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Addressing immediate public health needs as part of Afghan evacuees' resettlement to the United States during the COVID-19 pandemic

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ABSTRACT

Objectives: Since the removal of US troops from Afghanistan in 2021, the United States welcomed Afghan evacuees through Operation Allies Welcome. Using cell phone accessibility, the CDC Foundation worked with public-private partners to protect evacuees from the spread of COVID-19 and provide accessibility to resources.
Study design: This was a mixed methods study.
Methods: The CDC Foundation activated its Emergency Response Fund to accelerate public health components of Operation Allies Welcome, including testing, vaccination, and COVID-19 mitigation and prevention. The CDC Foundation began the provision of cell phones to evacuees to ensure access to public health and resettlement resources.
Results: The provision of cell phones provided connections between individuals and access to public health resources. Cell phones provided means to supplement in-person health education sessions, capture and store medical records, maintain official resettlement documents, and assist in registration for state-administered benefits.
Conclusions: Phones provided necessary connectivity to friends and family for displaced Afghan evacuees and higher accessibility to public health and resettlement resources. As many evacuees did not have access to US-based phone services upon entry, provision of cell phones and plans for a fixed amount of service time provided a helpful start in resettlement while also being a mechanism to easily share resources. Such connectivity solutions helped to minimize disparities among Afghan evacuees seeking asylum in the United States. Provision of cell phones by public health or governmental agencies can help to provide equitable resources to evacuees entering the United States for social connection, healthcare resources, and resources to assist in the process of resettlement. Further research is needed to understand the generalizability of these findings to other displaced populations.

Introduction

Since the removal of troops from Afghanistan in 2021, the United States has welcomed more than 78,000 Afghan evacuees through Operation Allies Welcome. During this time, Afghanistan experienced their third COVID-19 wave, with 155,132 confirmed cases and 7,128 deaths (September 25, 2021).[1,2] Measures were put in place to mitigate the spread of COVID-19 upon entry to the United States. When Afghans entered the United States through Operation Allies Welcome, the US government took steps to reduce the spread of COVID-19 and other communicable diseases.[3]

The CDC Foundation is an independent, non-profit organization that forges partnerships between the Centers for Disease Control and Prevention (CDC) and private and philanthropic sectors. The CDC Foundation is uniquely positioned to respond to this emergency because of existing strategic partnerships with federal and private partners willing and able to implement such a program. The conflict in Afghanistan and COVID-19 pandemic posed unique challenges to those experiencing these events simultaneously. In August 2021, CDC requested the CDC Foundation activate its Emergency Response Fund to accelerate public health components of Operation Allies Welcome, including COVID-19 testing,

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vaccination, and mitigation and prevention strategies.[4] To do so, the CDC Foundation provided cell phones to Afghan evacuees entering the United States. The phones served to provide reliable, direct, and critical connections between individuals, families, and public health authorities. The phones were also used to communicate vital public health alerts and messaging and to connect with health and resettlement resources.

Challenges of resettling in a new country, such as access to critical health care and social support services, are exacerbated by the COVID-19 pandemic. One way to help address these challenges is for aid agencies to offer access to mobile technology for evacuees; the evacuation of refugees to the United States provided an opportunity to understand how mobile technology can enhance the evacuee and refugee experience overall. The United Nations High Commissioner for Refugees has found that “refugees deem connectivity to be a critical survival tool in their daily lives and are willing to make large sacrifices to get and stay connected.”[5] There is now a desired vision of connectivity for refugees, emphasizing “access to available, affordable and usable mobile and internet connectivity … for protection, communications, education, health, self-reliance, community empowerment, and durable solutions.”[6] By providing such connections to Afghan evacuees, the CDC Foundation and partners were working to promote health equity.

Methods

Between September 2021 and ending in May 2022, cell phones were distributed to Afghan evacuees entering the United States via the Philadelphia International Airport in Pennsylvania and the Dulles International Airport in Virginia. In partnership with CDC US Quarantine Stations at the airports, staff were provided instructions on activating the phone during distribution. The process for phone distribution was then integrated into the steps taken to enter into the United States. When planes arrived at designated airports, evacuees were provided a pre-activated phone at a rate of one phone per family unit or single adult, with the average phone serving 3.5 individuals. Roughly 9,979 cell phones were distributed, facilitating health communications with a total of approximately 34,689 individuals—nearly half of the 78,717 evacuees who had arrived in the United States as of October 28, 2021. As of November 2022, 10,220 phones were actively used by evacuees and their families to remain connected. The value of the phones was quickly demonstrated, and the decision was made to extend phone service through April of 2023 for a total of 18 months of service.

Having mobile phones allows evacuees to seek out related resources, find means of documenting their identity, and a place where they can be contacted about potential job, housing, or other opportunities during resettlement. The leveraging of social connectedness via mobile phones helps to minimize inequalities for those seeking asylum. Through this program, at any point throughout the service period, evacuees can take control of their assigned phone number. This means that rather than losing the assigned US-based phone number at the end of the service period, at any time, they can take over the ownership of their number and service plan, avoiding any potential of loss of information or contact with job connections, resettlement resources, or other contacts they have established.

Results

Federal organizations enrolled the phones into a text-based messaging system in October 2021 to push public health and resettlement messages. As of October 31, 2021, 9,091 cell phone numbers began receiving text messages from the Text Illness Monitoring System (TIMS), a text-based messaging system. TIMS was originally developed to monitor symptoms during disease outbreak, allowing for two-way short messaging to help public health organizations quickly identify and respond to cases.[7]

For evacuees, the first round of texts sent included general public health messaging and information to prevent the spread of COVID-19, measles, chicken pox, polio, and tuberculosis—preventing the spread of communicable disease was the prominent concern at the time. Following the first round, message topics were determined by needs and concerns collected from staff working alongside evacuees. The second round included information about resettlement processes and resources. The third round of messages included information about handwashing, safe drinking water, and sneezing and cough etiquette. A fourth round of messaging included information about influenza, respiratory syncytial virus, lice, safe infant feeding, and bottle sanitation practices.

