types of physical activity or in exercising alone (39). This could be an explanation why certain participants did not find appropriate alternatives during the pandemic.

Our results further suggest that study participants favor consistency in physical activity patterns. The insecurity imposed by the COVID-19 specific context may pose an obstacle in the process of adapting activity behaviors. On the one hand, participants in our study outlined that they were waiting to the end of the pandemic (lasting longer than initially expected). On the other hand, analysis suggests that participants were frustrated by continued closings and reopenings of sport facilities. This implies that they might refrain from resuming indoor activities, that carry the risk of being restricted in the near future due to a newly upcoming pandemic wave.

Next, we found that the availability of a garden or the proximity to green natural areas emerged as a distinct factor shaping physical activity behaviors. More precisely, having an own garden supported participants to exercise in a private and safe environment. Also living close to green natural areas offered participants the possibility to be physically active in surroundings with a low perceived risk of exposure to the virus. Thus, possessing a garden or living in rural areas acts as an enabler for physical activity during the pandemic. Our findings are supported by the study of Rogers et al., who highlight the importance of access to green or open spaces for maintaining physical exercises during the pandemic (24). In a similar vein, Labib et al. suggest the exposure to the natural environment during the first 2 years of the COVID-19 pandemic inter alia improved physical activity (40). That nature helped individuals to cope with the pandemic and maintain health and wellbeing was also shown by Robinson et al. (41). Furthermore, our findings provide an explanation for the positive effect of living in rural areas observed in a study by of Chague et al. who interviewed congestive heart failure patients during the sixth and seventh weeks of the first lockdown in France (21). Over 40 percent had indicated a decrease in physical activity, whereas patients living in rural areas were less likely to decrease their physical activity (half as often) compared to urban populations.

To better understand how motivational drivers influence the level of physical activity, our analysis relied on Self-Determination Theory (SDT) which offers a conceptual basis for exploring physical exercise motivation (42, 43). Following SDT the motivation to participate and persist in physical activity may be self-determined (freely initiated by the individual) or externally controlled (through pressure from others) (33).

Our findings are consistent with previous research suggesting that individuals, who are more intrinsic and self-determined in their motivation, tend toward more frequent and regular physical exercise (44). Especially, *Intrinsic Motivation* and *Integrated Regulation*, the most self-determined form of external regulation, emerged as distinct motivational factors for increasing outdoor activities during lockdowns. In addition, cross-category analysis suggests a reinforcing effect of exercising in green and natural areas. Compared with exercising indoors, exercising outdoors results in greater feelings of revitalization, enjoyment, and satisfaction (45). Furthermore, a review by Gladewell et al. suggests that green exercise reduces perceived effort by enhancing mood and reducing awareness of physiological sensations, as well as negative emotions. This in turn might increase motivation (46).

Other studies referring to SDT in exploring the physical exercise behavior of CVD patients report self-determined motivation to be a significant predictor of long-term exercise behavior (47) as well as on exercise volume and length of exercise session duration (48). Consequently, physical activity programs are generally designed to facilitate more self-determined regulation of behavior, promote the fulfillment of basic needs, offer choice, and avoid external pressures for compliance (42).

In our sample, participating in physical activity was considered as a key component of maintaining a healthy lifestyle. Insights form the transcripts suggested that study participants felt confident in managing their disease and in exercising without the consultation of a trainer, therapist, or physician. Participants even reported that they had less personal contact to their physician or therapist during the lockdowns. On the one hand, the absence of external regulation (instructions by a therapist or physician) may have triggered study participants to take more responsibility for their own health and to improve their health behavior toward a healthier lifestyle. Consequently, they might be more self-determined in their motivation to exercise physical activity, which is suggested to enhance the frequency and persistence in exercising. In our sample, there

were only two individuals indicating that they followed the advice of their physician in exercising. However, these study participants referred to pre-COVID-19 times when having received physician's recommendation for exercising.

On the other hand, there are reasons to assume that external regulation in the form of supervised training may play a decisive role for patients' motivation. If less experienced or physically impaired individuals need more assistance, the absence of a therapist or physician might be discouraging for this group. The positive effect of external regulation has been suggested by a study of Kulnik et al. (49). The study assessed the change in exercise capacity during the first COVID-19 lockdown in spring 2020. The study was conducted on patients in cardiac rehabilitation, that had been attending weekly supervised group-based training sessions prior to the first lockdown. Their findings suggest that exercise capacity reduced over time. Especially this group of patients was in favor of professional supervision of their training and of the motivational effect of training together. The authors explicitly "acknowledge the potential for selection bias, whereby study recruits might represent more exercise-conscious patients who were more motivated to return to group-based CR sessions after lockdown" (p. 10). Kulnik et al. further outline that CVD patients found alternatives for a supervised group training as training at home or outdoors, going for walks, or doing gardening. But, those activities did not compensate for the group training (49).

In line with the findings of Kulnik et al. our study shows a decrease in physical activity for certain individuals from the group who used to exercise indoors. Only four participants in our sample missed the trainer and the group feeling when exercising alone and found it harder to adapt to changing circumstances and switch to autonomous training.

The effect of external regulation and autonomous training on the persistence in physical activity in people with CVD may be worth being examined in future research, given the distinct situation and health needs of this vulnerable group.

The results of this study can be used for refining public health initiatives. Previous studies recommend home-based exercise (50) programs combined with supervision for high-risk patients (16) to promote the maintenance of physical activity of people with CVD and other vulnerable groups during a pandemic. Our results show that participants prefer easily accessible media like television for participating in home-based exercising. Further, our findings emphasize the benefits of moderate outdoor exercising which resulted in the highest consistency in physical activity patterns throughout the pandemic. This implies that physical activity programs for vulnerable populations should include a mix of indoor and outdoor exercising, so that people can choose between different alternatives in the event of a closing of sports facilities. Home-based exercise programs could be extended to instruct participants in how to use walking sticks, or how to plan and organize activities like hiking or biking. Furthermore, home-based exercise programs could prepare participants for subsequent outdoor activities, for example offering joint warm-up sessions and motivating participants to continue exercising outdoors. In addition, supervised outdoor group training programs could attract persons who seek professional advice and group feeling.

In our sample, the decrease in physical activity resulted from difficulties experienced by certain study participants to adapt physical activity behaviors. Study participants who were used to exercise indoors were confronted with a discontinuation of accustomed exercising habits which seemed to impact their physical activity levels even beyond the lockdown period. We therefore recommend lifestyle coaching programs promoting adaptive capacities of people and thereby help individuals to leave familiar exercising habits and find alternatives. Supporting people in developing coping strategies could strengthen their resilience in future distortions.

In support of previous research, our findings show that family encouragement may facilitate or hamper physical activity (51). Results suggest that study participants prefer companionship of a partner, friend, or a dog when exercising outdoors. Analysis revealed an unintended negative effect on physical activity resulting from children or partners offering support in doing the shopping. On the one hand, the prime motivation was to protect a high-risk person from a possible exposure to the virus. On the other hand, this was reducing their daily steps. Public health planners are recommended to re-evaluate measures like introducing special shopping hours reserved for elderly or vulnerable persons to avoid crowded supermarkets, which has been introduced as a general recommendation in Austria during the first lockdown.

Assuming that the general population behaves similar than our study participants, our findings can be used to promote physical activity for a wider target group. Previous studies highlighted time availability as an important facilitator or barrier to physical activity during the pandemic (52, 53). This was also reflected in our study findings. Study participants pointed to the importance of having enough time for integrating regular exercising into daily routine. Adapting working times or opening times of public childcare facilities to enable a better time management could support people to introduce regular exercise in their daily routine. Based on the finding that individuals, who were used to outdoor exercising, continued to be active, we recommend urban planners to incorporate health aspects and design easily accessible spaces for walking, cycling, and active living. In a similar vein, Levinger et al. highlight the benefits of outdoors for physical and mental health in general and point to the importance of better access to parks and nature in urban locations. Thereby, needs of the elderly population and people with disability must be taken into account (54). Possible incentives could be the placement of information signs and outdoor equipment promoting easy to follow physical exercises or providing walking, running, or biking tours in living areas.

There are some limitations which need to be considered when interpreting study results. First, our sample consists of individuals with advanced disease self-management capacities. The majority of study participants were retired. Those who were working indicated that they had more leisure time during the lockdowns. This special group had more time at their disposal to reflect and manage their lifestyle. Therefore, the results presented in this paper are limited regarding representativeness. Second, the study is designed as exploratory research aiming to detect possible determinants of physical activity during the pandemic. The results, especially from the sub-analyses with small sample sizes, suggest relations, which need to be investigated in quantitative studies using larger sample sizes. Further research could also focus on gender or age differences, which we could not consider due to the small sample size especially in the sub-analyses. Third, compared to other research examining the impact of the pandemic on the level of physical activities, this study did not apply objective measures to assess the level of physical activity like using accelerometer data. Therefore, findings might be affected by imprecise assessments of physical activity due to differing reference frames of study participants. However, it allowed participants to evaluate changes in physical activity within their own reference framework, which can hardly be considered in quantitative study designs. For example, in the study of Vetrovsky et al. all patients were participants of an ongoing randomized controlled trial of an outside walking intervention (18). Their outcome measure are step counts based on wearing an accelerometer. Since their results are based on outdoor activity and might simply reflect restrictions on outside activities, the authors cannot rule out that a substitution with indoor activities took place. One participant from our study for instance outlined that he started the day with morning gymnastics in the bed. Moreover, certain intercorrelations can hardly be considered in large quantitative studies. Five participants (14%) in our sample reported a decrease in physical activity due to an injury, comorbidity, or aggravation of disease. In this case, the reduction in physical activity was not directly linked with lockdown measures.

Conclusion

Previous research on the impact of the pandemic on physical activity patterns of people with cardiovascular diseases pointed to a decline in physical activity levels during the first lock down phase. Consistent with recent longitudinal studies we show a recovery of physical activity levels under certain conditions. Findings suggest that participants, who were accustomed to moderate outdoor or home exercising, were able to maintain or even increase pre-pandemic physical activity levels by continuing or intensifying activities that were not impacted by public health restrictions. Only a few participants, who were used to indoor exercising prior to the pandemic, experienced difficulties in adapting their physical activity patterns to the pandemic situation. Furthermore, exercising in green natural areas turns out as multiplicator for engagement in physical activities presumably via motivation. Intrinsic motivation and self-determined motivation are shown to be main drivers for maintaining or even increasing physical activity. Results suggest that public health interventions should promote outdoor activities, design healthy cities with easily accessible green natural areas and provide lifestyle coaching to enhance adaptive capacities to be better prepared for a potential upcoming pandemic wave.

Data availability statement

The datasets presented in this article are not readily available because transcripts may include confidental and personal information about study participants. The interview schedule, main and sub-categories, their descriptions as well as original contributions of study participants (sample quotes) are provided in the article/Supplementary material. Requests to access the datasets should be directed to EK, eva.krczal@donau-uni.ac.at.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of the University for Continuing Education Krems, Austria. The patients/participants provided their written informed consent to participate in this study.

Author contributions

EK designed the study. EK and WH contributed to data interpretation. EK wrote the manuscript with support of WH. WH contributed to literature research, literature analysis, and focused on core messages and finetuning of the paper. Both authors have contributed to, read, and approved the submitted version of the manuscript.

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Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.947250/full#supplementary-material

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EDITED BY
Caress Alithia Dean,
Oakland University, United States

REVIEWED BY
Muhammad Salar Khan,
George Mason University,
United States
David Kitara Lagoro,
Gulu University, Uganda

*CORRESPONDENCE
Michaéla C. Schippers
mschippers@rsm.nl

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Aggressive measures, rising inequalities, and mass formation during the COVID-19 crisis: An overview and proposed way forward

Michaéla C. Schippers[1]*, John P. A. Ioannidis[2,3,4,5,6] and Ari R. Joffe[7,8]

[1]Department of Technology and Operations Management, Rotterdam School of Management, Erasmus University Rotterdam, Rotterdam, Netherlands, [2]Department of Medicine, Stanford University, Stanford, CA, United States, [3]Department of Epidemiology and Population Health, Stanford University, Stanford, CA, United States, [4]Department of Biomedical Data Science, Stanford University, Stanford, CA, United States, [5]Department of Statistics, Stanford University, Stanford, CA, United States, [6]Meta-Research Innovation Center at Stanford (METRICS), Stanford University, Stanford, CA, United States, [7]Division of Critical Care Medicine, Department of Pediatrics, Stollery Children's Hospital, University of Alberta, Edmonton, AB, Canada, [8]John Dossetor Health Ethics Center, University of Alberta, Edmonton, AB, Canada

A series of aggressive restrictive measures were adopted around the world in 2020–2022 to attempt to prevent SARS-CoV-2 from spreading. However, it has become increasingly clear the most aggressive (lockdown) response strategies may involve negative side-effects such as a steep increase in poverty, hunger, and inequalities. Several economic, educational, and health repercussions have fallen disproportionately on children, students, young workers, and especially on groups with pre-existing inequalities such as low-income families, ethnic minorities, and women. This has led to a vicious cycle of rising inequalities and health issues. For example, educational and financial security decreased along with rising unemployment and loss of life purpose. Domestic violence surged due to dysfunctional families being forced to spend more time with each other. In the current narrative and scoping review, we describe macro-dynamics that are taking place because of aggressive public health policies and psychological tactics to influence public behavior, such as mass formation and crowd behavior. Coupled with the effect of inequalities, we describe how these factors can interact toward aggravating ripple effects. In light of evidence regarding the health, economic and social costs, that likely far outweigh potential benefits, the authors suggest that, first, where applicable, aggressive lockdown policies should be reversed and their re-adoption in the future should be avoided. If measures are needed, these should be non-disruptive. Second, it is important to assess dispassionately the damage done by aggressive measures and offer ways to alleviate the burden and long-term effects. Third, the structures in place that have led to counterproductive policies should be assessed and ways should be sought to optimize decision-making, such as counteracting

groupthink and increasing the level of reflexivity. Finally, a package of scalable positive psychology interventions is suggested to counteract the damage done and improve humanity's prospects.

KEYWORDS

COVID-19, government response, mass formation, emergency management (EM), rising inequalities

Introduction

Historically, health crises have prompted governments and other authorities to act, with differing outcomes [cf. (1–3)]. Global and local health initiatives have long been in place [e.g., see (4)]. For the COVID-19 crisis, governments, and other authorities around the world (e.g., public health agencies, state and county leaders for their citizens, or businesses for their employees) adopted different ways of managing the pandemic. The response often included restrictive population-wide measures, summarized as non-pharmaceutical interventions (NPIs). Many countries opted for long-term strict and aggressive NPIs (5). However, there is little proof that most aggressive measures were more efficient than less disruptive, focused measures [e.g., (6–8)]. Some adopted measures may even have severe negative consequences [for reviews see e.g., (6, 9, 10)]. Furthermore, decision-makers have overly focused on one problem, COVID-19, instead of a more holistic approach (11–13). Together, this crisis management has led to rising inequalities and created new ones (14, 15).

Despite this, many countries opted for long-term strict and aggressive NPIs (5). A recent review and meta-analysis concluded that while lockdowns had little or no beneficial health effects, the economic and social costs were huge (16). Some scientists deem that lockdowns may be the "single biggest public health mistake in history" (17), worrying about long-term repercussions (10, 18). Measures such as closing businesses and disrupting global supply chains (19–21) have taken a toll on the world economy, and on physical and mental health (10, 22, 23). As early as November 2020, the World Bank estimated that the COVID-19 crisis would push 88–115 million people into extreme poverty (24), and a sharp increase in food insecurity worldwide led to hundreds of millions of additional people at risk of starving and food-insecurity (25–28). These macro-economic consequences can worsen mental health issues (29, 30) even cause fragmentation of society (31). Long-term negative economic and health consequences are exacerbated by increasing inequalities (32). Wealth distributions have become more skewed, worsening a pre-pandemic crisis. The top 10% of the global population owns 76% of the total wealth, while the bottom 50% share a mere 2% (33). In September 2021, 1% of the world's population held 45.8% of global wealth (34).

Prior research has shown that, both in the animal kingdom and within the human population, (extreme) levels of inequality often give rise to hierarchies and status dynamics that lead to negative health outcomes (35–39). The Whitehall studies investigating long-term social determinants of health found higher mortality rates in men and women of lower employment grades (40). Up to 20 years of difference in life expectancy has been observed between countries with a large status and economic differences vs. more well-off egalitarian countries (41). Some NPIs may have a large effect on increasing pre-existing inequalities and creating new ones, posing a threat to health and shortening longevity (15). Similarly, certain behavioral interventions along with NPIs used by governments to enforce compliance also worsened inequality. Concurrently, the COVID-19 crisis and the measures taken seem to have offered an opportunity to well-off people who profited from the transformation of life from physical to digital [e.g., (42)], and/or profited from the crisis (43). Many large companies profited, while many small companies crumbled, accelerating pre-existing trends (44).

The rising inequalities have consequences beyond mere financial insecurity, given the dynamism of extreme hierarchical differences (45). From a macro-dynamic perspective, aggressive health policies accompanied by psychological tactics to influence public behavior lead to mass formation and crowd behavior, and the breakdown of normal behavior [cf. (46, 47)]. The burden of financial and food insecurity and deterioration of mental and physical health fall disproportionally on already disadvantaged groups (48, 49), with predictable consequences for social capital and health (50–52). The general insecurity and trauma caused by the insecurity and uncontrollability of the events also contribute to mental health issues (46, 51, 53).

The current narrative and scoping review examines the consequences of aggressive NPIs on rising inequalities and adverse outcomes for humankind (see Figure 1). We describe how these NPIs impact mass formation and crowd behavior (Section Aggressive measures, mass formation and crowd behavior), *via* psychological tactics such as crowd manipulation and control (Section Psychological tactics). Section Centralized decision making and one narrative discusses the role of centralized decision making with one narrative and counter

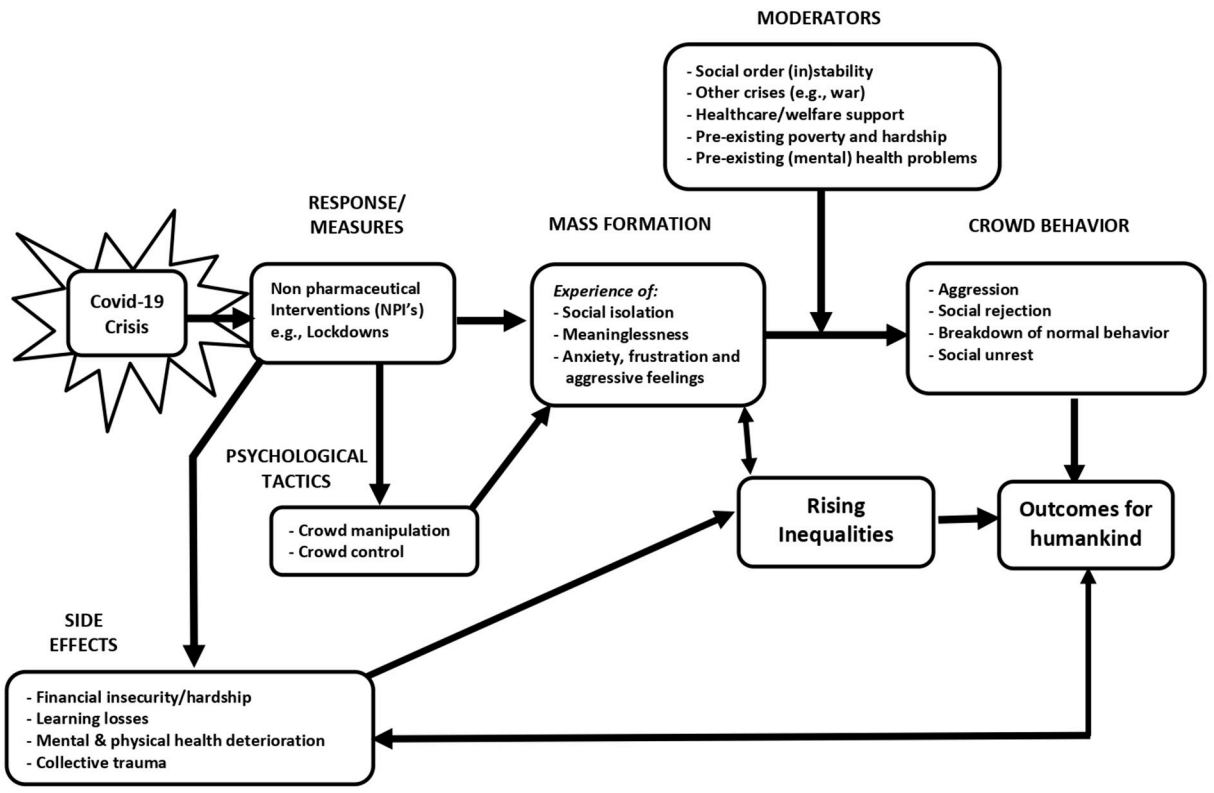

FIGURE 1
Theoretical model of the consequences of the NPIs on rising inequalities and outcomes for humankind.

movements. Section Collective trauma and conservation of resources addressed issues of collective trauma and offers perspectives from the conservation of resources theory. Section Rising inequalities offers an overview of the resulting increase in inequalities in multiple dimensions: socio-economic, gender, (mental and physical) health, and educational. Section Could we have done better? discusses whether we could have done better, and Section Discussion proposes ways forward. We end with a discussion and recommendations on ways to mitigate the negative effects resulting from aggressive measures.

Aggressive measures, mass formation, and crowd behavior

During the COVID-19 crisis, governments took the lead in managing the crisis for which they relied on NPIs. However, the 2007 and 2019 reports concluded that high-quality research on NPIs is lacking, and a list of NPIs was assessed in terms of effectiveness (54, 55). In the 2007 paper, it was commented that the scientific base of high quality studies on NPIs is exceedingly small (54), and interventions that were explicitly not recommended were the general use of masks and other protective equipment and social distancing (54). Also, the experts surveyed for this research mentioned that forcibly limiting assembly or movement was legally and ethically problematic; they thought that mandatory long-term community restrictions and compulsory quarantine would lead to public opposition, and practical and logistical problems. It was concluded that voluntary measures and guidelines would be more acceptable and thus effective (54). The 2019 WHO report speaks of spreading cases over a longer period to reduce the height of the peak in "cases" but mentions NPIs such as community use of face masks, border closures, entry- and exit screening, and school closures as generally ineffective. Of the 18 NPIs mentioned in the report, measures such as ventilation and isolation of sick individuals were seen as effective (55). The quality of most studies in the report was rated as (very) low, making it hard to determine effective NPIs, and the possible harmful effects were not weighed. In 2020, a WHO report appeared with considerations on how to ease measures and this report also discussed the importance of human rights protection and the protection of

vulnerable populations (56). The extent to which governmental decision-making was flawed is still a matter of debate [e.g., (57)].

Several social psychological theories can explain what could have gone wrong in terms of these interactions. Group processes and crowd psychology predicts that especially in times of crisis people will be inclined to look at governments and authorities to guide their behavior [cf. (1, 3)]. As these authorities respond with guidelines for behavior and NPIs, this can lead to mass formation and crowd formation, similar to the way molecules behave or swarm, with ensuing collective behavior (47, 58, 59). Members of such groups often develop a high degree of emotional like-mindedness, and conventional inhibitions in such groups often decrease (60). In light of the crisis, experts were asked to advise governments, and these used behavioral interventions to steer public behavior in the desired direction and, simultaneously, the debate became highly polarized and politicized (61, 62). Indeed, the behavior of people changed quite radically in the early days of the crisis (63, 64), as psychologists advised governments on how to use psychological tactics to affect behavior change [e.g., (65, 66)]. A special journal issue described the many social group psychological aspects such as impact on societies, social connectedness, and new collective behaviors and inequalities (67). Within the social psychological field of crowd psychology, explanations are offered as to why the behavior of a crowd differs from that of the individuals within the crowd. These theories view the crowd as an entity, where individual responsibility is lost (68). In such a crowd, individuals tend to follow predominant ideas and emotions of the crowd, in a form of shared consciousness, or "collective mind." Then it becomes relatively easy to violate personal and social norms and such crowds can become destructive (59). This theory may help explain deindividuation and aggression sometimes seen in large groups (69). In such groups, deindividuated people often show more sensitivity and conformance to situation-specific norms and support a social identity model of deindividuation (69).

In the early phase of a crisis, people are inclined to embrace a superordinate level of identity and look for (national) leaders for support and guidance (70). Strong responses toward group members who deviate from new norms are deemed legitimate by many (70, 71), although this may also be dependent on the status of the group member (72), and can change as the crisis progresses. Fluctuations or changes in group behaviors occur later on as people's expectations of a return to normalcy are not met, or if they realize the downsides (70). Indeed, as discontent rises around the globe, citizens may engage in activism (73) and lawsuits against authorities for what they perceived as poor crisis management (74). In times of crisis, blame is often laid on minority groups, who are subsequently scapegoated and persecuted (3). This effect adds to minorities and the poorest already carrying the largest burden for the NPIs (10, 75, 76).

Psychological tactics

Crowd manipulation, propaganda, and crowd control

As people turn to leaders in times of crisis (77, 78), leaders have the responsibility to make important and consequential decisions (13). These leaders can choose to intervene in different ways. In general, and especially at the beginning of a crisis, people are inclined to ask for and accept strong leadership [cf. (79, 80)]. Leaders faced the choice between espousing voluntariness in policies or mandating rules and regulations to deal with the crisis (81–83). Although during a crisis leaders tend to enforce rules (84), some voluntariness may be key to trust in government (85). There is some evidence that voluntary measures are more supported than the enforced ones (85), and that voluntariness may offset the experienced disadvantages of policies (5, 83). In general, citizen engagement has many advantages (86). Moreover, it seems that many assumptions on which the NPIs are founded, seem to be biased at best (10, 13, 57). A review of over 100 studies about the COVID-19 crisis handling revealed that overall, the net effects of the policies were negative (87). Studies that suggest substantial benefits of lockdown, typically have flaws or limitations that seriously question the validity, e.g., their counterfactual is based on tenuous assumptions in forecasting models (88), they use interrupted time-series designs without a stable long-term period before and after intervention and without controlling for confounders (89, 90), and/or have no control non-intervention group (i.e., not a difference-in-difference approach) (89, 90), and other flaws (16). Furthermore, it was shown that lockdowns were very costly economically, but probably did not save lives (6, 91). Despite this, citizens generally believed many unfounded COVID-19 scientific claims leading to strong support of NPIs (92). Other options such as involving communities in responses to collective threats, may have avoided many if not all of the negative side effects (63), and voluntary measures may have been better in terms of ethics and human rights (5, 93).

Crowd manipulation, or the use of behavior change techniques based on crowd psychology, could have both intended and unintended consequences (47). While the theory of mass formation has been criticized for being too general (94), it is a meta-theory that seems to be supported by more micro- and middle-range theories on the social psychology of group dynamics and group behavior. These include theories such as group cohesion and intergroup conflict (47). For instance, large increases in perceived threat to a group were significantly related to diminished problem-solving effectiveness (95). A meta-analysis studying 335 effect sizes from 83 samples across 31 countries found that under conditions of strong population norms, norm-behavior associations were also stronger (i.e. people acting according to their norms), and the level of

collectivism strengthened these norm effects (96). Governments around the world have strongly communicated a high level of threat and called on norms of collectivism, obedience, and solidarity to excuse NPIs and accompanying harms (10). Overamplifying the harms of COVID-19 leads to citizens becoming more acceptant of the lifestyle changes (97). While these manipulations can in theory benefit the public, the required behaviors have had harmful consequences, especially for vulnerable groups (10, 13, 16, 98). Note that one does not need to invoke some nefarious totalitarianism (99). There can be extreme bonding among people to defeat a real or imagined enemy, in this case, a virus (70). A meta-analysis showed that there is a tendency of ingroup bonding (closing the ranks) combined with a tendency to focus on the outgroup as the source of the threat (100). Even when external threats are not related to a specific outgroup, hostility, prejudice, and discrimination are aimed at outgroups, and detrimental intergroup outcomes occur (1). Dehumanization or the "act of denying outgroup members human-like attributes" [(1), p. 110] may be a mediating factor between a perceived threat and negative behaviors and attitudes toward that group (101). This is strengthened by the moralization of the COVID-19 response which led citizens to believe it is better to impose restrictions than to take no action (102). For the COVID-19 crisis, the superimposed economic crisis contributes to higher levels of hostility and discrimination (and dehumanization) of outgroups to which the cause of the crisis is attributed (1, 103–105). Interestingly, this prejudice against outgroups was not apparent when a system-level explanation for a crisis, i.e. the economic system, was made salient (103). Also, the status of the outgroup moderates this effect: the prejudice is lower when the status of the outgroup is higher (100).

Mass formation concerning reacting to an external threat combined with the resulting extreme inequality can potentially be very harmful [cf. (103, 105)]. Citizen behavior may be unfortunately steered in a direction of societal damage. Mass formation can make people adopt ideas that are incompatible with their previous beliefs. For instance, many people with supposedly progressive ideologies supported harsh measures against unvaccinated people, such as requiring unvaccinated individuals to always remain confined to their homes. Some thought governments should even imprison individuals who publicly questioned vaccine risk-benefit. Moreover, they also thought that unvaccinated individuals should have a tracking device, or be locked up in designated facilities or locations until they are vaccinated (106). These beliefs have nothing to do with improving the uptake of effective vaccines (a most welcome outcome) but delve into other priorities where aggression is the main theme. This kind of dehumanization of a large group could create a whole new kind of inequality: a privileged group of people religiously following governmental response vs. a scapegoated group questioning official policies.

The divide between those groups may have many consequences, from not being willing to work with a co-worker who fails to conform to condoning the violation of basic human rights for such a group with exclusion from society (61). A bias seems to work in the direction of the government responses: a study using a representative sample from 10,270 respondents from 21 countries showed that vaccinated people have a high antipathy against unvaccinated people, 2.5 times more than a more traditional target such as immigrants from the Middle East (61). Interestingly, the antipathy is larger in countries with higher social trust and fewer COVID-19 deaths. In the study, no bias from the unvaccinated toward the vaccinated was detected (61). Why would agreeable and average people hold such beliefs? The answer may be that redirecting the blame toward a scapegoat may help people restore a sense of control, easing feelings of uncertainty (107). For instance, participants "were especially likely to attribute influence over life events to an enemy when the broader social system appeared disordered" [(107); Study 3]. The consequences of crowd behaviors like dehumanization and scapegoating may be quite severe, and it would be advised to work toward reducing intergroup tensions instead of fueling them (1). However, many government responses may have increased these effects rather than reduced them. For political reasons, sometimes governments chose to attribute the blame to some "enemy" while presenting themselves as the savior (3, 108). For the general public, in addition to a social and economic divide, these NPIs and such framing of the message can lead to feelings of social isolation, loss of meaning in life, anxiety, and aggressive feelings (47).

Experience of social isolation, meaninglessness, anxiety, frustration, and aggressive feelings

The COVID-19 crisis, as with any crisis, spurs feelings of anxiety, frustration, and aggression (109). Social safety theory would predict that social threat greatly impacts human health and behavior (109). Social isolation has led to the experience of meaninglessness, although the role of mindsets about the COVID-19 situation has been important (110). Three mindsets that people formed early in the pandemic, namely considering the pandemic as a catastrophe, as manageable, or as an opportunity, had a self-fulfilling impact on emotions, health behaviors, and well-being (110). In general, the heightened level of mortality salience has been related to heightened frustration and aggression in society [cf. (109)] and especially aggression toward those with opposing world views (111). Human aggression refers to intentional harmful behaviors directed at other individuals, and violence is aggression that has extreme harm as a goal. Hostile aggression is seen as

a form of aggression that is rather impulsive or unplanned, while instrumental aggression is premeditated and a proactive form of aggression that is used as a means to an end [for a review see (112)]. Aggressive thoughts and feelings are probably even more common, as many situations and interactions with others can give rise to frustration and aggression. While pre-existing biological and learned tendencies may play a role, the current situation gives rise to a spike in aggressiveness, both verbal (e.g., people blaming certain groups for the current situation and thinking aloud about what should happen to such groups) and actual aggression. There is some evidence that interpersonal aggression and violence increased with aggressive NPIs, especially in places with lockdowns and stay-at-home orders (113, 114). As the crisis continued for much longer than initially expected, aggression and frustration could accumulate, without people having many chances to vent, e.g., by going to the gym.

Excitation transfer theory can explain why anger may be extended over longer periods, and this often happens when two or more arousing events are close in terms of time (115). When people are in a survival mode for prolonged periods, they become more fearful, distrustful, irritable, and aggressive (116). Although a survival mode can be an adaptive response to an immediate threat of existential danger, in the long-run over-exposure to stress-response hormones harms mental health and relationships and leads to intergenerational trauma (116, 117). Displaced aggression directed at another person or target, which is not the source of the arousing frustration, can also occur. A meta-analysis showed that the magnitude of the displaced aggression was bigger in a negative setting (e.g., the current crisis). Also, if the provocateur and target were more similar to each other e.g., in terms of gender, race, and/or values, displaced aggression was higher (118).

A study among 2,799 Chinese college students (119) showed that the relationship between fear of COVID-19 and relational online aggressive behavior is mediated by moral disengagement (i.e., the process by which people convince themselves that ethical standards do not apply to them in a certain context, by reframing their behavior as morally acceptable). High mortality salience can also increase aggression, often directed at others who threaten one's worldview (120). Note that terror management can also lead to a more positive way of coping, such as reflecting on the meaning of life (111), and this may be a more effective way of dealing with a crisis (46). However, a study among 1,374 participants in seven Arab countries showed that traumatic stress coupled with collective identity trauma increased death anxiety. This was in turn related to reduced well-being, post-traumatic stress syndrome, anxiety, and depression (45). The authors speak of a vicious cycle of inequalities increasing infection and death from COVID-19 and the COVID-19 crisis increasing inequalities further (45). As many of the behaviors aimed at reducing the spread of the virus, such as hand-washing or masking, can be seen as group rituals (i.e., acts that people regularly repeat together in the same way), symbolizing important group values (e.g., health and safety) people deviating from such rituals provoke anger and moral outrage (10, 121). Individuals more worried about contracting the disease made harsher moral judgments than less worried individuals, even after controlling for political orientation (122). Also, people that were high on health anxiety before the crisis may be more vulnerable to excessive anxiety about COVID-19 (123), and would need therapeutic interventions (124).

There is also evidence that the COVID-19 crisis has increased psychological distress that could be related to proximal and distal defenses against death-related thoughts (45). The crisis has increased anxiety and fear for personal and loved one's physical well-being (125). Conversely, physical activity could act as a buffer (126) but anxiety-buffering outlets such as social networks and sports were inaccessible for many, leaving people vulnerable to experiencing even higher levels of death anxiety (45, 111). A "perfect storm" ensued, whereby stress and anxiety increased and pathways for releasing stress were cut off for many.

Furthermore, all of the social determinants of health were affected; none of these was equally distributed even before the crisis started, but the crisis has accelerated this uneven distribution (127, 128). According to Broadbent and Streicher (129), many of these effects were foreseeable, especially the effects of lockdowns on the Global Poor. During the COVID-19 crisis, commitments to reducing health inequalities were lost from view, or not very salient for wealthy countries, foreseeable health costs were large on deprivation of livelihood, disruption of health services for other conditions, and disruption of education and foreseeable health benefits were minimal (reduction of social contact to the extent modeled was impossible due to overcrowding and non-compliance necessary to sustain a livelihood, the much younger average age while severe COVID affects mostly older people) (129). Much of these effects have been a result of the government's response to the crisis and the choices made in this respect (128). In many countries, decisions were made unilaterally and an official narrative was supported and defended (130).

Centralized decision making and one narrative

Decision making during a health crisis is difficult as many issues need to be considered concurrently while data may be lacking or massive but still flawed (13, 131). Collective decision-making and intelligence are key to effective decision-making (132). However, sometimes it is falsely assumed that centralized decision making is the only method that may work. Another potential bias may be that a small group of experts is listened to, at the expense of experts that advocate a different route (133). An official narrative approach was followed (130, 134)

with counter narratives routinely labeled as misinformation (135). Sometimes the experts in control acquire so much power that they take over even the role of the opposition and dissenters are ostracized (136–138). Authorities have used media and public communication to impose their narrative (134). People and groups challenging the narrative often face dire consequences, from social exclusion to arrest and molestation at demonstrations, in both authoritarian and democratic countries (134). Concurrently, the question has been raised if coercive measures are desirable policy responses, as these have been seen as ineffective and counterproductive in the past (139), leading to distrust in institutions, alienation, and avoidance of care (139–141). The combination of coercive measures and a cancel culture to preserve an official narrative may backfire (139, 142). Public persuasive communication may lead to the opposite effect or behavior than intended (143, 144).

Historically, mixing political ideology with science, when the state regulates science, has led to disastrous outcomes. For instance, a Soviet geneticist favored by Stalin, dominated biology and agricultural science, rejecting Mendelian genetics. The careers and lives of geneticists who opposed him were destroyed, and many were arrested or killed (145, 146). When the Chinese Communists adopted the same approach, starvation killed 30 million people (145). Favoring one ideology at the expense of other views can lead to unwanted outcomes (10, 11, 13, 147), for example, using free speech to shut down free speech (148, 149). The resulting "cancel culture" may frighten other academics who will then be careful in speaking out and/or publishing on certain topics (147). Extremely centralized decision making has other disadvantages, including diminishing democracy, diminished freedoms, and threats to human rights (150–154). Trust in government may diminish, and support for the NPIs may waver (85). While COVID-19 was a major problem, tackling it should never be done to the exclusion of all other problems we face as humanity (57). Decision making should serve most humans, and science can aid here, but it should not be pretended that "science" is perfect and error-free [cf. (155)]. Concurrently, journalism and science should avoid propaganda (154).

Countermovements

Grassroots movements and countermovements have gained more research attention lately (156–161). As the distribution of power has been unequal throughout history and is typically held by an elite minority, enabling people to use collective power is an important aim of those movements (162). Self-serving (or apparently self-serving) actions of the elite may cause a sharp decrease in trust in institutions for some people, while others keep being trustful. With the COVID-19 crisis, trust in governments and scientific institutions oscillated but mostly decreased (163). People may join countermovements because they give meaning and the opportunity to reinstate dearly held values and beliefs (164). Many citizen activists feel they contribute to a better world in this way; especially the younger generation may be driven more by moral issues rather than political ones (165). However, such groups often face stigmatization and criminalization, undermining of group identity, and institutionalized social subordination (165, 166).

The effectiveness of countermovements

In terms of mass formation, possible countermovements have received far less scientific attention (167, 168). Many people may realize that the direction society is moving in does not match with core values, such as humanness (e.g., consideration, empathy), critical thinking, and freedom [cf. (169, 170)]. Indeed, during the COVID-19 crisis, there has been a global wave of social justice movements that draw attention to the negative effects of a multi-dimensional crisis (134). While most of these movements have a strictly non-violent character, the tactics used by these movements range from civil disobedience and (strict) nonviolence to anti-authoritarian strategies and self-defense, and even guerrilla warfare (164). Whether or not these movements are effective and what methods are most effective remains a matter of debate (160). While the authors of this article do not approve of any violence, some writers even argue that violence against a state that has a violence monopoly is sometimes justified and necessary (171). However, recent historical research shows that non-violent approaches are much more effective than violent ones (172). Regardless, the righteousness of such movements can be debated (173). Several authors have claimed that these movements in current times are misinformed and hence see the rise of these movements as dangerous (174). However, simply claiming that those movements are misinformed and labeling all information, not in line with official guidelines as "conspiracy theories" [e.g., (175)] may be too naïve. Some countermovements may be strongly motivated to be well informed. Effectiveness may depend on whether such groups can create space for new social relations, spread awareness, show resilience, have elite support/permission such as that they are shielded from police and military suppression, and are able to improve people's lives (164, 176). A causal relationship between pressure on authorities and change in policies is difficult to determine, but possible (157).

Historical research from 1900 to 2006 comparing the effectiveness of 323 violent vs. non-violent resistance campaigns showed that non-violent civil resistance was more effective in producing change (177). Violent campaigns were successful in 26% of the cases, whereas non-violent campaigns were successful in 50%. In the last 10 years of the research, this effectiveness was reduced to only 6% for violent campaigns vs. 34% for non-violent ones (178–180). Countries in which there were non-violent campaigns were 10 times more likely to transition to democracies within 5 years after those campaigns, than countries

with violent campaigns. Interestingly, this was independent of whether the campaign succeeded or failed (178). Effectiveness was bigger under conditions of large, diverse, and sustained participation when the movement was able to elicit loyalty shifts among power elites (e.g., army, police, media, business elites), with campaigns entailing more than protests, with variation in methods used, and when campaigns did not descend into chaos or opt for violent methods despite repression (178). Preparation seems crucial for successful campaigns, for instance in South Africa the anti-apartheid movement organized a boycott of white businesses after preparing for months to become self-sufficient first (181).

The recent decline in the effectiveness of non-violent movements might reflect the smaller size of such campaigns, reliance on more symbolic displays of resistance and mass non-cooperation (such as street demonstrations rather than strikes) that do not weaken the opponent's sources of power, and less disciplined non-violent actions (182). Sometimes even one person can make a difference (183, 184). Della Porta (185) argues that three kinds of ruptures can be brought about by countermovements, often successively: cracking, or sudden ruptures; vibrating, contingently reproducing those ruptures; and sedimenting, stabilization of consequences of the rupture. If these historical lessons apply, perhaps effective countermovements could help in turning around the decisions of implementing non-effective and harmful NPIs, thereby buffering negative long-term effects.

Collective trauma and conservation of resources

Aggressive measures adversely impact physical and mental health (10, 13, 186). We will focus here on the result of collective trauma or the "psychological reactions to a traumatic event that affects an entire society" [(187), p. 1]. This trauma can affect the collective memory of an entire group and often invokes sense making (188, 189). COVID-19 collective trauma may be large (190). Four mental models seem to be associated with the current collective trauma, namely uncertainty, danger, grotesque, and misery, as well as four primary emotions, namely grief, disgust, anger, and fear (190). Although people have a propensity to hide negative emotions and trauma, the expression of emotions can yield both individual and collective benefits; sharing may alleviate emotional distress and aid in garnering social support (191).

A strong indication of collective hardship is the steep increase in mortality rates among adults under the age of 45, who are largely spared from COVID-19 deaths. Some additional deaths were caused by self-destructive behavior such as substance abuse, homicides, and traffic accidents (98).

Conservation of Resources theory (COR) can serve as an integrative theoretical lens for understanding how people gain and conserve resources (192–194). People differ in the extent to which they are good at gaining tangible resources (e.g., money and property) and intangible resources (e.g., strategic relationships to gain power) (195). According to COR, both individuals and groups, and even societies as a whole strive to obtain and maintain valuable resources (194). There may be an evolutionary need to acquire and conserve resources for survival (194). COR has been used to explain stress outcomes in various contexts, including organizational settings, following traumatic stress and for everyday stressors (192, 196).

Hobfoll speaks of "resource caravan passage ways," meaning that the ecological conditions often determine the extent to which people can create and sustain resources (194). E.g., women were already on a resource loss before the crisis, but the crisis has exacerbated it, and a resource loss spiral can jeopardize progress toward gender equality (197). For instance, as women work predominantly in service sectors, the shutdown of many such sectors has disproportionately affected them, leading to the largest gender-unemployment gap ever recorded [(198), see also (197)]. This, combined with the increased number of stressors at home, to do more household chores and care tasks, leads to increased stress, less leisure time, and increased burn-out (197). People became more socially conservative during the crisis regarding gender role conformity and gender stereotypes, while political ideology remained constant (199). Stress occurs when resources are lost. In Western contexts, 74 common and important resources are described, including sense of pride, goal accomplishment, hope, personal health, food, help with household chores and childcare, and stable employment (192, 196). The concurrent loss of so many resources during the COVID-19 crisis has been unprecedented [cf. (46), see Figure 2 for a downward spiral in resources].

This can be traumatic for many people, especially given the unpredictability of the duration and intensity of the situation (200). Fear has been identified as a strong predictor of posttraumatic stress disorder, often accompanied by negative thoughts about the self, others, and the world (200). This is compounded by a worldwide sense of insecurity, and loss of personal and social security (201), leading to psychological symptoms of grief (200). Also, job loss has been associated with symptoms of grief and loss of meaning in life (202). Staying-at-home orders are associated with loss of freedom and autonomy as well as loneliness (203), especially when measures were perceived as coercive (204). This may also lead to a fear of coercive policies being enforced over a longer or perhaps indefinite time (139). Fear- and anxiety-related disorders have spiked since 2020 (22). Overall, both tangible and intangible resources were lost during the crisis, thwarting physical and mental health [cf. (200, 205)]. People experiencing extreme resource loss (e.g., losing their income, going through a divorce, losing access to proper health care and ways to cope) may fall prey to the *desperation principle*. This understudied tenet of COR predicts that when people's resources are outstretched or

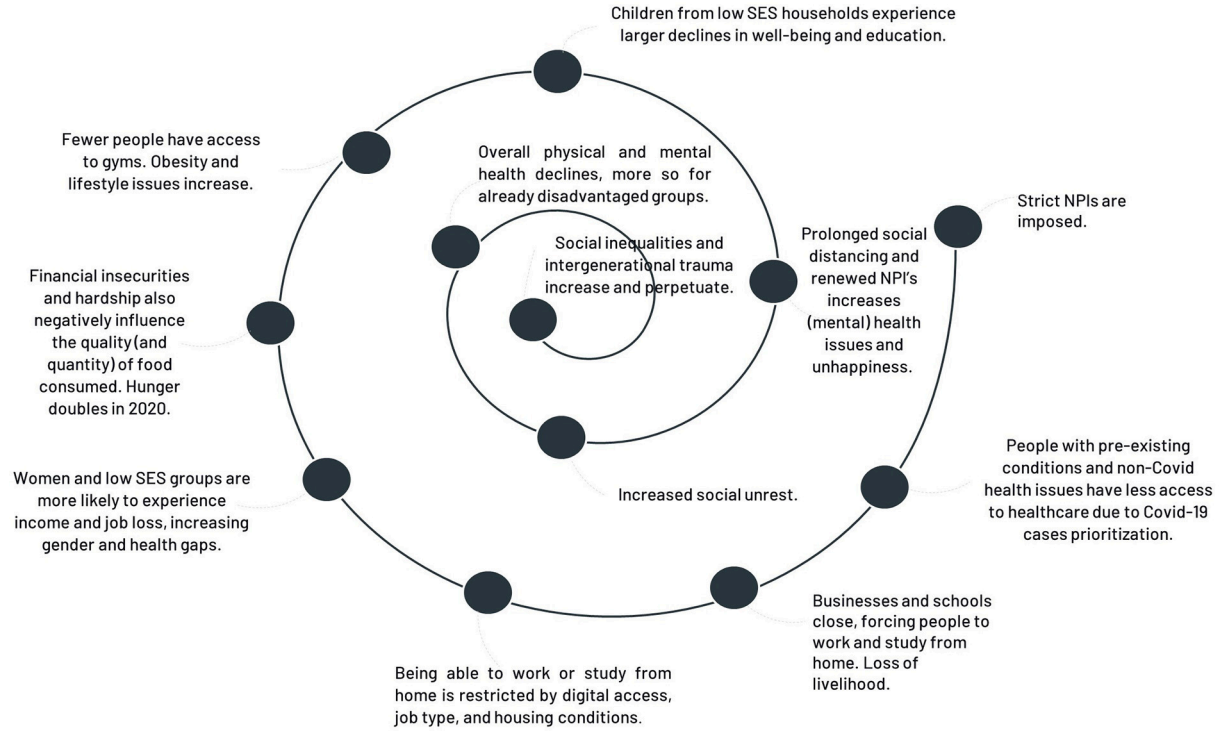

FIGURE 2
Downward spiral of rising inequalities resulting from aggressive and prolonged NPIs.

exhausted, they may enter a defensive self-preservation mode in which they behave increasingly aggressive and seemingly irrational (194, 206). They may defensively try to conserve the remaining resources (192). When people are subject to an increased number of stressful events, depression symptoms also increase (207), and major depression is a leading cause of suicide (208). An impact on suicide rates may take years to document. Current research indicates that suicide rates may indeed have increased (186), sometimes after an initial decline in suicides (209). People with more resources before the pandemic may be better suited for resource gain (200) ushering in psychological well-being, health, and functioning (210).

Groups that had fewer resources from the start included minority groups, youngsters, females, and individuals with a mental health history, and economic insecurity (211, 212). Harms induced by NPIs may also be exacerbated by pre-existing or induced lack of stability of the social order in a country or region and in case of pre-existing mental health issues (10, 213). During the crisis, those with pre-existing mental and physical health conditions reported the highest level of emotional distress, although mental health deterioration was population-wide (213). Also, poverty increase in already vulnerable regions made things worse. Additional, extreme events, such as riots and wars may add an extra layer of multiplicative harm (214).

People in comparable circumstances may differ in how resilient they are in dealing with those circumstances (215), and some may experience post-traumatic growth (216). Research by Yi-Feng Chen et al. (217) stresses the role of proactive personality and organizational support in coping with disruptions during COVID-19.

Rising inequalities

Social inequalities occur when resources within society are distributed unequally, e.g., income, goods, access to information, etc. (218). In the last decades, economic inequality increased in most countries, stabilizing in the 1990s (219), but increasing dramatically since 2020, prompting some authors to refer to this as the "second pandemic" (220). While the focus on making profits has created wealth for large groups of people, resources have become unevenly divided among the total population. There is evidence that economic inequality increased (15). Although this trend was already visible before the crisis started [for a review see (219)], this seems to have accelerated after the start of the crisis (221). While in the last 25 years, 1.1 billion people were lifted from poverty through economic growth (222), during the COVID-19 crisis global extreme poverty rose sharply and in October 2021 it was estimated that 100

million additional people were living in poverty (223). Very early on in the pandemic, warnings were expressed that the negative effects may outweigh possible positive ones (10–12, 57) and ways to optimize decision-making (13) and alternative ways forward were offered (6, 224). Note that other authors disagree and argue that the NPIs are proportional and have substantial benefits [e.g., (225, 226)]. There has indeed been substantial debate on whether lockdowns offer some benefits in reducing at least COVID-19 deaths and many studies have tried to answer this question. In general, these studies have limitations given that no randomized trial has assessed this question and modeling, or observational studies leave substantial uncertainties and are subject to selective reporting and interpretation (227). A meta-analysis has found very small benefits of lockdowns on COVID-19 mortality rates (16), and cost-benefit analyses find that the costs of lockdowns (including what we outline above) far outweigh any potential benefit that may occur (6, 228). Debate and disagreement will likely continue, given that assessments on the relative benefits of lockdown are based largely of weak observational data under very complex circumstances.