To ensure accessibility to the messages, recipients could choose to receive messages in preferred languages: English, Dari, or Pashto. On receipt of initial messages via TIMS, 44.9% of recipients actively engaged by indicating their language preference (25.1% Dari, 13.7% Pashto, and 6.1% English). The remaining phones (55.1%) defaulted to messages in Dari, which was identified as the most common language among the evacuees.

Beyond providing important public health messages, the phones proved useful to the public health protection effort in two unexpected and impactful ways. At the safe havens (i.e. bases that are housing Afghan evacuees), evacuees were provided written instructions to accompany their prescription medications along with other essential information. Some evacuees, however, lacked literacy and may have only heard their medication instructions one time from the interpreter. To ensure that individuals had ongoing access to critical information regarding their medications, medical providers provided QR codes that link to audio recordings of the evacuees’ specific prescription instructions. The evacuees were able to use their cell phones to scan the QR codes and access the recordings, which ensured that they were able to use their medicines correctly.

Phones were also able to provide unique solutions to health-related documentation during the evacuee's mobile situation. During the evacuation and resettlement process, evacuees were encouraged to keep and carry their medical documents with them in a folder provided by the International Organization for Migration. Ideally, the folder included their entire medical record with information about vaccination history, past pregnancies, nutritional status, and underlying or chronic health issues. The receiving health departments in the evacuees' resettlement communities use this information to facilitate ongoing care and referrals to specialists on resettlement. To ensure access to and safekeeping of these materials, the CDC Foundation worked with federal agencies to encourage evacuees and provided instructions to back up their medical documents by using cell phones to take photos of the materials. If evacuees left behind or misplaced their documents, they can use the photos to help maintain a record of their full medical history and ensure appropriate care, as needed, upon resettlement.

The phones have also assisted evacuees with continuation of ongoing medical care, activities at safe havens, access to virtual health education, and registration for state-administered benefits such as Medicaid, the Supplemental Nutrition Assistance Program (SNAP), and Women, Infants and Children (WIC) Supplemental Nutrition Program.

Discussion

The conflict in Afghanistan and the COVID-19 pandemic posed unique challenges to those experiencing refugees coming to the United States. The CDC Foundation helped to provide 10,000 phones to evacuees entering the United States as a part of Operation Allies Welcome to help assist with public health communications and access to health-related resources. For more information, you can visit this story on the CDC Foundation's Web site, titled “Supporting the Public Health Needs of Afghan Evacuees” at the link https://www.cdcfoundation.org/blog/supporting-public-health-needs-afghan-evacuees.[4]

Cell phones provided access to resources and means of identification, common barriers for evacuees entering the United States. Cell phones uniquely provided a supplemental way for evacuees to maintain their medical and resettlement records and a way to receive translated or spoken instructions for medications. Such solutions help to minimize disparities among evacuees seeking asylum in the United States. In the future, provision of cell phones by public health or governmental agencies can help to provide equitable resources to evacuees for social connection, healthcare resources, and resources to assist in the process of resettlement.

Limitations and future directions

Owing to the sensitive nature of the response, the benefits of the program are qualitative in nature and offered by those working alongside those provided phones. The impact of the phones was collected from partners working alongside evacuees and were reported to the CDC Foundation on an agreed upon structure and timeline. This led to a limit in supportive data points regarding the use of the phones, photo features, QR codes, and other technology-related items. This data limitation has been addressed through the creation of a prospective evaluation plan for future programs, which will be pilot tested in future phone distribution emergency responses. Despite supportive statistics, this emergency response is a case study into the impact that phone distribution can have in providing connectivity during times of humanitarian or public health crisis. This study is not generalizable, and further research should be conducted on the continued benefits of providing cell phones to displaced populations entering the United States.

Author statements

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All authors certify that this material has not been published previously and is not under consideration by another journal. The authors certify that they had substantive involvement in the preparation of this article and are fully familiar with its content.

Ethical approval

Ethical approval was not required.

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Competing interests

The authors have no financial conflict of interest.

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Original Research

COVID-19 vaccine hesitancy in a developing country: prevalence, explanatory factors and implications for the future

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ABSTRACT

Objectives: Vaccine hesitancy is a public health challenge highlighted during the COVID-19 pandemic. This study sought to determine the prevalence and explanatory factors leading to COVID-19 vaccine hesitancy in the Jamaican population to inform vaccination strategies.
Study design: This was an exploratory cross-sectional study.
Methods: An exploratory survey was distributed electronically between September and October 2021 to gather information on COVID-19 vaccination behaviour and beliefs among the Jamaican population. Data were expressed as frequencies and analysed using Chi-squared followed by multivariate logistic regressions. Significant analyses were determined at $P < 0.05$.
Results: Of the 678 eligible responses, most were females (71.5%, $n = 485$), between ages 18–45 years (68.2%, $n = 462$), had tertiary education (83.4%, $n = 564$) and were employed (73.4%, $n = 498$), with 10.6% ($n = 44$) being healthcare workers. COVID-19 vaccine hesitancy was present in 29.8% ($n = 202$) of the survey population, mainly because of safety and efficacy concerns and a general lack of reliable information about the vaccines. The likelihood of hesitancy increased amongst respondents under 36 years (odds ratio [OR] 6.8, 95% confidence interval [CI] 3.6, 12.9), those who delayed initial acceptance of vaccines (OR 2.7, 95% CI 2.3, 3.1); parents for their children and with long waits at vaccination centres. Likelihood of hesitancy decreased for respondents over 36 years (OR 3.7, 95% CI 1.8, 7.8) and with vaccine support from pastors/religious leaders (OR 1.6, 95% CI 1.1, 2.4).
Conclusions: Vaccine hesitancy was more prevalent in younger respondents who were never exposed to the effects of vaccine-preventable diseases. Religious leaders had more influence than healthcare workers to increase vaccine uptake.