Inequalities have several consequences for health, well-being and happiness, and longevity (218, 229). Countries that let inequality increase have lower happiness rates than countries with higher equality (230, 231). Population well-being, consisting of physical, emotional, and social health, explains variation in life expectancy. Communities with high well-being are characterized by engaging in healthy behaviors, strong social connections and support systems (229), and happy people who live longer (232), even though the causal mechanisms can be debated. Several meta-analyses have shown a favorable association between psychological well-being and survival (233), and well-being partially mediates the associations of race, poverty, and education with life expectancy (229). Importantly, life satisfaction and optimism about the future, access to housing, healthcare, and perceptions of safety, were also significantly associated with life expectancy (229). Poor housing conditions were related to greater stress and reduced well-being during the COVID-19 crisis (234). As psychological well-being is affected both directly and indirectly *via* the pandemic and the NPIs (i.e., losing one's job and housing, getting a divorce because of the aforementioned, or because of being quarantined for months), this may lead to more inequalities in terms of income, but also well-being [cf. (46, 235)]. General health and well-being during the crisis have been lowered [for a review see (236)], especially so for vulnerable groups and disadvantaged countries (237, 238). Below we first discuss the various inequalities affected by the pandemic and the adopted NPIs. We should caution that it is often difficult to disentangle how much of these effects were due to the pandemic vs. the measures taken. Occasionally the interaction of the pandemic with the measures taken may have had multiplicative negative effects. Then, we discuss options that may help in breaking this trend. In Table 1, we give a non-exhaustive overview of literature and findings regarding inequalities during the COVID-19 crisis.

Vulnerable populations

Many authorities responding to the pandemic often stated they aimed to protect the vulnerable. However, several adopted measures seem to have especially hurt this group instead of helping. Several measures disrupted and contracted the social networks of older adults during the crisis. Pre-pandemic racial/ethnic network disparities were exacerbated, with negative consequences for the physical and mental health outcomes of these groups (211). As networks are important not only in daily life, but especially in times of crisis, social distancing led to a limited ability to weather the crisis, especially for vulnerable populations (211). Many countries have chosen to put vulnerable elderly people in complete isolation. This forced social and physical isolation is a serious stressor (313). Resilience may have been further compromised (314, 315), creating paradoxical effects (10). Both regular and routine health care for non-COVID-19 disease was disrupted, posing a threat to health outcomes for many diseases (243, 292). The long-term consequences of the relative neglect of the public health care system, and that people were hesitant to visit their physician for the non-COVID-19 problems (279, 316–319), remain unfathomed. E.g., it was estimated originally that about 28.5 million operations worldwide were postponed during the initial 12-week peak of the crisis (320). Once more, vulnerable populations were hit hardest, increasing pre-existing inequalities (321).

Economic inequality: The rich got richer and the poor poorer

Economic inequality has hugely increased exacerbating pre-existing inequalities and this seems a self-reinforcing process as lockdown measures continue or keep being imposed (15, 49, 322–324). Hundreds of millions of people were driven into poverty, while others, individuals and corporations, gained (325). This has led to the paradoxical situation that in some countries people were more worried about starvation than becoming ill from COVID-19 (49). Almost 4 billion people, half of the world population, live on <6.70 dollars a day. A review across four continents showed that restrictive NPIs are especially hard on the poor as they unevenly impact the livelihood and socio-economic activities of those groups (326). A World Bank report concluded: "Taken together, COVID-19 has directly offset the reduction in the [poverty] gap between countries observed from 2013 to 2017" (324). Income loss was steepest for the poorest 20% of the world, resulting in the

TABLE 1 Non-exhaustive overview of the effects on inequality resulting from the non-pharmaceutical interventions enforced in response to the SARS-CoV-2 pandemic.

Effect on inequalities	References
Socio-economic status (SES) and ethnic groups	
Estimates that the side effects of attempting to fully mitigate the COVID-19 pandemic will negatively impact life expectancy. Over 10 years, the negative life expectancy from socio-economic inequalities alone will be around the equivalent of six unmitigated COVID-19 pandemics. This is not considering the negative effects on life expectancy due to increased mental health problems, suicides, and drug abuse	(239)
The effect of the COVID-19 pandemic and lockdowns differed across SES groups, e.g., groups or counties with lower SES had higher infection incidence and mortality	(32, 42, 240, 241)
Racial minorities (Black, Indigenous, and Hispanic) were more at risk of getting infected and had worse COVID-19 health outcomes during the pandemic. Existing inequalities were exacerbated	(42, 128, 242–248)
Children with low SES experienced worse health outcomes during the pandemic due to increased exposure to adverse health determinants (e.g., tobacco, unsuitable food, changes in physical activity, spending more time in front of the screen, less social contact, and more noise	(242, 245, 249–255)
People living in areas with higher levels of pre-existing inequalities experienced more adverse effects during the pandemic	(32, 240, 241, 244, 246, 255–259)
Healthy behaviors (e.g., physical activity, healthy eating) were lower, especially for low SES families	(241, 260)
Geographical economic effects of the crisis. Uneven economic effects uncorrelated to the epidemiological pattern. Lower educational levels related to higher mortality for working-aged women and people between 65 and 79 years old during the crisis. The rise in social inequality because of the burden of the disease and the measures have fallen disproportionally on already disadvantaged groups challenges solidarity and social justice	(32, 240, 246, 255–259, 261, 262)
The pre-existing inequalities of refugee teenagers compounded due to the response to the pandemic, with worse (mental) health outcomes, due to severe economic and service disruptions, as well as low social connectedness	(263)
Ethnic minorities had a lower COVID-19 vaccine uptake, higher mortality rates and larger decreases in life expectancy	(248, 264)
Food insecurities arise for low SES groups due to the rise in poverty, unemployment and food prices. In addition to the economic barriers, people living in rural areas also experienced insecurities due to decreased psychical access to food	(265–268)
Food insecurities lead to an increase in unhealthy eating behaviors (e.g., consuming high caloric products)	(260)
Digital inequalities led to disparate possibilities during the pandemic such as access to COVID-19 vaccinations, the ability to work or study from home and to maintain social connections with friends and family	(258, 269–273)
Gender inequalities	
Women experienced higher rates of mental health issues and psychological deterioration than men	(260, 274–277)
Women experienced a higher increase in suicide rates than men	(278, 279)
Women also more often experienced job loss and/or loss of income than men	(247, 276, 277, 280–283)
Gender gaps and unequal distribution of household chores increased during the pandemic. Women reported increased household chores and childcare and decreased leisure time. The propensity to work from home did not differ across genders. In Spain, by May 2020, women from middle-income households with kids experienced 3% larger income loss than men	(274, 277, 280, 283, 284)
Reinforcement of existing gender inequality in academic work. Women were underrepresented as (senior) authors of academic papers during the pandemic, deepening pre-existing inequality. While the quantity of women authored publications seemed to have been on par, quality seemed lower	(285–287)
Women were more exposed to the COVID-19 virus than men due to representing most frontline workers. In Spain, the cumulative incidence rate was higher for women than men	(244, 251, 288)
Males experienced higher COVID-19 mortality rates than females	(242, 244)
The COVID-19 pandemic caused serious setbacks in advancements in solving problems such as child marriages, gender-based violence, and female genital mutilation. Estimates show that 6 months of lockdown led to an additional two million more cases of female genital mutilation, 31 million cases of gender-based violence, and 13 million more child marriages over the next 10 years that wouldn't have occurred otherwise	(289)
Age group inequalities	
The risks of mortality from COVID-19 for people aged 60 and above are significantly higher than for younger people. This led to a life expectancy decrease in 27 out of 29 countries included in the study	(245, 251, 290):
Children subjected to school closure and other lockdown measures reported adverse mental health symptoms	(291)

(Continued)

TABLE 1 (Continued)

Effect on inequalities	References
Health inequalities	
Patients with non-COVID 19 conditions had less access to treatment and preventive measures during the crisis Taken together with other trends, such as privatization of healthcare, already marginalized sections of society were hit harder, leading to worsening existing and creating new health inequalities	(244, 292)
Physical activity health inequality was increased due to differences in access and availability to engage in physical activities during lockdowns	(293)
The switch to remote consultations especially impacted older people, unemployed, people with low SESs, migrants, and men, as these groups were less likely to use remote consultation	(250)
People with pre-existing health conditions (e.g., obesity or malnutrition) had worse COVID-19 outcomes. Oftentimes these people also experienced social inequalities and nutritional disparities long before the crisis	(262, 294–296)
Mental health inequalities	
The crisis increased existing mental health conditions and exacerbated preexisting inequalities in that respect. Financial insecurity mediated some of the effect of SES and mental health outcomes. People with a (family) history of mental health disorder also experienced greater difficulties adjusting after lockdown release. SES inequalities in social network, loneliness and mental health increased. A study in Japan showed positive effect on subjective well-being for socially advantaged people vs. negative effects for socially disadvantaged people, widening the gap	(241, 260, 262, 296–302)
Economic inequalities	
Income inequality was mainly created by the policy response to the crisis rather than its health consequences. By early June 2020, the pandemic has generated at least 68 million additional poverty years in 150 countries, mainly among already disadvantaged groups. Additionally, the health consequences worsen income inequality	(303)
Working from home increased inequalities in the labor market based on SES, digital access, job type, sector, and hierarchical position. Male, older, highly educated, and highly paid employees benefited from working from home	(42, 244, 257, 260, 273, 283, 304, 305)
Aggressive NPIs increased income inequality and poverty, with vulnerable groups impacted more. In Spain, by May 2020, households in the richest quintile lost about 7% of their income, while the poorest quintile lost 27% of their income	(247, 262, 306–308)
The pandemic did not affect between-country inequality, which continued to decrease as in the previous years	(309)
Educational inequalities	
Educational inequalities emerged or increased in terms of parental income, education, internet access, English and technology skills, and/or previous school performance. Search for online learning resources was substantially larger for areas with higher income, better internet access and fewer rural schools in the US. In Germany, daily learning time was halved, from 7.4 h. This decrease was significantly larger for low achievers, who displaced learning time with TV or computer games. In the Netherlands, where access to internet is better than other countries, with a relatively short school closures of 12 weeks, education learning loss sharply increased for students from disadvantaged households	(269–271, 310–312)

largest impact of the COVID-19 crisis on the world's poorest, increasing the global poverty rate from 7.8 to 9.1 percent by the end of 2021 (327). The effects on inequality and social mobility are expected to be long-term: people who lost income due to the pandemic have been about twice as likely to spend down on assets or savings. Hence, they will be less able to cope with continued or reoccurring income loss. Also, 57% of the people who lost income due to the pandemic have been more likely to go a full day without eating, and the aggregate loss of between 0.3 and 0.9 years of schooling also impacted the poorer families and their economic prospects. Government interventions such as unemployment insurance and benefits for furloughed workers in the short term at least, partially mitigate the effect of the loss of livelihood (14). In Spain, it has been estimated that without those interventions, inequality would have increased by almost 30% in just 1 month (14, 223). However, young people and foreign-born workers profit less from those interventions and experience a large loss of purpose in life (46, 328, 329).

Educational inequalities

Early in the pandemic, school closures were widespread. In March 2020 schools closed in 138 countries, affecting 80% of students worldwide (214). This is despite a heated scientific debate regarding the effectiveness of school closures on virus transmission. Without a clear answer on the effectiveness of school closures, students' education suffered and the "hurt can last a lifetime" [(330); for a review see (10, 214)]. As early as

April 2020 it was stated that school closures would affect poorer children most, as closures also exacerbated food insecurity and the non-school factors (e.g., parental availability for help and supervision, internet access and technology availability, quiet spaces, etc.) that are the primary source of inequalities in educational outcomes (214). Even though many schools switched to online education, this did not help much as a substitute. A study in the Netherlands among 350,000 students showed that students made little or no progress during the school closure and learning loss was "most pronounced among students from disadvantaged homes" [(331), p. 1]. This was despite that the Netherlands was seen as a best-case scenario, with a relatively short lockdown, equitable school funding, and one of the best rates in terms of broad-band access. While for children from high-income families learning might be possible at least theoretically, children from lower income families are faced with numerous hurdles. Besides this, as many parents lost their jobs, these children may be exposed to this stress as well. As "previous recessions have exacerbated levels of child poverty with long-lasting consequences for children's health, well-being, and learning outcomes." [(214), p. 243], the long-lasting consequences should not be underestimated (332). Recent studies showed a sharp increase in inequalities regarding education (269, 331) and student well-being (333). In addition, homeschooling caused high levels of parental stress (334). Taken together, educational inequalities increased sharply, and student, as well as parent well-being was at stake during and after the school closures.

Gender inequalities

While the year 2020 was earmarked for reflection on gender inequalities, it has been the year that saw an increase in both existing and new gender inequalities (278). The rising gender inequalities are in the domains of health and well-being, home, domestic violence, work and poverty, and leadership (278). Women reported greater stress and anxiety during lockdowns (335), especially women with children (336), and female students (333). The health and well-being of women were also disproportionally affected, lowering life expectancy, and increasing suicide rates (337). Moreover, reports of abuse, self-harm, and thoughts of suicide/self-harm were higher among women (338). Women were more likely to experience (physical) aggressive interactions in their dream content (339). Also, women's physical and reproductive health was jeopardized, as many countries reallocated medical care toward COVID-19 patients (340). Gender-based violence increased at an alarming rate [for a review see (341)]. Anxiety and depression tripled for pregnant and postpartum women (342). Mothers were more likely to take on more household chores during the crisis and they were responsible for homeschooling (343), and worked on average 5% less, while men worked on average the same number of hours (344). Women with young children reduced their work hours four to five times more than fathers (344).

In academia, pre-existing inequalities persisted, and new ones arose. While academic gender inequalities were already discussed for quite some time [e.g., (345)], the crisis increased pre-existing gender inequalities (346). For instance, in terms of academic output, while men working mainly from home became more productive in the first 10 weeks of the lockdown, and overall research productivity in the US increased by 35%, female productivity dropped by 13%. This productivity gap was found in six more countries (347). While women already faced inequity in terms of having a higher teaching load and more service tasks, which are rewarded less than academic publishing, this was exacerbated when teaching and mentoring had to be done online (347). This is compounded by women having to take on most household tasks, homeschooling, childcare and sometimes caring for aging parents and extended family (343, 348). Also, it was predicted that women's poverty rate would rise by 10% globally as a result of the NPIs, as many service jobs were affected (349). Taken together, women experienced more mental health problems, domestic violence, and a larger burden of household and professional tasks.

Results of inequalities: Increase in stress

The result of rising inequalities may be an increase in stress and resulting in mental health problems (350). A meta-analysis indeed showed that income inequality was negatively related to mental health (351). In general, humans cause stress on people lower in the hierarchy, and in the last few decades, a lot of research investigated the causes and consequences of this [for a review see (352, 353)]. For instance, Sapolsky researched the question of why primates (including humans) cause each other so much stress. Apes and other primates have more stress-related diseases than any other species, and this seems to be because having spare time in these species is used to cause stress to others, usually lower in the hierarchy (36). Stress levels for low-status baboons were significantly reduced when baboons high in the hierarchy were inadvertently killed due to eating tainted meat (37). The extent to which these studies have validity for human society is debatable. For obvious ethical reasons, it is very difficult to do a study in which extreme hierarchical differences are created and subsequently lifted to study the effects. However, the Whitehall studies, stretching over decades show that status differences and inequalities are related to ill health and mortality, even when controlling for lifestyle (38), and these differences in health outcomes and mortality even stretched until after retirement (352). Interestingly, this was the case even though mental health for low status workers, working in stressful jobs with little autonomy, increased after retirement (354). It goes without question that it is imperative to minimize inequalities.

Reducing inequalities

Good governance, or the actions governments and organizations take to govern society through laws, norms, power or language, is key to reducing inequalities in society (355). Reducing gender inequalities in academia is also important and several policies are promising (356). An Oxfam report suggested responding to the crisis with several measures to increase equality (357). In general, community development seems to be a promising avenue in this respect (358). Coordination and integration of the health sector and community development may help streamline efforts to influence health and well-being of especially vulnerable groups (358). Evidence-based policy making may help reduce inequalities (359) and to buffer the negative effects of the crisis. Going forward, citizens and governments should act to create a more equal and sustainable world (325). Below, we describe what governments could have done better and what can be learned from this crisis. This examination should not be construed as an effort to blame anyone–a blame culture would be a perpetuation of the crisis and the toxic environment that we described above that fosters inequalities. Conversely, it is important to learn from our mistakes to correct them and not repeat them, close the circle of the pandemic, and be prepared for future pandemics without disrupting life (360).

Could we have done better?

We could have done better in our response to COVID-19. Vast power was given to experts who had (or claimed) expertise on COVID-19. This resulted in an exclusive focus on illness and deaths from COVID-19, with implemented and mandated NPIs of unprecedented severity, and which had been recommended against in previous pandemic plans (54, 55, 141, 361). These NPIs were also implemented without adequate consideration of their collateral effects (as discussed above and predicted in previous pandemic plans). The response bypassed the lessons learned from past pandemics and other emergencies.

Emergency management (EM) is the prevention and mitigation of, preparedness for, response to, and recovery from emergencies, regardless of the risk/hazard (362). An EM Agency (EMA) is a coordinating agency that coordinates requests from the Subject Matter Agency (the agency dealing with the direct effects of the hazard, here, public health for the COVID-19 hazard), while also dealing with the indirect effects of the hazard (here, pandemic and response) (363). The EMA coordinates the four simultaneous EM critical functions (Table 3) during a public emergency, like COVID-19, with direct and indirect effects of the virus and any response to the virus on all of society.

The EM process is the same for any public emergency, including a pandemic. By following the process, the EMA, unlike the public health medical experts, is specifically trained to optimize the response. The seven EM process steps that must occur in any public emergency, and how these should have been taken for this pandemic, are shown in Table 2 (6, 363). By not following the established EM process, the wrong aim, governance, mission analysis, and courses open were more likely to be selected without any published pandemic plan (363). Many negative consequences and exacerbations of inequality discussed above were predictable and should have been considered in risk-benefit analyses (6, 11, 54, 55, 141, 361). Others concluded that crucial parts of the EM process were missed during the pandemic response, although these authors did not recognize that these were components of the EM process and that they were, so to speak, reinventing the wheel (11, 13, 365). In Table 3 we mention some priorities we believe the EM process would have discovered to enable a response with far less collateral damage, and some current priorities necessary for recovery.

Discussion

Possible ways forward

Governments and public health authorities worldwide have imposed their decisions, while having trouble using evidence-based policy and decision making (13, 359, 366). This has harmed many groups in society (10, 367). Many scientists also went along with the narrative that the most aggressive NPIs were necessary for the greater good, for instance, experts advising on how to modify behavior [e.g., (366, 368)]. Others have pointed out that the debate has been highly polarized and should ideally be more open-minded and nuanced (369). Society has fallen prey to groupthink (11) with the perpetuation of dysfunctional entrenched patterns in responding to the pandemic (13). It seems more important than ever to uphold and renew important values that societies fare by, to enhance the well-being of their citizens (370). Healing society should focus on people's dignity, rights, values, and humanity (370). Concurrently, it becomes imperative to use evidence-based policy and decision making (359, 371) and reflexivity (13), as used in the EM process (363).

It is key to restore the health and well-being of the wider population, and create a positive environment in which people can thrive (46). Well-being should matter to governments (230). Next to reversing the most aggressive and ineffective policies (360, 372), the way people cope with the situation is important (10, 373). Most people seem to be negatively affected in terms of health and well-being, and personality differences may also play a role (217). People that score high on proactive personality are better at spotting opportunities and acting upon them (374). They also are better able to foresee consequences and risks inherent in actions that they take and anticipate them, affecting environmental change (375). For many people access to intangible resources such as social support, and social belonging and access to tangible resources such as income, livelihood, and access to (healthy) food have been thwarted. Loss spirals accelerate once resource losses accumulate, while resource gain

TABLE 2 The emergency management process: seven steps and how they should have been applied during the SARS-CoV-2 pandemic.

Steps in the EM process	Specifics of this step during the SARS-CoV-2 pandemic
1. Identification of the hazard	The hazard is SARS-CoV-2
2. Selection and maintenance of the aim	The aim is to minimize the impact of SARS-CoV-2 and our response on the society of the jurisdiction The aim was not necessarily "to flatten the curve" or "to protect the medical system," which may be included in objectives
3. Establish a Governance Task Force, to provide leadership for all policy, programs, and actions taken, with many diverse stakeholders involved, and led by the most senior government official (e.g., the provincial premier in the provinces of Canada)	Governance Task Force was not assembled, and public health officers and medical advisors had undue influence
4. Risk/Hazard assessment	The risk from SARS-CoV-2 was very early on known to be extremely age-dependent (especially in older adults with comorbidities), and the potential impacts on critical infrastructure (including healthcare) predictable
5. Mission analysis to determine the *objectives* of *what* needs to be done	For SARS-CoV-2 this includes tasks given (pre-written pandemic response plans) and tasks implied required to meet the aim. This included maintaining confidence in government (by diminishing fear, ensuring mutual aid, and ensuring constant communications), protecting seniors, and protecting critical infrastructure and essential services (e.g., new medical surge capacity, full continued education, continuity of business and economy)
6. Defining courses open/options to determine *how* the mission analysis objectives can be met	This entails determining courses open for each grouping of tasks, as determined by assigned teams with appropriate diverse expertise (to prevent groupthink). Each course open has a full assessment of cost-benefit to justify options, and plan for solutions to expected collateral damage
7. Public issuing of a written comprehensive evidence-based Response Plan	Issuing a written Pandemic Response Plan forms the basis of confidence in government by transparently demonstrably justified due diligence

References: Joffe and Redman (6), Redman (363), and Redman (364).

cycles become weaker (194). It is easy to widen the inequality gaps, but these may take years and years to close. For instance, while it was estimated before the crisis that closing the gender gap could take up to 99.5 years, after the crisis it was estimated to take 135 years (376, 377).

Collective healing and restoring meaning

The current situation requires collective healing [(378); cf. (379)]. While programs such as Eye Movement Desensitization and Reprocessing [EMDR; (380)], brainspotting (381) and neurosculpting (382) may be effective for relieving (complex) trauma [for reviews see (383, 384)], more scalable positive psychology solutions are needed (230). Many people will feel the need to reinstate a sense of meaning in life (46). Scalable solutions may entail for instance life crafting (reflecting and setting goals and undertaking actions for important areas of life) to find meaning in life, as a written guided online intervention (385), or *via* a chatbot [e.g., (386, 387)]. Gratitude and grit may restore a sense of meaning in life and have been related to decreased suicidal ideations (388). Gratitude and well-being are correlated (389), and the connection between these seems to entail social connectedness and meaning in life (390). Communities could investigate possibilities to help many people *via* scalable solutions (10, 13, 46). For instance, life crafting and other positive psychology and mental health interventions delivered online or *via* a chatbot, could be a scalable solution and "first aid" for people experiencing issues such as anxiety, depression, and loss of purpose in life (46, 386). Goalsetting also seems promising in terms of reducing the gender and ethnic minority achievement gap for specific student populations (391). Interventions should be rigorously tested for effectiveness and they should preferably be done in concert with other positive psychology interventions tackling educational inequalities [see (392)]. Moreover, it is advisable to radically increase the voluntariness of measures. Giving people a choice instead of forcing policies upon them, might increase intervention effectiveness. For instance, when people work from home voluntarily, they experience fewer adverse effects of teleworking [e.g., (393)].

Increasing diverse citizen engagement in (global) problems (86), and grassroots movements may help counter authoritarian tendencies associated with the pandemic response, salvage democracy (151, 394–396), and increase democratization of companies post-COVID-19 (397). It may be better to strengthen people's sense of responsibility to take action after carefully laying out the pros and cons of behavior (398). Finally, we should

TABLE 3 Examples of emergency management function priorities in addressing the SARS-CoV-2 pandemic.

EM function	Priorities at the start of the pandemic	Priorities mid-2022 for endemic SARS-CoV-2
Preparation	Define the mission: to ensure minimum impact of SARS-CoV-2 on society as a whole Establish a Governance Task Force as the single decision-making body for policy, programs, and actions, with broad diverse representation, led by the Premier, and coordinated and supported by the Emergency Management Agency Release a comprehensive written Pandemic Response Plan	Define the mission: to ensure minimum impact of endemic SARS-CoV-2 on society as a whole, *and* to recover from the lockdown-based response collateral damage Establish the appropriate Governance Task Force and disband other advisory groups Release a comprehensive written Pandemic Response and Recovery Plan
Mitigation	Focused protection of the most vulnerable: a plan for long-term care homes and for those in the community aged ≥60 years with multiple comorbidities Plans for socially vulnerable groups: e.g., temporary housing support to reduce household crowding	Voluntary focused protection: understand that the risk for those aged <60 years is similar to that from seasonal influenza
Response	Ensure critical infrastructure is ready for people who get sick, including new surge capacity in hospitals so that continuity of the medical system is ensured Ensure equitable access to healthcare	Removal of fear of SARS-CoV-2 and of each other: ensure understanding of risk in relation to other daily risks, by age group and comorbidity Removal of fear of future use of NPIs: ensure understanding of accumulated evidence about trade-offs and efficacy to end talk of future mandated lockdowns, quarantine of exposed people, school closures, community masking, and border closures Establish capabilities for endemic SARS-CoV-2: new healthcare surge capacity without plans to sacrifice healthcare for all other conditions
Recovery	Reduce fear with daily information presented with context including plans for surge capacity, give hospitalizations and death numbers with denominators, by age group, in comparison to other risks causing deaths annually, and without a focus on raw case counts Give evidence on the cost-benefit balance of NPIs and lockdowns: explain the difficult trade-offs involved and the justification for focused protection	Develop a detailed plan to overcome the impacts from the use of fear and NPIs/lockdowns on mental health, societal health, our children's education and development, missed/delayed diagnosis and treatment of medical conditions, government debt, confidence in the economy, etc Replace fear with confidence by using the EM process, with cost-benefit analysis of all recovery options open, improved communication, and a written plan that is transparently demonstrably justified by due diligence

References: Joffe and Redman (6), Redman (363), and Redman (364).

acknowledge that for many of the proposed interventions, we would benefit from having stronger evidence from large (cluster) randomized trials, to understand whether they may work in different populations and circumstances. While the pandemic led to thousands of randomized trials of drugs, biologics, and vaccines (399, 400), few trials were performed on NPIs (401) and the research agenda on psychological and social-level interventions was even thinner. This deficiency should be remedied.

Conclusion

As the COVID-19 crisis and NPIs of unprecedented severity and duration are related to many negative side effects and increase inequalities worldwide (402), stress, health, and trauma for vulnerable populations must be addressed (403). The economic fall-out and rise in inequalities may be long-term (403). Governments should take well-being as a spearhead for decision-making in the upcoming years (230). Hopefully, with effective interventions, the tide may be turned.

Author contributions

MS played the primary role in the conception of the manuscript, writing, reviewing, and revising the manuscript. JI contributed to writing the manuscript, identifying studies on inequalities, and editing the manuscript. AJ wrote section on "Could we have done better", crafted Tables 2, 3, contributed to writing, and editing the manuscript. 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

Watch here Mass formation and rising inequalities, a proposed way forward - Michaéla Schippers - YouTube the interview MS gave about this article for the podcast "Follow the Science".

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EDITED BY
Caress Alithia Dean,
Oakland University, United States

REVIEWED BY
Changle Li,
Inner Mongolia Medical University, China
Wei Wang,
Xuzhou Medical University, China

*CORRESPONDENCE
Tian Xie
xietian@sjtu.edu.cn

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Relationship between internet use intensity and quality of life in chronic patients during the COVID-19 pandemic: The role of physical exercise and health insurance

Yangyang Wang[1,2], Jian Xu[1,3] and Tian Xie[3]*

[1]China Institute for Urban Governance, Shanghai Jiao Tong University, Shanghai, China, [2]School of International and Public Affairs, Shanghai Jiao Tong University, Shanghai, China, [3]School of Media and Communication, Shanghai Jiao Tong University, Shanghai, China

The internet use intensity of human has increased substantially during the COVID-19 Pandemic, and it is severely impacting the well-being of chronic patients. This study aimed to explore the underlying mechanism of the relationship between internet use intensity and quality of life in chronic patients, based on the cross-sectional data from China Family Panel Studies (CFPS) during the COVID-19 Pandemic in 2020. The results showed that the internet use intensity had significant positive association with quality of life among chronic patients, and such association has been found in both urban and rural samples. Among the relationship of internet use intensity and quality of life in chronic patients, the mediating effect of physical exercise reached 10.25%. Furthermore, health insurance positively moderated this relationship. There are new insights for policy recommendations and clinical guidance on the role of physical activity and health insurance aimed at improving chronic patients' quality of life. Meanwhile, in both rural and urban governance, public health agencies should promote the "Internet + Healthcare" program to improve health insurance and physical activity literacy, thus providing a higher level of quality of life for patients with chronic diseases during the COVID-19 Pandemic.

KEYWORDS

COVID-19 pandemic, internet use intensity, quality of life, health insurance, physical exercise, health management of rural and urban governance

Introduction

Since the outbreak of the COVID-19 Pandemic in China at the end of 2019, the pandemic has become a global public health event with a continuous impact on social development and people's daily life and health (1, 2). Numerous studies have pointed out that people experienced significantly lower quality of life and more mental health issues during the COVID-19 pandemic (3–5). As a vulnerable group, the quality of life of

patients with chronic diseases deserves special attention. Currently, studies show that chronic diseases which contain cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes are the largest cause of death globally (6, 7). As the population aging dramatically, the number of patients with chronic diseases substantially increases in China, and China faces a higher mortality rate than developed countries (8, 9). The previous study showed that chronic patients reported lower levels of quality of life during the COVID-19 Pandemic (10), such as drop-in emotional functioning and social functioning, and severe psychological problems (11). Therefore, it's essential to explore the factors influencing quality of life among chronic patients.

According to the World Health Organization (WHO), quality of life refers to "an individual's perception of their position in the life in the context of the culture in which they live and in relation to their goals, expectations, standards, and concerns" (12). The appraisal of quality of life is subjective, however, it is also affected by many objective factors, among which internet use is a significant factor. The use of digital technology has increased dramatically after the outbreak of COVID-19, up to 90% of the Chinese participants reported longer screen time for study, work, and entertainment (13–15). Many studies have shown that internet use was positively associated with quality of life from different aspects, such as decreasing loneliness (16), improving social relationships and personal well-being (17), and enhancing physical and mental health (18, 19). A study showed that moderate amounts of time spent on online activities are beneficial for enhancing the level of quality of life (19). However, some studies hold different views. The prevalence of internet addiction among vulnerable people in China has increased during the pandemic (20). While more time spent on the internet might increase social isolation and loss of contact with the social environment (21). This means that excessive use of the internet has a negative effect on the quality of life (22, 23). Thus, the relationship between internet use intensity and quality of life is still unclear, and its underlying mechanism is still to be confirmed during COVID-19.

Although a large number of studies have shown that internet use intensity was associated with quality of life, few studies have explored its underlying mediating mechanisms. One study pointed out that physical exercise mediated the relationship between internet use and mental health (24). The internet provides a favorable tool for physical exercises, such as searching for exercise information, using exercise apps (25), providing exercise guidance (26), self-monitoring (27), and transferring exercise data (28). Physical exercise has long been used as a means of rehabilitation for chronic patients. Some study have shown that internet-based physical activity is an effective way for quality of life improvement (29). Meanwhile, physical exercise has a positive effect on the quality of life among patients with chronic conditions, such as chronic brain disorders, chronic liver disease, and type 2 diabetes (30–32). As a significant intervention for patients with chronic diseases, physical exercise plays an irreplaceable role in optimizing bodily functioning (33), reducing morbidity and mortality (34), and improving patients' quality of life. In conclusion, internet use intensity is positively associated with physical exercise, and physical exercise predicts quality of life. Therefore, it can be assumed that physical exercise plays a mediating role in the relationship between internet use intensity and quality of life.

Health insurance has not to be sufficiently considered as a potential moderator for quality of life. The benefits of health insurance improved health-related outcomes in chronic patients (35). Ronksley et al. demonstrate that chronic conditions and distress were significantly related to unsatisfied healthcare needs (36). At the same time, the inclusion of chronic disease drugs in medical insurance reimbursement will benefit patients (37). With the promotion of China's "Internet +Healthcare" program, the internet provides a convenient way for medical consultation, treatment, and health insurance reimbursement. One study pointed that the higher the frequency of internet usage, the more likely Chinese households are to participate in private insurance (38). And patients who had private reimbursement insurance reported a higher quality of life than those with public insurance (39). Besides, some studies revealed that individuals who have health insurance reported a higher quality of life than those with no health insurance (40, 41). Hence, health insurance may moderate the association between internet use intensity and quality of life.

Taken together, the main goal of the current study is to explore the impact mechanism of internet use intensity on the quality of life of chronic patients during the COVID-19 pandemic. In order to improve the quality of life of chronic patients, policy recommendations and clinical guidance will be provided. There were the following hypotheses: (H1) There will be a positive relationship between internet use intensity and quality of life. (H2) Physical exercise mediates the relationship between internet use intensity and quality of life. (H3) Health insurance plays a moderating role in the relationship between internet use intensity and quality of life (see Figure 1).

Methods

Data and participants

The current study obtains the dataset from China Family Panel Studies (CFPS), funded by Peking University and carried out by the Institute of Social Science Survey of Peking University. It covers 25 provinces/municipalities/autonomous regions, and was officially launched in 2010 with a target sample size of 16,000 households. The CFPS sample is a multi-stage probability sample drawn using the implicit stratification method, and each subsample is drawn in three stages. The first two stages of the sampling process use

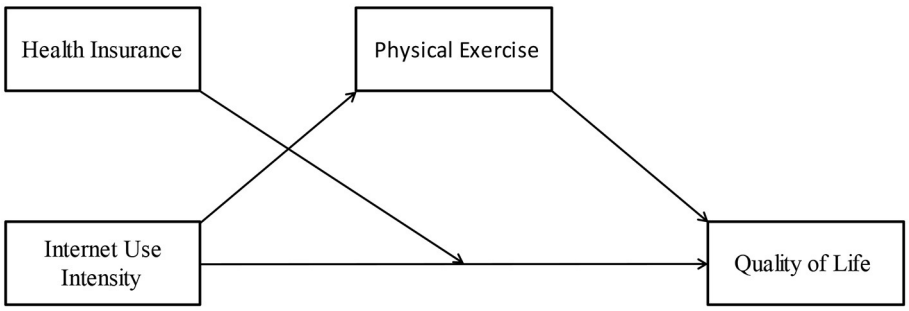

FIGURE 1
The relationship among internet use intensity, quality of life, physical exercise, and health insurance.

official administrative division information. This is because the administrative division structure of mainland China is strictly hierarchical and covers the entire population of mainland China. The third stage was to create end sampling frames in the selected sample villages/residences using the list of households obtained from the village survey map, and to draw a sample of households by expanding the sample size according to circular equidistant sampling with a random starting point to ensure that each sample village/residences could fulfill the target of 25 households. The 2020 wave of CFPS was conducted from July to December 2020 during the COVID-19 Pandemic and contained 28,590 individuals. The target population of this study was respondents with chronic diseases, and a final sample of 3,313 cases with chronic diseases was used after screening and cleaning invalid samples. Among them, 1,777 (53.64%) were female and 1,536 (46.36%) were male; 1,582 (47.75%) were rural residents while 1,731 (52.25%) were urban residents.

Variables

Dependent variable

Quality of Life. Since Flanagan developed the Quality of Life Scale (QOLS) in 1978 (42), measuring quality of life in terms of five dimensions has been accepted in many studies (43–45). The five dimensions of the QOLS include physical and material well-being; relationships with other people; social, community and civic activities; personal development and fulfillment; and recreation. Based on these five dimensions, this study selected 14 approximate question items to measure the quality of life from CFPS 2020, namely: (1) have health insurance (From the question "What health insurance do you have?"); (2) have high local income (From the question "How would you rate your income in your local area?"); (3) have good health (From the question "How do you consider yourself to be in good health?"); (4) have good interpersonal relationships (From "How well-connected do you think you are?"); (5) have a sense of subjective well-being (From the question "How happy do you think you are?"); (6) post comments related to political issues and national events (From the question "In the past 12 months, have you made any statements on your website related to political issues and national issues?"); (7) vote in village/neighborhood council elections (From the question "In the last 5 years, have you voted in village/neighborhood council elections?"); (8) read books in the past year (From the question "In the past 12 months, excluding reading for work and exams, have you read any books?"); (9) have high life satisfaction (From the question "How satisfied do you rate yourself with your life? "); (10) have confidence in the future (From the question "What is your level of confidence in your future?"); (11) think the living standard is likely to improve (From the question "In today's society, there are still many opportunities for people like me to improve their living standards"); (12) play online games (From the question "In the past week, have you played online games?"); (13) spend time watching TV, movies and other video programs (From the question "In general, how many hours per week do you spend watching TV, movies and other video programs by any means?"); (14) share my work or life in social media frequently (From the question "In the past year, how often did you share your work or life in your WeChat Friend Circle?"). For each of the above question items, respondents were coded "1" if they exceeded the median of the sample, otherwise they were coded "0." Finally, the coded answers of the 14 questions were summed to obtain a score between 0 and 14, with higher values indicating a higher quality of life.

Independent variable

Internet Use Intensity. According to the related studies (46–49), time spent online is measured by two questions: "In general, how long do you spend online with your mobile devices each day?" and "In general, how long do you spend online with the internet each day?". The total time spent online using computers and mobile devices was summed by hours per day to measure the internet use intensity of the respondents. The more time spent

on the internet per day, the higher the internet use intensity of the respondents.

Mediating variable

Physical Exercise. Physical activity was measured with a single-item question that asked "How often did you participate in physical fitness and leisure activities in the past 12 months?" that ranged from 1 (never participate) to 8 (twice a day or more). The higher the coded value, the more frequent the physical activity participation.

Moderating variable

Health Insurance. In CFPS 2020, respondents were asked about their health insurance coverage by one question "What health insurance coverage do you have?". According to the respondent's participation in health insurance, "have at least one type of health insurance" was coded as "1"; "none of health insurance" was coded as "0."

Control variables

Based on previous studies (50–52), socio-demographic characteristics, residential status, health behavior, and economic status were selected as control variables. Socio-demographic characteristics included gender (male, female), age, marital status (unmarried, other), and educational experience (code "not educated" as "1," "primary school" as "2," "junior high school" as "3," "high School/junior high school/technical school/vocational high school" as "4," and "college and above" as "5"; higher coding value indicates higher education level). Residence status includes residence type (urban, rural). Health behaviors include smoking, drinking, and self-assessed health status (Likert five-degree scale; the higher the number, the healthier it is). Economic status included annual personal income (unit is 100,000 RMB) and annual medical costs (include total hospital expenses and other injury expenses; unit is 100,000 RMB).

Statistical analysis

Descriptive analyses were conducted for all variables. The effect of internet use intensity on quality of life was analyzed using the ordered logistic regression model (Model 1) and separately for the urban subsample (Model 2) and the rural subsample (Model 3). The mediating effect of physical exercise was examined using the macro PROCESS4.0 tool (53) (Model 4, Model 5, Model 6). The moderating effect of health insurance was examined by constructing an interaction of health insurance × internet use intensity via ordered logistic regression model (Model 7). Robustness tests were conducted by recoding the independent and dependent variables and selecting urban and rural subsamples using OLS (Model 8, Model 9, Model 10). All the above analyses were performed with the help of SPSS26 and Stata17.

TABLE 1 Descriptive statistics of all variables ($N = 3,313$).

Variables	Type of statistics	Full sample
Quality of life	Mean (SD)	6.08 (2.03)
Internet use intensity	Mean (SD)	1.41 (2.80)
Physical exercise	Mean (SD)	2.89 (2.60)
Health insurance	Mean (SD)	0.93 (0.26)
Gender	*N* (%)	
Female		1,777 (53.64%)
Male		1,536 (46.36%)
Age	Mean (SD)	56.44 (14.34)
Marriage status	*N* (%)	
Married		3,151 (95.11%)
Others		162 (4.89%)
Education level	*N* (%)	
Not educated		2,688 (81.13%)
Primary school		80 (2.41%)
Junior high school		198 (5.98%)
HJTV		248 (7.49%)
College and above		99 (2.99%)
Residence type	*N* (%)	
Rural		1,582 (47.75%)
Urban		1,731 (52.25%)
Smoking	*N* (%)	
No		2,519 (76.03%)
Yes		794 (23.97%)
Drinking	*N* (%)	
No		2,951 (89.07%)
Yes		362 (10.93%)
Self-assessed health status	Mean (SD)	2.11 (1.12)
Annual personal income	Mean (SD)	0.13 (0.34)
Annual medical costs	Mean (SD)	0.10 (0.28)

HJTV, High School/Junior High School/Technical School/Vocational High School.

Results

Descriptive statistics of all variables

Table 1 presents the descriptive statistics for all variables. The mean value of quality of life is 6.08 (SD, 2.03), indicating that the respondents' quality of life is low on the average, and many respondents spend close to the average amount of time using the internet. the mean value of internet use intensity is 1.41(SD, 2.80) hours per day, indicating that most of the respondents spend very little time using the internet, and only a few users spend a lot of time using the internet, with great variation between respondents. The mean value of physical exercise is 2.89

TABLE 2 Correlation analysis between main variables ($N = 3,313$).

Variables	Quality of life	Internet use intensity	Health insurance	Physical exercise
Quality of life	–	–	–	–
Internet use intensity	0.099***	–	–	–
Health insurance	0.172***	0.002	–	–
Physical exercise	0.149***	0.112***	0.047***	–

***$p < 0.001$.

(SD, 2.60), indicating that most respondents have very little time doing physical exercise. And the mean value for health insurance was 0.93 (SD, 0.26), indicating that the majority of respondents had at least one type of insurance. In addition, the male and female samples were approximately equal in proportion, with an average age of 56.44; most samples were married, and had a low overall education level; more samples live in urban than rural but only a small number of people smoking and drinking; poor self-assessed health status, and low average annual personal income and average annual medical costs.

Correlation analysis between main variables

Table 2 shows the results of the bivariate correlation analysis using Pearson correlation for the main variables. Quality of life and internet use intensity ($r = 0.099$, $p < 0.001$), health insurance ($r = 0.172$, $p < 0.001$) and physical exercise ($r = 0.149$, $p < 0.001$) were significantly and positively correlated. It indicates that respondents with higher intensity of internet use, having health insurance and more frequent physical exercise have a higher quality of life. Physical exercise and internet use intensity ($r = 0.112$, $p < 0.001$) and health insurance ($r = 0.047$, $p < 0.001$) were significantly positively correlated. This suggests that respondents with more physical exercise and higher internet use intensity are more likely to have health insurance, but there is no association between internet use intensity and health insurance.

Internet use intensity and quality of life

In this part of the analysis, three ordered logistic regression models were constructed separately to examine the impact of internet use intensity on quality of life. Considering the large gap between rural and urban areas in China, this effect still presents in terms of internet use. Separate regression models were constructed for the rural sample and the urban sample. The total sample size is 3,313, 1,582 for the rural sample, and 1,731 for the urban sample.

Table 3 shows the regression results of internet use intensity on quality of life after excluding the effect of multicollinearity. The odds ratios (OR) of the ordered logistic regression model are reported here. The results indicate that there is a significant positive effect of internet use intensity on quality of life among respondents with chronic diseases, supporting hypothesis H1. The full sample regression of model 1 indicates that the OR of internet use intensity on quality of life is 1.078, which is statistically significant at the 1% level of significance. By increasing the internet use intensity of respondents with chronic diseases by 1 h per day, it improves the quality of life by 7.8%, holding other control variables constant. This reveals that the stronger the internet use intensity, the greater the probability of improving the quality of life for respondents with chronic diseases. For model 2, the regression results for the rural subsample show that the OR of the effect of internet use intensity on quality of life is 1.138, which is statistically significant at the 1% level of significance. This suggests that a 1 h increase in daily internet use intensity among respondents with chronic diseases in rural areas can bring about a 13.8% improvement in quality of life, with other control variables held constant. In model 3, the regression results for the urban subsample show that the OR of internet use intensity on quality of life is 1.059, which is statistically significant at the 1% level of significance. This indicates that an increase in internet use intensity of 1 h per day among chronic disease respondents in urban areas can lead to a 5.9% improvement in quality of life, when keeping other control variables constant.

It also can be found that the positive effect of internet use intensity on quality of life is strongest in the rural sample, second strongest in the overall sample, and weakest in the urban sample. The reason for this difference is that since the COVID-19 Pandemic, the number of new rural internet users far exceeds that of urban internet users (54, 55), making this effect relatively stronger. In addition, age, education level, health insurance, and self-assessed health status all had significant positive effects on quality of life.

The mediating effect test of physical exercise

Table 4 shows that physical exercise plays a mediating effect in the process of internet use intensity influencing quality of life after excluding the effect of multicollinearity. Specifically, model

TABLE 3 Results of global and subsample regression analysis ($N = 3,313$).

Variables	Full sample	Rural sample	Urban sample
	Model 1	Model 2	Model 3
Internet use intensity	1.078***	1.138***	1.059***
	(0.018)	(0.038)	(0.020)
Gender (ref: female)	1.194**	1.234*	1.163
	(0.094)	(0.141)	(0.125)
Age	1.035***	1.039***	1.030***
	(0.004)	(0.005)	(0.005)
Marriage status (ref: married)	1.254	1.422	1.125
	(0.229)	(0.409)	(0.268)
Education level (ref: Not educated)			
Primary school	1.017	1.416	0.675
	(0.215)	(0.410)	(0.217)
Junior high school	1.428**	1.357	1.393
	(0.230)	(0.344)	(0.300)
HJTV	1.917***	1.903**	1.828***
	(0.325)	(0.579)	(0.380)
College and above	1.506*	1.536	1.468
	(0.346)	(0.818)	(0.380)
Residence type (ref: rural)	1.087		
	(0.070)		
Health insurance (ref: none)	3.338***	3.611***	3.130***
	(0.416)	(0.706)	(0.497)
Smoking (ref: no)	0.924	1.010	0.833
	(0.084)	(0.133)	(0.106)
Drinking (ref: no)	1.157	1.098	1.207
	(0.125)	(0.171)	(0.183)
Self-assessed health status	1.575***	1.635***	1.516***
	(0.048)	(0.069)	(0.067)
Annual personal income	1.289*	1.079	1.388*
	(0.184)	(0.222)	(0.233)
Annual medical costs	0.987	0.816	1.072
	(0.107)	(0.173)	(0.158)
Observations	3,313	1,582	1,731
Wald chi^2	471.05	274.52	205.51
Pseudo R^2	0.037	0.043	0.032
Log pseudolikelihood	−6743.92	−3177.93	−3553.09

The parameters reported are the odds ratios (OR) of the ordered logistic regression model; robust standard errors in parentheses. HJTV indicates High School/Junior High School/Technical School/Vocational High School. ***p < 0.01, **p < 0.05, *p < 0.1.

4 shows that internet use intensity significantly and positively affects physical exercise ($\beta = 0.104$, $p < 0.01$); model 5 suggests that internet use intensity significantly and positively affects quality of life ($\beta = 0.078$, $p < 0.01$); model 6 indicates that internet use intensity ($\beta = 0.07$, $p < 0.01$) and physical exercise ($\beta = 0.08$, $p < 0.01$) significantly and positively affected quality of life. It suggests that physical exercise mediates the relationship between internet use intensity and quality of life. And hypothesis H2 was supported. Moreover, the physical exercise here exerts a partial mediating effect.

After confirming the mediating effect of physical exercise, this study proceeded to calculate the total effect, direct effect, and mediating effect (see Table 5). It showed that in the relationship between internet use intensity and quality of life, the mediating effect of physical exercise (0.008) accounted for 10.25% of the total effect (0.078), and 11.94% of the direct effect (0.067).

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TABLE 4 Results of the mediating effect test ($N = 3,313$).

Variables/Dependent variable	Physical exercise	Quality of life	Quality of life
	Model 4	Model 5	Model 6
Internet use intensity	0.104***	0.078***	0.070***
	(0.02)	(0.015)	(0.015)
Physical exercise			0.08***
			(0.013)
Gender (ref: female)	0.326**	0.201**	0.176**
	(0.108)	(0.08)	(0.08)
Age	0.017**	0.037***	0.036
	(0.005)	(0.004)	
Marriage status (ref: married)	0.306	0.289*	0.265
	(0.224)	(0.168)	(0.167)
Education level (ref: Not educated)			
Primary school	−0.745**	0.042	0.101
	(0.306)	(0.229)	(0.228)
Junior high school	−0.39*	0.377**	0.408**
	(0.22)	(0.165)	(0.164)
HJTV	−0.23	0.742***	0.761***
	(0.222)	(0.166)	(0.165)
College and above	−0.207	0.522**	0.539**
	(0.322)	(0.241)	(0.24)
Residence type (ref: rural)	1.032***	0.087	0.005
	(0.091)	(0.068)	(0.069)
Health insurance (ref: none)	0.51***	1.332***	1.291***
	(0.166)	(0.125)	(0.124)
Smoking (ref: no)	−0.464***	−0.073	−0.036
	(0.121)	(0.091)	(0.091)
Drinking (ref: no)	−0.029	0.149	0.151
	(0.148)	(0.111)	(0.11)
Self-assessed health status	0.067*	0.477***	0.472***
	(0.04)	(0.03)	(0.03)
Annual personal income	0.176	0.227	0.213*
	(0.157)	(0.117)	(0.117)
Annual medical costs	0.174	−0.004	−0.018
	(0.158)	(0.118)	(0.118)
Constant	0.618*	1.371***	1.321***
	(0.353)	(0.265)	(0.263)
Observations	3,313	3,313	3,313
R-squared	0.076	0.150	0.159
F statistic	18.30	38.66	39.01

HJTV, High School/Junior High School/Technical School/Vocational High School. Robust standard errors in parentheses; number of bootstrap samples for percentile bootstrap confidence intervals is 5,000; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

TABLE 5 Results of the mediating effect.