Introduction

Vaccines are effective interventions, designed to prevent and control infectious diseases, which are otherwise harmful or deadly, especially in immunocompromised citizens. In 2017, the World Health Organization (WHO) estimated that worldwide, vaccines prevented 10 million deaths between 2010 and 2015.[1] In Jamaica, the vaccination rate is high, averaging above 95% for the traditional vaccines, such as bacillus calmette–guérin; measles, mumps, rubella; diphtheria, pertussis, tetanus; polio; and hepatitis B.[2] Nonetheless, despite the proven efficacy and safety of vaccines, vaccine hesitancy, defined by WHO as willingness to accept some types of vaccines whilst delaying, being reluctant or refusing to accept others,[3] is a long-standing challenge related to widespread disinformation, cultural beliefs and concerns of the immediate and long-term effects.[4,5] This is no different for the COVID-19, as shown by recent reports of non-acceptance or hesitancy because of its perceived safety and efficacy.[6–11] There is a lack of trust and confidence in the importance of the vaccine, which poses direct and indirect threats to health in developed and developing countries.[8–13] Similar to other countries, Jamaica has a low COVID-19 vaccination rate with a myriad of possible factors that may influence the low vaccination rate.[14–17] As such, successful control of the pandemic is partially dependent on widespread acceptance from the public and healthcare workers.[18–20] The objectives of this exploratory study were to determine the prevalence and underlying causes of hesitancy towards the COVID-19 vaccine in the

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Jamaican population and propose recommendations to increase vaccination uptake for new vaccines.

Methods

Study design

Following ethical approval from the University's ethical review board (Reference number: 2021/07/FOSS/111), the study was conducted over a 1-month period between September and October 2021, with the use of an exploratory survey submitted through electronic media and various social media platforms. The survey instrument was adapted from validated questionnaires developed by WHO (2014) and Opel (2011).[3,21] A one-device lock was applied to discourage duplicate responses, where an anonymised unique identifier was generated once individuals clicked on the survey link. No personal traceable data were collected. Respondents gave informed consent for participation. The 46-item survey, a modification of established surveys,[3,21] used open- and closed-ended questions to derive information on immunisation behaviour, beliefs, attitudes and trust towards the COVID-19 vaccine among members of the general population (Supplementary material).

Study sample

The study targeted adults from the Jamaican population. An adequate sample size was determined to be 580 participants, using the Jamaican population of 2.948 million from the PAHO Immunization Newsletter,[2] at a 95% confidence level (CI) with a 5% margin of error, and applying a 50% addition, considering projected low response rates from surveys. Responses with incomplete or missing information on study variables were excluded. A total of 876 responses were obtained to the survey within the first 16 days of the 1-month study period. Of that total, 198 responses (22.6%) were incomplete and excluded, leaving 678 (77.4%) complete responses that were analysed.

Measures

Dependent variable

The main outcome variable was the self-reported hesitancy towards being vaccinated with the available COVID-19 vaccines. Respondents were asked, 'Have you personally received any of the COVID-19 vaccines?,' with response options being 1 = Yes, 2 = No, 3 = Don't know; and 'Have you ever delayed or decided not to get the COVID-19 vaccine/shot for reasons other than illness or allergy?', with response options being 1 = delayed, 2 = refused, 3 = Don't know.

For this study, hesitancy towards the COVID-19 vaccine was treated as a dichotomous variable, where hesitancy was defined as a refusal, non-acceptance or delayed acceptance of the vaccine; acceptance (non-hesitancy) was determined if participants were already vaccinated with a COVID-19 vaccine. In addition, the instrument provided 20 yes/no items for participants to respond on reasons for being hesitant (delaying or refusing) towards the COVID-19 vaccines (e.g. did not think it was needed or would work, possible side-effects, bad experiences, etc.).

Independent variables

The main independent variables used were sociodemographic variables, including gender, age, educational level and employment status, which were further divided into healthcare workers and non-healthcare workers. Parish in which participants live and residential area (urban, rural) were also included. Safety and efficacy concerns and reasons for hesitancy towards the COVID-19 vaccines were categorised as binary variable with yes/no. Additional items included the information source about the COVID-19 vaccines (traditional news sources [TV, radio, Web sites and newspapers], scientific sources, social media, friends or family members, guidance from government officials and healthcare providers).

Statistical analysis

Data collected were analysed using the Statistical Package for the Social Sciences (SPSS) software, version 23. Descriptive data were quantified and expressed as counts and percentages. The Pearson Chi-squared test was used to determine the relationship between different variables (demographics, beliefs and behaviour, etc.) and the COVID-19 vaccine hesitancy. Significant relationships were further analysed using multivariate logistic regressions to determine the contribution of various factors towards the COVID-19 vaccine hesitancy. The regression analysis was presented as adjusted odds ratios (ORs) and the corresponding 95% CIs and *P*-values. For all analyses conducted, significance was determined at $P < 0.05$ (two sided).

Results

Sample characteristics

The demographic characteristics of the sample population are displayed in Table 1.

Non-hesitancy/acceptance of the COVID-19 vaccine and explanatory factors

Acceptance for the COVID-19 vaccine was seen in 70.2% of the respondents. The main reasons indicated for accepting the COVID-19 vaccine were a general trust/understanding of the information garnered from personal research on the vaccine (29.8%), a low rate of adverse effects or death in vaccinated persons (25.8%) and the proven efficacy of the vaccine to reduce the severity of symptoms/hospitalisation (24.6%). Less than 10% of respondents accepted the COVID-19 vaccine based on the belief that it was just another vaccine and vaccines have been around for decades (9.7%), because it has the U.S. Food and Drug Administration/WHO approval (4.8%) and a general trust in the modern technology used (3.2%). Less than 1% of respondents had other reasons for accepting the COVID-19 vaccine (Fig. 1).