	Effect	Boot SE	Boot LLCI	Boot ULCI	Ratio of indirect to total effect	Ratio of indirect to direct effect
Total effect	0.078	0.015	0.049	0.107		
Direct effect	0.067	0.015	0.041	0.099		
Physical exercise	0.008	0.002	0.005	0.013	10.25%	11.94%

Boot SE, Boot LLCI and Boot ULCL is estimated standard error under bias-corrected percentile bootstrap method, and 95% confidence interval lower and 95% confidence interval upper, and Boot LLCI and Boot ULCL do not overlap with zero, number of bootstrap samples for percentile bootstrap confidence intervals is 5,000.

This suggests that 10.25% of the positive effect of internet use intensity on quality of life was mediated by the mediating effect of physical exercise. The 95% confidence intervals do not overlap with 0, which means that they are statistically significant.

The moderating effect test of health insurance

The regression results in Table 6 indicate that health insurance positively moderates the relationship between internet use intensity and quality of life. To avoid the effect of multicollinearity, internet use intensity and health insurance were centered separately, and then the interaction (Health Insurance × Internet Use Intensity) was constructed. Internet use intensity, health insurance, and the interaction (Health Insurance × Internet Use Intensity) were placed together in Model 7 for regression analysis. The results showed that the OR of the interaction (Health Insurance × Internet Use Intensity) on quality of life was 1.085, which was statistically significant at the 5% significance level; internet use intensity (OR = 1.082, $p < 0.01$) and health insurance (OR = 3.360, $p < 0.01$) positively affected quality of life, respectively. This suggests that, holding the control variables constant, an increase of 1 h per day in internet use among respondents with chronic diseases is linked with a 36% improvement in quality of life for respondents with health insurance compared to those without health insurance. It implies that the positive relationship between internet use intensity and quality of life is stronger in the sample with health insurance than in the sample without health insurance. These results also indicate that health insurance strengthened the positive relationship between internet use intensity and quality of life. Therefore, hypothesis H3 is supported.

Robustness test

The purpose of the robustness test is to examine the stability of the regression analysis. In other words, the effect of the independent variable on the dependent variable remains stable when the variable measurement is changed, other models are used, or the sample size is changed. At present, there is no standardized robustness test, and subsample regression, reselecting the regression model, making variable substitutions, and changing the sample size are all commonly used robustness tests. We use OLS models to re-test the effect of internet use intensity on quality of life by recoding the independent and dependent variables. Specifically, the 14 question items were formed into one variable using principal component analysis to measure quality of life; the measure of internet use intensity was a categorical variable recoded in five degrees for internet use time. The newly formed internet use intensity and quality of life were then used to conduct regression analyses for the full sample (Model 8), the rural subsample (Model 9), and the urban subsample (Model 10), respectively. The results are shown in Table 7, indicating that the effect of internet use intensity on quality of life is consistent with the results in Table 3, and the results are robust and reliable.

Discussion

Chronic patients' quality of life during the COVID-19 Pandemic should be given attention. Based on the cross-sectional data from the CFPS dataset of wave 2020, the current study validated the underlying mechanism between internet use intensity and quality of life among chronic patients during the COVID-19 Pandemic in China mainland.

This study found that internet use intensity was significantly and positively related to quality of life. In other words, the more frequently individuals use the internet, the higher level of quality of life they experience, and this relationship is strongest in the rural sample, followed by the overall sample and the urban sample. However, this finding is inconsistent with previous studies that more use of the internet could reduce social communication, increase loneliness (56), and enhance sedentary risk (57). A likely explanation is that chronic patients could gain social, emotional, and experiential support from the internet during the lockdown. According to the uses and gratifications theory (58), users seek gratifications from the internet to fill their basic needs. The internet can not only be used for entertainment, work, study, and information seeking, but also as an important intervention tools for people to promote psychological empowerment and rehabilitation (19, 59). This indicates that providing physical activity interventions via the internet will help chronic patients improve their quality of life.

TABLE 6 Regression results of the moderating effect for health insurance ($N = 3,313$).

Variables	Model 7
Internet use intensity	1.082***
	(0.018)
Health insurance (ref: none)	3.360***
	(0.415)
Health insurance × internet use intensity	1.085**
	(0.035)
Gender (ref: female)	1.195**
	(0.094)
Age	1.035***
	(0.004)
Marriage status (ref: married)	1.269
	(0.233)
Education level (ref: Not educated)	
Primary school	1.016
	(0.214)
Junior high school	1.433**
	(0.231)
HJTV	1.910***
	(0.323)
College and above	1.485*
	(0.343)
Residence type (ref: rural)	1.084
	(0.070)
Smoking (ref: no)	0.925
	(0.084)
Drinking (ref: no)	1.151
	(0.125)
Self-assessed health status	1.576***
	(0.048)
Annual personal income	1.275*
	(0.181)
Annual medical costs	0.984
	(0.107)
Observations	3,313
Wald chi^2	467.96
Pseudo R^2	0.037
Log pseudolikelihood	−6741.40

The parameters reported are the odds ratios (OR) of the ordered logistic regression model; robust standard errors in parentheses. HJTV indicates High School/Junior High School/Technical School/Vocational High School. ***p < 0.01, **p < 0.05, *p < 0.1.

Furthermore, it revealed that physical exercise mediated the association between internet use intensity and quality of life. This finding indicates that people who use the internet more frequently are more likely to participate in physical exercise and report a higher quality of life. It is acknowledged that physical exercise is an effective way to prevent and treat chronic diseases (60, 61). Previous studies have shown that users with higher eHealth literacy are more likely to be physically active, while physical inactivity is a primary cause of most chronic diseases (33, 62, 63). The lockdown policy during the COVID-19 outbreak may lead to sedentary and reduced regular activities, and fewer visits to the hospital to prevent infection, thereby increasing health risks (64, 65). However, people who use the internet more frequently may gain more exercise-related knowledge from online social media platforms, become more accustomed to using social media apps or smart exercise tools for physical exercise, and display physical exercise achievement (66, 67). Therefore, encouraging appropriate physical activity through the internet can help improve the health conditions and quality of life of people with chronic patients.

Besides, this is the first study that revealed the moderating role of health insurance in the relationship between internet use intensity and quality of life. One possible explanation may be that China rolls out online healthcare to tackle a growing number of patients with chronic conditions (68). Patients could use online medical services during the pandemic, and online medical care was covered by Chinese health insurance (69, 70). Prior research revealed that the internet is a major source of health insurance information (71). Another study found that individuals with no medical insurance have had higher disease risk anxiety and lower life satisfaction than those who had at least one insurance (72). The "Internet +Healthcare" policy encourages people to seek medical treatment through the internet. This finding suggests that more online medical insurance policies should be improved to address the medical needs of chronic patients during the lockdown. All in all, this study enlightens us that the internet use intensity can promote quality of life in chronic patients, but its effect is limited, if the internet as an independent factor. There are two mechanisms that play the influence role. One is that physical exercise mediates the positive association between internet use and quality of life, where 10.25% of the effect is mediated by physical exercise. The other is that health insurance enhances the positive relationship between internet use intensity and quality of life.

These findings shed new light on China's healthcare policy. The internet has been used as a substitute for medical suggestions among patients who lack insurance or have difficulty accessing medical treatment (73). In the background of Chinese "Internet +Healthcare" policy, on the one hand, the internet provides online medical services which have improved the efficiency of medical treatment for chronic patients and may improve their quality of life. On the other hand, medical insurance reimbursement through the internet provides convenience for patients with chronic diseases. During the Pandemic, it's necessary to further expand the scope of beneficiaries of the "Internet +Healthcare" policy, such as the application in rural groups, simplify the process of online medical treatment and medical insurance reimbursement, so as to improve the quality of life among chronic patients.

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TABLE 7 Results of the relationship between internet use intensity and quality of life ($N = 3,313$).

Variables	Full sample	Rural sample	Urban sample
	Model 8	Model 9	Model 10
Internet use intensity	0.035***	0.034***	0.035***
	(0.004)	(0.007)	(0.006)
Gender (ref: female)	0.022**	0.019	0.025*
	(0.010)	(0.014)	(0.015)
Age	0.004***	0.003***	0.004***
	(0.000)	(0.001)	(0.001)
Marriage status (ref: married)	−0.003	0.004	−0.007
	(0.024)	(0.038)	(0.030)
Education level (ref: Not educated)			
Primary school	0.010	−0.007	0.025
	(0.029)	(0.036)	(0.047)
Junior high school	0.029	0.018	0.035
	(0.022)	(0.035)	(0.029)
HJTV	0.060***	0.021	0.078***
	(0.023)	(0.039)	(0.029)
College and above	0.029	0.019	0.039
	(0.031)	(0.065)	(0.036)
Residence type (ref: rural)	0.009		
	(0.008)		
Health insurance (ref: none)	0.221***	0.232***	0.213***
	(0.016)	(0.026)	(0.022)
Smoking (ref: no)	−0.017	−0.013	−0.023
	(0.012)	(0.016)	(0.017)
Drinking (ref: no)	0.026*	0.008	0.040*
	(0.015)	(0.021)	(0.021)
Self-assessed health status	0.036***	0.043***	0.029***
	(0.004)	(0.005)	(0.006)
Annual personal income	0.039**	0.062*	0.034**
	(0.015)	(0.037)	(0.016)
Annual medical costs	−0.007	−0.026	0.001
	(0.015)	(0.023)	(0.021)
Constant	−0.412***	−0.419***	−0.393***
	(0.037)	(0.052)	(0.055)
Observations	3,313	1,582	1,731
R-squared	0.133	0.135	0.127
F statistic	30.68	15.98	16.98

HJTV, High School/Junior High School/Technical School/Vocational High School. Robust standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Our study also has some clinical significance. Our findings showed that internet-based physical activity interventions have great potential to improve chronic patients' quality of life. Besides, physical exercise helps to improve the physical function of patients with chronic diseases (74). The internet provides chronic patients with health plans, physical activity testing, goal setting, feedback functions, and self-health management. Generally, internet-based physical activity provides a non-invasive way for chronic disease prevention and treatment (33). In future studies, we should further develop internet-related treatment strategies for patients with chronic diseases clinically.

It is necessary to revise Flanagan's study, which considered quality of life to include five dimensions (physical and material well-being; relationships with other people; social, community and civic activities; personal development and fulfillment; and recreation) (42), but the background in which this idea was developed was in 1978, when the Internet was not shaping

human life as profoundly as it does today. It should be taken into consideration that the Internet as a factor is included in the concept of measuring quality of life. This study also responds to Link and Phelan's fundamental-causes theory, which holds that social condition is the underlying cause of health differentiation among people and has a persistent effect on health quality (75). Since the COVID-19 pandemic, the intensity of human internet use has dramatically increased, making the internet a new and important key influence on quality of life among the chronic patients. This extends the explanatory scope of the fundamental-causes theory.

Limitations

The strength of this study is reflected in several aspects. Firstly, the data we use are from CFPS of wave 2020, which is a national survey covering mainland China that has been ongoing for more than a decade, and ensures the scientific validity and representativeness of the data. Secondly, our data were conducted in the background of the COVID-19 Pandemic in mainland China in 2020, and the latest data were only allowed to be applied for use at the end of 2021, which reflects the latest situation regarding the quality of life of chronic patients. Then, to ensure the reliability of the study findings, we performed robustness tests on the data during the empirical analysis. Finally, we explored the effect mechanism of the relationship between internet use intensity and quality of life among chronic patients by introducing physical exercise (mediating variable) and health insurance (moderating variable).

However, there are some limitations of our study that should be acknowledged. Firstly, a cross-sectional survey has been used so that the causative interpretations could not be determined. Secondly, Due to the limitation of secondary data, we could only refer to the five dimensions of The Flanagan Quality of Life Scale (QOLS) with 14 approximate question items to measure the quality of life among chronic patients, which is still flawed despite validity and reliability tests. Thirdly, the present study focuses only on the internet use intensity and ignores the role of excessive internet use. To further promote chronic patients' quality of life in the future study, we can use the Flanagan Quality of Life Scale to measure quality of life, and focus on the overuse of the internet in chronic patients during the pandemic.

Conclusions

This paper empirically tested the underlying mechanism of the association between internet use intensity and quality of life among patients with chronic diseases. The findings show that internet use intensity is positively related to the quality of life directly, and indirectly through the mediating role of physical exercise and the moderating role of health insurance. Relevant policies should be developed to improve subjective and objective quality of life during the COVID-19 Pandemic. For patients with chronic diseases, the government can encourage them to use the internet in moderation and maintain physical activity to obtain a higher quality of life. In addition, in the context of universal healthcare, medical insurance should be further covered for each individual to reduce the economic pressure on chronic patients. Thirdly, the "Internet +Healthcare" program should be further promoted so that patients can get better and faster treatment during the COVID-19 Pandemic. Last but not least, even though our results showed that internet use had improved the quality of life of chronic patients, the risks of internet use should not be ignored. The frequency of people's internet usage has increased during the epidemic, so it is necessary to prevent internet dependence from adversely affecting the quality of life.

Data availability statement

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

Ethics statement

This study was conducted based on de-identified, publicly available CFPS data and did not interact with any individuals or use identifiable private information. Therefore, the ethics approval was waived. Written informed consent from the [patients/participants OR patients/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

YW: framework, model analyses, data curation, writing—original draft, and review and editing. TX: writing—original draft, review and editing, and funding acquisition. JX: supervision. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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

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Caress Alithia Dean,
Oakland University, United States

REVIEWED BY
Sina Kianersi,
Brigham and Women's Hospital and Harvard Medical School, United States
Anandakumar Shunmugavel,
Oregon Health and Science University, United States

*CORRESPONDENCE
Silvia Stringhini
silvia.stringhini@hcuge.ch

†These authors share first authorship
‡These authors share senior authorship
§The members of this group are acknowledged at the end of the article

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Socio-economic determinants of SARS-CoV-2 infection: Results from a population-based cross-sectional serosurvey in Geneva, Switzerland

Hugo-Alejandro Santa-Ramírez[1†], Ania Wisniak[1,2†], Nick Pullen[1], María-Eugenia Zaballa[1], Francesco Pennacchio[1], Elsa Lorthe[1], Roxane Dumont[1], Hélène Baysson[1], Idris Guessous[1,3‡] and Silvia Stringhini[1,3,4*‡] on behalf of the Specchio-COVID19 study group[§]

[1]Unit of Population Epidemiology, Division of Primary Care, Geneva University Hospitals, Geneva, Switzerland, [2]Institute of Global Health, Faculty of Medicine, University of Geneva, Geneva, Switzerland, [3]Department of Health and Community Medicine, Faculty of Medicine, University of Geneva, Geneva, Switzerland, [4]University Centre for General Medicine and Public Health (UNISANTE), University of Lausanne, Lausanne, Switzerland

Background: SARS-CoV-2 infection and its health consequences have disproportionally affected disadvantaged socio-economic groups globally. This study aimed to analyze the association between socio-economic conditions and having developed antibodies for-SARS-CoV-2 in a population-based sample in the canton of Geneva, Switzerland.

Methods: Data was obtained from a population-based serosurvey of adults in Geneva and their household members, between November and December, 2020, toward the end of the second pandemic wave in the canton. Participants were tested for antibodies for-SARS-CoV-2. Socio-economic conditions representing different dimensions were self-reported. Mixed effects logistic regressions were conducted for each predictor to test its association with seropositive status as the main outcome.

Results: Two thousand eight hundred and eighty-nine adults completed the study questionnaire and were included in the final analysis. Retired participants and those living in suburban areas had lower odds of a seropositive result when compared to employed participants (OR: 0.42, 95% CI: 0.20–0.87) and those living in urban areas (OR: 0.67, 95% CI: 0.46–0.97), respectively. People facing financial hardship for less than a year had higher odds of a seropositive result compared to those who had never faced them (OR: 2.23, 95% CI: 1.01–4.95). Educational level, occupational position, and household income were not associated with being seropositive, nor were ethnicity or country of birth.

Discussion: While conventional measures of socio-economic position did not seem to be related to the risk of being infected in this sample, this study

sheds lights on the importance of examining the broader social determinants of health when evaluating the differential impact of the pandemic within the population.

KEYWORDS

SARS-CoV-2, COVID-19, social determinants of health, socio-economic status, serological survey

Introduction

Since the beginning of the COVID-19 pandemic, studies have shown that SARS-CoV-2 infection and its health-related consequences have disproportionally affected disadvantaged socio-economic groups (1–3). Disadvantaged populations accumulate several vulnerabilities to infection, such as poor living conditions, higher job instability, fewer job opportunities, poorer social benefits, and lower financial security (4, 5), household crowding, and possible impairments of their immune status due, among others, to work-related and financial stress (6). This may lead to a higher need of continued work outside the home, particularly for essential workers. Socioeconomically disadvantaged populations are also known to have a higher burden of chronic diseases and reduced access to healthcare (7), both risk factors for COVID-19 severity (8). In New York City, underprivileged neighborhoods, neighborhoods with higher household density, and those with higher proportions of black and immigrant populations were more likely to have a positive COVID-19 test result (9). An analysis of data reported to the Swiss Federal Office of Public Health (SFOPH) during the first year of the pandemic revealed that people living in neighborhoods with a low socioeconomic position index were less likely to get tested, but had a higher proportion of positive SARS-CoV-2 RT-PCR and antigen test results and were more likely to be hospitalized or die compared to people living in socioeconomically advantaged areas (10). Another study has also shown persistence of SARS-CoV-2 clusters in more disadvantaged neighborhoods, when analyzing RT-PCR positive test results (11). Several studies revealing social inequalities related to COVID-19 have been based on confirmed RT-PCR test results, therefore missing a large part of the population who did not undergo testing (12, 13). Socio-economic conditions may also influence the probability of getting tested when presenting with symptoms of COVID-19 (14). A better picture of the distribution of the infection in the population is achieved with serological surveys as they yield more accurate estimations of the real number of infections including mild and asymptomatic cases (15). Further, most studies rely on area-based indicators of socioeconomic status, thereby not allowing a more precise characterization of factors associated with SARS-CoV-2 infection.

Previous work by our research team showed associations between employment status and seropositivity during the first wave of the epidemic in the canton of Geneva, with retirees having lower odds of a seropositive result, and found no association with education, occupational status, and neighborhood median income (16). A serological survey conducted among essential workers in Geneva after the first epidemic wave showed significant variation in seroprevalence across occupations (17). Nevertheless, other features that might influence serological status could not be assessed in those studies, such as ethnicity, individual income, country of birth and living, and residential conditions. Although the canton of Geneva never followed a strict lockdown, there were some differences between the first and second waves, with the relaxation of certain measures such as re-opening of primary schools, as well as shops and establishments, and allowing larger social gatherings. During the second wave, a more strict use of facemasks was mandated and tests were made available free of charge to any person with symptoms.

Understanding the influence of socio-economic conditions on the probability of being infected with SARS-CoV-2 is crucial for the implementation of equity-driven public health measures both to contain the spread of the virus during the pandemic phase and to structure the public health response in the post-pandemic phase. This study is one of very few conducted in Switzerland considering individual-level data on both infection status and socio-economic conditions, and contributes to the body of knowledge on health inequalities related to the pandemic, showing the experience of a high-income country with a specific demography, structure, and policy setting such as Switzerland. We aimed to analyze the association between socio-economic conditions and having developed antibodies for SARS-CoV-2 during the second COVID-19 wave (October–December 2020) in a representative sample of the population in the canton of Geneva.

Methods

We limited our sample to adults aged 18 years and older, recruiting participants from a random sample of individuals 65 years and older from population registries of the canton

of Geneva provided by the Swiss Federal Office of Statistics, and an age-, sex-, and education level-stratified random sample of individuals aged 18–64 years from a previous serosurvey conducted in Geneva in spring 2020 using a similar methodology as the current study (16). The spring 2020 serosurvey sample included household members of the original "index" participants invited to participate. Details of the selection process are available in the Supplementary material. Recruitment occurred between November 23 and December 23, 2020. Participants were required to fill in a questionnaire (online or in paper format) and had their blood drawn to determine their SARS-CoV-2 serological status. The study was approved by the Geneva Cantonal Commission for Research Ethics (Project N° 2020-00881). All participants provided informed written consent.

Socio-economic conditions were assessed through three main indicators commonly used in the literature, namely self-reported occupational position, education, and family income. We also assessed a broader set of socio-demographic determinants, including: ethnicity, country of birth, household residential area, household density, employment status, and the experience of financial hardship. Detailed information on the variables used, including their definitions and analytical operationalization, is available in the Supplementary material (Annex I). Serological status was determined using the Elecsys anti-SARS-CoV-2 S assay (Roche Diagnostics, Rotkreuz, Switzerland) detecting total immunoglobulins (IgM/A/G) targeting the spike protein, following manufacturer's recommendations ($\geq$0.8 U/ml considered seropositive) with a clinical sensitivity of 98.8% (95% CI: 98.1–99.3%) and specificity of 99.98% (95% CI: 99.91–100%) (18). Of note, the vaccination campaign in Switzerland started on December 23th, 2020. Thus, antibodies detected during this study could only have been produced in response to a SARS-CoV-2 infection.

Mixed effects logistic regressions were conducted for each individual predictor with seropositive status as the main outcome and the household as the second level random effect variable. Five types of models were developed: a crude model, one model adjusted for age and sex only, another model additionally adjusted for education, occupational position, and family income; another model adjusted for health-related variables (weight status classified through categories of BMI, having a chronic disease, smoking status, and blood group); and a final model adjusted for all of the variables used in the previous models (Annex II, Supplementary material). To account for the possible overestimation of ORs, sensitivity analyses were conducted for the crude models running multilevel Poisson regressions with robust variance. Reference categories were set to the most socially advantaged groups. Multicollinearity was assessed for each of the adjusted models with no variables showing noticeable collinearity. Analyses were conducted in the overall population and stratified by sex, as a differential risk for COVID-19 outcomes and SARS-CoV-2 infection have been documented between men and women (19) (Annexes III, IV, Supplementary material). Estimates were not corrected for imperfect test performance due to the high specificity of the serological test (100% analytical specificity and 99.8% clinical specificity) (20) (Annex I, Supplementary material). To account for the large amount of tests performed, we have used a significance level of 0.01 for reporting. Statistical analyses were conducted using STATA version 14.0 (StataCorp, College Station, TX, USA).

Results

A total of 2,986 adults participated in the study and had a blood sample taken, of which 2,889 completed the study questionnaire and were included in the final analysis. The mean (SD) age of participants was 47.8 (15.4) years, and 55% were women. Education, occupation, and income were not associated with being seropositive in the overall sample (Table 1 and Annex II, Supplementary material). Looking at other socioeconomic indicators, associations were found with employment status, financial hardship, and the residential area in the overall sample, with retired people and those living in a suburban area exhibiting lower odds of a seropositive result when compared with those employed and those living in an urban area, respectively. People facing financial hardship for less than a year had twice the odds of a seropositive result when compared to those that had never faced financial difficulties, all other variables remaining constant. This association did not hold for participants having faced financial difficulties for several years. People living in households with higher density also tended to have higher odds of a seropositive result. Ethnicity and country of birth were not associated with seropositivity in our sample. When stratifying by sex, men in the lower occupational position tended to have higher odds of a seropositive result when compared to those with a higher occupational position (OR: 1.79, 95% CI: 0.97, 3.32) (Annex IV, Supplementary material). Higher odds of a seropositive result were found for unemployed women compared to employed women (OR: 2.01, 95% CI: 1.01, 4.03) (Annex III, Supplementary material). Similar results were found in the sensitivity analysis of multilevel Poisson regression for the crude models (results not shown).

Discussion

In this population-based serological study, we found associations between financial hardship, employment status, residential area, and the odds of having developed antibodies for SARS-CoV-2. A higher household density tended to be associated with increased odds of a seropositive result. However, other socioeconomic conditions such as educational level,

TABLE 1 Association between socio-economic predictors and seropositive status to SARS-CoV-2 in the overall population.

	Unadjusted model		Age-and-sex adjusted model		Fully adjusted model+	
	OR	95%(CI)	OR	95%(CI)	OR	95%(CI)
Education						
Tertiary	Ref.	.	Ref.	.	Ref.	.
Secondary	0.83	[0.44, 1.57]	0.88	[0.58, 1.35]	0.82	[0.50, 1.32]
Apprenticeship	1.01	[0.67, 1.54]	0.92	[0.60, 1.41]	0.77	[0.47, 1.25]
Compulsory—None	0.79	[0.52, 1.22]	0.83	[0.44, 1.57]	0.75	[0.37, 1.53]
Occupational position						
Higher	Ref.	.	Ref.	.	Ref.	.
Lower	1.19	[0.86, 1.64]	1.16	[0.84, 1.61]	1.26	[0.86, 1.87]
Other[a]	1.38	[0.82, 2.32]	0.79	[0.45, 1.37]	0.82	[0.43, 1.57]
Family income						
High	Ref.	.	Ref.	.	Ref.	.
Medium	0.88	[0.54, 1.43]	0.93	[0.58, 1.51]	0.91	[0.55, 1.50]
Low	1.07	[0.60, 1.88]	1.07	[0.61, 1.88]	1.05	[0.58, 1.91]
Don't know/Don't want to answer	1.15	[0.67, 1.98]	0.99	[0.58, 1.69]	1.04	[0.59, 1.84]
Ethnicity						
Caucasian	Ref.	.	Ref.	.	Ref.	.
Other	0.79	[0.48, 1.31]	0.69	[0.42, 1.15]	0.66	[0.39, 1.12]
Country of birth						
Switzerland	Ref.	.	Ref.	.	Ref.	.
Other HICs	0.92	[0.65, 1.30]	0.99	[0.70, 1.40]	0.93	[0.65, 1.34]
LMICs	0.84	[0.51, 1.39]	0.81	[0.49, 1.34]	0.72	[0.43, 1.23]
Employment status						
Employed	Ref.	.	Ref.	.	Ref.	.
Independent	1.10	[0.62, 1.96]	1.21	[0.68, 2.18]	1.26	[0.70, 2.28]
Retired	0.27*	[0.16, 0.45]	0.46	[0.23, 0.93]	0.42*	[0.20, 0.87]
Student	1.33	[0.78, 2.28]	0.85	[0.44, 1.65]	0.81	[0.34, 1.95]
Unemployed	1.91	[0.91, 4.03]	1.78	[0.85, 3.76]	1.76	[0.82, 3.77]
Other	0.54	[0.28, 1.05]	0.54	[0.28, 1.05]	0.46*	[0.22, 0.93]
Facing financial hardship						
Never	Ref.	.	Ref.	.	Ref.	
Yes, not currently but have happened in the past	1.31	[0.92, 1.86]	1.30	[0.92, 1.85]	1.26	[0.88, 1.82]
Yes, for several years	1.74	[0.75, 4.02]	1.62	[0.70, 3.70]	1.65	[0.69, 3.93]
Yes, for less than a year	2.34	[1.07, 5.08]	2.19	[1.01, 4.72]	2.23	[1.01, 4.95]
Don't want to answer	1.11	[0.64, 1.91]	0.94	[0.55, 1.61]	0.89	[0.50, 1.61]
Residential area[b]						
Urban	Ref.	.	Ref.	.	Ref.	.
Suburban	0.61*	[0.42, 0.88]	0.65	[0.45, 0.94]	0.67	[0.46, 0.97]
Rural	0.86	[0.54, 1.37]	0.93	[0.58, 1.47]	0.95	[0.59, 1.52]
Household density[c]						
<2	Ref.	.	Ref.	.	Ref.	.
≥2	1.72	[1.06, 2.78]	1.55	[0.96, 2.51]	1.55	[0.95, 2.54]

Estimates are the result of models run separately for each predictor. Unadjusted models represent the total effect of the predictor. Adjusted models represent the direct effect of each predictor after controlling for the effect of (i) age and sex, and (ii) the variables listed below. OR, odds ratio; CI, confidence interval; HICs, high income countries; LMICs, low and middle income countries. *$p < 0.01$. + Adjusted for age, sex, traditional measures of socio-economic status (education, occupation, and family income), and health related variables (having a chronic disease, weight status, smoking status, and blood group).

[a]Other include students, unemployed, and others not concerned.

[b]Self-reported by participants.

[c]Defined as the ratio between the number of household members and the number of bedrooms.

occupational position, and income were not associated with serological status, nor were ethnicity and country of birth.

Our study shows lower odds of a SARS-CoV-2 seropositive result for the retired population when compared with the employed one, possibly due to the fact of being considered at higher risk of severe forms of COVID-19, potentially leading them to reduce social contact and increase the use of preventive measures. This result is consistent with previous findings from the first seroprevalence study in Geneva (16) and findings from seroprevalence reports in the UK, France, and Norway for the age group comprising the retired population (21–23).

We also found a protective effect of the residential area for people living in suburban areas compared to urban areas, which could be explained by increased use of private transportation and lower population density. While this may also be the case in rural areas, higher commuting times and a potentially lower sense of danger posed by the infection in these areas may explain the lack of significant difference in seropositivity between rural and urban areas. It has been suggested that a lower population density outside the urban areas might have contributed to lower incidence at the beginning of the pandemic in some regions in Europe (24) and some studies have shown lower seroprevalence in municipalities of <100,000 inhabitants (25). Further work is needed to uncover the potential mechanisms explaining the association of the residential area with a seropositive result in the population of Geneva, as considering the small size of the canton, the difference between urban and suburban areas is not clearly established and the distribution of SARS-CoV-2 infections might not follow a similar pattern as the one found in other places.

There seemed to be a trend in the association between duration of financial difficulties and the odds of seropositivity, with people facing financial hardship for <1 year having the highest odds of a seropositive result compared to those who reported never facing financial hardship. This could potentially be explained by the development of coping mechanisms in individuals being used to financial difficulties, while those with unexpected economic hardship may need more time to adapt to their new circumstances, putting them at higher risk of SARS-CoV-2 exposure as they cannot afford to miss work or need to look for economic alternatives. A consistent association of financial hardship due to COVID-19 with health behavior risk changes has been shown in a sample of women in the U.S., although the health behaviors assessed were based on lifestyle factors rather than on the risk of getting infected with SARS-CoV-2 (26); this may support a hypothesis of higher risky behaviors when facing economic stress. On the other hand, reverse causation cannot be excluded, with people affected by COVID-19 being more likely to reduce their work time due to symptomatic disease leading to financial instability.

Consistent with our previous findings (16), we did not find associations between educational level, occupational position, income, ethnicity or country of birth, and the seropositive status. However, seroprevalence surveys across Europe show conflicting results when looking at the role of these indicators (21–23, 27–32). For instance, income was not clearly related to a high risk of being seropositive in Germany (29) and France (22), while in the UK, a higher seroprevalence was observed in households with higher income (21). Similarly, while no effect of education on SARS-CoV-2 seroprevalence was found in British (21), Norwegian (23), and some German (27–29) cohorts, lower educated individuals had a lower seroprevalence of anti-SARS-CoV-2 antibodies in a French national serosurvey (22), and a higher seroprevalence in one German serosurvey (31). The association between education and seropositive status may be confounded by increased SARS-CoV-2 exposure in certain professions requiring tertiary education, such as in the health-related field. Future analyses should take into account professional exposure to SARS-CoV-2. The inconsistent effects of socio-economic determinants across studies may be due to differences in survey design and measurement. Heterogeneity in the socio-economic circumstances in different countries, as well as diverging policies for pandemic management, may also explain some of the conflicting results. In general, our study is in line with the European literature where these socioeconomic indicators do not seem to be related to the risk of getting infected. Regarding the effect of ethnicity and country of birth on seropositive status, inequalities were revealed in most European countries, with higher seroprevalence mainly found among non-white (21) and foreign-born participants (22, 23, 32), although differences were sometimes observed only among specific ethnicities (32) and disappeared after adjusting for living conditions (22). The lack of association with ethnicity or country of birth in our analysis may therefore be caused by a lack of detailed stratification among non-Caucasian and foreign-born participants, due to their limited number in our sample, as well as potentially heterogeneous living conditions among these populations.

Strengths of this study include the relatively large sample size and comprehensive information related to different social and economic circumstances at the individual level as well as objective information about individual health such as the serological status. Our study also has some limitations. A selection bias should not be disregarded, with people with higher health concerns being more prone to participate, and those most socioeconomically disadvantaged less likely to be included, limiting the generalizability of our results. In addition, the population that was hospitalized at the time of the study or that died because of COVID-19 could not be included in the study, therefore potentially masking the association between socio-economic conditions and SARS-CoV-2 seropositivity for severe cases. As other studies have documented, the severity of the disease might be higher in socioeconomically disadvantaged groups (4, 33). An additional limitation could relate to the time of our reporting. Our results are based on data from late 2020, and by the time of writing, new variants have been identified

and several measures taken. Nevertheless, while new variants of SARS-CoV-2 have emerged, socio-economic inequalities are unlikely to change considerably as a consequence of biological specificities of those variants, as transmission patterns among socio-economic groups are expected to be similar across variants. Of note, different transmission patterns have been observed among waves most likely due to the prevention and control strategies implemented (34) and to other environmental and occupational factors (35).

The COVID-19 pandemic has disproportionately affected socially vulnerable populations globally. However, the impact of socio-economic determinants can vary widely depending on geographical, political, and cultural contexts (36–38). In our study we have found associations of employment status, financial hardship, and residential area with the natural development of anti SARS-CoV-2 antibodies during the second wave of the pandemic (before the roll-out of the vaccination campaign in Switzerland); but not with other socio-economic conditions. There has been much debate around the adequacy of conventional indicators of socio-economic conditions (i.e., education, income, and occupation) to study the association between socio-economic status and various health outcomes. Such discussions have highlighted the need for alternative indicators to capture the impact of socio-economic determinants throughout the life course and among various social groups, as well as environmental determinants (39). While the three conventional indicators mentioned were retained in our analysis, we took into consideration the discussions around this issue by adding other indicators to our analysis highlighting the importance of examining the broader social determinants of health when evaluating the differential impact of the pandemic within the population. A better understanding of the structural determinants shaping the inequitable distribution of COVID-19 among the population is imperative for tailoring public health interventions and preparedness for future pandemics, such as vaccine prioritization and public health campaigns, and for setting up supportive mechanisms for vulnerable population groups.

Data availability statement

Our data are accessible to researchers upon reasonable request for data sharing to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Geneva Cantonal Commission for Research Ethics (Project N° 2020-00881). The patients/participants provided their written informed consent to participate in this study.

Specchio-COVID19 study group

Deborah Amrein, Isabelle Arm-Vernez, Andrew S Azman, Fatim Ba, Delphine Bachmann, Antoine Bal, Jean-François Balavoine, Michael Balavoine, Rémy P Barbe, Hélène Baysson, Lison Beigbeder, Julie Berthelot, Patrick Bleich, Livia Boehm, Gaëlle Bryand, Viola Bucolli, François Chappuis, Prune Collombet, Delphine Courvoisier, Alain Cudet, Vladimir Davidovic, Carlos de Mestral Vargas, Paola D'ippolito, Richard Dubos, Roxane Dumont, Isabella Eckerle, Nacira El Merjani, Antoine Flahault, Natalie Francioli, Marion Frangville, Clément Graindorge, Idris Guessous, Séverine Harnal, Samia Hurst, Laurent Kaiser, Omar Kherad, Julien Lamour, Pierre Lescuyer, François L'Huissier, Fanny-Blanche Lombard, Andrea Jutta Loizeau, Elsa Lorthe, Chantal Martinez, Lucie Ménard, Lakshmi Menon, Ludovic Metral-Boffod, Benjamin Meyer, Alexandre Moulin, Mayssam Nehme, Natacha Noël, Francesco Pennacchio, Javier Perez-Saez, Didier Pittet, Jane Portier, Klara M Posfay-Barbe, Géraldine Poulain, Caroline Pugin, Nick Pullen, Zo Francia Randrianandrasana, Viviane Richard, Frederic Rinaldi, Jessica Rizzo, Deborah Rochat, Irine Sakvarelidze, Khadija Samir, Santa Ramirez Hugo Alejandro, Stephanie Schrempft, Claire Semaani, Silvia Stringhini, Stéphanie Testini, Deborah Urrutia Rivas, Charlotte Verolet, Jennifer Villers, Guillemette Violot, Nicolas Vuilleumier, Ania Wisniak, Sabine Yerly, and María-Eugenia Zaballa.

Author contributions

SS and IG conceived the study. AW, NP, HB, M-EZ, FP, RD, and SS contributed to the scientific coordination and data management during the study. H-AS-R and AW drafted the first version of the manuscript. H-AS-R and NP did data analyses. NP, EL, HB, M-EZ, FP, IG, and SS contributed to draft the manuscript. All authors reviewed and approved the final manuscript.

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Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.874252/full#supplementary-material

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EDITED BY
Caress Alithia Dean,
Oakland University, United States

REVIEWED BY
Omar Irfan,
Amaris, United Kingdom
Leela Visaria,
Gujarat Institute of Development Research, India

*CORRESPONDENCE
Tannistha Samanta
tannistha.samanta@flame.edu.in

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Blocked by Gender: Disparities in COVID19 infection detection in Tamil Nadu, India

Tannistha Samanta[1]*, Kaushik Gopalan[2] and Tanmay Devi[2,3]

[1]Department of Sociology, FLAME University, Pune, Maharashtra, India, [2]Department of Computer Science, FLAME University, Pune, Maharashtra, India, [3]Department of Social Sciences, Rice University, Houston, TX, United States

Globally, a gender gap in COVID-19 has been noted with men reporting higher share of both morbidity and deaths compared to women. While the gender gap in fatalities has been similar across the globe, there have been interesting disparities in the detection of COVID-19 cases in men and women. While wealthier, more developed nations have generally seen similar case detection in men and women, LMICs especially in Asia have seen far greater proportion of COVID-19 cases among men than women. We utilize age and sex-disaggregated data from the southern Indian state of Tamil Nadu across two waves of the pandemic (May 2020 – Nov 2020, and March 2021, to June 2021) and find that there were only ∼70% as many detected COVID-19 cases among women as there were among men. Our initial reading suggested that this might be a protective effect of lower labor force participation rates among women across much of South Asia. However, subsequent sero-prevalence results from Tamil Nadu conducted on October-November 2020, and June-July, 2021 suggest that infection incidence has been similar among men and women; as is the case in countries with better health infrastructure. This empirical puzzle suggests that reduced case detection among women cannot be immediately associated with limited public exposure, but rather evidence of a chronic neglect of women in healthcare access. Overall, we contend that an attention to the gender context holds promise to effective interventions in detection and prevention that goes beyond the traditional epidemiological logic of diseases.

KEYWORDS

social determinants of health, infection, gender, India, COVID-19

Introduction

That gender is an important axis of inequality is well-documented in the public health scholarship globally (1). To be sure, health scholarship has consistently shown that women and girls make comparatively fewer gains in health care than men and boys across similar age and social registers in most societies. However, this empirical narrative was shifted in the early months of the COVID-19 pandemic when global data revealed that men were 2.5 times more likely to be infected and are also 2.4 times more at risk of dying from COVID-19 than women (2). For example, the Global Health 50/50 repository demonstrated significant gender gaps in infections and deaths,

where men seemed to fare worse in both counts. Since then, a considerable body of scholarship has attempted to explain this variation by privileging lifestyle and socio-economic factors (e.g., labor) and critiquing the biologically deterministic way of explaining disease risk (3, 4). Put simply, in societies that are governed by pervasive gender norms, the social realities of men and women are vastly different affecting their social and health outcomes. Or as a noted medical anthropologist, Paul Farmer, explains with the notion "the social production of disease" (p. 261) emphasizing how social and economic positioning produce gendered risk in epidemics and infectious disease outbreaks (4). Of all factors, the gender inequality in the labor force, finds particular attention among experts attempting to explain the variation in infection and mortality due to COVID-19 exposure. For instance, Adams showed that the percentage of female deaths due to COVID-19 were higher in countries that also have a higher proportion of women in the full-time workforce (5). In another study, Lewandowski and colleagues argue that when women work, they are largely concentrated in sectors where workplace interactions are higher (e.g., care, hospitality and education) and so is the exposure to the contagion (6). This study is significant since it undergirds the importance of labor market segregation in explaining disease risk. Finally, based on the case of Belgium that reported one of the highest rates of COVID-19 infections among women in the early months of the pandemic, Giscard Assoumou Ella argues how women's greater mobility outside home served as a potent route for infections as women traveled for work and family reasons (7). Yet again, authors have also attributed the difference in mortality as an outcome of underreporting bias against women and overall female neglect in matters of health and well-being even in industrialized countries (3). While causality cannot be conclusively ascertained given the evolving nature of the pandemic and the data, it is clear from these studies that disease risk among women is often tied to labor, mobility and the overall gender context.

It is also clear that there is a strong empirical association between age and case fatality from COVID-19 globally (8). However, owing to data unavailability in low-to-middle income countries, authors have contended how meaningful analysis remains limited in terms of guiding interventions that are age and context sensitive (9). We address this empirical lament and utilize age and sex-disaggregated data from the southern Indian state of Tamil Nadu, across two waves of COVID-19 pandemic, to show how age and gender intersect to create paradoxes in infection incidence.

Data and Methods

Data for this study comes from several sources. We rely on the daily Media bulletins put out by the Health and Family Welfare Department of the Government of Tamil Nadu (TN) (https://stopcorona.tn.gov.in/daily-bulletin/). The media bulletins are provided in PDF format, and the text content from these files using the *pdfminer* package in the Python programming language is extracted. Using an automated program appropriate keyword searches (https://github.com/kaubega/tn_scraping), we retrieve the cumulative caseload for Males and Females separately in the age groups 0–12, 13–60, and 60+ from the daily bulletins.

For the purpose of this study, we extracted the data from the TN for May 16, 2020 – June 30, 2021. We were able to process 407 daily bulletins out of the 410 days in this time period; the rest were either unavailable on the website or were formatted such that our software was unable to process them. Further, we analyze infection statistics separately for the 1st and 2nd COVID-19 waves that occurred in India. For our study, we define the 1st wave as having occurred in TN from May 16, 2020 – Nov 15, 2020, and the 2nd wave as having occurred between March 15, 2021, to June 30, 2021.

We examine the daily caseload data to analyze the spread of COVID-19 in different demographic groups. The TN media reports provide the number of detected infections in the 0–12, 13–60, and 60+ age groups, separately for males and females. In order to compare the extent of infection spread in the different demographic groups, detected infections are divided by the population of the respective demographic group as per Census 2011 to derive a "naive attack rate." We observe substantial gender differences in the attack rates among adults, as shown in Figure 1. In Wave-1, there were 14.2 infections detected per 1,000 individuals aged 13 to 60 among men, compared to 9.3 per 1,000 individuals among women. This gender-gap favoring women is somewhat lower in Wave-2 in the 13–60 age group (and statistically significant only to 90% confidence); however, the naive attack rate is still ∼35% higher among men. The gender difference is even greater in the older (60+ years) age group. The detected infections are ∼75% higher among men in Wave-1 and 50% higher in Wave-2. This difference is however not observed among children.

While the confirmed COVID-19 case reports from Tamil Nadu suggest that men were infected at highly greater rates than women, multiple sero-prevalence surveys conducted in Tamil Nadu paint a different picture. Multiple rounds of the sero-prevalence surveys [e.g., see Table 2 of Selvavinayagam et al. (10)] suggest that infection incidence among men and women was similar after both Wave-I and Wave-II in Tamil Nadu. The sero-prevalence surveys were conducted on October-November, 2020 and June-July, 2021 respectively. We discuss this contradiction in detail in the discussion section.

Discussion

As the COVID-19 pandemic continues to disrupt healthcare systems and lives, there is a growing recognition that availability

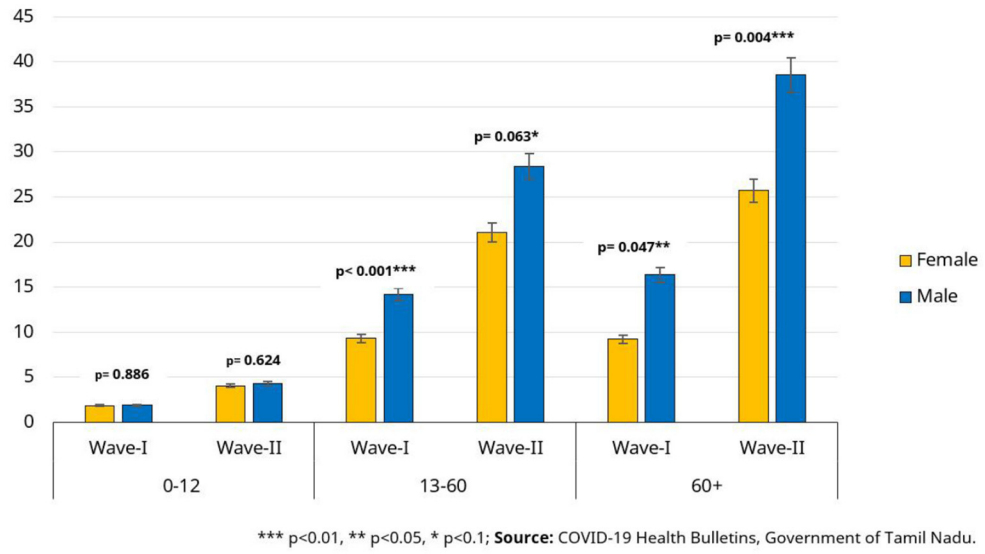

FIGURE 1
Confirmed cases per 1000 individuals (naive attack rate) for Tamil Nadu.

of quality data on infections, fatalities and socio-demographic parameters of health remain a challenge in the middle-to-low income countries. To address this empirical dilemma, we used data from a southern Indian state that has meticulously published age and sex-disaggregated data on infections and fatalities since the onset of the pandemic in March 2020. We summarized key commonalities and differences in infections and fatality rates among men and women with a particular attention to older adults in the subsequent waves of the pandemic in India. Although, statistical estimates of infection or fatality antecedents were not possible to be modeled due to the limited nature of the data, this empirical summary allowed us to reflect on the intersection of age and the gender context, while reflecting in the paradoxical vulnerabilities of women and men.

One pathway that has been known to explain gender differentials in disease and mortality risks is labor force participation. Building on this line of inquiry, we contended that patriarchal ideologies that are known to restrict women's social and economic opportunities, unwittingly offer protection for older women from disease risk through restricted mobility. As such, the complex nexus between mobility and gender has been variously studied in the social sciences including those that focus on social norms as well as built environments (e.g., infrastructure and transportation). Feminist research on women's mobility patterns has shown that the claim "how people move (where, how fast, how often) is demonstrably gendered" (11) and perhaps age-coded, holds true for both the developing and the developed contexts (12–14). For example, in the Indian context, Lei et al. (15) show that in a context where labor mobility for women is deeply governed by gender attitudes and domestic obligations, transportation improves women's chances of non-farm job opportunities. In particular, they argue that road access and bus frequency can not only increase women's non-farm employment but can also enhance their bargaining power and autonomy to make decisions about their own health. In other words, one could argue that by staying at home women "bargained" with the patriarchal norms and social constraints over mobility, thereby optimizing their chances of reduced disease risk (16).

However, this line of reasoning is refuted by the sero-prevalence surveys conducted in Tamil Nadu that show similar levels of infections among men and women at all stages of the pandemic. This suggests that instead of a patriarchal "bargain" (noted earlier) that unwittingly protects women from infection, the gender gap in confirmed cases is caused by gender biases in testing for COVID-19 infection. We must, however, include the caveat here that sero-prevalence surveys routinely assign different weights to demographic groups in order to normalize the proportion of observations from each group. We do not have access to the specific weights used in the Tamil Nadu sero-survey and thus must allow for the possibility that statistical normalization might have some role in bridging the gender gap in the infection incidence. Despite this uncertainty, a gender bias in testing would not come as a surprise given a persistent female neglect in healthcare access and treatment is well-documented in middle to low-income countries globally and particularly in India. Demographers and public health experts have shown that despite overall advances in healthcare and rising levels of women's education and employment in India, female disadvantage in terms of (excess) mortality,

neglect and discrimination continues throughout the life-course (17–19). Specifically, in terms of health access and outcomes, gender disparity has been remarkably stable in India with significant gradients by age and income (20–23). For example, in one estimate, out of 2,37,7028 outpatient visits, the authors calculated the overall sex ratio to be 1.69 male to one female visit (an equivalent of 4,02,722 missing female outpatient visits from four selected states in India) (21). As such, studies from other contexts have also emphasized how the pandemic has expanded the gender disparity in health. In their scoping review, Connor and colleagues report how the effects of heightened gendered disparity is felt more acutely among women vulnerable to poverty, IPV and racism in the United States (24). Specifically, the authors show that caregivers (who are typically women) have an increased exposure risk of contracting the infection while elevating the overall levels of multifactorial stress. Closer to home, feminist economist, Bina Agarwal's plea to understand the pandemic-led complex indirect gender effects on women is significant. She notes how preexisting gender inequalities and social norms can exacerbate unequal burdens of health and hunger, asset losses and abandonment of women and girls due to poverty (25). These household level disadvantages puts women at a higher risk since Indian women are known to have a higher incidence of comorbidities-malnourishment and anemia- and persistently lower levels of treatment seeking behaviors even when they carried higher burdens of multiple morbidities [see for example, Sandeep et al. (26)]. Notably, a persistent cultural regime of son-preference motived by social scripts that restrict women's economic and social freedoms with socio-legal implications (e.g., inheritance rules, remarriage laws), women continue to make losses in health and well-being throughout their life course.

Taken together, the COVID-19 data from Tamil Nadu thus tell us two contradictory stories: (a) the purported gender gap in the confirmed cases suggest a patriarchal "bargain" that protects women from infection as a consequence of their reduced mobility and (b) the sero-prevalence survey data that suggests that this gender gap may be an empirical illusion caused by systemic gender biases in COVID-19 infection testing. Given the history of persistent female neglect in healthcare in low-income, resource-constrained contexts, we believe that the second story is closer to the truth. In doing so, we address the plea of bridging the gap between feminist frameworks and empirical data. We hope this perspective piece offers an useful starting point to create synergies between evidence gathering, practice and research.

Data availability statement

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

Author contributions

TS contributed to the conceptualization and writing of the paper. KG contributed to data analysis and writing. TD contributed to data analysis. All authors contributed to the article and approved the submitted version.

Conflict of interest

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

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EDITED BY
Keith Elder,
Mississippi College, United States

REVIEWED BY
Rodrigo Vargas-Fernández,
Scientific University of the South, Peru
Ramendra Pati Pandey,
SRM University (Delhi-NCR), India
Vivek Mishra,
Amity University, India

*CORRESPONDENCE
Isain Zapata
izapata@rvu.edu

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Comorbidities, sociodemographic factors, and determinants of health on COVID-19 fatalities in the United States

Jacob Gerken, Demi Zapata, Daniel Kuivinen and Isain Zapata*

Department of Biomedical Sciences, Rocky Vista University, Parker, CO, United States

Previous studies have evaluated comorbidities and sociodemographic factors individually or by type but not comprehensively. This study aims to analyze the influence of a wide variety of factors in a single study to better understand the big picture of their effects on case-fatalities. This cross-sectional study used county-level comorbidities, social determinants of health such as income and race, measures of preventive healthcare, age, education level, average household size, population density, and political voting patterns were all evaluated on a national and regional basis. Analysis was performed through Generalized Additive Models and adjusted by the COVID-19 Community Vulnerability Index (CCVI). Effect estimates of COVID-19 fatality rates for risk factors such as comorbidities, sociodemographic factors and determinant of health. Factors associated with reducing COVID-19 fatality rates were mostly sociodemographic factors such as age, education and income, and preventive health measures. Obesity, minimal leisurely activity, binge drinking, and higher rates of individuals taking high blood pressure medication were associated with increased case fatality rate in a county. Political leaning influenced case case-fatality rates. Regional trends showed contrasting effects where larger household size was protective in the Midwest, yet harmful in Northeast. Notably, higher rates of respiratory comorbidities such as asthma and chronic obstructive pulmonary disease (COPD) diagnosis were associated with reduced case-fatality rates in the Northeast. Increased rates of chronic kidney disease (CKD) within counties were often the strongest predictor of increased case-fatality rates for several regions. Our findings highlight the importance of considering the full context when evaluating contributing factors to case-fatality rates. The spectrum of factors identified in this study must be analyzed in the context of one another and not in isolation.

KEYWORDS

CCVI, sociodemographic factors, politics, county level, determinants of health

Introduction

The SARS-CoV-2 Virus, which causes COVID-19, has currently led to over 1,000,000 deaths (July, 2022) in the United States (1). The virus has ravaged not only the United States financially and put a stop to every in-person activity for the last 2 years (2), but has highlighted how embedded community traits affect the outcome of a whole community. In the end, it is characteristics like comorbidities and sociodemographic factors that play a defining role in determining a community's fatality outcome (3).

While it has been shown that a wide range of comorbidities has an impact COVID-19 outcomes; there has been a great effort to define the specific contributions of comorbidities in their impact on COVID-19 morbidity and mortality rates (4–7). Comorbidities such as hypertension (8), diabetes mellitus (9), chronic kidney disease (CKD) (10), chronic obstructive pulmonary disease (COPD) (11), and cardiovascular disease or coronary heart disease (CHD) (12) among others, have important repercussions on COVID-19 outcomes. However, there are also a variety of reasons for which to consider some sociodemographic factors as deleterious. COVID-19 outcomes are strongly influenced by risk behaviors and many of these behaviors are a direct result of environmental and socioeconomic circumstances that affect specific portions of the populations (13). Factors such as lacking healthcare insurance, being of a specific racial background (7, 14), or even voting patterns. Political voting patterns and affiliation have previously been linked to COVID-19 fatality in both the United States (15) and other countries (16, 17). While political differences may not be important on an individual level, political affiliation may influence societal behaviors such as vaccination, masking (18), or social distancing (19). These behaviors can directly affect COVID-19 outcomes, and are an important component of our analysis. Voting patterns in the 2020 presidential election are representative of behaviors that can affect COVID-19 outcomes. All these factors combined would point in a direction that suggests that differences in COVID-19 fatality rates are a potential outcome of embedded community characteristics.

Even though previous studies have examined factors influencing COVID-19 fatalities (4–6, 20), no study has performed a comprehensive analysis of all the aforementioned factors together to the same extent as our study. In our study, a multitude of key community indicators such as comorbidities, sociodemographic factors (including voting patterns), and determinants of health (preventive health screenings) have been examined to reflect trends and potential associations that can be compared against each other. Therefore, the objective of this study was to perform a comprehensive evaluation of comorbidities, sociodemographic factors, and determinants of health at a national level using county aggregated to define their association to COVID-19 case-fatalities. These patterns may allow us to alter the way communities handle public health crises, utilize public health interventions that could deflect harmful outcomes, and provide resources to communities in a timely manner based on their community characteristics.

Methods

Datasets

The focus of this ecological study was to evaluate regional trends of COVID-19 case-fatality rate compared to comorbidities and sociodemographic factors. This study was vetted and categorized as exempt by the Institutional Research Board. Our study utilized countywide data for each county in the entire continental United States and Hawaii with Alaska and Puerto Rico excluded from the analysis due to differences in their county data reporting. COVID-19 case-fatality rates were gathered from the COVID-19 Community Profile Report (21) for the January 2-8, 2021 week cutoff, this report included the COVID-19 Community Vulnerability Index (CCVI) (22). This cutoff week was selected because it allowed for the evaluation of the COVID-19 case fatality rate, without the influence of the vaccines or newer, more infectious strains. Rates of various comorbidities such as chronic obstructive pulmonary disease (COPD), hypertension, cancer, asthma, chronic heart disease (CHD), cholesterol, diabetes, chronic kidney disease (CKD), smoking, stroke, and obesity were obtained on a per-county basis from the CDC 2020 Population Level Analysis and Community Estimates (PLACES) project (23). Rates of poor mental health, binge drinking, lack of health insurance, time allocated to leisurely activity, and preventive care consisting of cervical cancer screening, routine doctor visits, dental visits, cholesterol screening, and routine mammography were obtained from the 2020 CDC PLACES Project, as well. Other variables such as average household size and population density for each county were acquired from the United States Census Bureau COVID-19 website (24). Latitude of each county was also included in the analysis and obtained from the United States Gazetteer Files (25) from the United States Census Bureau. The 2020 Presidential voting records of each county were obtained from the Harvard Dataverse (26). Racial makeup in each county was obtained from the 2020 decennial United States census (27), while income, age, and education level were retrieved from the 2019 American Community Survey 5-year estimates (28). A summary of all mean values per variable on a national level and by HHS region are presented in Supplementary Table 1.

Statistical analysis

Data was evaluated for associations using a Generalized Additive Models (GAMs) approach. GAMs were chosen for

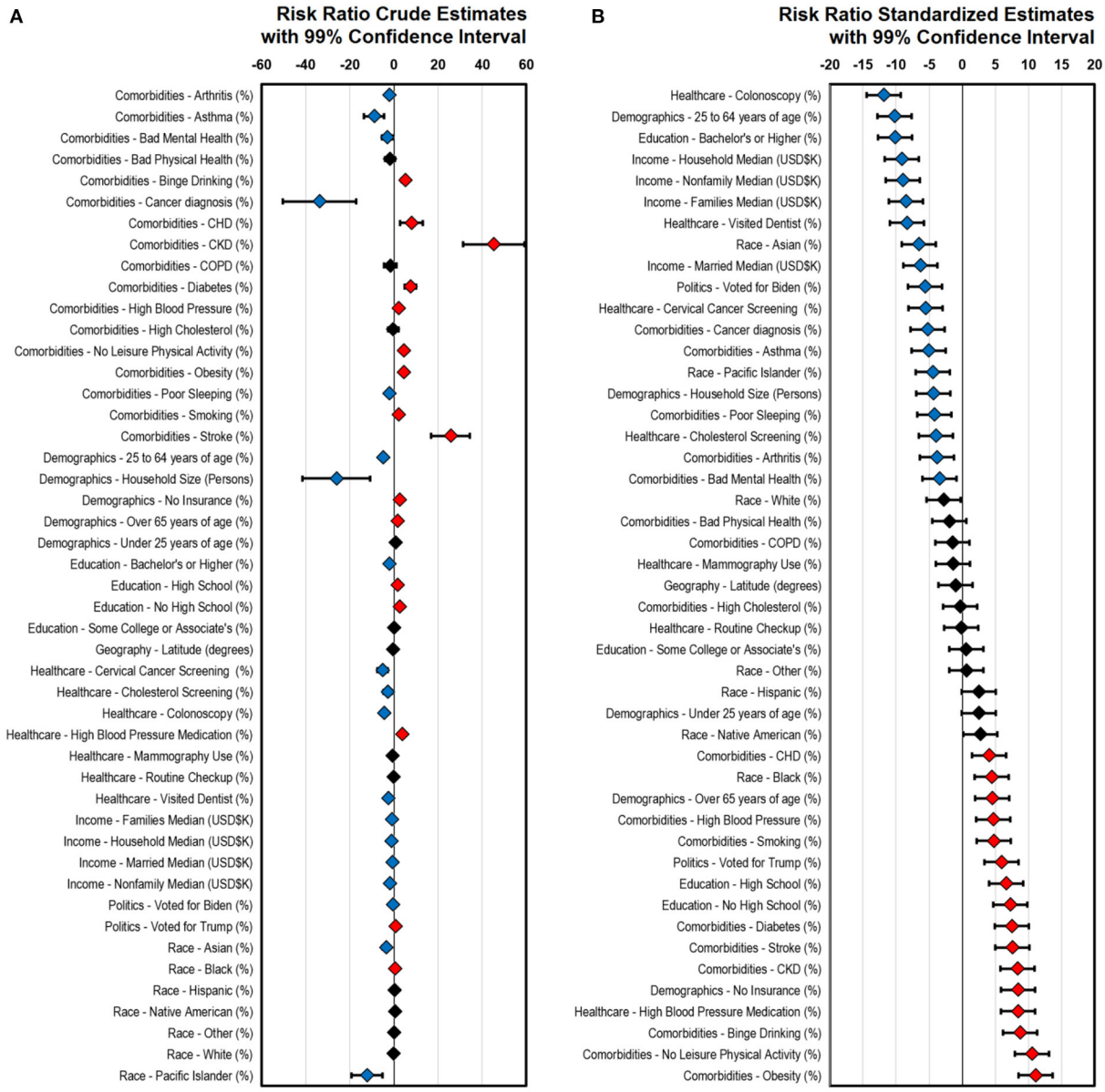

FIGURE 1
Comorbidity, sociodemographic and determinants of health associations to COVID-19 case-fatalities. All models are CCVI adjusted. **(A)** Risk ratio crude estimates. **(B)** Risk ration standardized estimates (ordered). Blue diamonds indicate case-fatality reduction, red diamonds indicate case-fatality increase, and Black diamonds indicate no association. A total of 3140 counties were included in the study. Even when 99% CI are presented, association are declared significant at a Bonferroni adjusted threshold (47 tests $P_{adj} \leq 1.06E-03$). COPD, Chronic Obstructive Pulmonary Disease; CKD, Chronic Kidney Disease; CHD, Coronary Heart Disease.

this application for their versatility in addressing deviations from normality that limit Generalized Linear Models (GLMs) such as those that occur in proportional data (29, 30). More specifically, when values approach the limits of the scales (such as percentages), these models take advantage of unspecific (non-parametric) functions or splines that are linked to the predictor (31). COVID-19 case fatality rates per 100 k people were set as the dependent variable while each comorbidity, sociodemographic and health determinant factor was set as an independent variable. All values are proportional data. All models were adjusted using CCVI (22) which normalized the data for inherent inequity on a county per county basis (32). This ecological study uses individual counties as the experimental unit. All analyses were evaluated twice, once nationally and once regionally. Analyzing using two different modes, allowed for us to identify national and regional patterns (US HHS

regions). Independent variables were introduced into the model using smoothing splines starting with three degrees of freedom. Models assumed Gaussian residual distributions. All analyses were performed using PROC GAM in SAS/STAT v.9.4 (SAS Inc., Cary, NC). Risk ratios were estimated with confidence intervals and the coefficients sign determined effect directions. GAMs estimates can be interpreted in a similar fashion a parametric GLMs. Therefore, negative coefficients indicated a reduction in COVID-19 case-fatality rates while positive coefficients indicated an increase in case-fatalities. Coefficient standardization was done with a normally distributed Z-score transformation. All associations presented were tested using two-tailed tests. Regional pattern models were performed independently to identify the top contributors—negatively and positively associated. Even with 99% confidence intervals, all tests were declared significant at a Bonferroni threshold. Regional pattern top contributors that did not reach the Bonferroni threshold are indicated in the figures.

Results

National level trends

Data from 3140 counties was included in our analysis. Our GAM approach examined the data for associations to case-fatalities, all these values were adjusted to CCVI to normalize the inherent differences a crude risk ratio would estimate, and the risk ratio standardized estimates are presented in Figure 1. Crude estimates showcase the extent of the association without considering their spread while standardized estimates adjust the extent of the association to the spread. Crude estimate findings (Figure 1A) revealed that comorbidities above sociodemographic factors have the largest effects associated with case-fatalities; however, these associations can go in both positive and negative directions. A diagnosis of cancer provided the largest effect decreasing COVID-19 case-fatalities while CKD and stroke had the largest effects increasing them. Similarly, asthma (decreased risk), CHD (increased risk) and diabetes (increased risk) displayed less extensive effects. Household size was the largest significant sociodemographic factor in positive outcomes of COVID-19 with an effect in a range comparable to relevant comorbidities. Other demographic effects such as age and education displayed significant associations that reduced or increased case-fatality risk. Populations with higher educational achievements displayed significantly reduced case-fatality rates. Increased income always displayed a protective effect. Political preference was significantly associated with case-fatalities such as voting for Biden reduced case-fatalities while voting for Trump had the opposite effect. Racial and ethnic backgrounds were only associated with COVID-19 case–fatalities for Pacific Islanders, Asian and Black groups. Determinants of health such as cervical cancer screening and people using high blood pressure medication also showed mixed direction associations. Cervical cancer screening had the largest case-fatality reducing effect from this category while the people using high blood pressure medication had the largest opposite effect. Standardized estimates (Figure 1B) show a different perspective and allow for comparisons across factors as they are standardized. In this case, a routine colonoscopy procedure was found to be the largest protecting effect against COVID-19 case-fatality followed by a combination of sociodemographic factors such as age, education, and income. On the other side of the spectrum, obesity had the largest negative impact deleterious outcome in COVID-19 patients followed by having no leisure physical activity, binge drinking and higher proportions of people taking high blood pressure medication in a specific county.

Regional trends

The main analysis was also replicated independently within each of the ten US Health and Human Services defined regions. These models were also adjusted by CCVI. Risk ratio effect estimates for the ten regions are displayed in Figure 2. These analyses detected a wide array of effects that in some cases go in opposite directions across all regions. No single factor was consistently associated for all regions suggesting that regional associations are not generalizable. These regional assessments all have different sample sizes that are based on the number of counties within each state. These can range from 67 (Region 1) to 736 (Region 4); however, this discrepancy did not affect the capacity of each regional analysis to detect associations at a Bonferroni level (adjusted for 470 tests across all sets). The top variables reducing and increasing COVID-19 case-fatalities for each region are presented in Figure 3. The map in Figure 3A shows that the strongest protective regional effects were observed toward the east of the country where Stroke and Cancer Diagnosis were highly protective in the Northeast regions (Regions 1 and 2) and being of Pacific Islander descent was protective in the Southeast United States (Region 4). The Midwest displayed some moderate protective effects where household size was the top reducing factor in two regions (Region 5 and 7). Western regions displayed smaller COVID-19 case-fatality protective effects. Regions in the Western United States displayed smaller effect sizes in comparisons to regions in the South or Midwest. Lastly, Figure 3B shows variables that most significantly contributed to increased COVID-19 case-fatalities. CKD was the most prevalent comorbidity across several regions (Regions 4, 6, 8 and 9). Among other findings, household size had a negative impact on COVID-19 outcomes specifically in the Northeast regions (Regions 1 and 2). As previously mentioned, some of the top variables displayed opposing effects which suggested that

Variable	US Health and Human Services Regions									
	Region 1 N=67	Region 2 N=83	Region 3 N=283	Region 4 N=736	Region 5 N=524	Region 6 N=502	Region 7 N=412	Region 8 N=291	Region 9 N=95	Region 10 N=147
Comorbidities - Arthritis (%)	-14.66	-21.29					-9.49			
Comorbidities - Asthma (%)	-40.97	-63.33	14.56	8.25		-10.64			33.08	-8.62
Comorbidities - Bad Mental Health (%)	-29.56	-26.42	3.60	6.33			-9.09		12.59	
Comorbidities - Bad Physical Health (%)	-25.44			7.34		5.93	-9.57		23.98	
Comorbidities - Binge Drinking (%)		-32.48	4.08	-11.89		7.71		16.44	-19.59	-7.10
Comorbidities - Cancer diagnosis (%)	-114.77	-177.57	46.24	-116.05		-45.73		154.49		
Comorbidities - CHD (%)	-57.94	-75.32		6.90		16.99	-21.83	54.86	46.98	
Comorbidities - CKD (%)	-132.53	170.62		96.73	33.65	79.73		77.96	165.69	
Comorbidities - COPD (%)	-39.76	-52.95					-13.52	26.83	22.09	
Comorbidities - Diabetes (%)		49.67		15.61		16.58		23.52	24.08	
Comorbidities - High Blood Pressure (%)		7.92		5.25	2.78			20.79	14.02	
Comorbidities - High Cholesterol (%)		29.87	-4.95	5.70	6.50		-9.17			-8.92
Comorbidities - No Leisure Physical Activity (%)		11.68		3.55	3.59	5.97	-4.87	15.22	11.45	3.08
Comorbidities - Obesity (%)	-6.94	-11.36		4.01		5.74		11.70	7.39	
Comorbidities - Poor Sleeping (%)	7.61	12.62					-6.05			
Comorbidities - Smoking (%)	-14.24	-14.96		3.16				12.75	5.99	
Comorbidities - Stroke (%)	-125.62			65.21	24.24	30.41	-36.24	64.67	88.24	
Demographics - 25 to 64 years of age (%)		8.66		-4.10		-3.34	-4.05	-8.08	-4.32	-2.97
Demographics - Household Size (Persons)	196.47	121.09	-52.33		-91.06		-102.57	-47.80		
Demographics - No Insurance (%)	-15.97	25.18	-3.53	5.80	9.69	2.26		-11.74	8.19	5.37
Demographics - Over 65 years of age (%)	-9.63	-11.70			3.22		3.87	4.42		
Demographics - Under 25 years of age (%)	9.69				-2.41				2.45	1.27
Education - Bachelor's or Higher (%)	3.58	3.80		-2.12	-1.48	-2.96		-4.49		-1.49
Education - High School (%)	-7.08	-4.71	1.08	1.91				6.53		
Education - No High School (%)		12.78		4.05		5.10		6.81	3.01	4.29
Education - Some College or Associate's (%)	-7.38	-11.61		-2.03	2.71	-3.23				
Geography - Latitude (degrees)	-36.75	-43.40	11.19	-7.62				15.99		-2.63
Healthcare - Cervical Cancer Screening (%)	17.67	-25.53	-10.89	-4.02	-14.83			11.18	-8.62	-4.63
Healthcare - Cholesterol Screening (%)	21.78	43.30						-7.99		-4.23
Healthcare - Colonoscopy (%)	9.57	-16.21		-10.27	-2.76	-2.25			-9.33	
Healthcare - High Blood Pressure Medication (%)	17.86	23.30		8.96	-6.50		-17.48	18.73	16.17	12.09
Healthcare - Mammography Use (%)	11.68		-4.85	-4.59	-6.51		4.88	11.90	-7.85	-3.28
Healthcare - Routine Checkup (%)	13.81	34.43	-6.32	2.92	-8.58			20.30		-8.14
Healthcare - Visited Dentist (%)	7.42			-6.08	-2.55	-6.96	3.28		-7.15	-1.98
Income - Families Median (USD$K)	2.61	2.12	-0.49	-2.38	-1.21	-1.58			-1.62	-1.16
Income - Household Median (USD$K)	2.96	2.50	-0.63	-2.64	-1.25	-1.49			-1.36	-1.20
Income - Married Median (USD$K)	2.46	2.10		-1.26	-0.98	-1.01			-1.24	-1.09
Income - Nonfamily Median (USD$K)	4.82	4.30	-0.97	-3.51	-1.83	-2.50			-1.94	-1.64
Politics - Voted for Biden (%)	2.21	2.82		0.56	-0.86		-1.22	-1.35		-1.03
Politics - Voted for Trump (%)	-1.74	-2.73		-0.53	0.85		1.24	1.42		1.03
Race - Asian (%)	15.58	8.64		-8.16	-4.16	-5.94	-11.47	-19.01		-2.32
Race - Black (%)	12.45	7.15		1.63						
Race - Hispanic (%)	7.43	5.64		-1.77		0.67		-4.09		1.41
Race - Native American (%)	-47.13					-1.35		2.52	5.00	-0.72
Race - Other (%)	12.90	9.69		-3.89		1.58		-10.08		2.08
Race - White (%)	-4.75	-3.41		-1.23		-0.56				0.65
Race -Pacific Islander (%)			-275.10	-156.81	43.97			-165.08		-12.05

Region 1: CT, ME, MA, NH, RI, VT. Region 2: NJ, NY. Region 3: DE, DC, MD, PA, VA, WV. Region 4: AL, FL, GA, KY, MS, NC, SC, TN. Region 5: IL, IN, MI, MN, OH, WI. Region 6: AR, LA, NM, OK, TX. Region 7: IA, KS, MO, NE. Region 8: CO, MT, ND, SD, UT, WY. Region 9: AZ, CA, HI, NV. Region 10: ID, OR, WA.

FIGURE 2
Regional risk ratio estimates for comorbidity, sociodemographic and determinants of health in association to COVID-19 case-fatalities. All models were performed independently by region and are adjusted to CCVI. Sample sizes correspond to the number of counties in the analysis for each region. Estimates signs indicate effect direction. Red boxes are significant to a Bonferroni level (470 tests $P_{adj} \leq 1.06E-04$). Orange boxes are significant to a 95% confidence level. COPD, Chronic Obstructive Pulmonary Disease; CKD, Chronic Kidney Disease, CHD, Coronary Heart Disease.

the interpretation must be done in context with the specific characteristics of that region, and interpretations cannot be generalized to others.

Discussion

The objective of this study was to perform a comprehensive evaluation of comorbidities, sociodemographic factors, and determinants of health at a national level using county aggregated to define their association to COVID-19 case-fatalities. Previous studies have evaluated the influence of various socioeconomic factors (7, 20, 33) and comorbidities (4–6) on COVID-19 case-fatality rate; however, these analyses do not pair together their findings to be comparable with each other. Our study evaluates COVID-19 fatality rates from a wide timeframe, without potential influence from vaccines reducing case-fatality rate and the addition of major

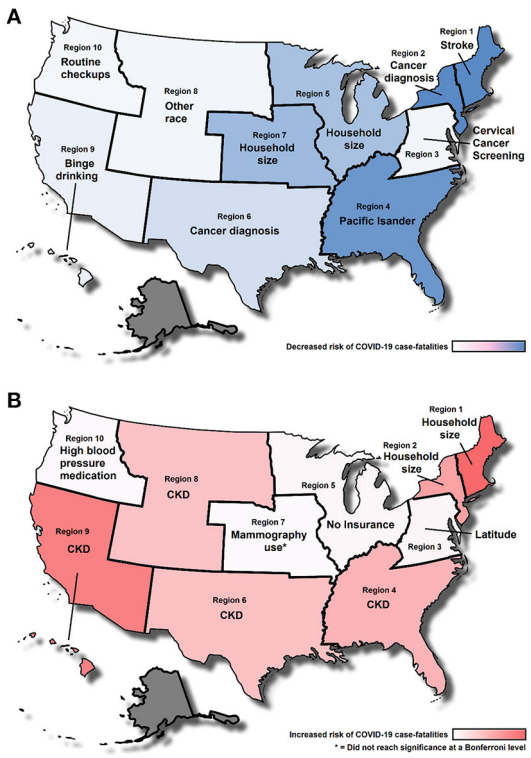

FIGURE 3
Top county level factors associated to COVID-19 case-fatalities for each United States Department of Health and Human Services regions. **(A)** Top factors associated with reduced case fatalities. **(B)** Top factors associated with increased case-fatalities. Shading indicates the effect size across regions (adjusted by COVID-19 Community Vulnerability Index, CCVI). Alaska was excluded from the analysis because of differences in their county level reporting. CKD, Chronic Kidney Disease.

COVID-19 variants. Our study builds on the efforts of previous studies by presenting together a wide array of variables that describe community characteristics. It is necessary to emphasize that the associations between these factors and case-fatalities is not necessarily or entirely causative. All comorbidities, sociodemographic and determinants of health variables presented describe characteristics of the population that are not isolated or independent and are antecedent of any causality. Therefore, any inference that could be attributed to each factor evaluated must always be provided with context as a community indicator as they are all dependent or interconnected on each other, examples of this are binge drinking, mammography and visits to the dentist rates, which are likely indirectly describing a characteristic of the community. In general, all these variables must be interpreted in a continuum of causality that can vary across regions depending on the context.

Comorbidities

Chronic kidney disease rates were the strongest predictor of increase COVID-19 case-fatality in several US regions. This relationship is likely to be predominantly causal due to people with this condition being medically vulnerable (34–37). Other comorbidities followed a similar trend such as higher rates of hypertension, diabetes, stroke, and smoking being associated with an increased case-fatality rate in a specific county. This finding aligns with other studies (5, 38, 39) linking increased rates of comorbidities to poorer COVID-19 outcomes. Even though comorbidities were most often associated with worse COVID-19 outcomes, stroke and cancer diagnosis were linked to reduced case-fatality rates in the Northeast region. We speculate that a potential explanation for this relationship is possible more frequent mask usage (40) and more precautions taken by this group of people (41). Northeastern states had mask adherence rates > 75% during the latter part of 2020 (40) with usage potentially diminishing the influence of comorbidities such asthma and COPD on COVID-19 case-fatality rate. Those with asthma and COPD in these communities were maybe more likely to wear a mask, further reducing their chance of acquiring and succumbing to COVID-19.

Sociodemographic factors

Household size was identified early on to be a risk factor for COVID-19 transmission (42). Our results have shown conflicting effects when viewing this factor across regions. Household size is a risk factor in the Northeast but has a protective effect in the Midwest. The difference between these regions is likely related to the specific context of living conditions. Although the mean household size for regions 1 and 2 is not far from the mean household size for regions 5 and 7, with 2.48 and 2.41 respectively, this difference may capture differences in housing quality and composition (43). This may also be indirectly identifying behavioral factors that are not obvious but can be implied such as house proximity (higher in cities) which can affect the capacity of self-isolation. Population density could partially be influenced by household size, which has shown to have an impact on transmission (44). Northeast states have higher population densities when compared to midwestern states. In summary, living conditions, housing quality and composition, and population density are all important components that define the impact of household size on case fatality rate. Generally, higher income was also associated with decreased COVID-19 case fatality rates. There could be a multitude of reasons why a higher income may be beneficial. This could include not being classified as an essential worker leading to being more likely to take time off or work from home (45), or even being able to live outside high-density population and compact housing areas

(7, 46). Income is often reflective and associated with racial discrepancies in COVID-19 outcomes (33, 47, 48). In a study examining neighborhood median income and COVID-19, when examining the neighborhoods, Black populations more often lived in neighborhoods with a significantly lower median income ($35,000) whereas White populations more often lived in wealthier neighborhoods ($63,000). Communities with lower median incomes are more often Medicaid patients and have COVID-19 complications that require invasive tactics such as mechanical ventilation (49). Income inequalities have been strong predictors of higher case numbers and fatalities throughout this pandemic (20).

Political affiliation

The context that defines the influence of social dynamics on COVID-19 is complicated. Political affiliation has been repeatedly evaluated as a potential factor influencing the pandemic's mortality (19, 50) *in prior* pandemics, with Republican party affiliation associated with decreased influenza vaccinations and Democratic party affiliation associated with increased vaccinations (51, 52). The politicization of pandemic response has continued into the COVID-19 pandemic, with behaviors such as masking, social distancing, and vaccination being often divided along party lines (17, 19). Some studies have shown a decrease in pandemic preventive health measures among Republicans while there has been increased adherence to public health recommendations among Democrats (53, 54). Similarly, Republicans have been shown to have lower COVID-19 risk perception (55, 56), when compared to other political parties which may influence their likelihood of contracting COVID-19. The behaviors exhibited by each political party may influence the results of this study. Our study showed that voting for Joseph Biden in the 2020 presidential election was mildly associated with decreased case-fatality rate while voting for Donald Trump was associated with increased rate. With Democrats being shown to be more likely to adhere to public health guidelines, they may be less likely to acquire and perish from COVID-19 while the inverse is true for Republicans. In December 2020, states with Republican governors had higher rates of cases, deaths, and positive tests than states with Democrat governors (57). This trend is evident in a similar approach using national data presented by NPR in collaboration with researchers at John's Hopkins University where it was shown that voting Republican also had a deleterious effect (58). Rural and urban differences have been shown to play a major role in case-fatality rate as well with rural counties having a higher case-fatality ratio than urban counties (4). Rural voters are more likely to vote Republican (59) and therefore, the influence of politics in our findings may also be capturing geographical differences. Rural areas tend to have worse health outcomes in general and have significantly less access to care compared to their urban counterparts (60). These disparities add to the likelihood of developing comorbidities and ultimately, poorer COVID-19 outcomes. The link between political affiliation and COVID-19 case fatality rate is far more complex than the individual candidates that people of a county voted for. Political affiliation in our study is an indicator of underlying sociodemographic, health, and psychological trends that are more causative rather than associative.

Limitations

Our study utilized aggregate data on a per-county basis instead of individual patient data; therefore, it is not possible to evaluate factors that contribute to COVID-19 case-fatality on a per case fashion which could help avoid any erroneous generalizations of specific regions. Another limitation of using county level data is that there is significant variability in the size and number of counties across the United States. Some counties may have only a few hundred people, while other counties may have a few million and this may lead, to some extent, representation bias.

Future prospective

Our study findings support a notion where all comorbidities, sociodemographic and determinants of health variables describe characteristics of the population; these characteristics are not isolated or independent but may share their etiology. For this reason, we believe our research can help inform future directions in public health including the evaluation of individual community factors that contribute directly to illness outcomes. Despite the application of our findings to public health, it is difficult to apply our findings to clinical practice recommendations due to the interdependent nature of the variables we evaluated. A future prospective should attempt to incorporate the factors identified into the population inclusion criteria of follow up approaches. In general, our study allows us to recommend expanding the list of confounders traditionally used in studies. These expanded confounders come in two main types: first, well defined groups at high risk (those with CKD, COPD or other prominent comorbidities) and second, less well defined groups with predisposition (those living in specific housing conditions, environments, or with specific political leanings). These factors are non-traditionally considered but have an important contribution to outcomes.

Conclusions

Our study identified several unique regionally dependent and independent relationships that highlighted the various factors that might influence COVID-19. Like other studies,

we determined that comorbidities and demographic factors together are strong drivers of COVID-19 case fatalities. However, our study presents an assessment that puts them side to side for direct comparison. Our study highlights how any association is often dependent on the regional context. For example, household size in the Northeastern region of the United States was associated with more fatalities, while larger household size in the Midwest regions had a protective effect. Political voting patterns were also indicative of underlying healthcare patterns, with overall reduced case fatality rates in Democratic voting counties compared to increased fatality rates in Republican voting counties. The trends we identified in our study emphasize the importance of interpreting each factor in the context of other variables instead of in isolation.

Data availability statement

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

Author contributions

JG: conceptualization, methodology, data curation, investigation, and writing of original draft. DZ and DK: conceptualization, methodology, investigation, and writing of original draft. IZ: conceptualization, methodology, investigation, formal analysis, visualization, supervision, writing and editing of final draft. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.993662/full#supplementary-material

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EDITED BY
Keith Elder,
Mississippi College, United States

REVIEWED BY
Dagmar Schaffler-schaden,
Paracelsus Medical University, Austria
Caress Alithia Dean,
Oakland University, United States

*CORRESPONDENCE
Lukas Richter
lukas.richter@fhstp.ac.at

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Poverty in old age in times of COVID-19—Empirical results from Austria

Lukas Richter[1]* and Theresa Heidinger[2]

[1]Department of Social Sciences, St. Pölten University of Applied Sciences, St. Pölten, Austria, [2]Department of Gerontology and Health Research, Karl Landsteiner University of Health Sciences, Krems an der Donau, Lower Austria, Austria

Early in the pandemic, researchers were cautioning that COVID-19 and the associated health policy countermeasures would have an increased negative impact on groups that were already vulnerable before the pandemic. One of these groups are older people affected by poverty, who according to official figures make up 13.9% of older population in Austria. Even before the pandemic, their living situation was considered precarious. Not without reason, this group has been identified as a high-risk group of the pandemic, due to their increased likelihood of severe COVID-19 related illness and their limited monetary resources and thus lower chances of coping with the pandemic. Nevertheless, research on this group has remained sparse to date. Therefore, the aim of the study is to focus on older people (60+ years) below the poverty line and to compare them with non-poor individuals. Data from the SHARE (Survey of Health Aging and Retirement in Europe) project is used, combining data from the two SHARE Corona Surveys (summer 2020 and summer 2021) and the SHARE Corona Special Austria Survey (December 2020) to gain the most complete picture of life situation during the pandemic. Results demonstrate that older people in poverty were more likely to report poor subjective health before as well as during the pandemic yet were significantly more likely to refuse vaccination against COVID-19, despite adhering to other measures against the pandemic to the same extent as non-poor people. Restrictions in the health care system affected both groups equally and no significant differences in the frequency of social contacts could be found. However, older people below the poverty line were significantly more likely to rely on social support to obtain necessities during the pandemic and were less likely to use the internet. Together, these results point out that disadvantage exist for the older poor in some but not all areas of life during the pandemic. This paper is aimed at providing first insights into the lives of poor older persons during a taxing time and may perhaps inspire more in-depth study of this particularly understudied population.

KEYWORDS

poverty in old age, Austria, inequality, COVID-19, AROP, Altersarmut, life situation, vaccination

Introduction

From a gerontological perspective, the COVID-19 pandemic presents a serious challenge for older people, who are considered a risk group due to a higher probability of severe course of disease and risk of mortality in case of infection (1) which have been related to age-related physiological changes and a higher prevalence of comorbid conditions (2). Additionally, many of the protective measures, taken in part with reference to protecting older people (3), have had far-reaching consequences in other areas of life (4). Systematic reviews and longitudinal studies show a decline in physical activity (5), mental (6) and physical health (7) as well as an increase in social isolation and loneliness (8) due to effects of the pandemic and it's countermeasures. These studies provide vital insights on the lives of older people during the pandemic. It must be pointed out however, that older persons oftentimes are assumed to be a homogeneous group in the scientific as well as in socio-political discourses, despite gerontological admonitions (9, 10). In fact, older people are a most heterogeneous group that differs, among other things, due to different abilities and limitations, biographies, and lifestyles, as well as socio-economic resources and thus their possibilities for action. Taking this heterogeneity into account, it is counterintuitive to assume that older people experience the COVID-19 pandemic in a uniform way or that all are confronted with the same problems and obstacles to an equal extent – for instance Whitehead and Torossian (11) identified different patterns of stressors and joys of the pandemic dependent on socio-economic determinants of older people.

At the beginning of the pandemic, researchers cautioned that the pandemic may have a more profound negative impact on groups that had already been vulnerable prior to the pandemic (12–14), one of which being older people affected by poverty. It is easily overlooked that 16.1% of older people in the European Union and 13.9% in Austria lived below the line of poverty even before the start of the pandemic (15). Despite these early warnings from the scientific community of further precarisation in the pandemic, scientific research on the effect of low income or poverty among older people has remained limited to date, even though as Valtorta and Hanratty (16) ascertained in a literature review, older people from lower socio-economic backgrounds are less financially resilient to shocks such as illness and experience greater financial stress as a result (17, 18). There are few studies explicitly addressing poverty in old age in times of the pandemic, most findings on the situation of older persons living in poverty have to be inferred from gerontological studies which include income or wealth as a control variable. Therefore, the aim of this paper is to inform on the lives of old people living below the poverty line during the pandemic and comparing the situation faced by poor vs. non-poor older (60+) people in Austria.

Life of older people living in poverty before the pandemic

Prior to touching on the current state of research in the pandemic, we briefly present general findings on poverty in old age. It should be mentioned at the outset that even within Europe the at-risk-of-poverty rate[1] for older (the age of 65+ is usually assumed) people varies widely (20), as pension systems differ considerably due to specific national designs of multi-pillar pension systems (21). Coupled with social benefits, differences in accessibility (e.g., due to costs) or availability of health care, housing, etc., the life situation of older people living in poverty varies at the national and even local level. Inequalities connected to economic status have been empirically proven, this can be shown by the example of health status: significant correlations have been shown between frailty and material deprivation (22) as well as an increase of multimorbidity with decreasing income (23), which finally culminate in different life expectancies of the lifetime rich as compared to the lifetime poor (24). Furthermore, significantly lower life satisfaction (25, 26) and wellbeing (27) as well as a higher probability of depressive symptoms (28, 29) have also been identified among older people in poverty. Turning to exclusion processes before the pandemic: Barnes et al. (30) stated that older people in the lowest income quintile are more often excluded from financial products, material goods and experience neighborhood exclusion as well as exclusion from social relationships. This accumulation of disadvantage is particularly problematic as social support for example is highly relevant for older people living in poverty as it helps to overcome challenges in everyday life (31) caused, for instance, by health restrictions (18).

To recapitulate, it can be said that older people living in poverty are confronted with disadvantages and precarious life situations, which are either due to or influenced by their economic status. It must be said, that precarity fortunately is not universally found in the poor as many have been able to develop coping strategies. An important explanatory factor for disadvantages is the persistence of poverty among older people – at least in Austria. Even though a certain income dynamic in old age does exist, Jensen and McLaughlin (32) state that income changes often occur on a small scale. The centrality of the state pension in old age as an expression or result of earned income in the employment phase and the structure of the pension system contribute to a largely steady income situation in old age in Austria – unless of course, changes occur to the household composition or marital status. In Austria 151,000 of the 210,000 poor older people in 2019 had been previously classed as such for

1 Eurostat defines the "at-risk-of-poverty rate" as the share of people with an equivalised disposable income below the "at-risk-of-poverty threshold," which is set at 60% of the national median equivalised disposable income after social transfers (19).

at minimum 2 years between 2016 and 2018 (33). This persistent monetary precariousness reduces the chances of coping with crises - rather persons are forced to draw on their limited material and immaterial resources. Approximately 30% of older people below the poverty line in Austria report not being able to save small amounts of money (even as low as 15 Euro) and 35% indicate a larger income as a necessary minimum income than they currently have at their disposal (Statistic on Income and Living Conditions - SILC 2019 - own calculations). In consequence unexpected expenses oftentimes cannot readily be covered and sometimes necessitate "disjunctive decision-making" (34). In short, unexpected expenses (e.g., medical needs, if not covered by health insurance) can only be met by cuts (18, 31) in the socio-cultural subsistence level (e.g., foregoing food or heating). The latter manifests in the non-utilization of the health care system despite actual needs (35) or reduced opportunities in care and nursing (36). In consequence, impoverished older people have a significantly lower chance of recovering from illness or disease than non-poor persons (37).

Life during the pandemic

With these findings in mind, we turn to the effect of economic status on the older persons life situation during the pandemic. As already mentioned, studies that explicitly deal with poverty in old age during the pandemic are sparse with insights being mostly based on indirect findings (i.e., studies investigating poverty and controlling for age or gerontological studies which include income or financial burden as a control variable). Although inequality or poverty research has dealt intensively with the impact of the pandemic in the overall population, for example with regard to the living situation (38–40) or probability of infection and mortality (41, 42) we focus on results from gerontological research, as these are suited to show how lives of older people in poverty and non-poor older people differ over the course of the COVID-19 pandemic.

A study carried out in the U.S. at the beginning of the pandemic, which mainly, although not exclusively, dealt with older people, was able to show that American respondents below the poverty line were significantly more likely to assume that they would not fall ill from COVID-19 (43) with the result remaining stable in a follow-up survey using the same respondents in the bivariate, but not in multivariate analysis (44). These assumptions could be shown to be false in empirical studies: early results from Sweden using microdata show a 1.35-fold higher mortality risk for older people in the lowest income tertile (45) [see also results from Belgium (46) or from Mexico (47)]. As expected, due to a higher likelihood of poor health, the mortality risk was shown to be higher among the older people below the poverty line.

Against this background, the question arises whether poor older individuals were more likely to adhere to protection measures against COVID-19 infection. Delerue-Matos et al. (48) interpreted the reduction of some social activities which was more probable in older people with financial difficulties than those without difficulty as a precautionary behavior; in contrast focussing on hygienic prevention measures Litwin and Levinsky (49) reported a negative association with better financial capacity. The two contrasting results can be explained by the fact that older people in poverty were already less engaged in (social) activities before the pandemic and therefore may have remained less engaged during the pandemic (50). Paradoxically, this inactivity can be seen on the one hand as an advantage in the pandemic, as costly measures [such as face masks as mentioned in Portacolone et al. (51)] may thereby have been used slightly less often. A problematic finding in this context is, that vaccination hesitancy was significantly higher among older adults reporting problems making ends meet or at risk of poverty (52, 53) at least in the first year of the pandemic. On the other hand reduced (social) activities may have also brought about negative effects: older people with difficulties to make ends meet had a significantly higher probability of feeling depressed (54, 55), anxious (55) and lonely since the outbreak of the pandemic (54, 56) and more often reported decreasing mental health (57, 58).

Cross country analysis of Europe additionally shows a significant higher risk of forgoing care for fear of contracting COVID-19 and a higher risk of being unable to obtain a medical appointment in the first months of the pandemic (59–61), although accessibility differs between European countries (62). Twelve percent of older people with difficulties making ends meet postponed regular payment of bills and 27% dipped into their savings (63) – unfortunately the later study didn't compare the results with non-poor older people. It is important in this context, that, although many older people receive a relatively stable pension, they also have had to face income losses from paid employment in addition to changes in household expenditure: results from the Survey of Health, Aging and Retirement show that older people (50+) with low income more frequently reported a job loss (64) or working less hours since the outbreak of the pandemic (65).

In summary, older people with low financial means seem (more) negatively affected by the pandemic than older persons without financial difficulty. However prior results are sparse and often must be extracted from large multivariate studies which do not focus on the topic of poverty explicitly. Complicating this further is the fact that the measurement concept of poverty differs across studies with some using indicators on financial difficulties (such as the ability to make ends meet) and other opting for a categorisation of income within the used sample. This constitutes the main difficulty for not being able to relate many of these study results with the frequently used monetary poverty concept "at risk of poverty" as used in the European Union or Eurostat. This paper therefore deals explicitly with older people below the at-risk-of-poverty

threshold and compares them to non-poor older persons in multiple dimensions of life during the pandemic such as health status, adherence to protective measures and perceptions and experiences related to the virus.

Methods

Sample

Survey data from three waves of the longitudinal Survey of Health, Aging and Retirement Study (SHARE) were combined in order to achieve the most accurate picture of life during the pandemic: data from the summer 2020 Corona survey 1 (SCSS20) was combined with the winter 2020 Corona survey (special survey of the Austrian study population- SCSAT20) as well as the summer 2021 Corona survey 2 (SCSS21); all the analyzed datasets are based on version 8.0.0 (66, 67). Normally, the survey is conducted *via* a face-to-face Computer Assisted Personal Interview (CAPI), but the pandemic forced a switch to Computer Assisted Telephone Interviews (CATI). Data at the three timepoints were therefore collected *via* CATI (68). Furthermore, sociodemographic information (age, household size) as well as information on household income was supplemented by importing information from wave 8 of the SHARE survey, conducted in 2019 (69, 70), or other most recently completed surveys, in order to achieve maximal explanatory power in the variables of socio-economic status. Persons were excluded from analysis if they did not take part in all three Corona surveys. A detailed coding plan for all analyzed variables can be found in Supplementary Table A.1. Additionally, only persons 60 and above were included. This threshold was chosen as this age constitutes the average retirement age in Austria.

Variables

The main variable of interest relates to whether a respondent is classed as income poor. To calculate this distinction the most recent information on the economic situation of the individual was used. Household income equivalency was computed for each participant and compared to the EU-SILC 2020 threshold for risk of poverty in Austria (15,933 Euro/year) (71). Participants were then classed as been "non-poor" or "poor." Validity of this variable is supported by a moderate correlation with the variable "being able to make ends meet" (*Cramer's* $V = 0.336$, $p < 0.001$). As the different survey waves included varying items, an overview of the variables their original and recoded manifestations as well as their survey wave of origin are presented in Supplementary Table A.1 (see Appendix).

Perception and own experience with the virus

Variables discussing the perception of the COVID-19 virus were included solely in the winter 2020 survey (SCSAT20) and covered the estimated probability of catching the virus ("How high do you estimate your risk of catching Corona within the coming 6 months?") as well as the estimated severity of COVID-19 illness ("How dangerous would a Corona infection be for you considering your health?"). Furthermore, participants were asked to inform on past COVID-19 infections in summer 2020 (SCSS20) and summer 2021 (SCSS21) – using both outcomes two groups were formed: respondents indicating a positive COVID-19 test vs. respondents without a positive COVID-19 test since the outbreak of the pandemic.

Vaccination willingness

Willingness to get vaccinated was surveyed in the winter 2020 survey ("If a vaccine against COVID-19 were available, would you get vaccinated?") as well as in the summer 2021 survey which included questions on realized COVID-19 vaccination ("Have you been vaccinated against COVID-19?") as well as ambition to get vaccinated ("Would you want to get vaccinated against COVID-19?"). Information of these two variables was combined to form the variable vaccination willingness in summer 2021 which combined persons who already had received their vaccination and those who were planning to get vaccinated to compare against those who were not willing or unsure about getting a vaccination. Attitude change toward vaccination between winter 2020 and summer 2021 was calculated and persons were classed as follows: consistently accepting of a vaccination, consistently rejecting vaccination, consistently unsure about vaccination, switch from rejection to acceptance, switch from unsure to acceptance, and switch from acceptance to rejection or uncertainty between timepoints.

Compliance

Variables describing the compliance with the pandemic mitigation measures included wearing a face mask in public, keeping a distance from others in public, washing the hands more frequently than usual and using hand sanitizer or disinfectant fluids more frequently than usual. Compliance with these measures was surveyed in summer 2020, in winter 2020 questions on the reduction of social contact were introduced ("Did you reduce your social contacts with people outside of your household at the beginning of the pandemic as well as at the time of the survey?"). Finally, the use of COVID-19 tests, a service put in place to prevent the spread of the virus, was surveyed retrospectively in the summer 2021 survey ("How many times have you been tested for COVID-19?").

Health status

Information on subjective health status was collected in summer 2020 and summer 2021. In the summer 2020 survey, subjects were asked to compare current health to the time before the outbreak of the pandemic; current health status was collected in the summer 2021 survey. Mental health was assessed in the winter 2020 survey. This included the Euro-D Scale (72) which informs on feelings of depression in late-life (range 0 "not depressed" to 12 "very depressed") as well as the GAD-7 scale by Spitzer et al. (73) which is a well-established, brief measure for assessing generalized anxiety disorder (range 0 "no anxiety" to 21 "high anxiety"). Additionally, the use of health care services was included to capture health behavior in the pandemic. Questions on forgoing or postponing medical appointments or being denied medical appointments were asked in the summer 2020 (retrospectively spanning the in time since the outbreak) and summer 2021 (retrospectively spanning the time since summer 2020) surveys. Furthermore, visits to hospital as well as to medical practices and other medical facilities were queried in summer 2021.

Social participation

Social participation during the pandemic was also analyzed for differences between poor and non-poor persons. Contact frequency to children, grandchildren and neighbors/friends/colleagues was surveyed in summer 2021. Information on face to face but also electronic contact was collected. Social support was also queried, whereby persons were asked to report whether they had received help in obtaining necessities by children, other relatives, or friends/neighbors/colleagues.

ICT use

Finally, the use of information and communications technology (ICT) was examined according to economic status in old age. Persons were asked whether they had (a) used the internet since the outbreak of the pandemic. If they answered affirmatively, they were asked whether they had used the internet in order to (b) find information on health-related issues, (c) gain information about government services (d) manage their finances and (e) buy or sell goods/ services. Furthermore, the use of remote medical services during the pandemic was queried. All information on ICT use was collected in the summer 2021 survey, participants were asked to retrospectively report ICT use in the time since the outbreak.

Analyses

The analysis was carried out using IBM SPSS 27. Bivariate comparisons of persons classed as 'poor' compared to those who were not classed as such on discrete variables were done by using Chi² tests (cross-sectional design). *Post-hoc* group comparisons were done using *z*-test with Bonferroni correction. Group comparisons on continuous variables were done *via* unpaired *t*-tests or if necessary, the non-parametric Mann–Whitney *U*-Test. All statistical testing was done using the significance level of $\alpha = 0.05$. Effect sizes were provided for all computations. A conscious decision was made not to perform multivariate procedures as the data was collected using differing questions and introducing or omitting specific questions at the different timepoints (an overview can be found in Supplementary Table A.1 of the Appendix). Because of this, no statements on the correlation of specific dependent variables and poverty can be made, instead this paper provides comparisons between poor vs. non-poor older individuals at three separate timepoints during the pandemic and thus is primarily exploratory or descriptive in nature.

Results

Sample composition

The final sample was comprised of 2,078 persons, due to missing values the sample for analysis was reduced to 1,862 persons, whereof 18.1% were classed as income poor and ∼10% reported at least some difficulty in making ends meet. A more detailed description of the sample structure can be found in the adjoining Table 1.