Age group ($\chi^2 = 35.3$, $P < 0.001$), education level ($\chi^2 = 9.9$, $P = 0.007$), healthcare work status ($\chi^2 = 4.1$, $P = 0.043$), parish ($\chi^2 = 22.0$, $P = 0.024$) and community area ($\chi^2 = 3.6$, $P = 0.049$) were significantly associated with the acceptance of the COVID-19 vaccine. However, age was the greatest contributing demographic factor. Acceptance of the COVID-19 vaccine was generally higher for respondents aged >36 years, but the likelihood quadrupled for respondents within the ≥56 years old age group (OR 3.7, 95% CI 1.8, 7.8). Simultaneously, the likelihood of hesitancy/non-acceptance of the COVID-19 vaccine increased significantly for respondents within the 18–25 years and 26–35 years age groups (OR 4.1, 95% CI 2.1, 8.0 and OR 6.8, 95% CI 3.6, 12.9). Respondents who accepted the COVID-19 vaccine were also more likely to have a tertiary level education (OR 2.0, 95%CI 1.3, 3.2) and be healthcare workers (OR 1.9, 95% CI 1.8, 3.5).

Many respondents (68.1%) agreed that the COVID-19 vaccine was safe (Table 2), which consequently increased the likelihood of acceptance of the COVID-19 vaccine by >6 times (OR 6.2, 95% CI 4.8, 7.8). Most respondents (93.8%) were also immunised with the traditional vaccines, bacillus calmette–guérin, measles, mumps, rubella, diphtheria, pertussis, tetanus, polio and hepatitis B. The immunisation rate was lower for the newer vaccines, chicken pox,

Table 1
Demographic characteristics for study participants ($N = 678$).

Characteristics ($n = 678$)	Frequency, n (%)	Hesitancy towards the COVID-19 vaccine, n (%)		Chi-squared analysis		Regression analysis	
		Yes ($n = 202$)[a]	No ($n = 476$)	χ^2	P	OR (95% CI)	P
Gender	193 (28.5)				0.926	1.0 (0.7–1.5)	0.926
Male		58 (28.7)	135 (28.4)	0.01			
Female	485 (71.5)	144 (71.3)	341 (71.6)				
Age group, years						4.1 (2.1–8.0)	0.001*
18–25	147 (21.7)	48 (23.8)	99 (20.8)	35.3	<0.001*	6.8 (3.6–12.9)	0.001*
26–35	172 (25.4)	73 (36.1)	99 (20.8)			3.5 (1.8–6.7)	0.001*
36–45	143 (21.1)	42 (20.8)	101 (21.2)			1.3 (0.7–8.1)	0.463
46–55	79 (11.7)	23 (11.4)	56 (11.8)			3.7 (1.8–7.8)	0.001*
≥56	137 (20.2)	16 (7.9)	121 (25.4)				
Education							
Primary	7 (1.0)	3 (1.5)	4 (0.8)	9.9	0.007*	0.7 (0.4–9.0)	0.100
Secondary	107 (15.8)	45 (22.3)	62 (13.0)			4.0 (1.0–1.9)	0.004*
Tertiary	564 (83.2)	154 (76.2)	410 (86.1)			2.0 (1.3–3.2)	0.002*
Job category ($n = 415$)						1.9 (1.0–3.5)	0.048*
Healthcare worker	44 (10.6)	14 (7.0)	58 (12.2)	4.1	0.043*		
Non-healthcare worker	371 (89.4)	187 (93.0)	417 (87.8)				
Community area				3.6	0.049*	0.3 (0.5–1.0)	0.193
Urban	471 (69.5)	130 (64.4)	341 (71.6)				
Rural	207 (30.5)	72 (35.6)	135 (28.4)				

OR, adjusted odds ratios determined from multinomial regression; CI, confidence interval.
*$P < 0.05$.
[a] Reference category for regression analysis.

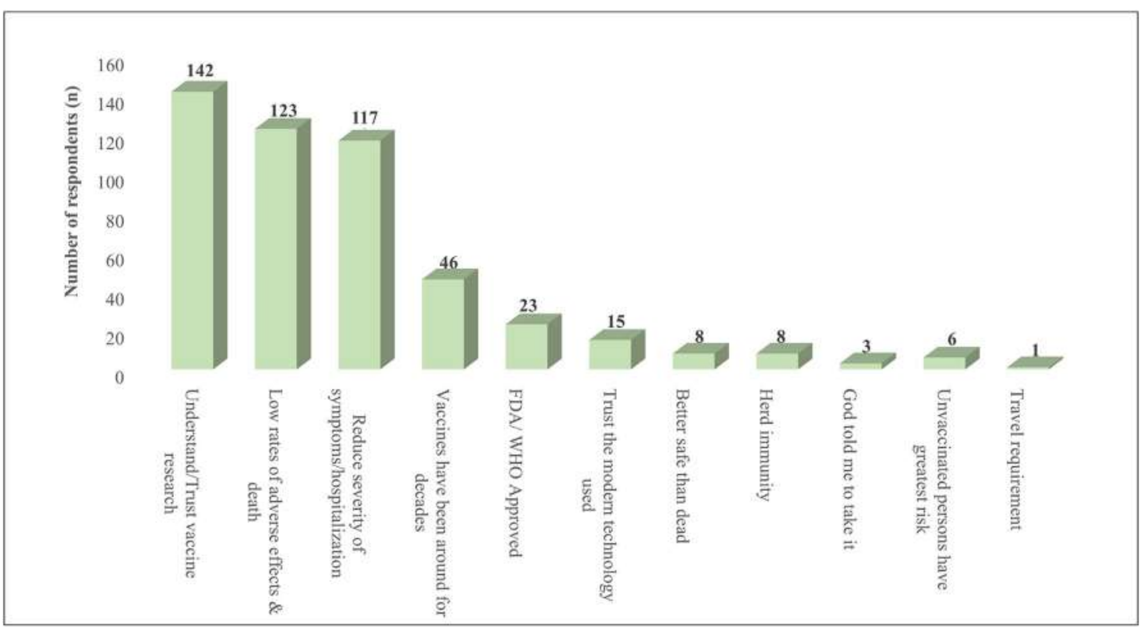

Fig. 1. Reasons indicated by respondents.

pentavalent, pneumococcus, human papillomavirus, rotavirus and influenza but remained high at 71.1%. Respondents who received the recommended vaccines were more likely to receive the COVID-19 vaccine (OR 4.7, 95% CI 2.5, 9.1 and OR 1.9, 95% CI 1.3, 2.7).