Perception and experience with the coronavirus

Poorer participants indicated a significant but marginally higher risk of becoming infected with the Coronavirus than those in the non-poor group even though most of both groups estimated to be at (very) low risk of infection: 68.5% non-poor vs. 61.9% poor participants (Table 2).

Neither the estimation of danger nor the comparison of past infection showed a statistically significant difference which can be interpreted as there being no disadvantage of low socioeconomical status on experience with the virus. For both groups the majority of participants considered COVID-19 to be a potentially serious threat to their health (53.5% non-poor, 58.7% poor participants). The high number may not be surprising here, as the survey took place mainly in December of 2020, shortly after the second wave of infection had reached its peak in Austria when the number of hospital admissions and deaths per day were at an all-time high (74, 75). However, seen from the current perspective, the 7-day incidence remained relatively low until the summer of 2021, with the highest number of newly identified cases of confirmed SARS-CoV2 infection being ∼560 per 100,000 inhabits (on 12.11.2020). For this reason, the low number of positive tests (aka evidenced

TABLE 1 Sample structure.

	Distribution in sample
Gender	
Male	39.0%
Female	61.0%
Age	
Metric	*Mean* = 73.31 years, *SD* = 7.97 years
ISCED 97	
Classification from 0 (no formal education) – 6 (high formal education)	*Mean* = 3.33, *SD* = 1.30
Household size	
Metric	*Mean* = 1.8 persons, *SD* = 0.8 persons
Income poor	
Yes	18.1%
No	81.9%
Make ends meet	
With great difficulty	1.4%
With some difficulty	8.8%
Fairly easily	36.3%
Easily	53.4%

Gender is restricted to two categories in the SHARE surveys.
ISCED, International Standard Classification of Education.

infections) in the sample (5% of all respondents with no significant differences between groups) can be explained.

Vaccination willingness

The free vaccination against COVID-19 had been promoted relatively early on in Austria with the first persons receiving a vaccination as early as December 27 2020, with abundant media attention (76). However, willingness to get vaccinated in winter of 2020 remained ambiguous with 55.1% of all participants indicating that they would like to receive a vaccination while 22.6% declined wanting to get vaccinated and the remaining 22.4% indicated feeling unsure about a vaccination (Table 3).

Comparing poor vs. non-poor participants showed a stark difference with persons classed as poor indicating far more unwillingness (34.7 vs. 19.9% in non-poor persons) or uncertainty (27.6 vs. 21.2% in non-poor persons) to get vaccinated against the virus (*Cramer's* $V = 0.17$, $p < 0.001$) in the winter of 2020. By the summer of 2021 most persons were already vaccinated with 6.6% of all participants continuing to decline a vaccination and another 3.8% stating that they were unsure whether they would like to receive a vaccination in the future. Comparing poor vs. non-poor persons showed significant differences between the groups (*Cramer's* $V = 0.154$, $p < 0.001$): poor persons were significantly more likely to be vaccination rejectors (14.7 vs. 4.9% of non-poor group), for the group of undecided persons, no difference across groups could be found.

Attitude change toward vaccinations was analyzed for the entire sample. Five percent of rejectors in winter 2020 remained rejectors in summer 2021, 1.2% of the previously uncertain remained in summer 2021 (Figure 1). Most change was seen from uncertainty in 2020 to acceptance in 2021 (20.6%) additionally 16.4% of rejectors in 2020 indicated an accepting stance toward the vaccine in 2021. Poor and non- poor persons differed significantly in attitude change (*Cramer's* $V = 0.26$, $p < 0.001$). Of the group of poor participants significantly more persons remained firm rejectors than from the non-poor (12.1 vs. 3.5%), however more rejectors also switched to acceptance from this group (22.4 vs. 15.1%). This fact is unsurprising seeing as the group of vaccination rejectors was far larger in the group of poor participants as compared to the non-poor in winter 2020. These variables show a differential picture of vaccination acceptance between the financially better off vs. poorer persons. Additionally, when subjective health was included (not shown here), 15% of old poor persons who indicated fair/poor health refused a COVID-19 vaccination in summer 2021 (*Cramer's* $V = 0.172$ $p < 0.001$).

Compliance

Most of the sample indicated being compliant with the pandemic mitigation measures. Comparing the groups of poor vs. non-poor participants showed no significant differences in compliance with all queried measures except for "using hand sanitizer more frequently" which was indicated less in the poor group (77% agree vs. 84.3% agree in non-poor group, *Cramer's* $V = 0.075$, $p < 0.001$). Comparing compliance to the measure "reduction of social contacts" (surveyed in summer 2020) yielded no significant difference between groups (Table 4), comparing the use of the COVID-19 tests however showed group differences: older people in poverty were twice as likely to have never used a COVID-19 test than those classed as non-poor (12 vs. 6.6%). Another difference could be seen in the "most frequent testers" (10 or more test) where non-poor were significantly more likely (29.5 vs. 12.3%) to have used a higher number of tests (*Cramer's* $V = 0.17$, $p < 0.01$).

Reported health

Most participants reported excellent to good health prior to the pandemic, one quarter reported having fair to poor health preceding the outbreak of COVID-19 (Table 5). Current health status was rated as "good" by 38% of participants, 32% assessed their health as being "fair/ poor" in the summer of 2021. Therefore, health seemed to have declined in a number of participants, which may be explained by the effects of the crisis however, due to the extended length of the pandemic, could also show a natural decline in health with increasing age. Comparing

TABLE 2 Perception of and experience with the coronavirus.

Risk of catching corona (SCSAT20)			Dangerous for own health (SCSAT20)		
	Non-poor	Poor		Non-poor	Poor
(very) Low risk	68.5%$_a$	61.9%$_b$	*Not/a bit dangerous*	15.4%$_a$	16.5%$_a$
Medium risk	26.5%$_a$	30.6%$_a$	*Medium dangerous*	31.1%$_a$	24.8%$_b$
(very) High risk	5.0%$_a$	7.5%$_a$	*Quite/very dangerous*	53.5%$_a$	58.7%$_a$
n	1,448	314	*n*	1,413	315
Cramer's V	0.060		*Cramer's V*	0.054	
p	0.048		*p*	0.082	

COVID-19 infection in the past until summer 2021 (SCSS20 + SCSS21)		
	Non-poor	Poor
No	95.1%$_a$	95.3%$_a$
Yes	4.9%$_a$	4.7%$_a$
n	1,525	337
Cramer's V	0.054	
p	0.082	

The lower-case letters in the tables show the result of the z-test. aa = no significant difference between poor and non-poor; ab = significant difference between categories. We recommend interpreting the z-test only if the respective chi² test in the table is significant (when $p < 0.05$). *Cramer's V* measures the strength of the relationship between variables, *n* = sample size, SCSS20 = SHARE Corona Survey – summer 2020, SCSS21 = SHARE Corona Survey – summer 2021. SCSAT20 = SHARE Corona Special Austria Survey – winter 2020.

TABLE 3 Vaccination willingness.

Vaccination willingness winter 2020 (SCSAT20)				Vaccination willingness summer 2021 (SCSS21)			
	Non-poor	Poor	Total		Non-poor	Poor	Total
Vaccinated, ready to be vaccinated	58.9%$_a$	37.7%$_b$	55.1%	*Vaccinated, ready to be vaccinated*	91.5%$_a$	80.8%$_b$	89.6%
Refusal	19.9%$_a$	34.7%$_b$	22.6%	*Refusal*	4.9%$_a$	14.7%$_b$	6.6%
Unsure	21.2%$_a$	27.6%$_b$	22.4%	*Unsure*	3.6%$_a$	4.5%$_a$	3.8%
n	1,524	337	1,861	*n*	1,522	334	1,856
Cramer's V		0.171		*Cramer's V*		0.154	
p		<0.001		*p*		<0.001	

The lower-case letters in the tables show the result of the z-test. aa = no significant difference between poor and non-poor; ab = significant difference between categories. We recommend interpreting the z-test only if the respective chi² test in the table is significant (when $p < 0.05$). *Cramer's V* measures the strength of the relationship between variables, *n* = sample size, SCSAT20 = SHARE Corona Special Austria Survey- winter 2020, SCSS21 = SHARE Corona Survey – summer 2021.

the two groups showed a disadvantage for poor older people before and during the pandemic. Persons classed in this category were significantly less likely to assess their current health as "excellent/very good" (21 vs. 35%) and were more likely to report "fair/poor" health (36%−23% in non-poor group) prior to the outbreak (*Cramer's* $V = 0.141$, $p < 0.001$). They were also more likely to report fair/poor health in the pandemic (summer 2021) with 41% as compared to 30% (*Cramer's* $V = 0.010$, $p < 0.001$).

Mental health was approximated with information on depression (Euro-D) (76) and anxiety (GAD-7) (77). Using the cut-off for the Euro-D scale used in the majority of SHARE studies (<4 "not depressed," 4–12 "case of depression"), 72% of all participants were classified as "not depressed" during the pandemic. Comparison of the two groups showed a significantly higher mean among the income poor (2.06) vs. the non-poor group (1.80). Since statistical requirements for parametric testing were not fulfilled, a Mann–Whitney-*U*-test was carried out to test statistical significance. This showed a small but significant difference between poor vs. non-poor persons: $U = 223{,}434.000$, $p < 0.001$, $r = 0.089$. In addition, most participants report few symptoms of anxiety: Using the GAD-7 scoring system 85% of the sample were classed as having "no or minimal anxiety," 13% could be classed as having "slight anxiety." Comparing both groups, a small effect (*Cramer's* $V = 0.086$, $p < 0.001$) can be stated: significant more older people above the poverty line reported "no or minimal anxiety" (86 vs. 78%).

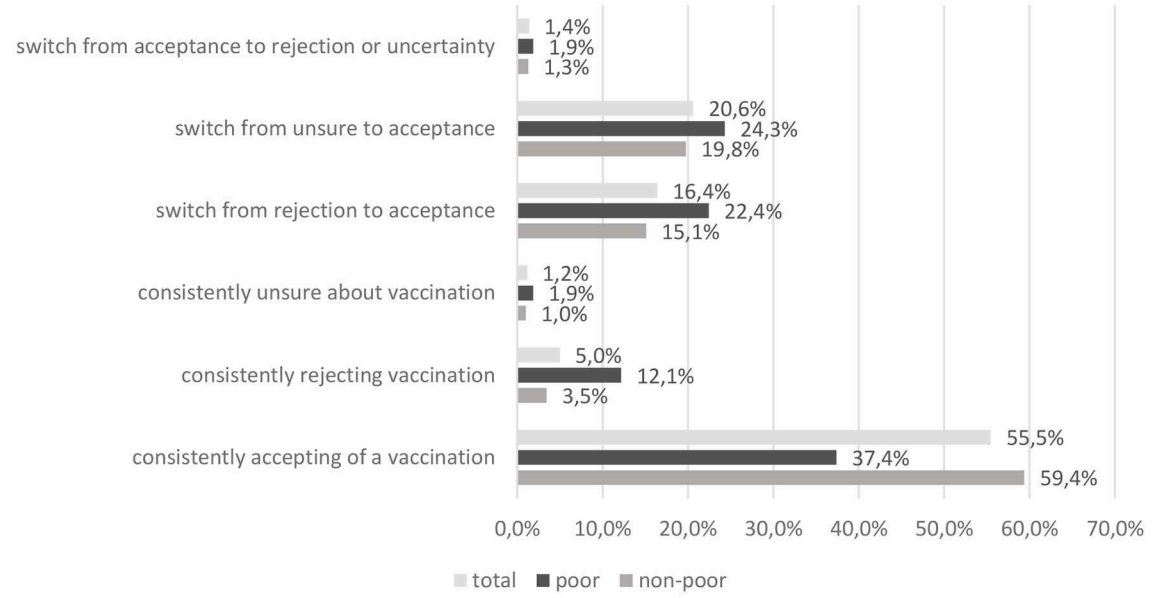

FIGURE 1
Attitude change toward vaccination.

Health care utilization

Examining limitations to the health care services during the pandemic showed that older people could partly not make use of health services (data taken from the summer 2020 survey): 14% of all participants reported forgoing, 27% postponing treatment due to COVID-19 and 5% reported having been denied an appointment. In the 2021 summer survey, the number of participants reporting health care difficulties was lower: 8% forwent an appointment, 11% postponed an appointment and 3% were denied an appointment in the second year of the pandemic. In addition, 28% of the sample were treated in hospital over the course of the pandemic, 82% confirmed having gone to a doctors practice or another medical facility outside of a hospital. Since there were no significant differences between poor/non-poor persons in any of the tested variables the corresponding Supplementary Table A.2 has been moved to the Appendix. In short, limitations in health care use were independent of economic status in Austria among the older population.

Social contact and support

Information on social contacts is summarized in the Appendix as well (Supplementary Table A.3), as no significant differences between the groups were found in this block of variables. Most participants reported having had face to face contact with children (69%), grandchildren (53%) or friends/neighbors/colleagues (59%) at least once a week in summer 2021. Electronic contact was found to be even higher with 87% of all participants with children reportedly having electronic contact with them at least once a week. Friends/neighbors/ colleagues were the second most frequent contact group – 75% reported a contact frequency of once a week or higher with this group. Social contact (face to face and electronically) did not differ significantly between poor and non-poor older persons in Austria.

Focussing on social support, 42% of the sample reported having been helped by their children, 15% reportedly leaned on friends/neighbors of colleagues for help obtaining necessities in the pandemic, 8% were helped by other relatives. Differences between poor and non-poor could be seen in the data (Table 6), whereby older people below the poverty line were more likely to receive support from children (49.4 vs. 39.4% non-poor, *Cramer's* $V = 0.078$, $p < 0.05$) and other relatives (14.9 vs. 7.7% non-poor, *Cramer's* $V = 0.10$, $p < 0.001$), social support by friends/neighbors/ colleagues did not differ according to economic status.

ICT use

Fifty-six percent of all participants reported using the internet, however, with significant differences between the two groups as shown in Table 7 (*Cramer's* $V = 0.175$, $p < 0.001$). Only 37.2% of older people in poverty use the Internet, indicating a significant digital gap which persisted during the pandemic.

It should be noted that the next results refer only to people who reported using the internet in both groups (see *n* in

TABLE 4 Compliance.

Summer 2020 (SCSS20)	Wore a face mask in public		Kept distance from others in public	
	Non-poor	Poor	Non-poor	Poor
Always	72.0%$_a$	74.7%$_a$	80.5%$_a$	80.1%$_a$
Often	22.7%$_a$	18.2%$_a$	16.8%$_a$	15.2%$_a$
Sometimes	4.8%$_a$	5.7%$_a$	2.2%$_a$	4.4%$_b$
Never	0.4%$_a$	1.4%$_a$	0.5%$_a$	0.3%$_a$
n	1,433	296	1,432	296
Cramer's V	0.062		0.053	
p	0.085		0.181	
	Washed hands more than usual		**Hand sanitizer or disinfection more than usual**	
	Non-poor	Poor	Non-poor	Poor
Yes	89.4%$_a$	86.1%$_a$	*yes* 84.3%$_a$	77.0%$_b$
No	10.6%$_a$	13.9%$_a$	*no* 15.7%$_a$	23.0%$_b$
n	1,525	337	*n* 1,525	335
Cramer's V	0.041		*Cramer's V* 0.075	
p	0.074		*p* 0.001	

Winter 2020 (SCSAT20)	Currently reduce your social contacts	
	Non-poor	Poor
Yes	94.9%$_a$	92.6%$_a$
No	5.1%$_a$	7.4%$_a$
n	1,521	337
Cramer's V	0.040	
p	0.086	

Summer 2021 (SCSS21)	Number of times tested for COVID-19	
	Non-poor	Poor
Not at all	6.6%$_a$	12.0%$_b$
Only once	7.6%$_a$	13.5%$_b$
2–5 times	36.2%$_a$	38.7%$_a$
6–10 times	20.0%$_a$	23.4%$_a$
More than 10 times	29.5%$_a$	12.3%$_b$
n	1,522	333
Cramer's V	0.17	
p	<0.001	

The lower-case letters in the tables show the result of the z-test. aa = no significant difference between poor and non-poor; ab = significant difference between categories. We recommend interpreting the z-test only if the respective chi² test in the table is significant (when p <0.05). *Cramer's V* measures the strength of the relationship between variables, n = sample size, SCSS20 = SHARE Corona Survey – summer 2020, SCSAT20 = SHARE Corona Special Austria Survey- winter 2020, SCSS21 = SHARE Corona Survey – summer 2021.

Table 7). Findings revealed that poor and non-poor old internet users differed significantly in use of the internet particularly for the purpose of "managing finances": 58.6% of non-poor users acknowledge using the internet for this purpose while only 49.2% of all income poor users do (*Cramer's* $V = 0.061$, $p = 0.048$). Similarly, the latter group were less likely to acknowledge using the internet "to buy/sell goods or services" (41.9 vs. 53.7%, *Cramer's* $V = 0.077$, $p = 0.014$). Although no significant differences were found, it is interesting to note that only about 30% of users report using the Internet for health-related issues, which, in light of the pandemic, seems quite low. In addition, all older respondents (see *n* in Table 7) were asked whether they

TABLE 5 Reported health.

Subjective health before the outbreak (SCSS20)				Subjective health in summer 2021 (SCSS21)			
	Non-poor	Poor	Total		Non-poor	Poor	Total
Excellent/very good	35.1%$_a$	20.8%$_b$	32.5%	*Excellent/very good*	31.9%$_a$	22.0%$_b$	30.1%
Good	42.2%$_a$	43.3%$_a$	42.4%	*Good*	38.4%$_a$	37.1%$_a$	38.1%
Fair/poor	22.7%$_a$	35.9%$_b$	25.1%	*Fair/poor*	29.8%$_a$	40.9%$_b$	31.8%
n	1,525	337	1,862	*n*	1,525	337	1,862
Cramer's V		0.141		*Cramer's V*		0.104	
p		<0.001		*p*		<0.001	

The lower-case letters in the tables show the result of the z-test. aa = no significant difference between poor and non-poor; ab = significant difference between categories. We recommend interpreting the z-test only if the respective chi² test in the table is significant (when $p < 0.05$). *Cramer's V* measures the strength of the relationship between variables, *n* =sample size, SCSS20 = SHARE Corona Survey – summer 2020, SCSS21 = SHARE Corona Survey – summer 2021.

TABLE 6 Social support.

Help received from own children (SCSSS21)			Help received from other relatives (SCSSS21)		
	Non-poor	Poor		Non-poor	Poor
Yes	39.4%$_a$	49.4%$_b$	*Yes*	7.7%$_a$	14.9%$_b$
No	60.6%$_a$	50.6%$_b$	*No*	92.3%$_a$	85.1%$_b$
n	1,399	310	*n*	1,453	322
Cramer's V	0.078		*Cramer's V*	0.097	
p	0.001		*p*	<0.001	

Help received from neighbors/friends/colleagues (SCSSS21)		
	Non-poor	Poor
Yes	14.2%$_a$	16.8%$_a$
No	85.8%$_a$	83.2%$_a$
n	1,494	333
Cramer's V	0.029	
p	0.221	

The lower-case letters in the tables show the result of the z-test. aa = no significant difference between poor and non-poor; ab = significant difference between categories. We recommend interpreting the z-test only if the respective chi² test in the table is significant (when $p < 0.05$). *Cramer's V* measures the strength of the relationship between variables, *n* = sample size, SCSS21 = SHARE Corona Survey – summer 2021.

used telemedical services during the pandemic. Telemedical care was used sparsely in the sample - 8% of all participants stated that they had used remote medical services at least once during the pandemic. A comparison between both groups yielded no significant result.

Discussion

The results show that there are no significant or marginal differences in perception of and experience with the coronavirus between older people below and above the poverty threshold. A possible explanation could be that the topic of COVID-19 was strongly represented in the Austrian media with older people, especially at the beginning, being generally addressed as a risk group. This is likely to have influenced the perceptions of the respondents independent of economic status. Looking at experience with the virus, it is noteworthy that positive testing (evidenced COVID-19 infections) was found not to differ between the two groups indicating similar familiarity with the virus. This result however, does not inform on possible differences in mortality or severity of disease, which has been shown to differ between the poor and non-poor in other studies (45–47). Additionally, it must be kept in mind that older people living in poverty reported having undergone significantly less COVID-19 testing up until summer 2021. It is therefore quite possible that some respondents had experienced an undetected infection (without or with mild symptoms). All in all, the result of the different test frequencies provides food for thought: even though Austria has established a generous (and largely free)

TABLE 7 ICT use.

	Usage of internet since the outbreak (SCSS21)	
	Non-poor	Poor
Yes	59.8%$_a$	37.2%$_b$
No	40.2%$_a$	62.8%$_b$
n	1,525	336
Cramer's V	0.175	
p	<0.001	

	Usage of internet in order to find information on health-related issues (SCSS21)		Usage of internet in order to gain information about government services (SCSS21)	
	Non-poor	Poor	Non-poor	Poor
Yes	69.3%$_a$	72.0%$_a$	39.1%$_a$	31.5%$_a$
No	30.7%$_a$	28.0%$_a$	60.9%$_a$	68.5%$_a$
n	912	125	908	124
Cramer's V	0.019		0.051	
p	0.538		0.1	

	Usage of internet in order to manage finances (SCSS21)		Usage of internet in order to buy/sell goods/services (SCSS21)	
	Non-poor	Poor	Non-poor	Poor
Yes	58.6%$_a$	49.2%$_b$	53.7%$_a$	41.9%$_b$
No	41.4%$_a$	50.8%$_b$	46.3%$_a$	58.1%$_b$
n	912	124	912	124
Cramer's V	0.061		0.077	
p	0.048		0.014	

	Remote medical consultation (SCSS21)	
	Non-poor	Poor
Yes	7.9%$_a$	6.3%$_a$
No	92.1%$_a$	93.8%$_a$
n	1,525	336
Cramer's V	0.024	
p	0.31	

The lower-case letters in the tables show the result of the z-test. aa = no significant difference between poor and non-poor; ab = significant difference between categories. We recommend interpreting the z-test only if the respective chi² test in the table is significant (when $p < 0.05$). *Cramer's V* measures the strength of the relationship between variables, *n* = sample size, SCSS21 = SHARE Corona Survey – summer 2021.

testing programme, persons living in poverty seem to have been less attainable and or persuadable for this effort. This may be an artifact carried over from the early days of the pandemic when testing was more difficult to access and (often) costly (75, 77). However more research is needed to determine whether the differences are due to continuing barriers to access for older people in poverty. Results regarding compliance show that most of older population strictly adhered to the mitigation measures set forth to decrease viral spread with no differences between older persons of higher or lower social status. With respect to the use of hand sanitizer or disinfectant minor significant differences could be seen with poor persons reporting lower adherence to this mitigation measure. A probable explanation for this difference could be the disparate financial means of the groups: persons living below the poverty threshold may not be able to afford sanitizer or disinfectant products.

Examining health in the pandemic, we see that older people in poverty show a less favorable state of health (55, 56). This is

evident in the pre-existing differences on subjective health which also extend into the pandemic. Although the effect size decreased from 0.141 to 0.104, the difference in share of persons classed in the lowest category (fair/poor health) when comparing poor to non-poor persons remained largely unchanged (before outbreak 13.2% points difference vs. 11.1% points difference in summer 2021). A deterioration of subjective health has nevertheless been apparent in the pandemic (78). Although age effects are likely to play a role here, pandemic effects cannot be ignored, which have been shown in previous studies (79–81). Considering mental health indicators, only minor (albeit significant) results emerge with poorer persons exhibiting higher likelihood to report symptoms of depression. No significant differences were found between groups in the limitations to health services of older people in Austria. In other words, cancellations and refusals of appointments were independent of the older person's financial background. This sets Austria apart from other countries in Europe, where the use of the health care system was shown to be more dependent on socioeconomic inequalities (60, 62). This is probably due to the fact that the health care system in Austria remains relatively egalitarian: according to official figures, 99.9% of the Austrian resident population is covered by health insurance (82).

Another positive aspect to note is that older people in Austria were able to stay in touch with their children, grandchildren or friends and neighbors during the pandemic, regardless of income poverty. This may be somewhat surprising in the case of electronic contact, when considering the ongoing costs of use. However, compared to many other European countries, the cost of mobile telephony in Austria is relatively low and usually comes with minute credit[2] which may have helped poorer individuals stay in touch with their social network. However, older people below the at-risk-of-poverty threshold were significantly more likely to depend on social support to obtain necessities since outbreak, this finding is consistent with previous findings on low income populations (31, 83). Older people reported primarily relying on their children during the pandemic, this is consistent with findings of as studies conducted prior to the pandemic. In addition, the aged poor were significantly more likely to be helped by other relatives, whereas this was not the case with friends. Interestingly, the support of friends plays a considerable role at 15%. All in all, it can be said that the pandemic with its mitigation measures meant that a not unremarkable proportion of older people were dependent on external support. The question must be asked whether the lost autonomy can be regained, especially since a definite end to the pandemic is not foreseeable at this time. An improvement was achieved with the roll out of the vaccination however, which lead to a significant reduction in severe courses of illness and hospital admissions. Most importantly, these results show how important social support is for older people below the poverty line (31, 34), as low financial means limit alternative actions (be it ordering goods or using a car when public transport appears unsafe due to the pandemic). Further analyses are necessary to examine the ways older persons without social support coped with the challenges posed by the pandemic.

The results regarding ICT use continue the pre-pandemic trends (84) showing that internet use among older and poor people significantly lags behind the non-poor older persons also in the time of the pandemic. Although the pandemic must be seen as a strong driver of change, limited financial resources are likely to continue preventing increased ICT utilization (84, 85). Another possibility is that older people living in poverty have not yet recognized the benefits of ICT use, although it must be pointed out that financial resources also counteract simple trial and error. This is underlined by the finding that the few poor respondents who report using the internet during the pandemic use it in much the same way as the non-poor, except for managing finances and online shopping, which seems logical. In summary, the results should draw attention to the importance of continuing to study ICT use among older people with low income or below the poverty line as a lag in these groups continues to exist. We must therefore ask how ICT can be brought closer to these vulnerable groups as the risk of digital exclusion is not only a possibility but a reality in many of their members.

Conclusion

Overall, the analysis of the life situation of older people below the poverty threshold in Austria presents both light and shadows. In some areas, older people in poverty were able to keep pace with non-poor people during the pandemic, such as in the upkeep of social contact and access to the health care system. It should also be emphasized that older people were very compliant with the majority of mitigation measures. However, findings on vaccination willingness paint a concerning picture with older people below the poverty line being more likely to refuse vaccination despite, as seen in some cases higher health risks due to poorer general health (86). Although many older people had chosen to become vaccinated by summer 2021, continuing deficits were noted among the poor group. As a recent study shows, differences in Austria along financial resources persist even after controlling for education and other factors (53). A mix of factors is probably responsible for this: although vaccinations are free of charge in Austria, they are and have been accessible to varying degrees (e.g., distance to the nearest vaccination center, etc.). From an economic perspective, these varying accessibilities are also associated with varying costs (e.g., travel costs) and may have disadvantaged older people in poverty. In addition, willingness to vaccinate is influenced, for

2 Contracts with 1,000 free minutes and several GB of data volume per month are available for 10 euros or even less in Austria.

example, by trust in government or proneness to conspiracy theories. Further work is needed to examine how poorer people (and thus often groups with lower education) can be more appropriately addressed and motivated for health measures. Furthermore, central differences between poor and non-poor older persons were evident in the need for social support and ICT use. In both areas, the limited financial resources - which on the one hand necessitate support and on the other hand limit ICT use - are relevant factors.

Finally, some limitations of the study must be acknowledged, the most prominent being that the description of the life situation of the older income poor during the pandemic only included particular variables and therefore cannot be seen as a thorough description of said life situation. Variables were selected according to previous scientific findings as well as data availability. Furthermore, information used for analyses were collected in three sperate surveys (aka three timepoints), limiting generalizability across the span of the pandemic. As the surveys included different variables at different timepoints, no longitudinal analyses could be calculated. Whenever possible (inclusion of the same variable at two timepoints into the survey), change coefficients were calculated to inform on temporal differences (see vaccination willingness). Additionally, this study forwent multivariate analyses overall opting to describe the life situation of the sampled persons as well as comparing poor vs. non-poor individuals in a rich country such as Austria. Against this background, it must also be pointed out that a causal direction between the tested variables and the group membership (poor/non-poor) cannot be assumed apart from logical and theoretical considerations. For example, poor health may have led to poverty and poverty may have led to poor health - studies point to both phenomena or an interaction. For the present study, however, the relevant result is whether there are differences between the groups.

The aim of this study was to give first insights into a sparsely studied field in order to incite interest and possibly initiate further research into better understanding the living situation of a group that is, at least partially, considered vulnerable, during the pandemic and beyond. Study results showed, that while vulnerability of income poor older persons can be seen in a certain share, particularly in some areas, not every poor person was affected by precarisation during the pandemic with many people having learned to cope with limited resources and overcoming crises. However, this should not distract us from continuing to address the issue of old age poverty and to intervene in a socio-politically supportive manner.

Data availability statement

Publicly available datasets were analyzed in this study. This paper uses data from SHARE Waves 8 and 9 (https://doi.org/10.6103/share.w8.800, https://doi.org/10.6103/share.w8ca.800, and https://doi.org/10.6103/share.w9ca.800), see Börsch-Supan et al. (70) for methodological details.

Author contributions

LR was the primary author of this manuscript. Analysis and writing were done in collaboration with TH. 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.2022.972076/full#supplementary-material

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EDITED BY
Echu Liu,
Saint Louis University, United States

REVIEWED BY
Joana R. Zózimo,
Pordata, FFMS; SOCIUS/ISEG, Portugal
Cheng-Chia Chen,
University of Illinois at Springfield, United States
Kathleen Gillespie,
Saint Louis University, United States

*CORRESPONDENCE
Tino Plümecke
tino.pluemecke@soziologie.uni-freiburg.de

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Differences in mortality in Switzerland by citizenship during the first and second COVID-19 waves: Analysis of death statistics

Tino Plümecke[1,2]*, Heiner Mikosch[3], Steffen Mohrenberg[4], Linda Supik[5], Isabelle Bartram[1], Nils Ellebrecht[1], Andrea zur Nieden[1], Laura Schnieder[1], Hannah Schönberger[1], Charlotte Schulze-Marmeling[1] and Andreas Gutzeit[2]

[1]Independent Research Group SoSciBio, Institute of Sociology, University of Freiburg, Freiburg, Germany, [2]Department of Health Sciences and Medicine, University of Lucerne, Lucerne, Switzerland, [3]KOF Swiss Economic Institute, ETH Zürich, Zürich, Switzerland, [4]Demo SCOPE AG, Adligenswil, Switzerland, [5]Otto Suhr Institute of Political Science, Free University of Berlin, Berlin, Germany

Background: Early in the COVID-19 pandemic, it became apparent that members of marginalized populations and immigrants were also at risk of being hospitalized and dying more frequently from COVID-19. To examine how the pandemic affected underserved and marginalized populations, we analyzed data on changes in the number of deaths among people with and without Swiss citizenship during the first and second SARS-CoV-2 waves.

Method: We analyzed the annual number of deaths from the Swiss Federal Statistical Office from 2015 to 2020, and weekly data from January 2020 to May 2021 on deaths of permanent residents with and without Swiss citizenship, and we differentiated the data through subdivision into age groups.

Results: People without Swiss citizenship show a higher increase in the number of deaths in 2020 than those who were Swiss citizens. The increase in deaths compared to the previous year was almost twice as high for people without Swiss citizenship (21.8%) as for those with it (11.4%). The breakdown by age group indicates that among people between the ages of 64 and 75, those without Swiss citizenship exhibited an increase in mortality (21.6%) that was four times higher than that for people with Swiss citizenship (4.7%).

Conclusion: This study confirms that a highly specialized health care system, as is found in Switzerland, does not sufficiently guarantee that all parts of the population will be equally protected in a health crisis such as COVID-19.

KEYWORDS

COVID-19, migration, Switzerland, death rates, vulnerable groups, age groups

Introduction

COVID-19 has caused a sizeable global outbreak and a fundamental public health issue but the pandemic did not affect everyone to the same extent. Early on, it became apparent in many studies that various socioeconomic factors cause people to be affected very differently (1–8).

A recent systematic review of 52 studies found moderate to solid evidence that in the US, especially African American/Black and Hispanic populations experience a disproportionate burden of SARS-CoV-2 infections and COVID-19-related mortality (9). However, analyses in the United States always face the problem that the health care system is considered particularly expensive and inefficient and that, unlike in most European countries, there is no guaranteed care for the entire population (10).

Switzerland is considered to have one of the best health care systems in the world, which reaches the entire population in essentially the same manner and scope (11). A major study has shown that Switzerland ranks among the top three healthcare systems in the world regarding access to healthcare and successful treatment of diseases (12). The life expectancy in Switzerland (82.8 years) is the highest in Europe after Iceland, and healthy life expectancy is several years above the EU average (11).

Despite this good health care system, it is difficult in Switzerland to uncover differences in the impact of COVID-19 on marginalized populations and to compare them to data from the United States or other countries. This is because data on hospitalized patients' ethnic or racial identity or immigrant status are not recorded regularly in Switzerland. However, in Switzerland death data can be linked to citizenship data, allowing a subdivision into people with and without Swiss passports. People without Swiss citizenship make up about 26% of the permanent resident population in Switzerland (27% of men and 24% of women), with Italy, Germany, Portugal, France, Kosovo, Spain, and Turkey as the main countries of origin. They include immigrants and—due to high naturalization barriers—the children and grandchildren of immigrants who are born in Switzerland.

If one considers only the effectiveness of the health care system, the risk of dying from COVID-19 in Switzerland could be expected to be better managed than in countries without guaranteed access to health care services. Furthermore, differences between various segments of the population in infection rates, hospitalization, and mortality should be small. To address how the pandemic affects the two population segments of people with and without Swiss citizenship, we compared the increase in the number of deaths in the first year of the pandemic. With the data provided by the death statistics, only limited conclusions can be drawn about the effects of social inequality and discrimination on health variables. Nevertheless, the differences in the number of deaths make it possible to spotlight one area of concern.

Methods

We analyzed the death statistics of people with and without Swiss citizenship provided by the Swiss Federal Statistical Office. We used weekly deaths from January 2020 to May 2021 (the first two infection waves where general vaccination was not yet available) as well as annual death numbers from 2015 to 2020 (1969–2020 in the Supplementary material), disaggregated by age groups and citizenship status. The number of deaths without Swiss citizenship is calculated as the difference between the total number of deaths and the number of deaths with Swiss citizenship. Hence, the deaths among those without Swiss citizenship also include persons who died without any citizenship (stateless persons) and deaths with status "unknown" regarding their citizenship. Swiss authorities record data such as citizenship for all residents of Switzerland who have a residence title based on the Ordinance on Civil Status of the Federal Council (*Zivilstandsverordnung*). In the event of a death, these data are checked by the authorities, which makes it practically impossible—according to the Swiss Federal Statistical Office—for a person with Swiss citizenship to be listed in the official death statistics with the citizenship status "unknown." In 2019 and 2020, only one deceased person was "stateless," and 27 (2019) and 73 (2020) deaths were recorded as "unknown" regarding their citizenship status.

In this article, we first analyze the total number of deaths (13) in a year-to-year comparison (see also Supplementary Figure 1) as well as weekly data from 2020 and the first weeks of 2021 relative to the death data in 2019. Second, we compare the increase in mortality (deaths per 100,000 persons) for all deaths in 2020 and for the age groups for both segments of the

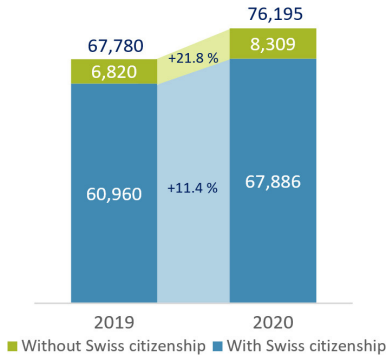

FIGURE 1
Total number of deaths in Switzerland in 2019 and 2020. Data source: Swiss Federal Statistical Office (13).

population (14). This separate mortality calculation is necessary, since in Switzerland demographic changes are mainly caused by younger people added through births and immigration, while it is mainly older people who die from COVID-19. In order to compare the increase in mortality in different age groups, we show the difference between the measured value for 2020 relative to the mortality that would have been expected for 2020 based on the extrapolation of a citizenship and age group-specific linear trend (using linear regression, the confidence level was set at 95%). We consider that a linear trend based on the last 5 years describes relatively well the development of the observed data of the number of deaths for most age groups, both with and without Swiss citizenship. Therefore, we believe that a linear trend can also provide a realistic expected value for 2020 and offers an advantage over the repeatedly used method of setting the expected mortality for a year to the average mortality of the previous 5 years. In particular, the method we use accounts for the group-specific trends in mortality over time, which is especially relevant for age groups without Swiss citizenship, as can be inferred from Supplementary Figure 1.

Results

Increase in the number of deaths in 2020

In 2020, the overall number of deaths in Switzerland increased by 12.4% compared to the previous year. The increase in deaths in the first year of the COVID-19 pandemic is thus the highest annual increase since 1918 and more than double the highest annual growth measured in the previous 10 years (15). Of course, the number of deaths varies yearly, mainly due to severe influenza epidemics or heat waves during the summer. Nevertheless, the number of 8,415 additional deaths in 2020 compared to the previous year is close to the 9,294 COVID-19-related deaths documented by the Federal Statistical Office (16).

Figure 1 shows the differences in the increase in the number of deaths among people with Swiss and without Swiss citizenship. In 2020, the increase in the total number of deaths compared to the previous year was almost twice as high for people without Swiss citizenship (21.8%) as for those who were Swiss citizens (11.4%). It should be noted that the population with Swiss citizenship grew by 0.45% compared to 1.6% for people without. However, a correction to the population growth should be made with caution (see material and methods section).

It is essential to note that among people living in Switzerland without Swiss citizenship, the proportion of elderly people is lower than among people with Swiss citizenship. For example, people aged 80 and older account for 6.4% of people with a Swiss passport, while the proportion of those without Swiss citizenship among those 80 or older is only 2.1% (17). This means that one should suppose that during the pandemic—under otherwise identical conditions—the increase in deaths among persons with Swiss citizenship would exceed that among persons without Swiss citizenship. Our data analysis, by contrast, shows the opposite.

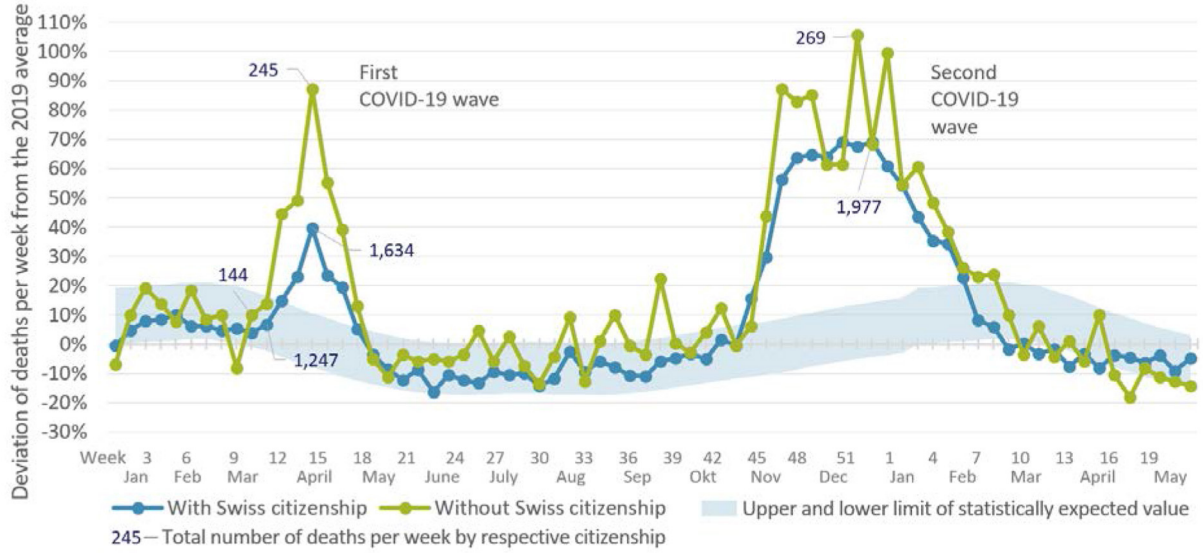

FIGURE 2
Changes in weekly deaths in Switzerland from 2020 to May 2021 relative to the average number of deaths per week in the previous year (1,169 people with Swiss citizenship and 131 people without Swiss citizenship). The light blue band represents the number of deaths expected within the framework of random fluctuations, based on the development of the case numbers of all those who died in Switzerland in the previous 10 years. Source: Unpublished data from the Swiss Federal Statistical Office.

Differences during waves of COVID-19

Figure 2 compares the weekly data on deaths in the two population segments during the first and second infection waves. The level differences are plotted based on the ratio to the respective number of deaths in 2019. The number of deaths of people without Swiss citizenship showed a greater increase in both waves than for those with Swiss citizenship.

At the peaks of both waves, about twice as many people without Swiss citizenship died than would have been expected based on the data before the COVID-19 pandemic (first wave: week 14, 245 deaths; second wave: week 52, 269 deaths). In addition, the number of people who died without Swiss citizenship increased in the first wave even before the increase in deaths in the total population.

Different mortalities across age groups

Further differences in the increase become apparent in Figure 3, where we differentiate by age group. The figure shows, for each population segment, the percentage increase in mortality in 2020 relative to the mortality that would have been expected for 2020 based on the extrapolation of a linear trend over the years 2015–2019 (see Supplementary material for more details). The upper bound of the confidence interval for each group is shown in the small bars as the percent change in the distribution relative to the mean expected number of deaths for 2020. As can be seen from the figure, this percentage change is positive for all considered groups, i.e., the mortality in the year 2020 shows a greater increase than expected in all groups. For persons without Swiss citizenship, however, the increase is much more substantial than for those with Swiss citizenship (+17.5 vs. +12.3%).

When distinguishing between the three age groups of those over 64, further differences between persons with and without Swiss citizenship become visible. For example, the actual number of deaths in 2020 in the age group of 65–74 without Swiss citizenship is significantly higher than the expected mortality for the year 2020 and more than four times higher than for persons with Swiss citizenship (+21.6 vs. +4.7%). This is noteworthy because, among persons with Swiss citizenship, an increase was observed particularly in the age group of 75–84 years old and even more strongly in the age group of 85 years and older. Not presented are the years from 0 to 44, since they are not regarded as highly affected by increased mortality associated with COVID-19 (19). In our analysis, these age groups (0–44) also do not differ significantly in mortality. In addition, because of the small number of deaths in these age groups, the results that can be obtained have only limited statistical validity. These difficulties with small death numbers are still visible in the graph for the age group of 45–64. This group's annual number of deaths is comparatively low, while the variations are relatively high. Nevertheless, there was an increase of mortality in both groups in 2020 compared to the mortality expected in the same year.

Discussion

This analysis of the death statistics during the first two waves of the COVID-19 pandemic revealed a substantial increase

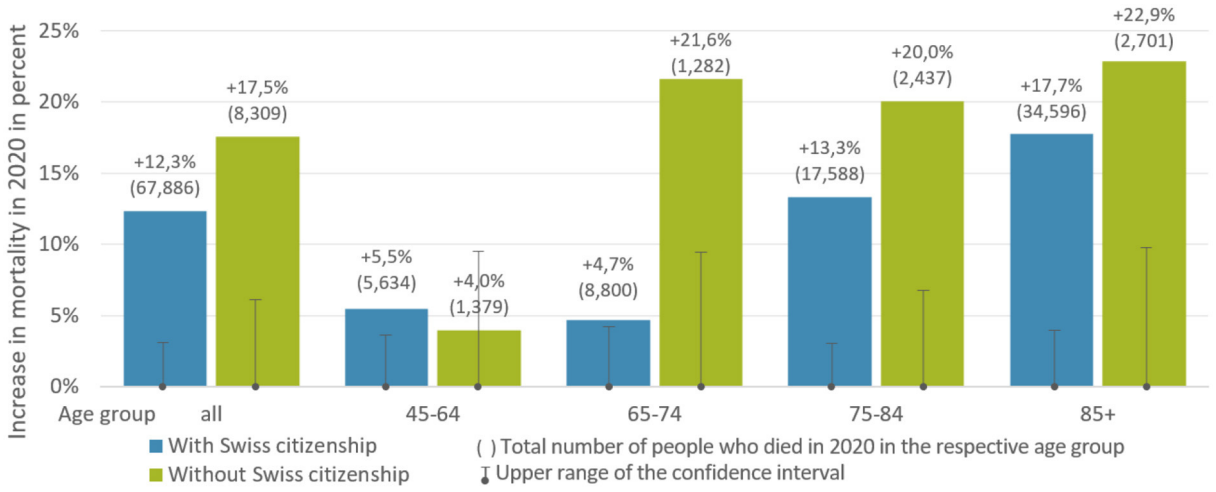

FIGURE 3
Citizenship and age group-specific increase in mortality in 2020 relative to the mortality expected for 2020 based on the extrapolation of a respective group-specific linear trend over the years 2015–2019. Data source: Death statistics of the Swiss Federal Statistical Office (18).

in the number of deaths among people with and without Swiss citizenship in Switzerland. Among people with Swiss citizenship, an increase in deaths of 11.4% over the year before the pandemic was recorded, whereas the proportion of deaths among people without Swiss citizenship increased by 21.8% in the same period. Further differentiation—by weekly data and by age groups—shows that the increased number of deaths among people without Swiss citizenship started 1 week before that of people with Swiss citizenship and shows a much larger increase compared to the year before. In addition, the comparison of the mortality of age groups shows a particular vulnerability of people without Swiss citizenship in early retirement age (65–74). However, our findings from the analysis of the death statistics of people with and without Swiss citizenship should not be understood as limited to these segments of the population. Instead, they point to a broader area of concern.

Numerous studies worldwide have shown an increased risk for members of marginalized and underserved communities and immigrants dying from COVID-19 compared to the majority population. This is usually interpreted as resulting from inadequate medical care in the respective health systems, a generally high level of inequality in society that also leads to differing comorbidities, and differences in the level of trust in the medical profession and the health sector in general (9, 20, 21). The question that arises is whether these reasons are also the cause of the differences in mortality between people with and without Swiss citizenship presented in this study.

The Swiss healthcare system is considered to be one of the best healthcare systems in the world, with a high degree of specialization and low-threshold access to health care for the entire population (12). It is necessary to mention that the cost of this effort is relatively high. In 2019, Switzerland invested 11.3% of gross domestic product (GDP) in healthcare spending as a percentage of national income, whereas the average of all OECD states was nearly 9% in the same year (22). Despite the high quality of the health care infrastructure, our analyses show that the COVID-19 pandemic affected people without Swiss citizenship substantially more.

Based on international research on health inequities, differences in the increases in deaths associated with citizenship can be expected to correlate with socioeconomic disparities (23, 24). Income and wealth inequalities, household crowding, occupations with direct customer contact or in labor-intensive or physically demanding areas, and reliance on public transport may all increase the risk of infection (25, 26). Socioeconomic status also correlates with a higher risk for a wide range of diseases, such as hypertension, hyperlipidemia, brain ischemia, alcoholism, nicotine addiction, and obesity (27) that are also associated with severe disease progression in COVID-19 infection. In addition, economic segregation and experiences of discrimination can significantly affect health status and disease risks (28–30).

The measured disparity in the effect of COVID-19 on different segments of the population in Switzerland can be attributed to comparatively high inequality in income, besides the factors just mentioned. Mortality from COVID-19 is closely related to income inequality, for example, as quantified in the Gini coefficient (31, 32). When considering economic equality, Switzerland performs relatively poorly compared to other European countries. The prevailing paradigm that highly specialized medicine and high total spending lead to better care for the entire population must be questioned in light of the data presented here. Social equity may be more relevant than the degree of specialization and overall health care spending (33). This means that in addition to classic risk factors, social determinants should be considered as the more relevant factors for improving and maintaining health (34). We advocate for closer cooperation between public health and prevention efforts, in addition to a good health care infrastructure, as the most vulnerable parts of society will again be at high risk of insufficient protection and support during future health crises.

Limitations

The health data available in Switzerland to date do not adequately reflect the impact of social inequality and structural disadvantages, with the consequence that health inequity and support needs may be difficult to identify. It should be noted that it is not the possession or non-possession of citizenship that causes the differences in death rates. It is not migrants *per se* who die at a higher rate; what is significant here is that social and health inequalities have different effects on different segments of the population.

To determine health inequity, the differentiation between people with or without Swiss citizenship can only serve as an imprecise proxy for identifying severe mortality differences in underserved or marginalized populations. It is also important to note that we cannot use the relatively crude category of citizenship to represent diversity within individual population groups. This is because people with a migration history who hold a Swiss passport yet may be particularly vulnerable are not included in the category of people without Swiss citizenship, while foreign professionals and managers, for example, are included, even though most of them do not face increased vulnerability. In the future, it would be useful to look at how socioeconomic differences affect mortality. Unfortunately, this data is not systematically recorded in death statistics in Switzerland.

In addition, only data on all deaths, that is, without differentiating causes of death, are available for Switzerland. Therefore, processes unrelated to the COVID-19 pandemic but affecting different segments of the population differently could also play a role. The Swiss Federal Office of Public Health (FOPH) has made an additional record of COVID-19-related

deaths that also asks about the "nationality" of those who died. However, in 51% of the cases, no information was given on nationality. A valid analysis is therefore not possible with these incomplete data.

Additional possible limitations exist in our choice of the prediction method for the expected number of deaths in the respective age groups and the possession and non-possession of Swiss citizenship. The 5-year period chosen for the trend calculation seemed to us to be the most reasonable based on the developments since 1969 (see Supplementary material). Since the differences between predicted and observed values were highly significant, the choice of a slightly different period (e.g., 3 or 7 years) would also not produce serious deviations in the results.

Biases in the analysis are also to be expected due to the different age structures of the population segments with or without Swiss citizenship. The healthy migrant effect can also lead to a potential distortion. However, both of these factors are likely to result in a lower number of deaths among persons without Swiss citizenship, and thus to have reduced rather than increased the differences in death rates presented here.