Delayed acceptance of the COVID-19 vaccine and explanatory factors

Even with acceptance of the COVID-19 vaccine for themselves, respondents were three times more likely to delay/refuse this vaccine for their child (OR 2.6, 95% CI 1.2, 5.3). This resulted in a COVID-19 vaccine hesitancy rate of 29.8% ($n = 202$) for themselves and 27.4% ($n = 186$) for their child/children. A total of 302 (44.5%) respondents delayed acceptance of the vaccine, with only 36.4% ($n = 110$) later accepting the vaccine, which accounted for 23.1% of the COVID-19 vaccine acceptance (Table 2). In fact, the likelihood of hesitancy towards the vaccine tripled in respondents who initially delayed acceptance of the vaccine for themselves (OR 2.7, 95% CI 2.3, 3.1). Respondents who delayed acceptance of the COVID-19 vaccine indicated that this was mainly due to safety concerns for themselves (97.3%) or their child/children (91.4%). Accordingly, hesitancy also increased significantly when respondents had concerns about the side-effects for themselves/loved ones (OR 5.1, 95% CI 1.8, 14.3) or the technology surrounding the vaccine development (OR 3.6, 95% CI 1.2, 8.9; Table 3).

Reasons for delaying acceptance of the COVID-19 vaccine

As presented in Fig. 2, respondents delayed acceptance of the COVID-19 vaccine because they heard/saw negative comments

Table 2
Immunisation status of respondents and their children ($N = 678$).

COVID-19 vaccination ($n = 678$)	Frequency, n (%)	Hesitancy towards the COVID-19 vaccine, n (%)		Chi-squared analysis		Regression analysis	
		Yes ($n = 202$)[a]	No ($n = 476$)	χ^2	P	OR (95% CI)	P
Received traditional vaccines	636 (93.8)	175 (86.6)	461 (96.8)	25.5	<0.001*	4.7 (2.5, 9.1)	<0.001*
Yes	42 (6.2)	27 (13.4)	15 (3.2)				
No							
Received newer recommended vaccines	482 (71.1)	124 (61.4)	358 (75.2)	13.2	<0.001*	1.9 (1.3–2.7)	<0.001*
	196 (28.9)	78 (38.6)	118 (24.8)				
Yes							
No							
Delayed COVID-19 vaccination for self	302 (44.5)	192 (95.0)	110 (23.1)	297.1	<0.001*	2.7 (2.3–3.1)	0.001*
	376 (55.5)	10 (5.0)	366 (76.9)				
Yes							
No							
COVID-19 vaccination for child/children	77 (11.4)	21 (27.3)	56 (72.7)	8.1	0.005*	2.6 (1.2–5.3)	0.006*
	109 (16.1)	76 (69.7)	33 (30.3)				
Delayed acceptance	242 (35.7)	–	–				
Refused	250 (36.9)	–	–				
Not applicable, no children							
No response							
COVID-19 vaccine is safe	462 (68.1)	28 (13.9)	434 (91.2)	268.6	<0.001*	6.2 (4.8–7.8)	<0.001*
Yes	176 (26.0)	138 (68.3)	38 (8.0)			0.3 (0.2–0.3)	0.001*
No	40 (5.9)	36 (17.8)	4 (0.8)			–	
Unsure of safety							

OR, adjusted odds ratios determined from multinomial regression; CI, confidence interval.
*$P < 0.05$.
[a] Reference category for regression analysis.

about the vaccine (90.9%) or did not have reliable information about the vaccine (46.4%). Information about the vaccine was mainly obtained from electronic or social media platforms ($n = 299$, 44.1%). Only 2.9% of vaccine information ($n = 20$) was obtained from a medical/scientific source. As such, the negative information and lack of reliable information about the vaccine both accounted for a significant increase in the hesitancy towards the COVID-19 vaccine (OR 4.6, 95% CI 2.9, 7.2 and OR 3.5, 95% CI 1.9–6.2). In addition, vaccine support from politicians significantly increased hesitancy in over 60% of respondents who did not accept the vaccine (OR 1.1, 95% CI 1.0, 1.2, $P < 0.001$). However, hesitancy was significantly reduced when the vaccine was supported by pastors/religious leaders (OR 1.6, 95% CI 1.1, 2.4, $P = 0.004$), teachers (OR 1.5, 95% CI 1.2, 2.0, $P = 0.043$), nurses (OR 1.3, 95% CI 1.1, 1.7, $P = 0.046$) and physicians (OR 1.6, 95% CI 1.3, 2.2, $P = 0.007$).

Perceived ineffectiveness (44.5%) of the vaccine was also a major deterrent to getting vaccinated (44.5%), and the belief that the vaccine was unnecessary (45%) resulted in delayed acceptance of the COVID-19 vaccine and doubling of vaccine hesitancy (OR 2.3, 95% CI 1.0, 5.1). Vaccine hesitancy quadrupled with the belief that the COVID-19 vaccine was ineffective against the disease (OR 4.8, 95% CI 1.8–12.4). No respondent identified the cost of the vaccine as a deterrent to acceptance of the vaccine (Fig. 2).

Refusal of the COVID-19 vaccine and explanatory factors

Refusal of the COVID-19 vaccine was mainly due to a fear of adverse effects and/or death for self or loved ones (53.0%) and a lack of reliable information about the vaccine (41.6%). Many respondents also indicated that there were too many uncertainties surrounding the vaccine (35.6%), as it relates to the technology and speed of development. As such, they refused the vaccine because they believed that there was a sparsity of clinical evidence about safety (31.7%) and vaccine ineffectiveness, as it cannot stop/prevent the COVID-19 disease (23.8%). The number of new variants and number of boosters required (13.4%), the long waiting period at the vaccination sites (26.2%) and the coercion/mandate/incentives from the government to take the vaccine (12.9%) were identified as major deterrents to being vaccinated. Other reasons for the refusal of the COVID-19 vaccine were <10% and are shown in Fig. 3.

Beliefs and attitudes contributing to the hesitancy towards the COVID-19 vaccine

Regression analysis showed that the likelihood of hesitancy towards the COVID-19 increased due to various beliefs and practices related to access, awareness and attitude as summarised in Table 3. The odds of hesitancy towards the COVID-19 vaccine increased more than five times if respondents could not be bothered to go to the clinic to get vaccinated (OR 5.0, 95% CI 0.8–30.4) or if getting vaccinated was against the respondents' religion (OR 5.7, 95% CI 0.9–35.5; Table 3).

Discussion

Non-hesitancy/acceptance of the COVID-19 vaccine and explanatory factors

This exploratory online survey assessed the prevalence of vaccine hesitancy towards the COVID-19 vaccine and the contributing factors amongst the Jamaican population. The WHO in 2019 defined vaccine hesitancy as the delay in acceptance, reluctance or refusal of vaccination despite the availability of vaccination services.[3] This hesitancy was noted in 29.8% of the Jamaican population towards the COVID-19 vaccine, which is similar to other studies in Jamaica,[14–16] and the United States at 31%,[22] but lower than Portugal at 65%.[23] This means that the willingness to accept the vaccine is high at 70.2% in our population. This encouraging acceptance rate is similar to findings reported amongst Caribbean countries, including Jamaica,[13–16,24] in the United States,[22] and in a few other countries around the world.[7,11,25] Despite this high acceptance of the vaccine, the actual vaccination rate in Jamaica remains low at 21.1%, as reported on the WHO Coronavirus Dashboard.[26] This low vaccination rate materialised with only 9% of hospitalised patients isolated in public hospitals ($n = 32/360$) and 1% of patients with COVID-19–related deaths ($n = 21/2201$) being fully vaccinated as of

Table 3
Beliefs and concerns about the COVID-19 vaccine amongst respondents ($N = 678$).

Respondent's beliefs/concerns ($n = 678$)	Hesitancy towards the COVID-19 vaccine, n (%)		Chi-squared analysis		Regression analysis	
	Yes ($n = 202$)[a]	No ($n = 476$)	χ^2	P	OR (95% CI)	P
Vaccines protect against serious diseases						
Agreed	136 (67.3)	436 (91.8)	68.6	<0.001*	0.5 (0.2–1.4)	0.204
Disagreed	29 (14.4)	10 (2.1)			3.0 (1.6–5.6)	0.001*
Unsure	37 (18.3)	29 (6.1)			–	–
Heard/saw negative information about vaccines						
Yes	60 (29.7)	40 (8.4)	51.2	<0.001*	4.6 (2.9–7.2)	<0.001*
No	142 (70.3)	436 (91.6)				
Lacked reliable vaccine information						
Yes	29 (14.4)	22 (4.6)	19.3	<0.001*	3.5 (1.9–6.2)	<0.001*
No	173 (85.6)	454 (95.4)				
Vaccine is not needed						
Agreed	33 (16.3)	17 (3.6)	33.8	<0.001*	2.3 (1.0–5.1)	0.041*
Disagreed	169 (83.7)	459 (96.4)				
Vaccine does not work						
Agreed	41 (20.3)	8 (1.7)	73.3	<0.001*	4.8 (1.8–12.4)	0.001*
Disagreed	161 (79.7)	468 (98.3)				
Vaccine is not safe						
Agreed	80 (39.6)	27 (5.7)	122.9	<0.001*	4.5 (2.5–8.3)	<0.001*
Disagreed	122 (60.4)	449 (94.3)				
Someone told me it is unsafe						
Yes	13 (6.4)	5 (1.1)	15.9	<0.001*	0.8 (0.2–3.7)	0.772
No	189 (93.6)	471 (98.9)				
I know someone who had a bad reaction						
Yes	29 (14.4)	6 (1.3)	49.7	<0.001*	4.5 (1.3–15.3)	0.016*
No	173 (85.6)	470 (98.7)				
Could not find the time						
Agreed	28 (13.9)	17 (3.6)	24.2	<0.001*	4.2 (1.9–9.1)	<0.001*
Disagreed	174 (86.1)	459 (96.4)				
Fear of needles						
Agreed	27 (13.4)	18 (3.8)	21.0	<0.001*	1.4 (0.6–3.2)	0.415
Disagreed	175 (86.6)	458 (96.2)				
Against my religion						
Agreed	7 (3.5)	1 (0.2)	12.9	<0.001*	5.7 (0.9–35.5)	0.022*
Disagreed	195 (96.5)	475 (99.8)				
Long wait at clinic						
Agreed	30 (14.9)	18 (3.8)	26.4	<0.001*	2.3 (1.0–5.2)	0.047*
Disagreed	172 (85.1)	458 (96.2)				
Prefers alternative therapy						
Agreed	11 (5.4)	0	26.3	<0.001*	0.3 (0.2–1.3)	0.998
Disagreed	191 (94.6)	476 (100)				
Couldn't bother going to the clinic						
Agreed	6 (3.0)	1 (0.2)	10.6	0.001*	5.0 (0.8–30.4)	0.037*
Disagreed	196 (97.0)	475 (99.8)				
Use of nanotechnology concerns me						
Agreed	38 (18.8)	10 (2.1)	60.2	<0.001*	3.6 (1.2–8.9)	0.020*
Disagreed	164 (81.2)	466 (97.9)				
Use of viral RNA concerns me						
Agreed	55 (27.2)	17 (3.6)	83.6	<0.001*	3.3 (1.5–7.3)	0.003*
Disagreed	147 (72.8)	459 (96.4)				
Side-effect for self/loved one concerns me						
Agreed	174 (86.1)	218 (45.8)	95.7	<0.001*	5.1 (1.8–14.3)	0.002*
Disagreed	20 (9.9)	216 (45.4)			1.0 (0.3–3.2)	0.962
Unsure	8 (4.0)	42 (8.8)			–	–
Side-effect for child concerns me						
Agreed	85 (63.0)	105 (34.9)	50.1	<0.001*	0.9 (0.5–1.5)	0.587
Disagreed	13 (9.6)	130 (43.2)			0.3 (0.1–0.7)	<0.001*
Unsure	37 (27.4)	66 (21.9)			–	-