Conclusion

Switzerland is considered to have one of the highest quality healthcare systems in the world, providing a broad access to health care for the whole population. Nonetheless, in the first two COVID-19 waves, there were significant differences in the death rates of people with or without Swiss citizenship. In addition to the known risk factors of age and preexisting conditions, further vulnerabilities are also associated with an increased risk and indicate a corresponding need for social protection and support. To reduce health risks and increased mortality in the future, socioeconomic risks and social equity should be given much greater consideration than they are now.

Data availability statement

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

Author contributions

Material preparation, data collection, and analysis were performed by TP, LS, SM, and HM. Those responsible for the first draft of the manuscript and editing the manuscript were TP and AG. The data analysis and presentation were conducted by TP, SM, HM, HS, NE, and CS-M. All authors contributed to the study conception and design, commented multiple times on previous manuscript versions, read, and approved the submitted version.

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Conflict of interest

Author SM was employed by Demo SCOPE AG.

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.992122/full#supplementary-material

SUPPLEMENTARY FIGURE 1
Observed annual number of deaths from 1969 to 2020 broken down by citizenship status and age groups (1969–2020 in black, blue dots for 2020). For each of the subpopulations, we calculated a linear trend based on the annual numbers of deaths from 2015 to 2019 (red lines) and, by extrapolating this trend 1 year into future, a mean expected

number of deaths for 2020 (red dots) together with a probability range (vertical red lines). For the calculation of the probability range for each subpopulation, we assume that the number of deaths of each year *t* (e.g., the year 2020) follows a Poisson distribution, with the rate parameter being equal to the respective mean expected death number for year *t*. The lower bound and the upper bound of the probability range are the 2.5th percentile and the 97.5th percentile of the Poisson distribution, respectively. It should be noted that due to the very different ranges of observed y-values across the subfigures, different scaling and a shortening of the y-axes was necessary.

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EDITED BY
Echu Liu,
Saint Louis University, United States

REVIEWED BY
Lanlan Chu,
St. Catherine University, United States
Hsin-Ling Hsieh,
Northern Michigan University,
United States

*CORRESPONDENCE
Jessica Y. Islam
jessica.islam@moffitt.org

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Financial hardship and mental health among cancer survivors during the COVID-19 pandemic: An analysis of the US COVID-19 Household Impact Survey

Jessica Y. Islam[1,2]*, Kea Turner[2,3,4], Huda Saeb[5], Margaux Powell[5], Lorraine T. Dean[6,7] and Marlene Camacho-Rivera[8]

[1]Cancer Epidemiology Program, H. Lee Moffitt Cancer Center and Research Institute, Tampa, FL, United States, [2]Department of Oncological Sciences, University of South Florida, Tampa, FL, United States, [3]Health Outcomes and Behavior Department, H. Lee Moffitt Cancer Center and Research Institute, Tampa, FL, United States, [4]Department of Gastrointestinal Oncology, H. Lee Moffitt Cancer Center and Research Institute, Tampa, FL, United States, [5]Morehouse School of Medicine, Atlanta, GA, United States, [6]Department of Epidemiology, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD, United States, [7]Department of Oncology, School of Medicine, Johns Hopkins University, Baltimore, MD, United States, [8]Department of Community Health Sciences, SUNY Downstate Health Sciences University, Brooklyn, NY, United States

Purpose: Our objective was to (1) identify associated characteristics of financial hardship (FH), and (2) evaluate associations of FH with mental health symptoms among cancer survivors during the COVID-19 pandemic.

Methods: Using data from the nationally representative COVID-19 Impact Survey, we defined cancer survivors as those with a self-reported diagnosis of cancer (n = 854,7.6%). We defined FH using the following question: "Based on your current financial situation, how would you pay for an unexpected $400 expense?" Multivariable Poisson regression was used to estimate adjusted prevalence ratios (aPR) with 95% confidence intervals (95%CI) to identify associated characteristics of FH and associations of FH with mental health symptoms among cancer survivors overall and by age (18–59 years/60+ years).

Results: Forty-one percent of cancer survivors reported FH, with 58% in 18–59 and 33% in 60+ year old respondents. Compared to cancer survivors aged 60+ years, those aged 30–44 (aPR:1.74,95% CI:1.35–2.24), and 45–59 years (aPR:1.60,95% CI:1.27–1.99) were more likely to report FH. Compared to non–Hispanic(NH)–White cancer survivors, NH–Black cancer survivors had a 56% higher prevalence of FH (aPR:1.56; 95% CI: 1.23–1.97). Among 60+ years aged cancer survivors, NH–Black (aPR:1.80; 95% CI: 1.32–2.45) and NH–Asian cancer survivors (aPR:10.70,95% CI:5.6–20.7) were more likely to experience FH compared to their NH–White counterparts. FH was associated with feeling anxious (aPR:1.51,95% CI:1.11–2.05), depressed (aPR:1.66,95% CI:1.25–2.22), and hopeless (aPR:1.84,95% CI:1.38–2.44).

Conclusion: Minoritized communities, younger adults, and cancer survivors with low socioeconomic status had a higher burden of FH, which was associated with feelings of anxiety, depression, and hopelessness.

KEYWORDS

cancer survivors, COVID-19, SARS-CoV-2, pandemic, financial hardship, mental health, depression, anxiety

Introduction

In the United States, as of November 2022, the COVID-19 pandemic has resulted in over one million deaths and over 97 million cases of SARS-CoV-2, the infection that leads to COVID-19, since early 2020 (1). The pandemic led to significant changes in everyday life, including behavioral changes to curb the spread of SARS-CoV-2, such as social distancing, wearing of face masks, and quarantining (2–4), particularly among adults with chronic conditions, such as cancer survivors, due to their increased risk of COVID-19 associated morbidity. In addition to these social changes, the US has experienced a significant economic impact, including the highest unemployment rates since World War II (5, 6). Almost half of US adults have reported either they or someone in their household has experienced a loss of employment or experienced a reduction in salary due to the pandemic (7). Cancer patients may be particularly vulnerable to financial hardship during the pandemic from both costs of cancer care and financial strains imposed by the pandemic. In fact, a recent study found that 50% of gynecological cancer patients treated at a hospital in New York City (NY) reported feeling more financial stress since the start of the pandemic (8).

Financial strain or hardship among cancer survivors is of particular concern given the high costs associated with cancer treatment, including survivorship care. Engagement in high quality cancer survivorship care is vital to extending survival, improving quality of life, and surveillance for recurrence detection or progression of diagnosed cancers. One of the major barriers to engagement in survivorship care is cost, specifically lack of reimbursement structures/insurance coverage for survivorship care services (9). Prior research focused on cancer costs associated with active treatment in the US demonstrate that cancer care spending is projected to grow from $183 billion in 2015 to $246 billion by 2030, an increase by over one-third (10). The average monthly out-of-pocket spending of patients undergoing active cancer treatment range from $180 to $2,600 per month in the US (11), and costs continue beyond the active treatment phase (12). In addition to high out-of-pocket spending, cancer survivors are at risk for productivity losses due to employment disruption (13). As a consequence, cancer survivors are at risk for medical debt, bankruptcy, and financial distress (14, 15), with long-term impacts on consumer credit (16). A systematic review illustrated that approximately half of US cancer patients reported experiencing financial distress and psychologic stress during the pre-pandemic period, with 47–49% of survivors reporting some form of financial distress (17). Recent work based on the 2013–2018 National Health Interview Survey (NHIS) demonstrates that cancer survivors frequently report financial worry, which was also associated with psychological distress (18). Financial hardship among cancer survivors may have been exacerbated during the COVID-19 pandemic. The COVID-19 pandemic led to increased healthcare costs [e.g., COVID-related care costs (19)] and additional financial strain (e.g., pandemic-related unemployment, productivity losses, and health insurance coverage disruption) for many US adults (20). Given the extent to which the pandemic affected the US economy, research is needed to better understand how COVID-19 has affected financial hardship among cancer survivors in the US. Research during the pandemic period suggests that cancer survivors may have been disproportionately affected by rising unemployment (20) potentially leading to loss of insurance and income. Additionally, the economic impact of the pandemic on vulnerable populations of cancer survivors, specifically adolescent or young adult cancer survivors (21, 22) and those with low-income (8), has been evaluated in the pandemic period. However, to our knowledge, limited prior research (20) has been conducted nationally among a representative sample of cancer survivors to evaluate financial hardship and the potential impacts on mental health during the pandemic, particularly among older cancer survivors.

To address this gap, this study will evaluate (1) the prevalence and associated characteristics of financial hardship and (2) the association between financial hardship and self-reported mental health symptoms among younger (<60 years) and older (≥60 years) US cancer survivors during the COVID-19 pandemic. Information from this study may inform future policies and interventions to address financial hardships and poor mental health among cancer survivors in the context of the ongoing public health crisis in the US.

Methods

COVID-19 impact survey

Data for these analyses were obtained from the publicly available COVID-19 Household Impact Survey, conducted by the nonpartisan and objective research organization NORC at the University of Chicago (23). The COVID-19 Household Impact Survey provides national and regional statistics about physical health, mental health, economic security, and social dynamics in the US (24). The pooled cross-sectional survey is designed to provide estimates of the US adult (ages 18 and older) household population nationwide and for 18 regional areas including 10 states (CA, CO, FL, LA, MN, MO, MT, NY, OR TX) and 8 Metropolitan Statistical Areas (Atlanta, Baltimore, Birmingham, Chicago, Cleveland, Columbus, Phoenix, Pittsburgh). For these analyses, we pooled cross-sectional national data collected during Week 1 (April 20-26, 2020), Week 2 (May 4-10, 2020), and Week 3 (May 30th–June 8th, 2020), based on data availability. Details regarding the dataset and data collection methods have been previously published (25, 26).

Study population

The COVID-19 Impact Survey was administered through the AmeriSpeak® panel, which is designed to be representative of the US population. The sampling frame covers ∼97% of US households. The sampling strategy includes random selection of US households using area probability and address-based sampling from the NORC National Sample Frame. The sampled households were contacted by US mail, and telephone to allow for multiple modalities for survey participation (e.g., if a participant does not have internet). The surveys are conducted in English and Spanish. In households with more than one adult, only one was selected at random for the sample. The average survey response rate across weeks 1–3 was 21.8%.

Cancer survivors

We defined cancer survivors as those participants with a self-reported cancer diagnosis. Participants were asked the following question: "Has a doctor or other health care provider ever told you that you have any of the following: Diabetes; High blood pressure or hypertension; Heart disease, heart attack or stroke; Asthma; Chronic lung disease or COPD; Bronchitis or emphysema; Allergies; a Mental health condition; Cystic fibrosis; Liver disease or end-stage liver disease; Cancer; a Compromised immune system; or Overweight or obesity." We defined those who selected "Cancer" as a cancer survivor, similar to our previously published work (26).

Primary measures

Our primary measures for this analysis were financial hardship and mental health symptoms. We defined financial hardship using the following question: "Suppose you have an unexpected expense that costs $400. Based on your current financial situation, how would you pay for this expense?" The following options were provided to respondents and they were able to select all that apply: (1) put it on my credit card and pay it off in full at the next statement; (2) put in on my credit card and pay it off over time; (3) use money currently in my checking or savings account or with cash; (4) use money from a bank loan or line of credit; (5) borrow from a friend or family member; (6) use a payday loan, deposit advance or overdraft; (7) sell something; and (8) I would not be able to pay for it right now. Respondents were categorized as experiencing financial hardship if they only chose any of the following options: put it on my credit card and pay if off over time; use money from a bank loan or line of credit; I wouldn't be able to pay for it right now; sell something; use a payday loan, deposit advance or overdraft; borrow from a friend or family member. We used this definition based on prior research conducted by the U.S. Federal Reserve in the general population (27).

Next, to evaluate mental health symptoms, participants were asked: "In the past 7 days, how often have you? (1) Felt nervous anxious or on edge, (2) Felt depressed, (3) Felt lonely, and (4) Felt hopeless about the future." Participants were able to choose from the following list of options for each mental health symptom: (1) Not at all or less than 1 day; (2) 1–2 days, (3) 3–4 days, and (4) 5–7 days. For multivariable analyses stratified by age group, we recategorized self-reported mental health symptoms to either not at all or <1 day or 1–7 days per week due to sample size concerns and to avoid small cell sizes to effectively conduct regression modeling.

Covariates

Prior studies suggest that factors such as household income and education level are associated with financial hardship among cancer survivors (28–31). Therefore, we selected covariates that have demonstrated a prior relationship with financial hardship, including: age (18–59, 60+), gender (male/female), marital status (married/living with a partner, widowed/divorced/separated, never married), race/ethnicity categories [non-Hispanic (NH) White, NH- Black, Hispanic, NH-Asian, NH-Other], education categories (no high school diploma, HS graduate or equivalent, some college, baccalaureate degree or above), household income (<$30,000;$30,000-<$50,000;$50,000-<$75,000; $75,000-<$100,000;≥$100,000), population density (rural, suburban, urban), census region (Northeast, Midwest, South, West), any comorbid chronic conditions, (yes/no),

and insurance type (purchased plan/employer-sponsored /TRICARE/Medicaid/Medicare/Dually-eligible/VA/uninsured). Detailed information regarding employment status was available to delineate the following employment categories: employed in the last 7 days, retired, or not interested in working at this time, or under/unemployed due to COVID-19 or unable to find employment.

Data analyses

Descriptive statistics were summarized, by cancer survivorship status and age categories, in percentages among all respondents with 95% confidence intervals (CIs). We present the study results stratified by age group as prior research conducted in the pre-pandemic period has demonstrated that the prevalence and associated characteristics of financial hardship experienced by cancer survivors vary by age category due to social and behavioral factors (e.g., insurance status, employment status) (17, 32). To identify demographic groups that may be more likely to report financial hardship, we estimated associated characteristics of financial hardship among cancer survivors. We computed prevalence ratios with Poisson regression using robust estimation of standard errors (33–35). Potential variables for inclusion in the model were assessed using available sociodemographic variables and unadjusted Poisson regression analysis. Due to the exploratory nature of this analysis using a predictive framework, a $p < 0.10$ was used as criteria for variable selection in the multivariable Poisson regression model. For multivariable Poisson regression models, adjusted prevalence ratios (aPR), and 95% CIs for each independent variable were calculated.

Next, we used multivariable Poisson regression to assess associations between financial hardship and self-reported mental health symptoms experienced at least 1 day in the last week. We adjusted for survey week, age (when appropriate excluding age-stratified models), sex, race/ethnicity, annual household income, education, insurance status, employment status, and area of residence (urban/rural). To address concerns regarding existing mental health symptoms before the COVID-19 pandemic, we conducted a sensitivity analysis to evaluate mental health symptoms among those without a history of a mental health condition based on self-report. We were able to assess the history of a mental health condition through the following question: "Has a doctor or healthcare provider ever told you that you have any of the following?", which includes a response option for mental health condition. Based on the exploratory nature of this analysis, we did not include an adjustment for multiple comparisons (36, 37). Missing data were minimal (<3% of observations), and we used a complete case approach. All statistical analyses were conducted using Stata IC 15 (StataCorp LLC, College Station, TX). Sampling weights were applied to provide results that were nationally representative of the U.S. adult population. We conducted a sensitivity analysis and repeated our analyses using fixed-effects multivariable logistic regression modeling and have included those results in the Appendix. The analytic sample includes 10,760 adults nationwide.

Results

Table 1 summarizes characteristics of the overall sample and our study population of interest, cancer survivors, stratified by age categories 18–59 years and 60+years. We provide sample characteristics of all adults and cancer survivors overall in Supplementary Table 1. Sixty percent of cancer survivors were over the age of 60 years. Sixty percent of cancer survivors aged 18–59 years were female, whereas 48% of those aged 60+ years were female. Cancer survivors aged 18–59 years and 60+ years were most frequently married or living with a partner (54, 59%), NH-White (70, 76%), at least some college education (64, 63%), and resided in urban areas (71, 64%). One-quarter of cancer survivors 18–59 years were unemployed due to COVID-19 or unable to find employment, and 72% of 60+ cancer survivors were retired or not interested in working at this time. Over one-third of 18–59 cancer survivors had a household income $100,000 or greater. Seventy percent of 60+ cancer survivors had a comorbid cardiometabolic condition. Twenty-one percent of 18–59 cancer survivors had an existing diagnosed mental health condition as compared to 9% among 60+ cancer survivors. Most 18–59 cancer survivors had either employer sponsored health insurance (62%) or Medicaid (33%). Seventy-seven percent of 60+ cancer survivors were Medicare insured. Twenty-one percent of 18–59 cancer survivors reported they would not be able to cover a $400 unexpected expense based on their current financial situation, compared to 10% among 60+ cancer survivors. About half of both 18–59 (49%) and 60+ (54%) cancer survivors reported they would be able to use money currently in their checking or savings account.

Prevalence and associated characteristics of financial hardship among cancer survivors

Overall, forty-two percent of cancer survivors reported financial hardship. By age group, 58% of 18–59 years and 33% of 60+ cancer survivors reported financial hardship. Table 2 summarizes comparisons of prevalence of financial hardship by cancer survivorship status and age group. We also summarize financial hardship prevalence estimates for the overall study sample in Supplementary Table 2. Overall, across age groups certain demographic groups of cancer survivors experienced high (significantly greater than overall prevalence i.e., <58% in 18–59 & <33% in 60+) burden of financial hardship. Among

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TABLE 1 Characteristics of COVID Impact Survey respondents (n = 10,760), a nationally representative survey of the US, stratified by cancer diagnosis (April-June 2020).

	Total (n = 10,760)				Cancer survivors (n = 854)*			
	18–59 years		60+ years		18–59 years		60+ years	
	Col %	95% CI	Col %	95% CI	Col %	95% CI	Col %	95% CI
Sex								
Male	48.5	46.9, 50.2	48.0	45.7,50.2	39.9	32.7,47.6	51.7	46.4,57.0
Female	51.5	49.8, 53.1	52.0	49.8,54.3	60.1	52.4,67.3	48.3	43.0,53.6
Marital status								
Married/living with partner	57.7	56.1, 59.4	56.2	54.0,58.5	53.5	45.6,61.3	58.8	53.6,63.9
Widowed/divorced/separated	11.7	10.7, 12.6	34.5	32.3,36.6	27.6	21.1,35.4	33.1	28.5,38.2
Never married	30.6	29.0, 32.3	9.3	8.1,10.7	18.8	13.0,26.5	8.0	5.6,11.4
Race/ethnicity								
White, NH	57.9	56.2, 59.5	72.0	69.8,74.1	70.4	62.7,77.1	76.4	71.2,80.9
Black, NH	11.6	10.6, 12.6	11.6	10.2,13.3	10.9	6.6,17.6	12.0	8.4,16.9
Hispanic	6.3	5.4, 7.3	1.7	1.2,2.4	11.6	7.3,18.0	5.6	3.6,8.8
Asian, NH	19.3	17.9, 20.8	9.5	8.1,11.1	3.0	1.5, 6.1	0.6	0.1, 4.1
Other, NH	3.6	3.1, 4.1	3.5	2.8,4.4	1.5	0.7, 3.3	3.2	2.2, 4.7
Employment status								
Employed in the last 7 days	61.3	59.7, 62.9	22.0	20.3,23.9	57.7	49.8,65.3	17.2	13.8,21.2
Retired/not interested in working at this time	12.2	11.2, 13.3	68.6	66.5,70.6	17.3	12.4,23.7	71.9	66.9,76.5
Unemployed due to covid-19 or unable to find employment†	26.5	25.0, 28.0	9.3	8.1,10.7	24.9	18.3,33.0	10.9	7.7,15.2
Education								
No HS diploma	10.8	9.5, 12.1	7.0	5.7,8.6	8.3	4.6,14.4	5.4	3.2,8.7
Hs graduate	27.6	26.0, 29.2	29.5	27.4,31.7	27.4	20.3,35.9	31.9	26.8,37.4
Some college	27.5	26.2, 28.7	28.4	26.7,30.1	26.2	20.8,32.5	28.8	24.9,33.1
Baccalaureate or above	34.2	32.8, 35.7	35.2	33.0,37.4	38.1	30.9,45.8	33.9	29.1,39.1
Household income								
<$30,000	26.5	25.0, 28.1	27.4	25.4,29.5	23.5	17.1,31.3	28.8	24.0,34.1
$30,000-<$50,000	17.1	16.0, 18.3	22.5	20.7,24.4	18.5	13.4,25.0	23.4	19.2,28.1
$50,000-<$75,000	19.2	18.0, 20.5	17.1	15.6,18.8	13.3	9.4,18.5	19.0	15.3,23.5
$75,000-<$100,000	13.7	12.7, 14.8	13.1	11.7,14.8	8.1	5.1,12.4	10.9	8.2,14.4
≥$100,000	23.5	22.1, 24.9	19.8	18.1,21.6	36.7	29.4,44.7	17.9	14.5,21.9
Region								
Northeast	17.2	15.9, 18.5	17.9	16.1,19.8	18.9	12.8,26.9	16.3	12.7,20.6
Midwest	20.5	19.3, 21.7	21.5	19.9,23.3	23.7	17.9,30.7	21.7	17.9,26.2
South	37.8	36.2, 39.4	38.0	35.8,40.3	27.5	21.4,34.6	38.9	33.7,44.3
West	24.6	23.2, 26.0	22.5	20.8,24.3	29.9	23.3,37.5	23.1	19.2,27.5
Population density								
Rural	8	7.2, 8.9	11.5	10.1,13.1	7.3	4.7,11.2	16.7	12.5,21.9
Suburban	17.6	16.4, 18.8	21.3	19.6,23.1	21.7	16.2,28.4	19.1	15.4,23.3
Urban	74.4	73.0, 75.8	67.2	65.1,69.2	70.9	63.9,77.1	64.3	58.9,69.3
Comorbid conditions								
Cardiometabolic diseases‡	26.2	24.8, 27.6	65.0	62.9,67.1	41.8	34.3,49.6	70.3	65.4,74.8
Respiratory diseases§	23.3	21.9, 24.7	24.0	22.2,26.0	36.9	29.6,44.8	25.2	21.0,29.9
Overweight/obesity	32.3	30.8, 33.8	35.7	33.6,37.8	47.1	39.4,54.9	38.6	33.5,43.8
Mental health conditions	18.7	17.5, 20.0	7.5	6.4,8.7	21.7	15.8,29.2	8.7	6.1,12.2
Insurance type or health coverage plans								
Purchased plan	12.5	11.4, 13.7	28.3	26.3,30.5	10.4	6.6,16.0	25.6	21.3,30.3

(Continued)

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TABLE 1 (Continued)

	Total ($n = 10,760$)				Cancer survivors ($n = 854$)*			
	18–59 years		60+ years		18–59 years		60+ years	
	Col %	95% CI	Col %	95% CI	Col %	95% CI	Col %	95% CI
Employer-sponsored	58.8	57.2, 60.5	35.4	33.3,37.6	62.1	54.1,69.5	38.5	33.5,43.8
Tricare	4	3.5, 4.7	6.8	5.8,7.9	1.9	1.0,3.8	9.5	6.6,13.5
Medicaid	22	20.7, 23.4	26.9	24.8,29.0	32.5	25.2,40.7	29.0	24.2,34.4
Medicare	5.7	5.0, 6.5	71.7	69.7,73.6	18.7	13.5,25.4	76.5	71.7,80.7
Dually eligible (medicare & medicaid)	4.5	4.0, 5.2	22.3	20.4,24.3	15.4	10.6,21.9	26.0	21.3,31.4
VA	3	2.5, 3.5	8.0	6.9,9.2	2.7	1.3,5.4	12.3	9.1,16.4
Indian health service	1.6	1.2, 2.2	0.2	0.1,0.5	0.7	0.2,2.2	0.1	0.0,0.3
No insurance	11.4	10.3, 12.5	2.6	2.0,3.3	3.8	2.0,7.1	2.5	1.1,5.4
Financial hardship measure								
Suppose that you have an unexpected expense that costs $400. Based on your current financial situation, how would you pay for this expense? If you would use more than one method to cover this expense, please select all that apply								
Put it on my credit card and pay it off in full at the next statement	29.1	27.7, 30.6	46.1	43.9,48.3	19.3	14.0,25.9	50.4	45.1,55.7
Put it on my credit card and pay it off over time	19	17.8, 20.3	17.6	16.0,19.4	20.4	14.9,27.3	16.3	13.1,20.2
Use money currently in my checking or savings account or with cash	48.5	46.9, 50.2	57.0	54.7,59.2	48.8	41.1,56.5	53.7	48.4,59.0
Use money from a bank loan or line of credit	2.9	2.4, 3.4	3.2	2.6,4.1	4.3	2.2,8.2	5.6	3.5,9.0
Borrow from a friend or family member	11.4	10.3, 12.5	4.4	3.5,5.6	14.1	9.0,21.5	2.7	1.7,4.2
Use a payday loan, deposit advance or overdraft	2.2	1.8, 2.8	1.1	0.7,1.5	1.9	0.8,4.7	0.4	0.2,1.2
Sell something	8.4	7.5, 9.4	3.8	3.0,4.8	6.3	3.7,10.4	3.3	1.9,5.7
I would not be able to pay for it right now	17.7	16.4, 19.1	9.9	8.6,11.5	20.6	14.6,28.4	10.2	6.7,15.1

*2.46% of participants either chose: not sure, skipped or refused, when asked about their chronic conditions including cancer.
† Response Options: I was laid-off temporarily or furloughed, I was not at my usual jobs because I was caring for children not in school, I was not at my usual jobs because I was caring for an elderly person, I was not at my usual jobs because I was caring for someone with COVID-19, I was not at my usual jobs because I was recovering from COVID-19 or isolating due to exposure to COVID-19, I was unemployed but looking for work since March 1st, 2020 when COVID-19 began spreading in the US, I was unemployed and began looking for work after March 1, 2020 when COVID-19 began spreading in the US.
‡ Cardiometabolic conditions: diabetes, high blood pressure, heart disease, liver disease or end stage liver disease.
§ Respiratory conditions: Asthma, chronic lung disease or COPD, bronchitis, or emphysema.

18–59 cancer survivors, those who were never married (85%), NH-Black (82%), unemployed due to COVID-19 or unable to find employment (81%), those without a high school diploma (93%) or high school graduates (92%), those with a household income <$30,000 (91%), those living in rural areas (68%), and with an existing mental health condition (76%) had a high prevalence of financial hardship. Cancer survivors aged 18–59 on Medicaid (91%), Medicare (84%), dually insured with Medicaid + Medicare (95%), insured through the Indian Health Service (100%) or uninsured (87%) also had a high burden of financial hardship.

Among cancer survivors aged 60 + years, we observed a similar trend in terms of key demographics with a higher burden of financial hardship. Women (41%), those who are widowed, divorced, or separated (43%), NH-Black (79.2%), NH-Asian (100%), without a high school diploma (76%), with a household income <$30,000 (60%), and living in rural areas (51%) who were 60+ cancer survivors had a high burden of financial hardship. Cancer survivors over 60+ years of age with mental health conditions (48%), Medicaid insured (52%) or uninsured (58%) also had a high burden of financial hardship.

Table 3 summarizes associated characteristics of financial hardship among cancer survivors. In the overall model, compared to cancer survivors aged 60+ years, those aged 30–44 (aPR:1.74, 95% CI:1.35–2.24), and 45–59 years (aPR:1.60, 95% CI:1.27–1.99) were more likely to experience financial hardship. Adult cancer survivors below the age of 60 who were never married (aPR: 1.32; 95% CI: 1.01–1.73) and Medicare insured (aPR: 1.33; 95% CI: 1.04–1.71) or uninsured (aPR: 2.13; 95% CI: 1.23–3.71) were more likely to report

TABLE 2 Prevalence of financial hardship overall and among cancer survivors stratified by age groups among COVID Impact Survey respondents ($n = 10,760$), a nationally representative survey of the US (April-June 2020).

	Total ($n = 10,760$)				Cancer survivors ($n = 854$)*			
	18–59 years old		60+ years		18–59 years old		60+ years	
	Row %	95% CI	Row %	95% CI	Row %	95% CI	Row %	95% CI
Overall prevalence	48.9		32.4		57.6		33.2	
Sex								
Male	44.0	41.6, 46.4	27.5	24.8, 30.5	52.8	41.5, 63.9	25.6	19.9, 32.2
Female	53.4	51.3, 55.6	36.9	33.9, 40.0	60.8	50.6, 70.1	41.4	33.6, 49.6
Marital status								
Married/living with partner	42.3	40.3, 44.4	24.2	21.7, 26.9	44.5	34.9, 54.4	29.2	22.7, 36.7
Widowed/divorced/separated	61.8	57.6, 65.8	43.2	39.4, 47.1	64.5	49.6, 77.0	42.8	34.4, 51.6
Never married	56.3	53.1, 59.4	42.0	35.0, 49.4	84.8	71.6, 92.5	22.8	12.7, 37.4
Race/ethnicity								
White, NH	42.0	40.0, 44.0	25.8	23.6, 28.0	53.2	44.1, 62.1	26.3	21.4, 31.9
Black, NH	67.4	63.3, 71.3	64.6	57.7, 71.0	81.7	57.4, 93.7	79.2	61.7, 90.1
Hispanic	63.9	59.9, 67.8	37.3	29.8, 45.6	62.2	39.4, 80.6	17.4	8.5, 32.4
Asian, NH	31.3	24.3, 39.2	35.6	19.9, 55.2	63.6	28.7, 88.3	100.0	
Other	44.5	37.8, 51.4	42.8	32.3, 53.9	34.4	10.8, 69.5	45.6	28.0, 64.3
Employment status in the past 7 days								
Employed in the last 7 days	40.0	38.0, 42.0	29.4	25.4, 33.8	45.8	36.2, 55.8	28.0	19.7, 38.1
Retired/not interested in working at this time	54.1	49.5, 58.6	30.8	28.3, 33.4	62.7	45.5, 77.1	33.9	28.0, 40.3
Unemployed due to COVID-19 or unable to find employment†	66.6	63.4, 69.6	50.8	43.6, 58.0	81.3	67.0, 90.3	36.8	21.0, 56.1
Education								
No HS diploma	75.9	70.0, 80.9	59.6	48.4, 69.9	93.0	74.2, 98.4	76.0	53.6, 89.7
Hs graduate	60.7	57.1, 64.3	40.4	36.0, 44.9	92.0	82.5, 96.6	41.1	30.7, 52.3
Some college	52.1	49.8, 54.4	34.0	31.0, 37.1	49.2	37.9, 60.6	32.0	25.6, 39.1
Baccalaureate or above	27.8	25.6, 30.0	19.2	16.6, 22.2	30.9	20.6, 43.5	20.0	13.8, 28.3
Household income								
<$30,000	70.3	66.9, 73.4	55.6	51.1, 59.9	91.0	81.9, 95.8	59.6	49.0, 69.4
$30,000-<$50,000	59.4	55.8, 62.9	35.0	30.7, 39.6	61.4	44.7, 75.8	34.1	24.8, 45.0
$50,000-<$75,000	44.0	40.5, 47.6	24.8	20.7, 29.4	50.7	33.8, 67.5	22.5	13.7, 34.8
$75,000-<$100,000	37.3	33.4, 41.4	21.5	16.6, 27.4	39.7	21.8, 60.7	19.1	10.1, 33.3
≥$100,000	27.2	24.2, 30.6	11.2	8.8, 14.3	40.7	27.9, 54.9	9.5	5.1, 17.0
Region								
Northeast	45.3	41.0, 49.6	35.5	30.1, 41.3	63.1	43.4, 79.2	31.0	19.7, 45.3
Midwest	44.8	41.7, 47.9	30.4	26.4, 34.6	56.3	41.5, 70.1	29.9	21.2, 40.3
South	52.7	49.9, 55.4	33.9	30.4, 37.6	56.9	43.2, 69.5	39.2	30.3, 48.7
West	49.0	45.8, 52.2	29.4	25.6, 33.4	55.8	41.9, 68.9	27.8	20.0, 37.2
Population density								
Rural	49.1	43.8, 54.3	38.9	32.3, 45.9	67.5	44.8, 84.1	51.2	35.8, 66.4
Suburban	50.6	47.1, 54.2	25.1	21.4, 29.1	50.0	35.0, 65.0	18.6	11.6, 28.7
Urban	48.4	46.5, 50.4	33.7	31.1, 36.3	58.9	49.5, 67.7	32.9	27.2, 39.0
Comorbid conditions								
Cardiometabolic diseases‡	55.3	52.3, 58.3	36.5	33.8, 39.3	59.8	48.0, 70.5	37.4	31.1, 44.0
Respiratory diseases§	58.0	54.7, 61.2	39.2	34.8, 43.8	69.1	57.0, 79.1	41.7	32.0, 52.1

(Continued)

TABLE 2 (Continued)

	Total ($n = 10,760$)				Cancer survivors ($n = 854$)*			
	18–59 years old		60+ years		18–59 years old		60+ years	
	Row %	95% CI	Row %	95% CI	Row %	95% CI	Row %	95% CI
Overweight/obesity	54.6	51.9, 57.2	37.7	34.1, 41.4	60.9	49.5, 71.2	36.5	28.3, 45.5
Mental health conditions	59.8	56.2, 63.3	46.3	38.6, 54.1	76.3	59.6, 87.5	47.6	30.4, 65.3
Insurance type or health coverage plans								
Purchased plan	52.6	47.6, 57.6	28.5	24.8, 32.5	55.5	33.0, 75.9	26.4	18.5, 36.0
Employer-sponsored	37.0	35.0, 39.1	28.2	24.9, 31.8	45.1	35.8, 54.8	28.4	21.3, 36.7
Tricare	41.8	34.9, 49.0	20.6	15.2, 27.4	37.3	12.6, 70.9	19.9	8.9, 38.6
Medicaid	74.9	72.0, 77.7	51.6	47.0, 56.1	91.4	82.7, 95.9	52.3	41.7, 62.7
Medicare	66.6	59.9, 72.6	31.6	29.1, 34.2	83.9	68.3, 92.7	34.1	28.4, 40.3
Dually eligible (medicare and medicaid)	74.8	68.1, 80.5	50.9	45.9, 55.9	95.2	83.6, 98.7	55.5	44.0, 66.3
VA	39.9	32.0, 48.4	31.3	24.8, 38.6	26.4	7.8, 60.3	30.6	18.4, 46.2
Indian health service	73.9	60.2, 84.1	32.1	9.8, 67.3	100.0		0.0	
No insurance	67.4	62.6, 71.9	44.2	32.0, 57.2	86.6	57.6, 96.8	58.2	21.2, 87.8

*2.46% of participants either chose: not sure, skipped or refused, when asked about their chronic conditions including cancer.

† Response Options: I was laid-off temporarily or furloughed, I was not at my usual jobs because I was caring for children not in school, I was not at my usual jobs because I was caring for an elderly person, I was not at my usual jobs because I was caring for someone with COVID-19, I was not at my usual jobs because I was recovering from COVID-19 or isolating due to exposure to COVID-19, I was unemployed but looking for work since March 1st, 2020 when COVID-19 began spreading in the US, I was unemployed and began looking for work after March 1, 2020 when COVID-19 began spreading in the US.

‡ Cardiometabolic conditions: diabetes, high blood pressure, heart disease, liver disease or end stage liver disease.

§ Respiratory conditions: Asthma, chronic lung disease or COPD, bronchitis, or emphysema.

financial hardship compared to their counterparts. Among older (60+) cancer survivors, women had a 35% higher prevalence of financial hardship compared to men (aPR: 1.35; 95% CI: 1.02–1.78). Racial disparities exist in financial hardship among older cancer survivors: Compared to NH-White cancer survivors, NH-Black (aPR: 1.80; 95% CI: 1.32–2.45) and NH-Asian (aPR: 10.70; 95% CI: 5.55–20.66) had higher prevalenceof financial hardship. Lower income in cancer survivors aged 60+ led to higher prevalence of financial hardship with those earning <$30,000 over three times the prevalence of financial hardship compared to those earning over $100,000 (aPR: 3.63; 95% CI: 1.74–7.57). Like younger cancer survivors, older cancer survivors insured through Medicaid were more likely to experience financial hardship (aPR: 1.45; 95% CI: 1.03–2.06). Higher educational level decreased the prevalence of financial hardship among cancer survivors aged 18–59 and 60+ years. Supplementary Table 3 summarizes the associated characteristics of financial hardship among the general population overall and stratified by age demonstrating similar trends in risk factors, particularly in the 60+ years age group, excluding associations with sex, suggesting that women with cancer may be a particularly vulnerable group to financial hardship. Supplementary Table 4 summarizes estimates using logistic regression and demonstrates similar results to our main findings.

Mental health and financial hardship among cancer survivors

Figure 1 summarizes the prevalence of mental health symptoms at least 1 day a week of financial hardship with mental health symptoms among cancer survivors. Cancer survivors 18–59 years were more likely to report feeling anxious (45 vs. 32%, $p = 0.004$), depressed (54 vs. 31%, $p < 0.001$), lonely (50 vs. 28%, $p < 0.001$), and hopeless about the future (49% vs. 33%, $p = 0.001$). Among cancer survivors without a self-reported diagnosed mental health condition, we observed similar differences across age group. Table 4 summarizes the associations of financial hardship with mental health symptoms overall and stratified by age group. Overall, among cancer patients without a history of mental health conditions, financial hardship was associated with feelings of anxiety (aPR:1.51; 95% CI:1.11–2.05), depression (aPR:1.66; 95%CI:1.25–2.22), and hopelessness about the future (aPR:1.84; 95% CI:1.38–2.44). Specifically, among 18–59 cancer survivors, financial hardship was associated with feelings of depression (aPR: 2.09; 95% CI: 1.45–3.02). And among 60+ cancer survivors, financial hardship was associated with feeling hopeless about the future (aPR: 1.76; 95% CI: 1.19–2.59). Supplementary Table 5 summarizes our estimates using logistic regression and demonstrates the same findings as our main analyses.

TABLE 3 Associated characteristics of financial hardship among cancer survivors in the COVID Impact Survey, a nationally representative survey of US (n = 854) (April–June 2020).

	Overall				18–59 years				60+ years			
	PR	95% CI	aPR	95% CI	PR	95% CI	aPR	95% CI	PR	95% CI	aPR	95% CI
Age					–							
18–29	1.51	0.88–2.59	1.32	0.90–1.95								
30–44	2.24	1.79–2.81	1.74	1.35–2.24								
45–49	1.56	1.22–1.98	1.60	1.27–1.99								
60+	Ref.		Ref.									
Sex												
Male	Ref.		Ref.		Ref.		–		Ref.		Ref.	
Female	1.46	1.18–1.82	1.10	0.89–1.35	1.15	0.88–1.51			1.61	1.19–2.20	1.35	1.02–1.78
Marital status												
Married/Living with partner	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Widowed/divorced/separated	1.45	1.15–1.82	1.16	0.94–1.42	1.45	1.06–1.98	1.14	0.77–1.68	1.47	1.07–2.01	1.28	0.94–1.74
Never married	1.68	1.26–2.24	1.13	0.85–1.50	1.91	1.48–2.46	1.32	1.01–1.73	0.78	0.43–1.42	0.86	0.46–1.60
Race/ethnicity												
White, NH	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Black, NH	1.89	1.21–2.94	1.56	1.23–1.97	1.54	1.16–2.03	1.36	0.90–1.07	3.01	2.30–3.93	1.80	1.32–2.45
Hispanic	0.92	0.44–1.94	0.89	0.64–1.24	1.17	0.79–1.73	1.07	0.77–1.50	0.66	0.33–1.34	0.58	0.27–1.22
Asian, NH	1.23	0.36–4.21	1.81	0.79–4.14	1.19	0.68–2.10	1.29	0.77–2.18	3.80	3.11–4.64	10.70	5.55–20.66
Other, NH	1.37	0.79–2.37	1.29	0.97–1.72	0.65	0.24–1.73	0.59	0.34–1.02	1.73	1.09–2.75	1.16	0.79–1.69
Insurance type*												
Purchased plan	0.70	0.52–0.94	1.05	0.76–1.45	0.95	0.61–1.47	–		0.72	0.49–1.06	1.45	0.94–2.22
Employer–sponsored	0.77	0.62–0.96	1.38	0.98–1.93	0.58	0.45–0.74	1.19	0.76–1.85	0.78	0.56–1.08	–	
Tricare	0.49	0.26–0.94	0.61	0.30.1.29	0.62	0.25–1.54	–		0.58	0.27–1.25	–	
Medicaid	2.19	1.80–2.66	1.61	1.19–2.18	2.15	1.71–2.70	1.48	0.94–2.32	2.14	1.59–2.89	1.45	1.03–2.06
Medicare	0.91	0.73–1.12	–		1.63	1.30–2.03	1.33	1.04–1.71	1.14	0.78–1.66	–	
VA	0.69	0.44–1.08	0.87	0.54–1.39	0.45	0.15–1.32	–		0.89	0.54–1.46	–	
No insurance	1.73	1.20–2.51	1.63	0.99–2.68	1.53	1.19–1.97	2.13	1.23–3.71	1.79	0.88–3.62	–	
Any comorbid conditions	1.53	1.13–2.06	1.09	0.84–1.41	1.24	0.86–1.78	–		1.77	1.16–2.69	1.29	0.81–2.06
Employment status												
Not employed	Ref.		–		Ref.		Ref.		Ref.		–	
Employed/self–employed	0.93	0.74–1.17			0.62	0.48–0.80	0.98	0.75–1.29	0.83	0.57–1.21		

(Continued)

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TABLE 3 (Continued)

	Overall				18–59 years				60+ years			
	PR	95% CI	aPR	95% CI	PR	95% CI	aPR	95% CI	PR	95% CI	aPR	95% CI
Education												
No HS diploma	Ref.		Ref.		Ref.		Ref		Ref.		Ref.	
Hs graduate	0.68	0.56–0.84	1.03	0.77–1.39	0.99	0.87–1.13	1.43	0.99–1.91	0.54	0.38–0.77	0.78	0.51–1.19
Some college	0.45	0,37–0.55	0.79	0.51–0.96	0.53	0.41–0.69	0.76	0.56–1.04	0.42	0.30–0.58	0.83	0.56–1.22
Baccalaureate or above	0.29	0.21–0.39	0.52	0.35–0.77	0.33	0.22–0.49	0.61	0.38–0.97	0.26	0.17–0.41	0.49	0.28–0.88
Household income												
<$30,000	2.67	1.87–3.80	1.59	1.10–2.28	2.24	1.58–3.17	1.03	0.73–1.45	6.26	3.34–11.75	3.63	1.74–7.57
$30,000–<$50,000	1.63	1.09–2.43	1.18	0.83–1.69	1.51	0.98–2.33	0.96	0.62–1.48	3.59	1.83–7.04	2.61	1.26–5.42
$50,000–<$75,000	1.17	0.74–1.84	1.04	0.72–1.51	1.25	0.76–2.03	0.87	0.58–1.30	2.37	1.10–5.10	1.78	0.82–3.86
$75,000–<$100,000	0.96	0.57–1.62	1.09	0.72–1.67	0.97	0.52–1.81	0.87	0.53–1.44	2.01	0.85–4.74	1.93	0.88–4.26
≥$100,000	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Region												
Northeast	Ref.		–		Ref.		–		Ref.		–	
Midwest	0.91	0.64–1.30			0.89	0.60–1.33			0.96	0.57–1.64		
South	1.01	0.73–1.41			0.90	0.62–1.32			1.26	0.78–2.05		
West	0.91	0.64–1.28			0.88	0.60–1.30			0.90	0.53–1.51		
Population density												
Rural	1.27	0.97–1.68	0.99	0.77–1.27	1.14	0.81–1.62	–		1.56	1.09–2.23	1.09	0.75–1.60
Suburban	0.72	0.53–0.98	0.76	0.58–0.99	0.85	0.60–1.20			0.57	0.35–0.93	0.71	0.41–1.22
Urban	Ref.		Ref.		Ref.				Ref.		Ref.	

PR, Unadjusted prevalence ratio; aPR, Adjusted prevalence ratio; CI, Confidence intervals; Ref, Reference.

– : This variable was not included in the final full model due to specifications outlined in the method section ($p < 0.10$).

*Insurance variables modeled as binary (i.e., those with the specific insurance type vs. not).

All models are adjusted for survey week.

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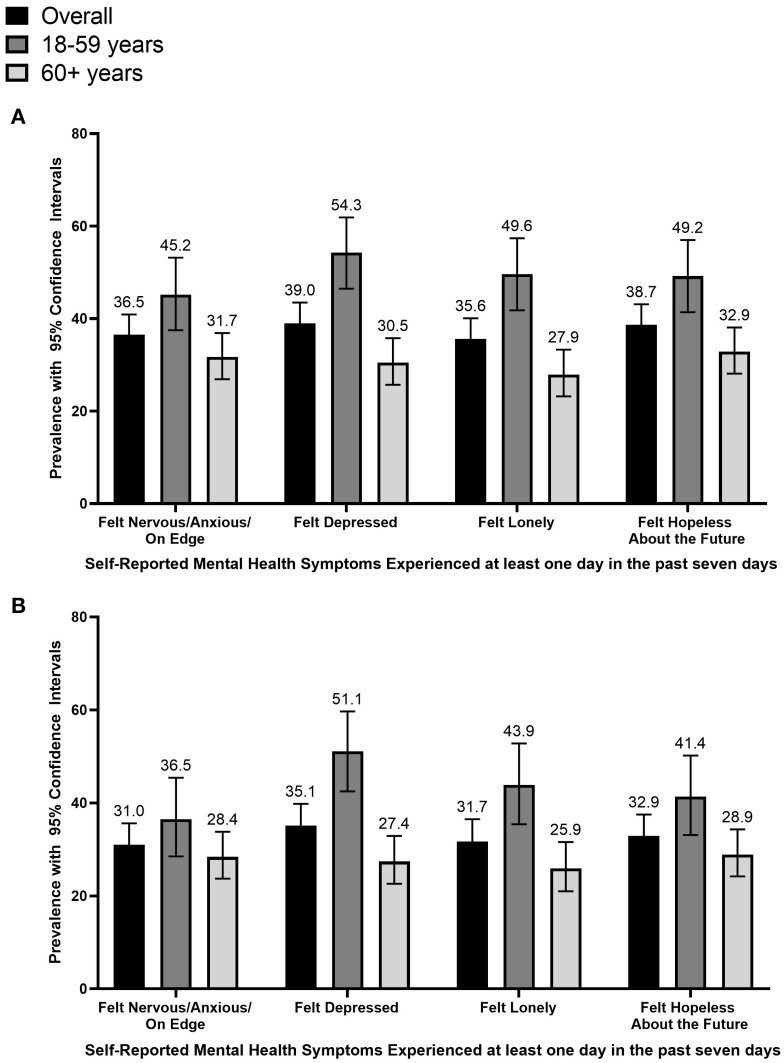

FIGURE 1
Prevalence of mental health symptoms among cancer survivors stratified by age group, COVID-19 Household Impact Survey (April–June 2020) ($n = 854$). This figure summarizes the prevalence of mental health symptoms experienced at least one time in the past seven days, specifically among **(A)** all cancer survivors and **(B)** cancer survivors without a diagnosed mental health condition.

Discussion

Overall, our study demonstrated that over four in 10 cancer survivors reported financial hardship during the COVID-19 pandemic in the United States. Cancer survivors of younger age groups (<60 years), lower educational attainment, lower income, Medicaid-insured, and racial/ethnic minoritized cancer survivors had a higher burden of financial hardship during the COVID-19 pandemic. Financial hardship was associated with mental health symptoms, including depression, anxiety, and hopelessness, among cancer survivors, even amongst those without an existing mental health condition. Findings from our analyses are consistent with prior studies focused on financial hardship among cancer survivors (28, 31, 38, 39). Our analyses underscore the potential impact of the pandemic on mental health given that associations between adverse mental health symptoms was associated with financial hardship, even amongst those without a history of a mental health condition.

In our study we found that financial hardship among cancer survivors is most common among those of younger age, racial/ethnic minoritized communities, and those with markers of lower socioeconomic status, including Medicaid insurance, lower income, and lower educational attainment.

TABLE 4 Associations of financial hardship with mental health symptoms experienced at least 1 day in the past week among cancer survivors by age groups among COVID Impact Survey cancer survivors, a nationally representative survey of the US (April–June 2020).

	Overall			18–59 years			60+ years		
All cancer patients (n = 854)	**aPR**	**95% CI**		**aPR**	**95% CI**		**aPR**	**95% CI**	
Felt nervous, anxious, on edge	1.76	1.37	2.25	1.63	1.13	2.35	1.58	1.11	2.26
Felt depressed	1.83	1.44	2.31	2.00	1.46	2.75	1.24	0.87	1.77
Felt lonely	1.48	1.18	1.84	1.13	0.83	1.54	1.38	1.00	1.91
Felt hopeless about the future	1.95	1.53	2.47	1.42	0.99	2.04	1.73	1.22	2.46
	Overall			**18–59 years**			**60+ years**		
Cancer patients without a self–reported diagnosed mental health condition (n = 737)	**aPR**	**95% CI**		**aPR**	**95% CI**		**aPR**	**95% CI**	
Felt nervous, anxious, on edge	1.51	1.11	2.05	1.38	0.84	2.28	1.36	0.89	2.10
Felt depressed	1.66	1.25	2.22	2.09	1.45	3.02	1.02	0.66	1.57
Felt lonely	1.31	0.99	1.73	1.12	0.75	1.66	1.21	0.81	1.80
Felt hopeless about the future	1.84	1.38	2.44	1.23	0.80	1.89	1.76	1.19	2.59

Models were adjusted for: age (when appropriate), survey week, sex, race/ethnicity, annual household income, education, insurance status, employment status, and area of residence (urban/rural).