OR, adjusted odds ratios determined from multinomial regression; CI, confidence interval.
*$P < 0.05$.
[a] Reference category for regression analysis.

Friday, 11 February 2022; based on the COVID-19 Clinical Management Summary published by the Ministry of Health and Wellness, Government of Jamaica.[27] Vaccine hesitancy has been identified by the WHO as one of the top 10 threats to global health.[3] Notably, the COVID-19 vaccine hesitancy has been a major hindrance in the global efforts of controlling the negative

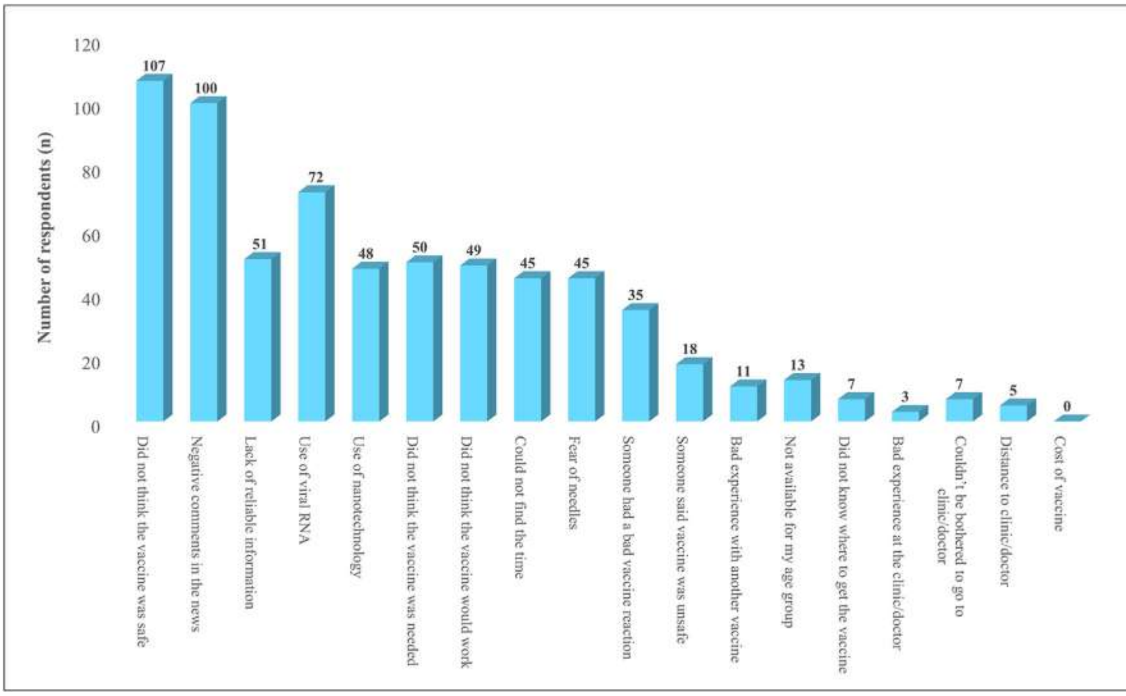

Fig. 2. Factors contributing to delay.

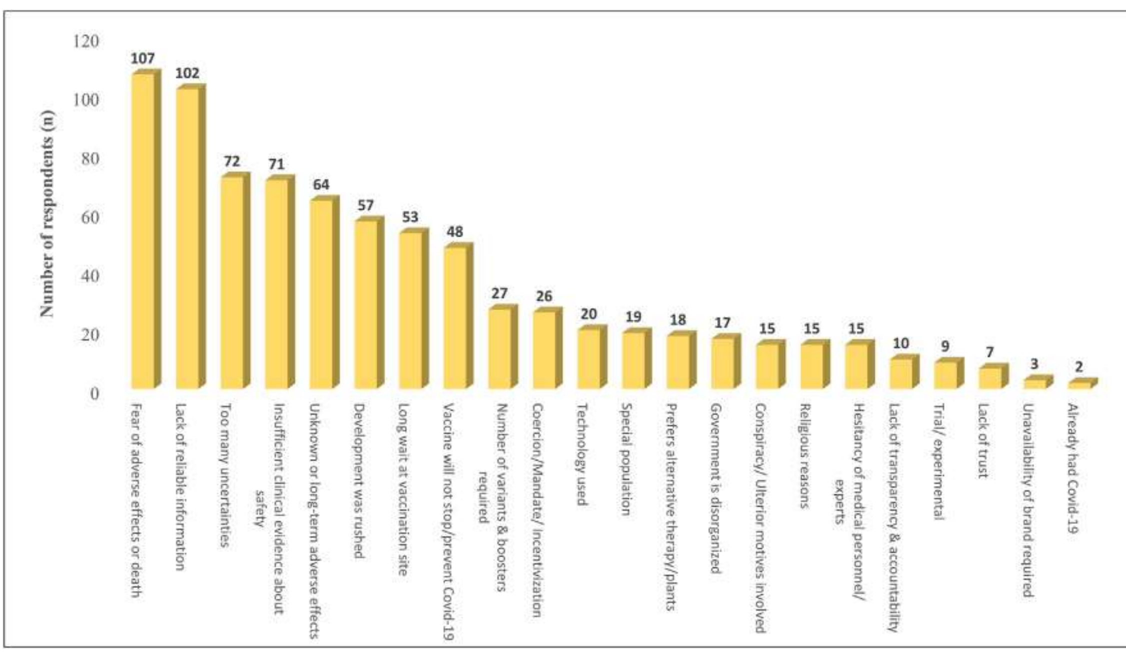

Fig. 3. Reasons for vaccine refusal.