Our findings are consistent with research focused on financial hardship among cancer survivors prior to the pandemic, which has shown that certain demographic groups are more vulnerable to financial toxicity, a phenomenon coined to underscore the detrimental impact of the costs of cancer care in the U.S. (40). Sociodemographic associated characteristics of financial toxicity among cancer patients identified prior to the pandemic include female sex, non-partnered marital status, Black and Hispanic race and ethnicity, low income, loss of income, younger age, and being uninsured (41, 42). While we observed a similar prevalence in financial hardship across cancer survivorship status among all ages, younger (18–59 years) cancer survivors experienced a significantly higher burden of financial hardship compared to their counterparts in the total population. In fact, one in five younger cancer survivors reported they would not be able to cover a sudden $400 expense based on their current situation. Younger age (<65 years) has been positively associated with financial hardship among cancer patients, including a dose-response relationship across the age spectrum (43). Younger cancer survivors, particularly those of working age, may be more likely to report financial hardship due to employment interruptions or reduced hours due to limitations in the ability to work leading to potential concerns regarding health insurance coverage (44). In fact, we observed that one-quarter of cancer survivors aged 18–59 reported they were either under- or unemployed due to COVID-19 or unable to find employment; Financial hardship was very high amongst this group with 81% experiencing economic precarity. As employment is closely tied to health insurance coverage in the U.S., these cancer survivors are particularly vulnerable to toxic financial shocks associated with both active and survivorship care even after their cancer may be in remission. Older adults over the age 65 years are covered through Medicare, and other benefits such as Social Security, which may alleviate the financial burdens associated with a cancer diagnosis. In addition to younger age, lower income and lower education have been associated with financial hardship among cancer survivors (44–48). Prior research has also demonstrated Medicare (49, 50), supplemental (51), and commercial insurance (52) coverage are associated with decreased financial burdens compared with patients covered with Medicaid. Insurance coverage plays a pivotal role in financial hardships among cancer survivors due to the associated out-of-pocket spending based on type of insurance plan, premiums, and deductibles.

Racial/ethnic disparities in financial toxicity among cancer survivors have been previously demonstrated, with NH-Black or African American and Hispanic/Latinx cancer patients frequently cited as experiencing higher odds of financial toxicity (41, 42). In our study population of cancer survivors, racial/ethnic inequities in financial hardship were particularly prominent among cancer survivors aged 60+ years as demonstrated in Table 3. We observed that NH-Black or African American cancer survivors as well as NH-Asian American cancer survivors had the highest burden of financial hardship. While our sample of Asian American cancer survivors was small, it is a striking finding and should be explored further given the novelty of this finding. Although limited prior work has evaluated financial toxicity among this group specifically, research focused on Asian American cancer patients suggests

that cost of cancer treatment and care contribute to poor outcomes in this demographic group (53). Qualitative work conducted among Chinese American cancer patients residing in an urban area of California suggest that up to 80%, or a large majority, were interested in culturally-tailored educational programs regarding financial and social assistance during their cancer treatment (53). Another survey of Asian American cancer patients to identify their unmet needs during cancer treatment found that almost one-third of respondents indicated they have difficulties meeting basic living expenses and almost half reported they have some type of financial difficulty (54). Future research to further investigate the financial wellbeing of Asian American cancer patients, and the population in general, should be prioritized, particularly after the COVID-19 pandemic during the rise of anti-Asian hate in the United States and the associated job security experienced by this group (55).

Financial hardship was measured in the COVID-19 Impact Survey using a question developed by the US Federal Reserve and included in the Economic Wellbeing of U.S. Households (SHED) survey, which is implemented to "share the wide range of financial challenges and opportunities facing individuals and households in the United States (56)." In 2018, the latest year of data available, the SHED survey results suggested that 40% of adults would experience hardship covering a $400, which was a 2% point increase from the prior year (27). We similarly observed the prevalence of financial hardship was 44%. Our study was unable to specify whether financial hardships experienced by cancer survivors were directly due to costs associated with cancer treatment; however, cancer is a chronic disease that often involves long-term adjuvant care and management of long-term adverse effects that continue to elevate medical costs over the patient's life (57). The inability to cover an unexpected $400 expense, however, is telling of the financial precarity of cancer survivors during the COVID-19 pandemic (58). In our definition of financial hardship, we included those who reported they would have to resort to one of the following options: put it on my credit card and pay if off over time; use money from a bank loan or line of credit; I wouldn't be able to pay for it right now; sell something; use a payday loan, deposit advance or overdraft; borrow from a friend or family member. Given the high costs associated with cancer survivorship care, these options for covering a sudden $400 expense may be unsustainable and suggests that additional health care associated costs may not be prioritized. Based on data from SEER-Medicare, average cancer survivorship annualized costs for those aged 65 years or above can range from $5,300–105,000 for medical care and $1,100–4,200 for oral prescription drugs depending on the phase across the cancer care continuum (59). Based on a 2018 review, annual out-of-pocket costs to recently diagnosed cancer survivors were more than $1,000 for medical care and time costs (i.e., patient time associated with cancer treatment such as round-trip travel time, waiting for care, and receiving care), approximately $2,000 for productivity losses, and from $2,500 to >$4,000 for employment disability, depending on age. For longer term survivors, the cost of medical care was approximately $1,500 for older survivors and $747 for younger survivors, time costs ranged from $831- $955 for older survivors and $459-$630 for younger survivors, and productivity losses were approximately $800 (12). Strategies to mitigate the financial hardships experienced by cancer survivors, particularly in the context of the negative economic downstream effects of COVID-19 in the US (20, 60), should be prioritized.

The COVID-19 pandemic has led to increased mental health symptoms among cancer survivors, even among those without an existing mental health condition (61). Reports from early in the pandemic demonstrate that US cancer survivors are more likely to report frequently feeling nervous anxious or on edge, depressed, lonely, and hopeless during the week, particularly those with limited social interaction with friends or family (61). Similarly, among older breast cancer survivors in the US, increased loneliness during the COVID-19 pandemic was associated with worsening depression symptoms and higher stress (62). Stressors contributing to poor mental health outcomes among cancer survivors during the pandemic include uncertainty regarding future cancer care, fears about in-person appointments, cancer recurrence due to care delays, and distress about untreated symptoms including mental health issues (63). Indeed, cancer survivors during the COVID-19 pandemic resorted to canceling or delaying care (26), which presents barriers to cancer survivor's ability to discuss their concerns and worries with their health care team. Our study demonstrates the potential role of financial stressors, including financial hardship, on the mental health outcomes of cancer survivors during the COVID-19 pandemic. As the COVID-19 pandemic continues to disproportionately impact patients with chronic conditions including cancer survivors, providers or care teams may consider prioritizing conversations or assessments of mental health during opportunistic care visits.

There are several limitations that should be considered when interpreting the results of our analyses. First, data leveraged for this analysis are cross-sectional in nature and may lead to reverse causality when evaluating associations of mental health with financial hardship. Second, our main outcome of financial hardship was based on a questionnaire item that has not been previously used in studies evaluating financial hardship or toxicity among cancer survivors. The questionnaire is generally used in economic US surveys such as the annual Survey of Household Economics and Decision-making (SHED) (64). We were unable to assess if the survey respondent's financial situation has changed since the COVID-19 pandemic began or were these financial constrains already in existence. Further, data collection occurred early in the pandemic period (April–June 2020), however, financial hardship and mental health may have worsened in later periods of the pandemic given the persistent adverse economic impact of the pandemic. Next, the definition of our study population of cancer survivors was based on

self-report leading to the potential for measurement error in our definition of a cancer survivor. Similarly, we relied on self-report of mental health symptoms reported in the seven days before survey administration. Data on psychological distress measured using validated scales, such as the General Anxiety Disorder-7 (GAD-7), were not available. We were unable to measure and account for important cancer-related variables such as cancer site, stage, time since diagnosis, type of treatment (surgery/chemo/radiation), and whether the respondents were currently in active treatment. Patients with very aggressive cancers and potentially expensive treatment may have been unlikely to be reached or may not have survived long enough to be part of the survey; thus, our analysis may underestimate financial hardship and its impact. Further it is important to note that about one in five adults offered the survey provided a response, which may have led to a non-response bias given those who are experiencing adverse social issues may be less likely to respond. Nevertheless, a notable strength of our analysis is we utilized nationally representative survey data and therefore, obtained a representative sample of cancer survivors in the US. Through this analysis we were able to provide preliminary insights into the financial impact of cancer survivors in the U.S. during the COVID-19 pandemic and potentially identify demographic groups that may be most affected.

In conclusion, our study demonstrates that four out of ten cancer survivors are experiencing financial hardship during the COVID-19 pandemic, with the most vulnerable being younger adults, those with low income, racial/ethnic minorities, and the Medicaid-insured. Given the negative impact the COVID-19 pandemic has had on the US economy, considering financial strife in the context of cancer survivorship care should be prioritized among US oncologists when discussing future care plans. Additionally, plans to alleviate or address mental health outcomes among cancer survivors during the pandemic should also be addressed. As poor mental health outcomes have been associated with adverse health consequences including forgoing or delaying necessary medical health, as well as poor adherence to treatment (17), strategies to address cost barriers to accessing high-quality survivorship care are needed to alleviate the negative impacts on quality of life of cancer survivors.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://www.covid-impact.org/.

Ethics statement

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

Author contributions

JI and MC-R conceived the study idea, developed the analysis plan, and drafted the first version of the manuscript. JI conducted all data analyses. All authors contributed to the interpretation of results and the final version of the manuscript. 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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.946721/full#supplementary-material

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EDITED BY
Elham Hatef,
Johns Hopkins Medicine, United States

REVIEWED BY
Dhirendra Nath,
Pokhara University, Nepal
George N. Chidimbah Munthali,
Yangtze University, China

*CORRESPONDENCE
Echu Liu
✉ echu.liu@slu.edu

†These authors share first authorship

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Factors associated with food insecurity among the chronically ill population during the COVID-19 pandemic in the United States

Caress A. Dean[1†], Echu Liu[2*†], Kimberly R. Enard[2], Zhengmin Qian[3] and Keith T. Elder[4]

[1]School of Health Sciences, Oakland University, Rochester, MI, United States, [2]Department of Health Management and Policy, College for Public Health and Social Justice, Saint Louis University, Saint Louis, MO, United States, [3]Department of Epidemiology and Biostatistics, College for Public Health and Social Justice, Saint Louis University, Saint Louis, MO, United States, [4]Mississippi College, Clinton, MS, United States

Introduction: Little is known about food insecurity among Americans with chronic diseases, one of the vulnerable groups in health care. Factors influencing food insecurity among this population group are especially poorly understood.

Methods: Using data from the COVID Impact Survey, this cross-sectional study sought to examine food insecurity among adults with chronic diseases in the United States and to identify factors associated with their risks for food insecurity during the COVID-19 pandemic.

Results: Nearly 28% of the national and 32% of the regional samples from the COVID Impact Survey were at risk for food insecurity. The logistic regressions show that chronically ill US adults with one of the following characteristics have higher odds of being at risk for food insecurity: younger than 60 years, having financial stress, unemployed, having received food from a food pantry, without health insurance, having a household income lower than $100,000, and without a college degree.

Discussion: Targeted policies and programs are warranted to address underlying determinants of food insecurity that adults with chronic illnesses experience.

KEYWORDS

food insecurity, chronically ill, COVID-19, pandemic, United States

Introduction

A growing body of literature has identified a relationship between food insecurity and chronic conditions (1–5). For example, Gundersen and Ziliak's study indicated that decreased nutrient intake is associated with fair or poor health and chronic illnesses such as diabetes, depression, and hypertension among non-senior adults (5). The literature has also shown lower food security related to the number of reported chronic conditions among working-age adults (2). Research has ascertained underlying factors of food insecurity among the chronically ill, in which the receipt of Supplemental Nutrition Assistance Program (SNAP) benefits has been identified as a determinant (2). Before the pandemic, studies showed that SNAP beneficiaries had a higher mortality rate for chronic conditions, such as cardiovascular disease and diabetes, compared to their non-SNAP

counterparts (6–8). Their employment status may play a role in decreasing their food insecurity and accessing disease management services that may affect their mortality rate. However, research suggests that many SNAP recipients experience unstable employment (9). Specifically, a longitudinal study examining employment patterns among SNAP recipients determined that about two thirds of non-disabled SNAP recipients had unemployment periods within the study's 3.5-year timeframe (9). Several studies have documented that SNAP beneficiaries who were not working reported their health, such as chronic conditions, as the reason (9, 10). These studies demonstrate the vulnerability of SNAP recipients with chronic diseases and food insecurity.

Unemployment and food insecurity have also been associated with being chronically ill among non-SNAP recipients (11). Previous research has identified the highest prevalence of chronic conditions among working-age adults who cannot work, followed by those who have been unemployed for at least 1 year, and then those unemployed for less than 12 months (12). Unemployment, along with the presence of chronic conditions, may create financial stress, which may affect adults' health behaviors (13, 14). Multiple studies have reported that US adults with chronic illnesses have delayed care or do not adhere to their medication regimen due to cost concerns (15, 16). Their financial stress may also affect their dietary behavior, such as decreasing the consumption of healthy foods (13) and increasing the use of food pantries. A substantially high number of chronically ill US adults have been reported to utilize food pantries (17–20), with individuals having a high prevalence of modifiable conditions, including obesity, diabetes, hypertension, high cholesterol, heart disease, and stroke (20). With the increased use of food pantries among the chronically ill, disease management interventions have been implemented in food pantries to reach this population (19, 20). However, the COVID-19 pandemic may have affected this population's use of these pantries.

Before the COVID-19 pandemic, food insecurity was one of the leading public health issues, with nearly 820 million people worldwide being food insecure in 2018 (21). The pandemic amplified this burden, as the United Nations reported in 2020 that 928 million people were severely food insecure (22), which may affect the diet and health outcomes of those with chronic conditions. Chronically ill individuals who experience food insecurity are a high-risk population, and the COVID-19 pandemic may have exacerbated their food insecurity. However, this relationship is understudied. Moreover, the pandemic has affected employment, SNAP benefits, and food pantry use, identified as factors associated with chronic condition status and food insecurity. Therefore, this study sought to address these gaps in the literature by examining food insecurity among adults with chronic diseases in the United States and identifying factors associated with their risks for food insecurity during the COVID-19 pandemic.

Materials and methods

Data source

This cross-sectional study used data from the COVID Impact Survey (23). The COVID Impact Survey was fielded by the National Opinion Research Center (NORC) at the University of Chicago over 3 weeks (April 20–26, 2020; May 4–10, 2020; and May 30–June 8, 2020). Data collected from these weeks are available for download on the survey's website (23). We merged these three data sets for the analysis in this work.

One of the COVID Impact Survey's critical aims was to generate national and regional statistics about various aspects of Americans' lives during the pandemic; therefore, it surveyed a subset of the national and regional population to reflect accurately the larger group's characteristics (4). The subset of the national population, the national sample hereafter, is from the NORC's AmeriSpeak Panel (23), a panel of individuals selected from a 48-strata sampling based on age, race/Hispanic ethnicity, education, and gender (24). The subset of the regional population, the regional sample hereafter, includes adults from 18 regional areas, including 10 states (CA, CO, FL, LA, MN, MO, MT, NY, OR, and TX) and eight metropolitan statistical areas (Atlanta, Baltimore, Birmingham, Chicago, Cleveland, Columbus, Phoenix, and Pittsburgh) (23). These individuals were contacted via a U.S. Postal Service delivery-sequence file encompassing approximately 97% of US households (24).

The COVID Impact Survey was conducted in English and Spanish among US adults 18 years and older to examine their physical and mental health, economic status, and social systems (23). A total of 25,269 individuals completed the study. All participants in this survey received a monetary incentive (23). Additional details on the methodological approach of the COVID Impact Survey can be found on the Data Foundation's website (25).

Study sample

Our analysis focuses on those participants of all three waves of the COVID Impact Survey with at least one of the following chronic conditions: (1) diabetes; (2) high blood pressure or hypertension; (3) heart disease, heart attack, or stroke; (4) asthma; (5) chronic lung disease and COPD; (6) bronchitis and emphysema; (7) allergies; (8) a mental health condition; (9) cystic fibrosis; (10) liver disease or end-stage liver disease; (11) cancer; (12) a compromised immune system; or (13) overweight or obese. As a result, 4,964 of the national sample and 14,530 of the regional sample remained valid for analysis. After excluding those observations with missing responses to the survey questions used as the basis for constructing dependent and independent variables in this study, 4,809 of the national sample and 13,486 of the regional sample are used for the analysis.

Measures

Dependent variable

The dependent variable of interest is a binary indicator constructed according to participants' responses to the following two questions in the COVID Impact Survey: (1) "Please indicate whether the following statement was often true (=1), sometimes true (=2), or never true (=3) for you or your household in the past 30 days: We worried our food would run out before we got money to buy more." (2) "Please indicate whether the following statement was often true (=1), sometimes true (=2), or never true (=3) for you or your household in the past 30 days: The food we bought did not last, and we did not have money to get more." If a participant's answer to the above two questions is "often true" or "sometimes true," their

households are at risk for food insecurity, and the dependent variable equals 1. Otherwise, the dependent variable equals 0 (26).

Independent variables

The following variables, created in line with the demographics or characteristics reported in the COVID Impact Survey, were considered as the potential predictors of being at risk for food insecurity: (1) age, (2) whether an individual respondent has financial stress, (3) whether an individual respondent has worked in the past 7 days, (4) whether an individual respondent has received SNAP or Food Stamps, (5) whether an individual respondent has received food from a food pantry, (6) whether an individual respondent has health insurance, (7) gender (whether an individual respondent is a female), (8) race (whether an individual respondent is a minority), (9) household income, (10) educational attainment, (11) household size, (12) census region, and (13) area of residence. Given that the responses to the COVID Impact Survey's age, household income, and household size questions were recorded on an ordinal scale, age, household income, and household size are categorical variables.

Age is a variable with four categories: 18–29, 30–44, 45–59, and 60 or older. Financial stress is a binary indicator that equals 1 if a participant said they would need to cover an unexpected $400 expense by relying on one or more of the following outlets: (1) putting it on a credit card and paying it off over time; (2) money from a bank loan or line of credit; (3) borrowing from a friend or family member; (4) using a payday loan, deposit advance, or overdraft; (5) selling something, or (6) would not be able to pay for it right now.

Whether an individual respondent has received SNAP or Food Stamps is a binary indicator that equals 1 if they have received SNAP or Food Stamps when being interviewed. Whether an individual respondent has worked in the past 7 days, whether an individual respondent has received food from a food pantry, whether an individual respondent has health insurance, and gender are defined similarly. The COVID Impact Survey asks and solicits information about its respondents' racial backgrounds by categorizing them into (1) White, non-Hispanic; (2) Black, non-Hispanic; (3) Hispanic; and (4) Other, non-Hispanic. Because non-White respondents account for a smaller percentage (less than 30%) of the national sample, we created a binary indicator of a minority that equals 1 if an individual respondent is non-white and 0 otherwise.

Based on the survey responses, we used five binary indicators to categorize our sample's household income: less than $10,000; $10,000 to $29,999; $30,000 to $49,999; $50,000 to $99,999; and higher than $100,000. Because educational attainment critically determines income, we also considered the respondent's highest level of education by including the following four dichotomous variables in our analysis: less than high school, high school, some college, and a bachelor's degree or higher. Household size is also associated with household income; therefore, we used six dummy variables to categorize our study sample's household size according to data the COVID Impact Survey collected: one, two, three, four, five, and six or more.

Income levels reportedly varied across regions (27), so the four dummies, equal to 1 if a survey respondent's household is in the Northeast, Midwest, South, or West region, were included in our analysis as potentially independent variables. People living in some urban and rural areas may have limited access to full-service supermarkets or grocery stores (28); therefore, a variable defining area of residence (urban, suburban, and rural) was also included.

Statistical analysis

Our statistical analysis consists of three steps. First, we summarize our data by creating a frequency table (Table 1). Second, we summarize the characteristics of our study sample by their food insecurity status and test whether the features are independent of food insecurity status (Tables 2, 3). Third, multivariate logistic regressions were used to estimate the odds of being at risk for food insecurity. Any variable having a significant univariate test at a 5% level in the previous step was selected as potential independent variables for the multivariate analysis. The variance inflation factor (VIF) was computed for these predictors chosen before they were included in the regressions to ensure the non-existence of multicollinearity. Sampling weights from the COVID Impact Survey were considered when performing the regressions, and a $p < 0.05$ was considered the significant level for statistical tests. All analyses were conducted using STATA 15.1.

Results

Approximately 29% of the national sample in our analysis reported being at risk for food insecurity (Table 1). This percentage was slightly higher among the regional sample, with over 31% reporting being at risk for food insecurity. The age distributions of the national and regional samples included in this study are similar, but the national sample has a slightly higher percentage of individuals over 45 years old. A more significant portion of the regional sample (51.87%) reported experiencing financial stress than the national sample (45.87%) did. A higher percentage of the regional sample, compared to the national sample, reported receiving SNAP or Food Stamps (13.90% vs. 11.29%). The same conclusion is applied to food pantry assistance (8.50% vs. 7.60%).

Table 1 also reports that most national and regional samples included in this study have health insurance coverage (92.82 and 89.60%, respectively). Additionally, the regional sample has more minorities than the national sample (40.26% vs. 34.81%) does. Both national and regional samples, as Table 1 indicates, have a similar household income distribution; most households have income between $50,000 and $99,999. Table 1 also shows that most national and regional samples included in this study have a high school or above degrees and live in the south and urban areas. The household size distributions for national and regional samples differ, as Table 1 indicates. For the national sample, households with a single person have the highest frequency, while two-people households have the highest frequency for the regional sample.

As Table 2 demonstrates, whether an individual in the national sample included in this study is at risk for food insecurity differs according to their ages, financial stress status, working status, the status of receiving public assistance (SNAP or Food Stamps), the status of receiving food assistance (food pantry), health insurance status, gender, race, household income, educational attainment, and household size. Table 3 shows whether an individual in the regional sample included in our analysis is at risk for food insecurity, which differs by the same set of variables and the US census region. The VIF value for these variables ranges between 1.04 and 3.10 for the national sample and 1.05 and 3.53 for the regional sample. Therefore, multicollinearity does not seem to be a concern for including these variables as predictors in the logistic regressions.

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TABLE 1 Frequency of characteristics: national and regional samples.

Variables	National sample*		Regional sample†	
	n	%‡	*n*	%‡
Being at risk for food insecurity				
Yes	1,305	28.72	2,484	31.68
No	3,504	71.28	11,002	68.32
Age				
18–29	566	17.51	1,464	18.35
30–44	1,346	23.86	2,854	25.68
45–59	1,153	25.05	3,238	23.46
60+	1,744	33.58	5,930	32.51
Having financial stress				
Yes	2,097	45.87	4.947	51.87
No	2,712	54.13	8,539	48.13
Working in the past 7 days				
Yes	2,296	46.84	6,692	46.12
No	2,513	53.16	6,794	53.88
Having received SNAP or food stamps				
Yes	581	11.29	1,043	13.90
No	4,228	88.71	12,443	86.10
Having received food from a food pantry				
Yes	358	7.60	644	8.50
No	4,451	92.40	12,842	91.50
Covered by health insurance				
Yes	4,480	92.82	12,834	89.60
No	329	7.18	652	10.40
Being a female				
Yes	2,538	53.36	7,889	52.75
No	2,271	46.64	5,597	47.25
Being a minority				
Yes	1,633	34.81	2,947	40.26
No	3,176	65.19	10,539	59.74
Household income				
Less than $10,000	256	5.65	664	9.03
Between $10,000 and $29,999	1,013	21.14	2,114	22.63
Between $30,000 and $49,999	962	19.52	2,199	17.54
Between $50,000 and $99,999	1,587	31.56	4,427	28.18
More than $100,000	991	22.12	4,082	22.63
Education				
Less than high school	240	9.73	357	8.56
High school	865	27.15	1,407	27.66
Some college	2,045	28.98	3,832	31.59
College or above	1,659	34.13	7,890	32.19
Household size				
One	1,516	35.20	4,183	28.01
Two	1,346	25.67	5,200	33.03
Three	688	13.72	1,862	16.04

(Continued)

TABLE 1 (Continued)

Variables	National sample*		Regional sample†	
	n	%‡	*n*	%‡
Four	479	9.64	1,340	11.63
Five	308	5.96	584	6.67
Six or more	472	9.82	317	4.63
Census region				
Northeast	709	18.01	1,534	14.76
Midwest	1,212	21.03	3,889	18.67
South	1,695	38.47	4,210	36.94
West	1,193	22.49	3,853	29.62
Are of residence				
Urban	3,474	70.39	10,816	81.78
Suburban	935	20.19	2,001	13.72
Rural	400	9.42	669	4.51

*$N = 4,809$.
†$N = 13,486$.
‡Weighted percentages.

TABLE 2 Characteristics of the national sample* by the risk status of food insecurity.

Variables	Being at risk for food insecurity	Not being at risk for food insecurity	*p* value
Age (%‡)			0.00
18–29	212 (25.87)	354 (14.14)	
30–44	475 (32.52)	871 (20.37)	
45–59	325 (22.64)	828 (26.02)	
60+	293 (18.97)	1,451 (39.47)	
Having financial stress (%‡)			0.00
Yes	1,050 (82.03)	1,047 (31.29)	
No	255 (17.97)	2,457 (68.71)	
Working in the past 7 days (%‡)			0.00
Yes	502 (38.92)	1,794 (50.04)	
No	803 (61.08)	1,710 (49.96)	
Having received SNAP or Food Stamps (%‡)			0.00
Yes	353 (25.80)	228 (5.45)	
No	952 (74.20)	3,276 (94.55)	
Having received food from a food pantry (%‡)			0.00
Yes	245 (18.99)	113 (3.01)	
No	1,060 (81.01)	3,391 (96.99)	
Covered by health insurance (%‡)			0.00
Yes	1,139 (87.39)	3,341 (95.01)	
No	166 (12.61)	163 (4.99)	
Being a female (%‡)			0.00
Yes	774 (59.99)	1,764 (50.68)	
No	531 (40.01)	1,740 (49.32)	
Being a minority (%‡)			0.00

(Continued)

TABLE 2 (Continued)

Variables	Being at risk for food insecurity	Not being at risk for food insecurity	*p* value
Yes	665 (46.30)	968 (30.17)	
No	640 (53.70)	2,536 (69.83)	
Household income (%‡)			0.00
Less than $10,000	156 (13.46)	100 (2.51)	
Between $10,000 and $29,999	459 (34.08)	554 (15.93)	
Between $30,000 and $49,999	301 (20.89)	661 (18.97)	
Between $50,000 and $99,999	301 (24.17)	1,286 (34.54)	
More than $100,000	88 (7.40)	903 (28.05)	
Education (%‡)			0.00
Less than high school	128 (18.87)	112 (6.05)	
High school	317 (34.76)	548 (24.09)	
Some college	606 (30.10)	1,439 (28.53)	
College or above	254 (16.27)	1,405 (41.33)	
Household size (%‡)			0.00
One	356 (30.92)	1,160 (36.93)	
Two	258 (17.98)	1,088 (28.76)	
Three	199 (15.00)	489 (13.20)	
Four	155 (11.53)	324 (8.88)	
Five	126 (7.59)	182 (5.30)	
Six or more	211 (16.98)	261 (6.93)	
Census region (%‡)			0.48
Northeast	183 (19.25)	526 (17.51)	
Midwest	300 (19.59)	912 (21.61)	
South	516 (39.67)	1,179 (37.98)	
West	306 (21.48)	887 (22.90)	
Are of residence (%‡)			0.47
Urban	926 (69.00)	2,548 (70.95)	
Suburban	249 (20.48)	686 (20.08)	
Rural	130 (10.53)	270 (8.98)	

*$N = 4,809$.
‡Weighted percentages.

Table 4 depicts the association between those predictor variables identified from Table 2 and the odds of being the risk for food insecurity among the national sample included in our study. According to this table, the odds for the national sample aged at least 60 years old to be at risk of having food shortage is 0.41 times that of those who are under 60 (odds ratio [OR] = 0.41, 95% Confidence Interval [CI]: 0.28–0.61). In addition, financially stressed respondents' odds of experiencing food shortage are 5.54 times that of those who are not economically stressed (OR = 5.54, 95% CI: 4.37–7.03). Compared to those who did not work in the past 7 days, respondents who worked in the past 7 days had lower odds of being at risk of running out of food (OR = 0.72, 95% CI: 0.56–0.93). Regarding the use of food assistance services, the national sample in our study who reported receiving SNAP or Food Stamps (OR = 1.49, 95% CI:1.08–2.06) or receiving food at a food pantry (OR = 3.26, 95% CI:2.13–5.00) had significantly higher odds of being at risk for food insecurity.

Table 4 also shows that for national samples with health insurance coverage in our study, their odds of being at risk for food insecurity is 0.66 times that of those without (OR = 0.66, 95% CI: 0.46–0.96). Compared to survey respondents with a household income of more than $100,000, the odds of being at risk for food insecurity are significantly higher for those with less household income, as Table 4 indicates. In general, respondents with less educational attainment and a larger household size were estimated to have higher odds of being at risk of running out of food, based on the estimated ORs reported in Table 4.

Similar to the results from the analysis of the national sample reported in Tables 4, 5 shows being at risk of food insecurity is more common among those who are financially stressed (OR = 5.25, 95% CI:

TABLE 3 Characteristics of the regional sample* by the risk status of food insecurity.

Variables	Being at risk for food insecurity	Not being at risk for food insecurity	*p* value
Age (%‡)			0.00
18–29	492 (28.26)	972 (13.76)	
30–44	735 (31.51)	2,119 (22.98)	
45–59	676 (22.10)	2,562 (24.08)	
60+	581 (18.12)	5,349 (39.18)	
Having financial stress (%‡)			0.00
Yes	2,115 (88.78)	2,832 (34.75)	
No	369 (11.22)	8,170 (65.25)	
Working in the past 7 days (%‡)			0.00
Yes	943 (33.48)	5,749 (51.99)	
No	1,541 (66.52)	5,253 (48.01)	
Having received SNAP or Food Stamps (%‡)			0.00
Yes	676 (31.12)	367 (5.92)	
No	1,808 (68.88)	10,635 (94.08)	
Having received food from a food pantry (%‡)			0.00
Yes	441 (20.76)	203 (2.81)	
No	2,043 (79.24)	10,799 (97.19)	
Covered by health insurance (%‡)			0.00
Yes	2,145 (79.53)	10,689 (94.28)	
No	339 (20.47)	313 (5.72)	
Being a female (%‡)			0.00
Yes	1,784 (64.23)	6,105 (47.43)	
No	700 (35.77)	4,897 (52.57)	
Being a minority (%‡)			0.00
Yes	1,070 (57.83)	1,877 (32.11)	
No	1,414 (42.17)	9,125 (67.89)	
Household income (%‡)			0.00
Less than $10,000	434 (21.57)	230 (3.21)	
Between $10,000 and $29,999	903 (40.60)	1,211 (14.30)	
Between $30,000 and $49,999	539 (19.00)	1,660 (16.86)	
Between $50,000 and $99,999	483 (15.52)	3,944 (34.04)	
More than $100,000	125 (3.31)	3,957 (31.58)	
Education (%‡)			0.00
Less than high school	233 (19.15)	124 (3.65)	
High school	548 (38.36)	859 (22.70)	
Some college	1,016 (32.27)	2,816 (31.28)	
College or above	687 (10.22)	7,203 (42.38)	
Household size (%‡)			0.00
One	761 (23.80)	3,422 (29.96)	
Two	650 (22.76)	4,550 (37.79)	
Three	425 (19.96)	1,437 (14.22)	
Four	293 (12.26)	1,047 (11.34)	
Five	205 (11.83)	379 (4.28)	

(Continued)

TABLE 3 (Continued)

Variables	Being at risk for food insecurity	Not being at risk for food insecurity	*p* value
Six or more	150 (9.40)	167 (2.41)	
Census region (%‡)			0.01
Northeast	291 (16.14)	1,243 (14.12)	
Midwest	626 (15.97)	3,263 (19.93)	
South	943 (39.56)	3,267 (35.73)	
West	624 (28.33)	3,229 (30.22)	
Are of residence (%‡)			0.07
Urban	1,931 (79.52)	8,885 (82.84)	
Suburban	393 (15.47)	1,608 (12.89)	
Rural	160 (5.01)	509 (4.27)	

*$N = 13,486$.
‡Weighted percentages.

TABLE 4 Estimated odds ratios from the logistic regression using the national sample.*

Characteristics	Estimate	SE†	95% CI‡		*p*
			LL§	UL§	
Age					
18–29 (reference)					
30–44	1.24	0.22	0.88	1.75	0.23
45–59	0.75	0.14	0.52	1.08	0.12
60+	0.41	0.08	0.28	0.61	0.00
Having a financial stress					
Yes	5.54	0.67	4.37	7.03	0.00
No (reference)					
Working in the past 7 days					
Yes	0.72	0.09	0.56	0.93	0.01
No (reference)					
Having received SNAP or food stamps					
Yes	1.49	0.25	1.08	2.06	0.02
No (reference)					
Having received food from a food pantry					
Yes	3.26	0.71	2.13	5.00	0.00
No (reference)					
Covered by health insurance					
Yes	0.66	0.13	0.46	0.96	0.03
No (reference)					
Being a female	1.11	0.13	0.88	1.39	0.39
Being a minority	1.20	0.14	0.95	1.52	0.13
Household income					
Less than $10,000	6.17	1.99	3.28	11.62	0.00
Between $10,000 and $29,999	3.24	0.69	2.14	4.90	0.00
Between $30,000 and $49,999	2.31	0.47	1.55	3.45	0.00
Between $50,000 and $99,999	1.91	0.36	1.32	2.76	0.00
More than $100,000 (reference)					

(Continued)

TABLE 4 (Continued)

Characteristics	Estimate	SE†	95% CI‡		p
			LL§	UL§	
Education					
Less than high school	2.23	0.56	1.36	3.66	0.00
High school	1.33	0.22	0.97	1.83	0.08
Some college	1.39	0.19	1.07	1.81	0.01
College or above (reference)					
Household size					
One (reference)					
Two	1.07	0.17	0.79	1.46	0.67
Three	1.49	0.28	1.03	2.14	0.03
Four	1.43	0.28	0.97	2.09	0.07
Five	1.41	0.33	0.88	2.24	0.15
Six or more	2.37	0.51	1.56	3.60	0.00

*$N = 4{,}809$.
†SE, standard error.
‡CI, confidence interval.
§LL, lower limit; UL, upper limit.

TABLE 5 Estimated odds ratios from the logistic regression using the regional sample.*

Characteristics	Estimate	SE†	95% CI‡		p
			LL§	UL§	
Age					
18–29 (reference)					
30–44	1.29	0.21	0.93	1.77	0.12
45–59	0.90	0.16	0.64	1.26	0.53
60+	0.46	0.08	0.33	0.65	0.00
Having a financial stress					
Yes	5.25	0.61	4.18	6.59	0.00
No (reference)					
Working in the past 7 days					
Yes	0.77	0.09	0.61	0.98	0.03
No (reference)					
Having received, applied for, or tried to apply for SNAP					
Yes	1.25	0.21	0.90	1.75	0.19
No (reference)					
Having received food from a food pantry					
Yes	3.47	0.66	2.38	5.04	0.00
No (reference)					
Covered by health insurance					
Yes	0.57	0.11	0.39	0.83	0.00
No (reference)					
Being a female	1.17	0.13	0.94	1.45	0.16
Being a minority	1.45	0.16	1.16	1.80	0.00
Household income					
Less than $10,000	13.84	3.85	8.02	23.89	0.00

(Continued)

TABLE 5 (Continued)

Characteristics	Estimate	SE†	95% CI‡		p
			LL§	UL§	
Between $10,000 and $29,999	9.54	2.15	6.13	14.84	0.00
Between $30,000 and $49,999	5.66	1.22	3.71	8.63	0.00
Between $50,000 and $99,999	2.84	0.59	1.89	4.27	0.00
More than $100,000 (reference)					
Education					
Less than high school	3.23	0.76	2.03	5.13	0.00
High school	1.89	0.28	1.41	2.53	0.00
Some college	1.63	0.20	1.28	2.08	0.00
College or above (reference)					
Household size					
One (reference)					
Two	1.43	0.20	1.09	1.87	0.01
Three	1.99	0.36	1.39	2.85	0.00
Four	1.49	0.29	1.01	2.20	0.04
Five	3.73	0.86	2.37	5.85	0.00
Six or more	2.54	0.74	1.44	4.48	0.00
Census region					
Northeast	1.16	0.21	0.82	1.64	0.41
Midwest	0.95	0.12	0.74	1.21	0.68
South (reference)					
West	0.98	0.13	0.75	1.28	0.88

*N, 13,486.
†SE, standard error.
‡CI, confidence interval.
§LL, lower limit; UL, upper limit.

4.18–6.59) and have food from a food pantry (OR = 3.47, 95% CI: 2.38–5.64). Additionally, those aged at least 60 years old in the regional sample for our analysis have lower odds of being at risk for a food shortage (OR = 0.46, 95% CI: 0.33–0.65). Furthermore, for non-White respondents in our regional sample data, the odds of being at risk of food shortage is 1.45 times that of White respondents, according to Table 4 (OR = 1.45, 95% CI: 1.16–1.80). In contrast, the regional sample aged over 60 years, working in the past 7 days, having health insurance, having a household income of more than $100,000, having a college education, or households with only one member in the household included in this study has lower odds of being at risk for food insecurity.

In summary, our logistics regression results show that, among the chronically ill US population, those who are older, work, have health insurance coverage, have higher income, or are more educated tend to have lower odds of a food shortage. Conversely, people with financial challenges or who rely on food assistance programs tend to have higher odds of a food shortage.

Discussion

The COVID-19 pandemic increased food insecurity, which may affect the diet and health outcomes of the chronically ill. This cross-sectional study determined that, among the national sample of the COVID Impact Survey, those who were chronically sick and received SNAP benefits or food from a food pantry had a higher risk of running out of food. However, no studies have examined the relationship between SNAP benefits, chronic illnesses, and food insecurity during the pandemic nationally. One prior study found that receiving SNAP benefits significantly associated with food insecurity among adults aged 65 and older during the pandemic (11). The same study also found a high prevalence of chronic conditions among older adults who were food insecure (11). These findings highlight the importance of ensuring access to food assistance programs among the chronically ill during public health emergencies.

Note that the relationship between SNAP benefits and food security risk among the regional sample of chronically ill participants was not statistically significant. State-level differences in SNAP benefits may have influenced this relationship. Additional research should be conducted to understand the influence of geographic location on receiving SNAP benefits for the chronically ill during the pandemic.

Among the national and regional samples, the odds of reporting financial stress were five times higher among chronically ill participants at risk of food insecurity than their non-risk counterparts. These findings are disconcerting as previous studies have linked

delayed care and nonadherence to treatment regimens to cost concerns (15, 16) and economic pressure to consume an unhealthy diet (13, 14). As a result, chronically ill individuals' conditions may have worsened. Further research should be performed to assess the impact of this population's financial stress during the pandemic on health behaviors and determine the implications of their financial stress on their current and future disease status.

In the national and regional samples, chronically ill participants who did work in the past 7 days had significantly lower odds of being at risk for food insecurity. Similarly, sick, chronically participants who reported having health insurance coverage had significantly lower odds of being at risk for food insecurity. No studies have examined job loss among the chronically ill during the pandemic. However, an unprecedented number of job and wage losses did occur due to the stay-at-home orders (14, 15) and may have affected those with chronic conditions. Additionally, previous research has found chronically ill US adults are more likely to have some form of health insurance (29). Therefore, the association with no coverage among chronically ill participants with food insecurity risk may stem from the high unemployment rate and loss of employer-sponsored health coverage. This theory is supported by a study that determined 2.7 million Americans lost health insurance during 12 weeks of the pandemic (30). However, this study did not focus on the chronically ill population. Therefore, future research should be conducted to ascertain health insurance loss among the sick chronically at risk of food insecurity during the pandemic.

This study has limitations to consider. The study utilized a cross-sectional design; therefore, a causal relationship cannot be determined. Participants self-reported their responses, allowing for recall bias. This study is also subjected to selection bias due to online and telephone interviews. Data collection occurred from March 2020 to June 2020. It utilized different sample populations during each data collection point, which prohibits understanding food security of the chronically ill over time during the pandemic. The data do not contain information on the food insecurity risk among participants before the pandemic; therefore, this study cannot determine the direct effect of COVID-19 on food insecurity among the chronically ill.

A growing body of literature describes the complex and bidirectional relationship between food insecurity and chronic illnesses (12, 13, 19). However, little is known about the effect of COVID-19 on this relationship. This study's outcomes address this void because it identified factors associated with a risk of food insecurity among the chronically ill during the pandemic. These findings can be utilized in future research to inform targeted policies and programs to support this vulnerable population and to ensure access to food assistance programs and health insurance during future public health emergencies.

Data availability statement

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

Author contributions

KRE, ZQ, and KTE contributed to the study's conception and design. EL and CAD organized the database and wrote the first and second drafts of the manuscript. EL performed the statistical analysis. CAD, KRE, ZQ, and KTE reviewed and revised all manuscript sections. All authors contributed to the article and approved the submitted version.

Conflict of interest

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

Publisher's note

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EDITED BY
Keith Elder,
Mississippi College, United States

REVIEWED BY
Maria Eugenia Jimenez-Corona,
National Institute of Cardiology Ignacio Chavez, Mexico
Liane S. Canas,
King's College London, United Kingdom

*CORRESPONDENCE
Gustavo Mora-Aguilera
✉ morag@colpos.mx

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

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Were metabolic and other chronic diseases the driven onset epidemic forces of COVID-19 in Mexico?

Gerardo Acevedo-Sánchez[1†], Gustavo Mora-Aguilera[1*†], Juan J. Coria-Contreras[1] and Ikuri Álvarez-Maya[2]

[1]Laboratory of Epidemiological Risk Analysis (LANREF), Postgraduate College, Montecillo Campus, Texcoco, State of Mexico, Mexico, [2]Center for Research and Applied Technology in Jalisco (CIATEJ), Guadalajara, Jalisco, Mexico

The underline hypothesis of this study was that SARS-CoV-2 can infect individuals regardless of health condition, sex, and age in opposition to the classical epidemiological assumption of an identifiable susceptible subpopulation for epidemic development. To address this issue, a population cohort with 24.4 million metadata associated with 226,089 official RT-qPCR positive and 283,450 negative cases, including 27,769 deceased, linked putatively to *B.1.* and *B.1.1.* SARS-CoV-2 lineages were analyzed. The analysis baseline was to determine the infection and mortality structure of the diseased cohort at the onset-exponential phase of the first epidemic wave in Mexico under the assumption of limited herd immunity. Individuals with nonchronic diseases (NOCDs) were compared with those exhibiting at least one of 10 chronic diseases (CDs) adjusted by age and sex. Risk factors for infection and mortality were estimated with classification and regression tree (CART) and cluster analysis based on Spearman's matrix of *rho*-values in RStudio®, complemented with two proposed *mortality indices*. SARS-CoV-2 infection was independent of health condition (52.8% NOCD *vs.* 47.2% CDs; $p = 0.001–0.009$) but influenced by age >46 in one risk analysis scenario ($p < 0.001$). Sex contributed 9.7% to the overall risk. The independent effect was supported by the health structure of negative cases with a similar tendency but a higher proportion of NOCDs (61.4%, $p = 0.007$). The infection probability in individuals with one CD was determined by the disease type and age, which was higher in those older individuals (≥56 years) exhibiting diabetes (12.3%, $cp = 0.0006$), hypertension (10.1%, $cp < 0.0001$), and obesity (7.8%, $cp = 0.001$). In contrast, the mortality risk was heavily influenced by CD conditioned by sex and age, accounting for 72.3% of total deaths ($p = 0.001–0.008$). Significant mortality risk (48%) was comprised of women and men (w, m) aged ≥56 years with diabetes (19% w and 27.9% m, $cp < 0.0004$), hypertension (11.5% w, $cp = 0.0001$), and CKD (3.5% w and 5.3% m, $cp = 0.0009$). Older people with diabetes and hypertension comorbidity increased the risk to 60.5% ($p = 0.001$). Based on a *mortality-weighted index*, women were more vulnerable to preexisting metabolic or cardiovascular diseases. These findings support our hypothesis and justify the need for surveillance systems at a communitarian level. This is the first study addressing this fundamental epidemiological question.

KEYWORDS

SARS-CoV-2, comorbidities, mortality risk, infection risk, first wave

Introduction

SARS-CoV-2, the most successful zoonotic coronavirus in human history, has caused over 668 million infection cases and more than 6.8 million deaths worldwide through several epidemic waves (1, 2). Since the Wuhan outbreak in China (3), at least 19 variants of the epidemic have emerged and spread rapidly before an effective natural immunological response (4). In infectious epidemic diseases, the classical paradigm behind the susceptible, infected, and recovered (SIR) individuals and any descriptive or predictive epidemiological model imply the preexistence of a susceptible subpopulation due to genetic, epigenetic, clinical, and environmental determinants as the driving forces for contagion (5–10). With COVID-19 epidemics, early findings supported that chronic diseases (CDs), age, and, to a less extent, sex were associated with the success and clinical outcomes of SARS-CoV-2 infection. However, most results were derived at the hospital level, from a small diagnostic dataset, or framed for descriptive epidemiological studies (3, 11, 12). More vital efforts should be addressed from the perspective of mechanistic epidemiology to enhance comprehensive prevention health systems to cope with the increasing risk of emerging and reemerging new human diseases. This study hypothesized that SARS-CoV-2 can infect individuals regardless of their health condition in opposition to the classical epidemiological assumption of an identifiable susceptible subpopulation for epidemic development. It was assumed that fast spreading, limited and unsteady immunological response toward a newly encountered pathogen, constrained clinical knowledge for treatment, and unprepared public health systems were fully expressed during the first wave of the COVID-19 outbreak, thus allowing unrestricted infection scenarios. The first epidemic wave also involved a higher global fatality rate reaching 15.2% (13). The Mexican population, with a high SARS-CoV-2 infection risk due to populated territorial clusters and high incidence of metabolic and cardiovascular chronic diseases in the world, was suitable to address this research (14–16). Previous efforts in Mexico mainly focused on demonstrating the CDs association with COVID-19 clinic course and mortality, thereby lacking a mechanistic epidemiological framework (17–20). This comprehensive study contributes to understanding the epidemiological behavior of new diseases in human populations and provides insights for surveillance and prevention of potential zoonotic outbreaks (21). Moreover, this study was based on big data associated with 509,539 official RT-qPCR test results, comprising 24.4 million metadata (22), which were putatively related to *B.1.* and *B.1.1.* SARS-CoV-2 lineages (23, 24), representing the onset-exponential phase of the first epidemic wave in Mexico (28 February to 30 June 2020). Our approach was to determine the subpopulation structure of infection in ambulatory and hospitalized cases, associated with 10 CDs and nonchronic diseases (NOCDs), considering age and sex as demographic factors in a cohort of 226,089 accumulated positive and 283,450 negative individuals, including 27,769 deaths. Therefore, the objective of this study was to establish the subpopulation attributes toward SARS-CoV-2 infection and the contribution of CDs and baseline demographic factors in shaping population vulnerability under the assumption of unrestricted immunological responses, treatments availability, and preventive constraints for contagion during the onset of the first epidemic wave.

Materials and methods

COVID-19 data source

The first step was to collect the official COVID-19 public databases (MS Excel®, dBase-COVID) of the Mexican Ministry of Health (25), from the first positive SARS-CoV-2 reported on 28 February to 30 June 2020, selected for comprising the onset-exponential phase of the first epidemic wave in Mexico. The dBase-COVID, updated daily, had 581,580 individual records (population–N) and 35 variables (20.4 million metadata), including state and municipal locations, diagnosis results, symptoms expression date, death date, sex, age, and 10 CDs, among others (Figure 1 and Supplementary Table 1). All diagnostic tests were officially regulated and conducted with certified protocols based on real-time reverse transcription-polymerase chain reaction (RT-qPCR).

Metadata structure

The second step was to set up the database structure to conform the research objective. The dBase-COVID data were imported into RStudio® v1.4.1106 – R Project® v4.1.1 and performed in a workstation (HP Z1-G6. IntelCore i7 of 10th generation). Data extraction was performed with *readxl*, *base*, *rattle*, and *dplyr* functions of Rstudio®. Sixteen numerical variables were transformed into categories, e.g., sex 1 = "female", sex 2 = "male", or CD 1 (presence of any chronic disease) = "yes", CD 2 = "no". The geo-location variables were transformed using the official nomenclature of the National Institute of Statistics and Geography (26). Additional 13 synthetic variables were created to potentially enhance the analyses, e.g., days with symptoms at testing or days from detection to death in the hospital settings. The final structured and conform database contained a cohort A of 226,089 positive individuals including 27,769 deaths, linked to 48 variables totaling 10′852272 metadata (Figure 1). A total of 72,041 unconfirmed RT-qPCR tests were excluded from the analysis (Figure 1). In this study, the infected cohort A was conform for all positive cases, symptomatic or asymptomatic at testing, including those individuals who eventually died. Death cases were considered subcohort A' of the infected cases (Figure 1).

To properly assess the age effect on infection, this variable was grouped into five categories (age$_c$): <29, 30–37, 38–46, 47–56, and >56 years. Similarly, 10 CDs were independently analyzed, as well as by categories (CD$_c$) according to clinical typology: metabolic (diabetes, obesity, immunosuppressants, and chronic kidney disease); cardiovascular (hypertension and cardiovascular disease); respiratory (asthma, COPD, and smoking), even though smoking is not a CD, it was considered due to implications on pulmonary diseases; "other-CDs" (this general category was specified as such in original data matrix); and a nonchronic

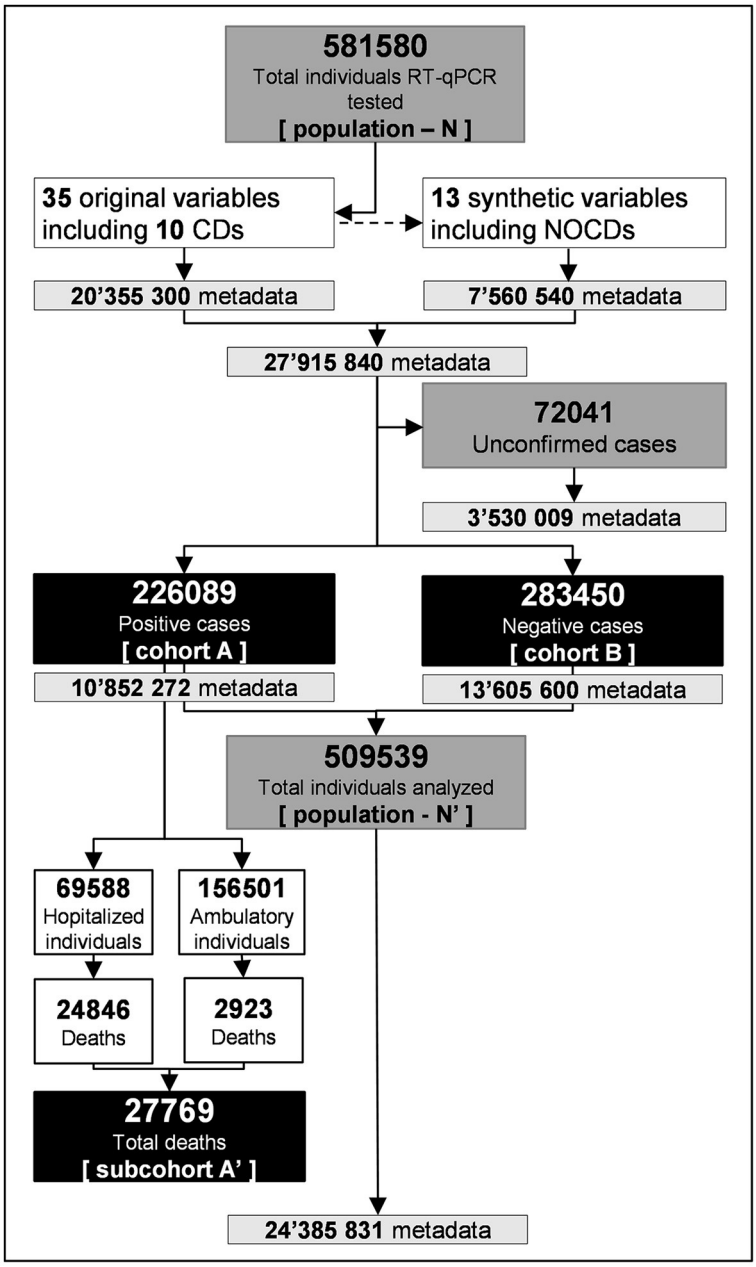

FIGURE 1
Data extraction flow (black boxes) from 581,580 official database entries accumulated during the onset-exponential phase of the first COVID-19 epidemic wave in México (population-N), from 28 February to 30 June 2020. The final big data matrix was associated with 509,539 total individuals analyzed comprising 24.4 million metadata conform in cohort A with 226,089 RT-qPCR-positive cases including subcohort A' with 27,769 deaths and cohort B with 283,450 negative cases.

disease (NOCD) category for the absence of any reported CD on the dataset.

Onset-exponential phase modeling

The third step was to confirm and characterize the onset-exponential epidemic phase intensity by fitting it to the exponential model and comparing 10 COVID-19 epidemics selected from an equal number of countries with the highest reported positive cases at the first wave onset (1). The significant epidemic rate-r_e estimation was fundamental to validate the fastest contagion assumption required to prove the working hypothesis. The comparison among epidemics to depict Mexico's scenario framed the study assumptions' validity. The plotting of all curves characterization was performed with *ggplot* function of RStudio® using cumulative daily (x) positive cases from onset (y_o) to the inflection curve point. The positive and death data (y) were independently fitted in SAS® v9.4 using the nonlinear model:

$\hat{y} = y_o{}^{r_e(x)}$. The r_e-parameter and y_o estimated the exponential epidemic rate and positive cases of primary infection, respectively. The goodness-of-fit (R^2) and significance level ($p < 0.0001$) were obtained for comparison purposes.

Probabilistic risk categorization for infection and mortality

The fourth step was to conduct an independent risk categorization analysis for the infection cohort A and mortality subcohort A' by using two approaches: the classification and regression tree (CART) and Spearman's *rho* correlation linked to a clustering analysis. CART allows for identifying and weighting tree-decision rules to generate splitting stratified groups of similar risk toward SARS-CoV-2. These rules were fitted using *rpart*, *rpart.plot*, and *prp* functions and the analysis of variance (ANOVA) among groups in RStudio®. The *rpart* and *rpart.plot* best-fitting function for major splitting generated an overall *complexity parameter* (*cp*) value, $cp = 0.000003$ ($p = 0.001$) and $cp = 0.000024$ ($p = 0.001$), for infection and mortality CART, respectively. The splitting stratification process runs *n*-iterations for each encountered group until a homogeneity value lower than the *complexity parameter* (*cp*) is reached, thus providing the optimal solution. This parameter estimated and compared the variance homogeneity within groups for the final decision. Each CART was fitted as multiple regression model: $y_i = x_1 + x_2 + x_3 ... x_n$, where y_i was the infected or death cases as dependent variables, and $x_1 ... x_n$ were 10 CDs, NOCD, age, and sex as variable predictors. Finally, with *prp*, a risk tree was built via cross-validation, thus creating stratified groups at the lowest error (27). Only nodes with statistically significant *p*-values ($p \leq 0.05$) were plotted. Nodes per quartile of cases number were colored using a bar-scale. The CART procedure was selected because (1) it establishes rules based on multivariate criteria to explain overall variance (28); (2) it does not make any statistical distribution assumptions associated with dependent or independent variables (29, 30); and (3) it stratifies and classifies data based on weighted variables to create high- or low-risk homologous groups (30).

The second approach used was Spearman's correlation matrix based on 10 CDs, NOCD, age, and sex variables for pairings *rho* estimations. Furthermore, a hierarchical cluster analysis was performed using the Euclidian distance of *rho*-values as a dissimilarity measure among clusters and Ward's minimum variance to minimize the within-cluster variance. Independent dendrograms for the infection cohort A and mortality subcohort A' were plotted with the *tanglegram* function of RStudio® for comparison purposes. In addition, per dendrogram, the infection and mortality relative risk (r) for tree clusters were estimated with $r = [y_i / \sum y] \, 100$, where y is the total infected or death cases and $\sum y$ is the total infected cohort A or mortality subcohort A' (Figure 1). Spearman's correlation matrix and clustering were selected because 1) it standardize data based on the variables' association level, reducing the effect of sample size and 2) it allow estimating a statistical significance ($p \leq 0.05$).

The fifth step was to perform analogous analyses with cohort B comprising 283,450 negative cases, assuming individual exposure to the SARS-CoV-2 virus by social contact with positive cases. The purpose was to analyze the whole population–N' structure toward SARS-CoV-2 infection risk. The overall analyses included 509,539 individuals and 24.4 million metadata (population–N', Figure 1).

A deterministic risk categorization for mortality

To further explain the implication of CD categories on COVID-19 mortality subcohort A' (Figure 1), two relative epidemiological indices were developed to estimate the mortality stratified by age_c and sex. A *mortality index* (MoI) was calculated with the following equation:

$$\mathbf{MoI} = \frac{\sum_{ij}^{n} \mathbf{Deaths}_{ij}}{\sum_{j}^{n} \mathbf{Cases}_{j}}$$

where $Cases_j$ is the number of positive individuals in *j*; *i* represents the age_c category from n =1 to 5; *j* is the CD_c category from n =1 to 4; and NOCD.

A *mortality-weighted index* (MWI), weighted by the average ($\bar{x}$) of age in each category, was calculated with the next equation:

$$\mathbf{MWI} = \frac{\sum_{ij}^{n} \mathbf{Deaths}_{ij} * \bar{x}_{ij}}{\sum \mathbf{Deaths}}$$

where *i* and *j* are described as beforehand.

Results

SARS-CoV-2 metadata structure

A total of 226,089 individuals infected with SARS-CoV-2 during the onset-exponential phase of the first COVID-19 epidemic wave in Mexico were included in the study (cohort A; Figure 1 and Supplementary Table 1). The mean age was 45.7 years (range: 10–98 years), with 54.7% male cases. The overall positivity was 44.4% [(infected individuals/total individuals tested) x 100], with an official lethality rate of 12.3%. Hospitalized individuals accounted for 30.8% (62.2% of whom were men), with fatalities reaching 35.5% (65.1% of whom were men). The outpatient mortality was 1.8%. The data represented 32 Mexican states, of which 36% was associated with the metropolitan area of Mexico City and Mexico State with a combined 23.1 million habitants and a density of 6,163.3 and 760.2 residents by square kilometer, respectively. The data comprised a well-conform exponential phase as in selected comparative epidemics but with a relatively lower epidemic rate ($r_e = 0.040$ units day^1), in contrast to Spain, USA, Italy, Russia, the UK, and Peru, which ranged from 0.15 to 0.17 (Figure 2A). In all cases, the exponential model fitted with $R^2 > 0.96$ (Figure 2B). The lethality rate of Mexico was among the highest, in conjunction with Italy, Spain, UK, and Peru.

The infected cohort A, i.e., the total number of positive individuals regardless of the COVID-19 outcome, included 52.8% with NOCDs (53.9% of whom were men). The remaining 47.2%

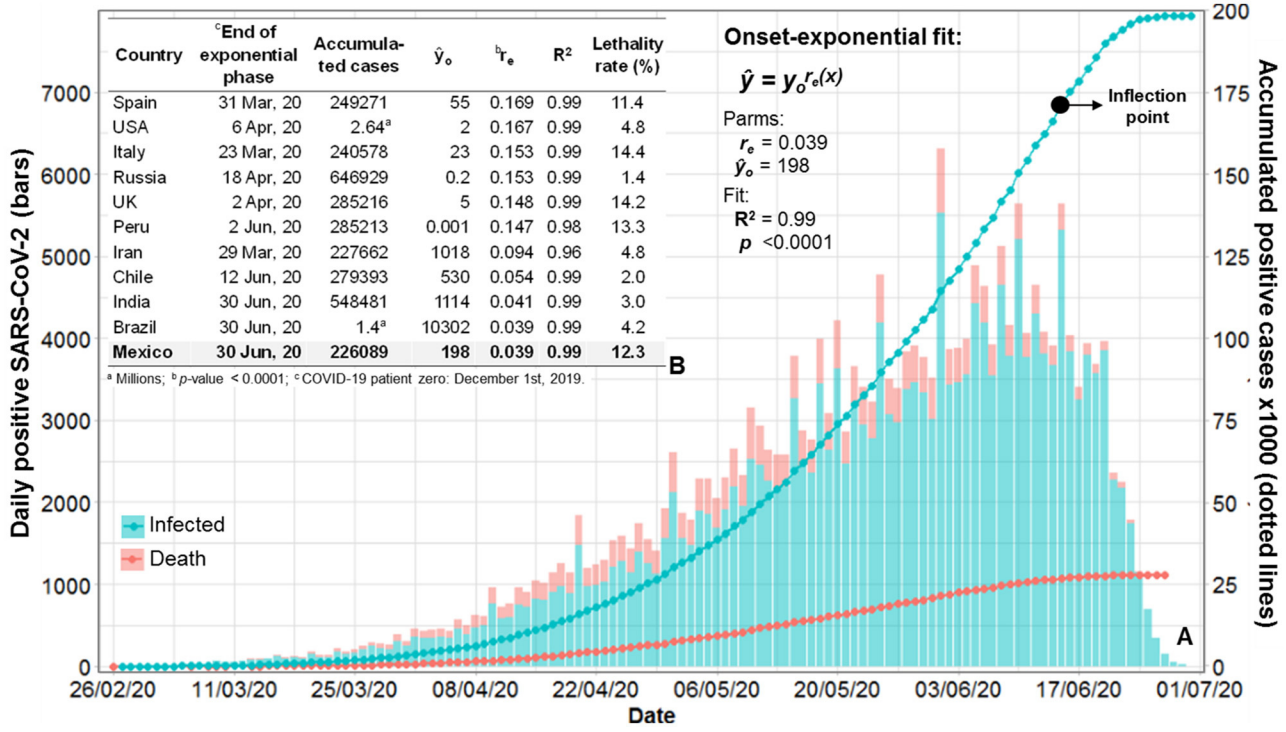

FIGURE 2
Confirmatory modeling of the first COVID-19 exponential epidemic phase in Mexico and selected countries. **(A)** First COVID-19 epidemic wave in México from 27 February to 30 June 2020. Absolute (bars) and cumulative (lines) daily cases of RT-qPCR-positive individuals representing the infected cohort A and the mortality subcohort A′. **(B)** Estimated epidemic rate (r_e) fitted (R^2 and p-value) with the exponential model from the onset (y_o) to the curve inflection point (•) of the first COVID-19 wave in Mexico compared with that of ten countries with the highest infection accumulated positive cases. Lethality rate and epidemic rate variability ($r_e = 0.04–0.17$), with high fitting model precision ($R^2 > 0.96$) indicate fast but differential SARS-CoV-2 spreading on populations. Source: Original data matrix of selected countries downloaded from Johns Hopkins University. All analyses were performed by authors.

exhibited at least one CD (55.5% of whom were men), representing 27.1, 13.1, and 7% of single CD, comorbidity, and multimorbidity, respectively. The most reported chronic diseases were obesity (20,539 cases, 52.3% men) and hypertension (14,048 cases, 54.1% men). Grouped into categories, metabolic diseases (i.e., diabetes, obesity, immunosuppressants, and CKD) represented 39.7% of CD cases (Table 1). Diabetes–hypertension (4.5%) and diabetes–hypertension–obesity (2%) were the most prevalent comorbidity and multimorbidity, respectively. The control dataset (cohort B), with 283,450 RT-qPCR negative cases (Figure 1), had similar age, gender, and CD structure to cohort A.

Probabilistic risk categorization for SARS-CoV-2 infection and mortality

As the first probabilistic classificatory approach applied to the infected cohort A (226,089 individuals), tree risk categorization significantly selected age as the primary factor of infection risk, with 46.9% of the explained variance (cp-value = 0.000003) (Figure 3A). The age cutoff onto two main probabilistic branches, from which a significant classificatory risk node was derived, was 46 years, which represented 123,047 ($p = 0.001–0.009$) and 103,042 ($p = 0.001–0.002$) for younger and older than the significant age cutoff, respectively. Furthermore, age (29 years) and sex were the second most significant subordinated factors toward infection ($p = 0.001$). Notably, NOCD represented only 6.4% of the explained variance due to restricted probabilistic combinations only within age and sex toward infection. This restricted determination resulted in 58,679 and 28,204 infection cases associated with NOCD in the root branches determined by sex and age (29–46 years), respectively.

A similar low variance contribution was found on infection associated with CDs. The type of disease determined the probability of infection in individuals with one CD, conditioned by age, being higher in those individuals exhibiting diabetes (12.3%, $cp = 0.0006$), hypertension (10.1%, $cp = 0.0001$), and obesity (7.8%, $cp = 0.001$) accounting for a total of 30.2%. Sex contributed 9.7% of the overall infection risk, mainly associated with ages older than 46 years. For instance, for women younger and older than 46 years threshold, 12,829 and 28,702 had SARS-CoV-2 infection, respectively, and exhibited at least one chronic disease (Figure 3A). For the same contrasting risk scenario considering only diabetic women, there were 2,918 and 13,293 positive cases for younger and older than the 46-year cutoff, respectively. Notably, this combinatory effect was even higher in men, with 2,481 and 42,117 cases, indicating a higher infection probability in diabetic older men

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TABLE 1 Structure of 226,089 SARS-CoV-2 infected cohort A, including the subcohort A' with 27,769 mortality cases, and MoI and MWI epidemiological relative indices adjusted by age and sex.

Category	Age	$\bar{x}$ age	Men			Women			Total	
			Death	Cases	MoI[X]	Death	Cases	MoI	Deaths/cases	MoI
Metabolic	<29	24.6	124	3,077	0.040	126	3,077	0.041	250/6,154	0.041
(diabetes, obesity, Imm, and CKD)	29–37	33.7	438	5,381	0.081	195	4,746	0.041	633/10,127	0.063
	37–46	42.3	1,243	9,001	0.138	601	7,534	0.080	1,844/16,535	0.112
	46–56	51.4	2,730	12,267	0.223	1,549	10,589	0.146	4,279/22,856	0.187
	> 56	67	7,004	18,038	0.388	5,137	16,089	0.319	12,141/34,127	0.356
Subtotal			**11,539**	**47,764**	**0.242**	**7,608**	**42,035**	**0.181**	**19,147/89,799**	**0.213**
MWI[Y]			**37.22**			**48.47**			**25.36**	
Cardiovascular	<29	23.9	44	689	0.064	46	504	0.091	90/1,193	0.075
(hypertension and CVD)	29–37	33.9	118	1,506	0.078	62	1,004	0.062	180/2,510	0.072
	37–46	42.6	504	3,569	0.141	260	2,812	0.092	764/6,381	0.120
	46–56	51.6	1,421	6,675	0.213	843	5,760	0.146	2,264/12,435	0.182
	>56	70	5,771	15,045	0.384	4,114	12,991	0.317	9,885/28,036	0.353
Subtotal			**7,858**	**27,484**	**0.286**	**5,325**	**23,071**	**0.231**	**13,183/50,555**	**0.261**
MWI			**27.49**			**36.39**			**18.85**	
Respiratory	<29	24.4	44	2,681	0.016	16	1,663	0.010	60/4,344	0.014
(COPD, asthma, and smoking)	29–37	33.5	129	3,102	0.042	35	1,994	0.018	164/5,096	0.032
	37–46	41.6	312	3,292	0.095	95	2,204	0.043	407/5,496	0.074
	46–56	51	569	3,194	0.178	223	2,071	0.108	792/5,265	0.150
	>56	68	2,224	5,705	0.390	976	3,117	0.313	3,200/8,822	0.363
Subtotal			**3,278**	**17,974**	**0.182**	**1,345**	**11,049**	**0.122**	**4,623/29,023**	**0.159**
MWI			**10.88**			**8.80**			**6.28**	
Other CDs	<29	20.7	16	207	0.077	10	260	0.038	26/467	0.056
	29–37	33.7	7	176	0.040	2	308	0.006	9/484	0.019
	37–46	42	19	224	0.085	19	328	0.058	38/552	0.069
	46–56	51.1	36	189	0.190	23	276	0.083	59/465	0.127
	>56	68	128	276	0.464	60	220	0.273	188/496	0.379
Subtotal			**206**	**1,072**	**0.192**	**114**	**1,392**	**0.082**	**320/2,464**	**0.130**
MWI			**0.65**			**0.67**			**0.41**	
Nonchronic disease	<29	22.9	117	13,554	0.009	58	14,070	0.004	175/27,624	0.006
	29–37	33.5	275	13,678	0.020	96	12,917	0.007	371/26,595	0.014
	37–46	41.9	721	14,262	0.051	231	12,136	0.019	952/26,398	0.036
	46–56	51.1	1,468	11,960	0.123	426	9,262	0.046	1,894/21,222	0.089
	>56	66	3,058	10,948	0.279	1,242	6,649	0.187	4,300/17,597	0.244
Subtotal			**5,639**	**64,402**	**0.088**	**2,053**	**55,034**	**0.037**	**7,692/119,436**	**0.064**
MWI			**17.50**			**12.50**			**9.75**	
Total			**18,289**	**123,616**		**9,480**	**102,473**		**27,769/226,089**	

COVID-19 data of the first onset-exponential epidemic phase in Mexico.
[X] Relative mortality index (MoI) associated to CDc and age_c. [Y] Relative mortality-weighted index associated to CDc (MWI).

than in diabetic women. In individuals younger than 29 years, the infection risk associated with those exhibiting at least one CD was 25.6%. The remaining CDs cases, independent of sex, were associated with obesity (4,393 cases), smoking (596 cases), and immunosuppressants (314 cases) with a risk of 14.5%. Other CDs, such as kidney (CKD), cardiovascular (CVD), smoking, and immunosuppressants, accounted for 6.9% of the infection risk variance. Lower risk of infection, but significant ($p = 0.009$),

probably due to underrepresentation in cohort A, was found to be associated with individuals with comorbidities, i.e., more than one CD, such as obesity and smoking (1,556 men); diabetes–obesity–smoking (1,009 men); diabetes–CVD (953 women); and obesity–immunosuppressant (60 women) (Figure 3A).

In the restricted analyses of the mortality subcohort A' (27,769 cases), age was again the primary significant risk factor with 72.3% of the explained variance conditioned by the type of CD (*cp*-value < 0.000024), from which a significant tree classification risk was derived upon a 56-year cutoff ($p = 0.001$–0.008) (Figure 3B). NOCD accounted only for 3.7% of the variance, representing 26.9% of all death cases ($cp = 0.0006$, $p = 0.001$). A robust significant risk, representing 48% of the cases, was composed of women and men (w, m) older than the 56-year cutoff who mainly exhibited diabetes (19% women, 27.9% men; $cp = 0.0004$), hypertension (11.5% women, nonsignificant in men, $cp = 0.0001$), and CKD (3.5% women, 5.3% men; $cp = 0.0009$). Deaths with comorbidity combinations involving diabetes were significantly associated with CKD among patients aged 56 years, regardless of sex (401 cases). Conversely, in those individuals older than 56 years, diabetes was significantly combined with hypertension (1,748 women and 2,261 men) (Figure 3B). Multimorbidity disease significant combinations, regardless of the age category, included diabetes–CKD–CVD (10 cases), diabetes–hypertension–immunosuppressants (14 women), and diabetes–hypertension–CVD (8 men) (Figure 3B). For individuals younger than 29 years, mortality was independent of sex and mainly associated with obesity and hypertension (60 and 32 deaths, respectively). However, this node was not significant.

The second probabilistic associative approach applied to the infected cohort A and subcohort A', based on the matrix of the Spearman's *rho*-values (Figures 4A1, B1), confirmed that CD, age, and sex did not fully explain infection risk toward SARS-CoV-2. NOCD, with 52.8% of infection probability and conform for 119,436 positive cases, represented a well-separated independent cluster ($p = 0.05$) at a Euclidean distance of 1.4 cutoff. The CDs and demographic factors formed four risk clusters with 47.2% infection probability (Figure 4A2) ($p = 0.04$–0.06). Age and sex conform a cluster with diabetes and hypertension, and obesity and smoking, respectively ($p = 0.05$). The infection risk increased to 25.4% and 15.3%, respectively, for individuals who presented the two diseases (i.e., comorbidity). Age influenced the vulnerability of older people with diabetes or hypertension to developing SARS-CoV-2 infection ($p < 0.00001$). Age-related associations with diabetes and hypertension had the highest positive *rho*-values of 0.39 and 0.33, respectively (Figure 4A1).

Contrary to the infection scenario and targeting only the subcohort, the higher probability for mortality was associated with CDs and age totaling 72.2% (Figure 4B2) ($p = 0.05$; rho = −0.51–0.31). NOCD and sex defined a well-distant risk cluster of 27.8% ($p = 0.05$). Older people with comorbidity of diabetes–hypertension ($p = 0.04$) had an increased risk of death at 60.5%, whereas those with a single CD accounted for only 18.8%. These conditions were more determinant over the threshold of 56 years (Figure 4B2). The comparison between infection and mortality dendrograms showed a slight displacement of risk-cluster location with an estimated 66% similarity, thus indicating differences in influencing health factors toward SARS-CoV-2 outcome (Figures 4A2, B2).

In the negative cases of cohort B, the variance structure was similar to cohort A (Supplementary Figures 1A, 2 and Supplementary Table 2). The primary statistically significant age cutoff was also 46 years ($p = 0.001$–0.007) (Supplementary Figure 1A). For those older than 46 years (51,206), smokers were the first cutoff linked to obesity. Meanwhile, nonsmokers were associated with diabetes, obesity, and hypertension. For those under 46 years (58,337), obesity was the leading cutoff, but linked to diabetes and smokers. In NOCD-negative individuals (173,907), the population structure variance was determined only by sex and age as expected (Supplementary Figure 1 and Supplementary Table 2). The cluster structure was also similar to positive SARS-CoV-2 in cases of cohort A. The cross-dendrogram correlation revealed associativity of $r^2 = 0.93$ among cohorts. Notably, asthma was included in the sex–obesity–smoking cluster (Supplementary Figure 2).

SARS-CoV-2 relative *mortality indices*

The relative *mortality index* (MoI) stratified by age confirmed the differential effect of CD category (CD_c) and NOCD on mortality (Figure 5A). Cardiovascular and metabolic diseases represented the higher index with 0.26 and 0.21, respectively, whereas NOCD was the lowest with 0.06 (Table 1). MoI values increased by age category (age_c) and were higher, but similar, for patients older than 56 years among CD_c (0.35–0.37) compared to NOCD (0.24), thus indicating a significant conditional age effect on mortality (Figure 5A). Conversely, for ages less than 56 years, the MoI did not exhibit clear differences between CD_c and NOCD. As for sex, the MoI was consistently higher among men than women, independent of age, CD_c, or NOCD (Table 1).

The relative *mortality-weighted index* (MWI) showed that mortality was also influenced by CD_c and sex (Figure 5B). Again, the individuals with metabolic or cardiovascular diseases were associated with a higher mortality risk index of 25.4 and 18.9, respectively, compared to NOCD (9.8). However, contrary to MoI, women were notably the most vulnerable in metabolic and cardiovascular categories with 48.5 and 37.3, respectively. Furthermore, men had a higher risk associated with respiratory diseases and NOCD (Table 1; Figure 5B). These indices were calculated relative to each CD_c to avoid biases due to sample underrepresentation of specific chronic disease category in cohort A.

Discussion

Despite massive vaccination and lethality reduction, the recent COVID-19 pandemic, which was characterized by fast virus contagion, a dynamic prevalence of variants, and a reduction of the age threshold for infection, raises questions about our mechanistic comprehension of SARS-CoV-2 epidemiology at the communitarian level (6). Most studies continue to focus on an understanding of the infection clinical outcome,

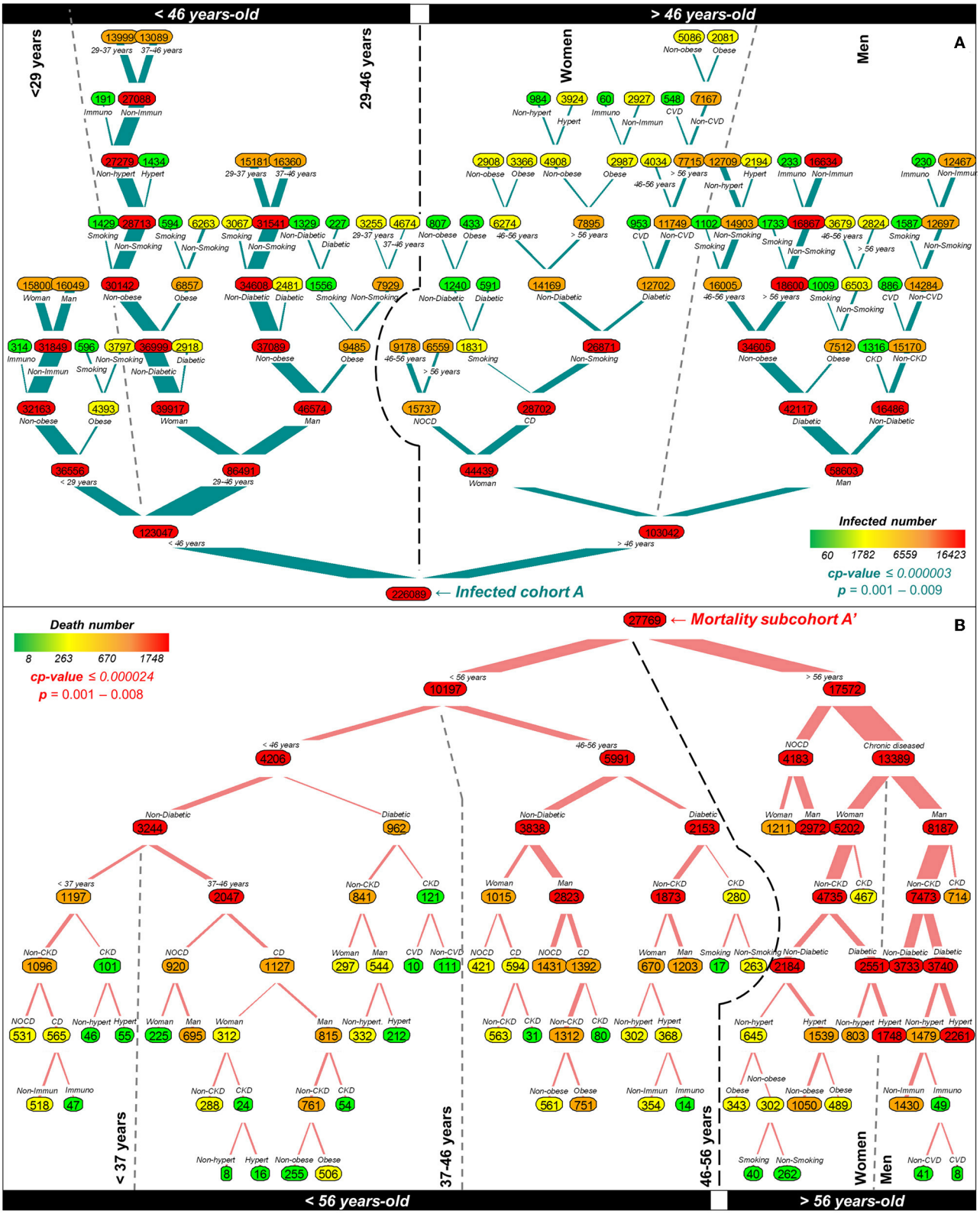

FIGURE 3
Tree risk categorization of infection and mortality due to SARS-CoV-2 during the onset-exponential phase of the first COVID-19 epidemic wave in Mexico based on 226,089 positive cases and 10'857,272 metadata records comprising 13 variables including NOCD and CDs. Branch thickness represents the main root of significant risk. The colored bar scale represents the number range of positive cases applied to nodes. **(A)** The major virus infection risk implicated four main branches, highlighted by upper black boxes and vertical dotted lines, determined primarily by age, followed by sex, with a *cp*-value ≤ 0.000003 ($p < 0.009$). The infection risk for individuals with NOCD represented 52.5%. **(B)** The mortality risk was also influenced by age (*cp*-value ≤ 0.000024; $p < 0.008$) but conditioned by chronic diseases with a higher association in older to 56 years (48%) and splitting the risk by sex (women = 38.9%; men = 61.1%). NOCD accounted for 26.9% of the mortality risk. Main and secondary tree branches are highlighted in bottom black boxes and vertical dotted lines, respectively.

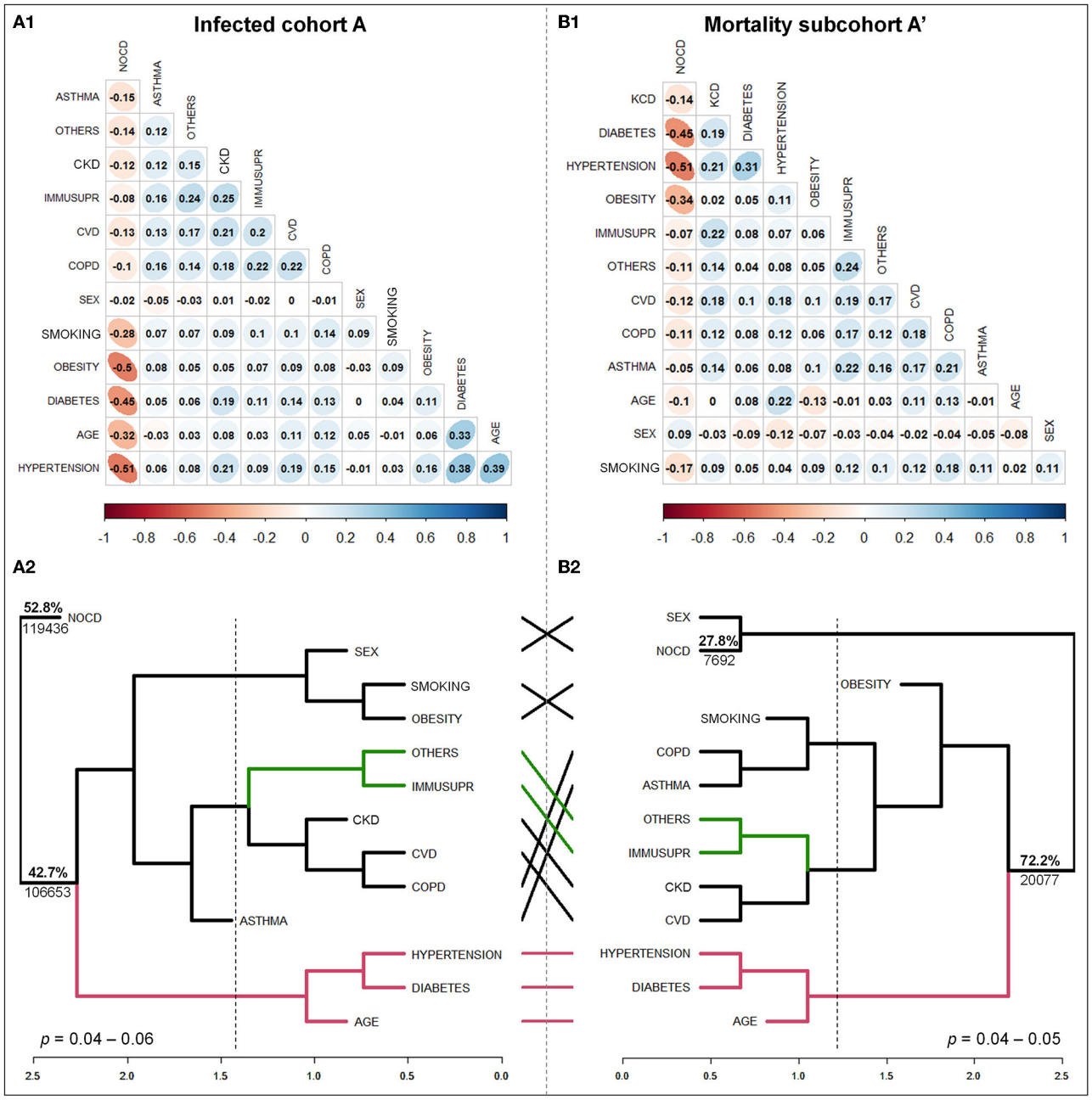

FIGURE 4
Differential risk structure toward infection **(A1, A2)** and mortality **(B1, B2)** due to SARS-CoV-2 based on Spearman's *rho*-values estimated with 13 variables, comprising sex, age, nonchronic (NOCD), and 10 chronic (CDs) non-infectious diseases associated with 226,089 infected individuals during the onset-exponential phase of the first COVID-19 epidemic wave in Mexico. **(A1, B1)**: correlation matrix for the infected cohort A and mortality subcohort A', respectively. The colored bar-scale represents the *rho*-value. If closer to ± 1 indicates a higher correlation between variables. **(A2, B2)**: Dendrogram of rho, linked to cluster analyses for the infected cohort A and mortality subcohort A', shows respectively, a clear independent and dependent risk effect on CD, age, and sex, respectively. The scale at the bottom represents the dissimilarity of Euclidean distance. The dotted line represents the cutoff for risk-cluster conformation, and the percentage is the estimated risk based on positive cases associated with a specific branch ($p = 0.04–0.06$). Lines connecting dendrograms identify the clustering variables. Others. Other CDs.

particularly the post-COVID condition, the development of cure treatments, and the enhancement of vaccines to include children (7, 8, 11, 31–33). However, there is still a strong need for comprehensive studies associated with virus behavior at the ambulatory population level for surveillance and prevention purposes (21). Current forecasting relies on limited clinical and hospital settings data (34–38). Moreover, current data availability and quality of detection and monitoring have been strongly compromised based on the worldwide expectation of immunization coverage to cope with the disease.

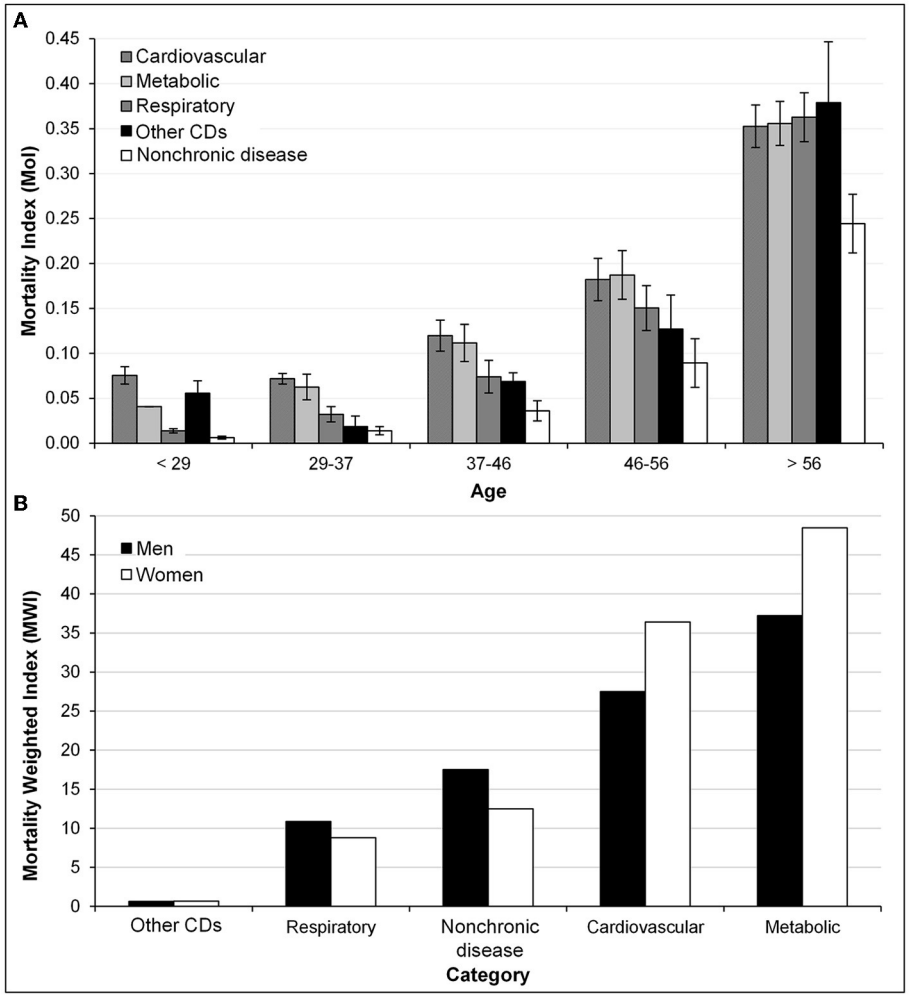

FIGURE 5
Association of SARS-CoV-2 positive individuals exhibiting nonchronic diseases (NOCD) or any CD within five categorized chronic diseases (CD_c) with COVID-19 mortality at the first exponential epidemic phase in Mexico. **(A)** Differential increase of relative *mortality index* (MoI) values on individuals with NOCD and CD_c upon age category increase (age_c). Bars represent the standard deviation. **(B)** Differential effect on relative mortality-weighted index (MWI) values of men versus women on respiratory and NOCD (higher) and on cardiovascular and metabolic category (lower).

The recent endemic and seasonal statement may even more discourage keeping epidemiological studies at the communitarian level (39).

This study deals with a fundamental epidemiological assumption of the preexistence of a susceptible population as a driving force for SARS-CoV-2 epidemics. Our findings challenge the presence of such a subpopulation. The analyses of 226,089 positive individuals and 10′852272 metadata records representing the specific onset-exponential first wave in Mexico (Figure 1) suggest that infection at the communitarian level relies more on infectious sources in the proximity of individuals independently of their health conditions, sex, or age as has been commonly implied (40–42). Rather than 'choosing' vulnerable subpopulation(s), this random infection was supported by the fact that baseline chronic diseases, extensively associated with COVID-19, did not condition infection. In one probability scenario, our structural risk analyses showed that individuals with NOCD have a slightly higher infection probability (52.8%) than those exhibiting any CD, including comorbidities, without age and sex influence ($p = 0.05$). In a second scenario, a cutoff of 46-year individuals was conditioned to diverse risk categories of virus infection ($p = 0.001$–0.009). However, although age and sex have been extensively associated with COVID-19 severity and always associated with CDs under our analytical scenarios, age standalone was a significant factor in shaping the infection risk structure in the population but decreased the age threshold with respect to most reports, wherein older people appear to be more vulnerable. In such reports, the focus on the clinical evolution of inpatients may explain this discrepancy (11, 33, 38, 40, 41, 43). The independent effect of infection regarding CDs toward COVID-19 was supported by the health structure of negative cases with a similar tendency but a higher proportion of NOCDs (61.4%, $p < 0.007$) (Supplementary Figures 1, 2 and Supplementary Table 2).

After restricting the analysis to the mortality subcohort, the results are in agreement with extensive studies suggesting that CD, age, and sex are implicated in COVID-19 severity (33, 40, 41,

44–47). Nonetheless, severity is the outcome of the pathogenesis process beyond infection. This subpopulation included 89.5% of inpatients (age: 24–98 years; men and women 1.9:1). However, in our findings, CD risk categories were conditioned explicitly by age, with an age threshold of 56 years ($p = 0.001–0.008$). Moreover, an age cutoff at 46 years associated with sex was determined as a second significant risk level with some chronic diseases. Similar to other reports, mortality associated with CD increased with age (40, 44), and individuals with hypertension and diabetes, adjusted by their implication on comorbidities, had a differential increase in infection and mortality risk (44, 45, 48, 49). Moreover, sex implication for CD and COVID-19 fatality outcomes are recognized, but not a clear-cut specific association (11, 41, 49). In our results, women exhibited a higher vulnerability to death associated with metabolic diseases (i.e., diabetes, obesity, immunosuppressant, and CKD). In contrast, men showed a higher vulnerability to respiratory diseases (i.e., COPD, asthma, and smoking), even though infection in diabetic individuals was more than 3-fold concerning women.

The CD factor in our research framework was based on the suitability of the Mexican population due to the high incidence of metabolic and cardiovascular chronic diseases (14, 15). However, the analyzed metadata ($N = 581,580$) accounted for 16.2, 12.5, and 16.3% of obesity, diabetes, and hypertension, respectively, which is in contrast with the 40.2, 10.6, and 13.4% of the last official survey specifically designed to estimate the status of CD ($n = 120,843$) (50). When conceding that the slightly lower prevalence of diabetes and hypertension, and higher prevalence of obesity in the official data were the proper estimations, such values may not change our fundamental findings. Specifically, the independent SARS-CoV-2 infection probability and age are significant factors in shaping the infection risk.

These findings shape the classical paradigm of the preexistence of a specific susceptible population for the occurrence of epidemics. This may be true for diseases framed by long host–pathogen coevolutive processes and endemicity but not for pathogens encountering a new host. The SARS-CoV-2 strain diversity and mutational patterns through time and space (51, 52), as well as the parasitic fitness switch from aggressivity to spreading survival, appear to be indicators of an early evolutionary process involving a pathogen obligated to survive on the host (53). In this development, vaccination as a massive host intervention has played a minor role in comparison to host genetics and health attributes of the population itself, as inferred from this study and many clinical studies (8, 9, 51, 54, 55).

The spread of SARS-CoV-2 and pathogenicity support the rationality of these findings. The airborne virus spreading, which is the main contagious mechanism through respiratory droplets and, to a lesser extent, via aerosols (56, 57), is not host-target specific, which allows the virus acquisition by any individual upon inoculum exposure (58). Primary infection requires upper respiratory tissues for rapid multiplication before host internalization (59–61). This pathway is mediated through high angiotensin-converting enzyme 2 (ACE2) receptor expression in epithelial cells lining salivary gland ducts (60, 62), and other respiratory tissues, heart, and gastrointestinal tracts but with lower expression and infectivity (8, 55, 63). The coding gene of ACE2 is constitutive to the human genome with low protein-coding variability and no differential expression due to sex, age, or population (55, 64, 65).

Therefore, we postulate that infection with SARS-CoV-2 originates from random virus exposures rather than a specific health condition. Infection is the first stage of pathogenicity involving virus–host recognition and entry into epithelial cells to initiate virus multiplication (61). Infection may not lead to disease, as asymptomatic conditions imply (21). This scenario departs from the general usage of infection as equivalent to disease or severity [e.g., (51)]. Once the virus infection is established, health, genetics, and other determinants may play a role in the COVID-19 outcome, including asymptomatic and severe courses with acute respiratory distress syndrome, multiorgan involvement, and death (9). However, at least at the early virus replication stage, it follows an evolutionarily conserved path common to viruses, thus allowing for unrestricted multiplication (61). Current epigenetic studies have shown that ACE2 hypomethylation in the nasal epithelium can lead to increased SARS-CoV-2 infectivity and COVID-19 severity via a greater abundance of ACE2 receptors (7, 8). A meta-analysis of plasma ACE2 also demonstrated that elevated ACE2 levels had a causal relationship with COVID-19 infection, severity, and hospitalization and that a solid X-linked locus associated with ACE2 may explain sex differences in ACE2 expression across various tissues (51).

Although the framework of this extensive study was the high occurrence of obesity/overweight (33–60%), hypertension (32–45%), and diabetes (3.1–10.6%) in the Mexican population (14, 15, 50), as well as one of the highest lethality rates (12.3%), further epidemiological studies may be needed to unveil the driving question of this research. The inclusion of diverse core populations, as implied by contrasting fatalities and epidemic rates of selected countries in this study (Figure 2), may provide advanced insights when considering ethnicity and geographical disparities, coupled with significant genomic data and health determinants. However, these results encourage the imperative need for communitarian approaches to develop preventive surveillance systems. The development of algorithms to address ambulatory populations may improve COVID-19 management and cope with zoonotic threats, without assuming a specific susceptible subpopulation that is reached through clinical or hospital settings (21). Our results may also support the benefit of massive ambulatory SARS-CoV-2 testing conducted for several countries during the critical contagious stage (58), rather than using digital risk assessment or directing tests on individuals upon presumptive COVID-19 symptoms to assist disease control treatment (66–70). It is well known that asymptomatic individuals, estimated at 22.1% under lockdown conditions (58), may exhibit a comparable virus titer to those with symptoms and thus could play a significant role in transmission chains (21). A web-app surveillance platform, linked to testing at clustering labor, social, and household environments, may overcome the cost-time factors of massive testing and effectively accomplish the confinement strategy and clinical monitoring at the community level (21). Although WHO and many countries have recently declared the end of COVID-19 as public health emergency (2), the risk of new variants and emerging diseases should encourage us to continue our comprehension of this epidemic to enhance local and global preventive health systems.

Conclusion

Based on 24.4 million metadata records associated with 509,539 official RT-qPCR cases accumulated during the onset-exponential phase of the first epidemic wave in Mexico, we provided robust epidemiological evidence to support our hypothesis that SARS-CoV-2, a novel pathogen to the human population, did not encounter a susceptible subpopulation with a specific set of health condition for the infection establishment and epidemic development. However, the clinical evolution of COVID-19, such as disease severity and mortality, was associated with vulnerability factors explicitly conditioned by age and sex, as has been extensively published. The differentiation of infection, as the process of the successful virus, entering and early multiplication in the host, independent of the disease outcome, was fundamental in this research to primarily account for an ambulatory and hospitalized cohort. The specific selection of the onset-exponential phase of the first epidemic wave was also essential to assess the cohort risk structure based on the assumptions of random population exposure to the virus due to the fast spreading of the virus (lethality rate $=$ 12.3%, $R_o > 1$), limited and unsteady immunological response, pathogen capabilities to evade or subvert host defense mechanisms, constrained clinical knowledge for treatment, and unprepared health systems. These findings encourage the addressing of communitarian approaches to develop preventive surveillance systems to target ambulatory populations. Such systems may complement conventional and specific surveillance platforms, such as SUIVE (https://sinave.gob.mx/) or SISVER (https://sisver.sinave.gob.mx/influenza/), respectively, that are currently in operation in Mexico. This view may effectively intervene in COVID-19, which remains a global health risk, and potential zoonotic threat without assuming a specific susceptible subpopulation targeted by new pathogens with no signals at the human coevolutive microbiological core. To our knowledge, this is the first work addressing this fundamental epidemiological question.

Limitations

The limitation of this research was derived from SARS-CoV-2 diagnostic data upon presumptive COVID-19 symptoms or associations with infected individuals. Therefore, the database does not represent an entirely random sampling of the ambulatory population. Despite the high lethality rate observed during the addressed epidemic phase, the epidemic rate was lower compared to many countries, thus restricting the sampling size and health structure of the studied population. Data on social, behavioral, and environmental determinants and cases with asymptomatic conditions were unavailable. Although confinement was not mandatory in Mexico, restricted activities limited the children and young people's movements, thus preventing data of these cohorts despite reports of less susceptibility (58).

Data availability statement

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

Author contributions

GM-A was responsible for the conception, conceptualization, and design of the study. JC-C and GA-S were responsible for the data acquisition. GA-S and GM-A were responsible for the statistical analyses. GM-A, GA-S, and IÁ-M were responsible for the preparation of the manuscript. 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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.995602/full#supplementary-material

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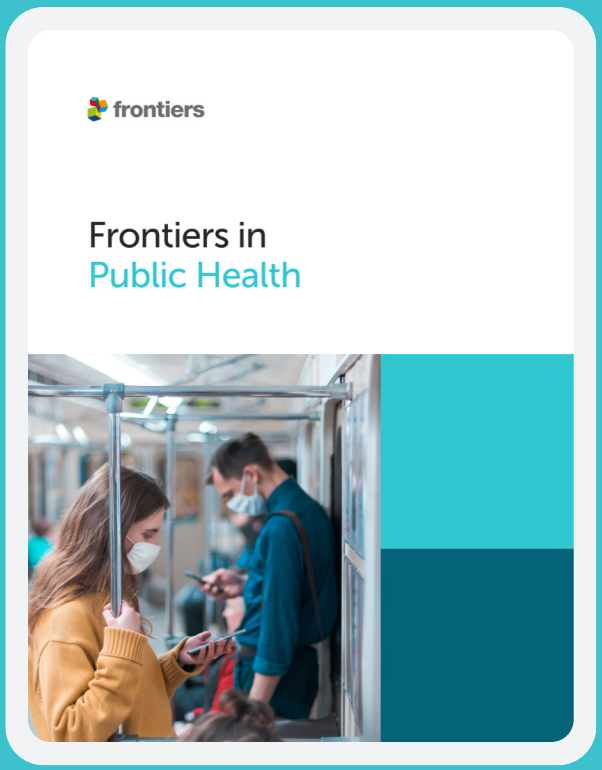

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