consequences of the COVID-19 pandemic on health and economies.[9,11,28–30]

COVID-19 vaccination services have been available in the country since March 2021,[31] but almost 1 year later, the uptake remains low, suggesting that other factors are at play. Vaccine hesitancy is a complex decision-making process with multiple sources of influences,[4,5] as seen by the many factors that significantly increased the odds of hesitancy towards the COVID-19 vaccine in Jamaica. Similar to other studies, the likelihood of COVID-19 vaccine hesitancy increased significantly below 36 years but was significantly reduced for persons above 36 years, especially ≥56 years.[8–12] This could be related to the older respondents being accustomed to vaccines, having received same and being confident of the safety of vaccines, which was noted as the fourth major reason for acceptance of the vaccine. In addition, the greater vaccine confidence in the older age groups could be related to the recommendations issued by the Jamaican government in the initial stages of the vaccination programme for persons aged >60 years to be vaccinated.[31] Greater focus, through media communications, was placed on the older population because of the greater perceived risk of getting infected or developing severe symptoms of the COVID-19 disease. A similar approach was adopted for healthcare workers, where there was higher risk perception of getting infected or developing severe symptoms due to repeated exposure to sick patients. Similar reports showed that older patients and healthcare workers were more likely to get vaccinated due to the higher risks associated with contracting the disease.[7,23,32] Indeed, reports from While (2021) and Pires (2022) identified low-risk perception as a barrier to vaccine uptake.[9,33] Strategic communication to reduce vaccine hesitancy is a well-recognised approach supported by literature.[9,10,12,34,35]

Delayed acceptance of the COVID-19 vaccine and explanatory factors

Delayed acceptance of the COVID-19 vaccine contributed significantly to the vaccine hesitancy and consequent refusal of the vaccine. Even with acceptance of the vaccine for themselves, some respondents were three times more likely to delay/refuse the vaccine for their children. This was related to the lack of reliable information about the vaccine and the belief that the vaccine was unsafe or ineffective against the COVID-19 disease. These were major determinants of the delayed acceptance or refusal of the COVID-19 vaccine and align to the identified determinants published by the SAGE Working Group.[3] The personal acceptance of the vaccine depicts the confidence that the parent has in the vaccine's importance,[3] which can co-exist with the individual's views that the vaccine is unsafe or may cause harm to the child. This underpins the complexity of vaccine hesitancy and the many determinants, which are part of the decision-making matrix. Safety concern is a major deterrent in getting vaccinated[9–11,22,23,37] and so is the use of social media as a source of vaccine information.[17,36–39] In this study, most information about the COVID-19 vaccine was obtained from social media platforms, with some information from print media, public/community spaces and family members/close associates. This is significant, as social media allows individuals to rapidly create and share content globally without editorial oversight. Only 2.9% of vaccine information was obtained from a medical/scientific source, which additionally contributed to hesitancy, possibly related to the complicated nature of scientific information that may be difficult to understand and aligns to recommendations to simplify targeted vaccination messages.[17,34–36]

Beliefs and attitudes contributing to the hesitancy towards the COVID-19 vaccine

Persons with higher level of education were more likely to get vaccinated, showing that greater health education with knowledge and understanding of the vaccine can facilitate greater acceptance.[5,11,36,40,41] This was endorsed by the finding that acceptance of the vaccine was significantly increased with support from trusted sources, such as pastors/religious leaders, teachers, nurses and physicians,[13,36] but was significantly reduced with support from politicians.[12,17,42,43] Mistrust is identified as a major factor in vaccine hesitancy,[42] with the belief that government and pharmaceutical interests are pushing vaccines that are unnecessary.[8,9,12] The 95% successful vaccination rate with the traditional vaccines in Jamaica may well be a factor in vaccine hesitancy, as younger persons have not seen the effects of some vaccine-preventable diseases, such as measles and polio,[5] and therefore consider protection from vaccines as a myth perpetuated by government and pharmaceutical companies.[8,9] Another probable cause for vaccine hesitancy among younger individuals is that their primary source of information is social media with the attending misinformation, rumours and scaremongering.[17,36,38,39]

Notably, the likelihood of hesitancy decreased precipitously with the belief that the vaccine was safe. As such, a collaborative effort amongst trusted sources on all electronic and social media platforms is recommended to build COVID-19 vaccination trust by increasing the awareness and knowledge about the currently available vaccines and in assuring the public about the safety and benefits of the vaccine.[28,34–36] Providing reliable, up-to-date and accessible sources of information on the vaccine and dispelling the myths and concerns about vaccines, can foster a better understanding of the vaccination process and build confidence in the safety and effectiveness of the COVID-19 vaccine.[34–36] This in turn can help to control the virus spread and alleviate some of the negative effects and burden imposed by this unprecedented pandemic.[25]

The results also showed that the likelihood of hesitancy towards the COVID-19 vaccine increased additionally when respondents had a fear of needles, could not find the time or could not be bothered to go to the clinic to get vaccinated, had to wait for long periods at the clinic/vaccination centre or had religious reasons. These results were similar to reports that injection fears and vaccine accessibility were factors that affected vaccine hesitancy.[22,44–47]

In conclusion, the prevalence of COVID-19 vaccine hesitancy (delay or refusal) was 29.8%, with increased odds amongst respondents aged <36 years, who are unlikely to have seen the effects of vaccine-preventable diseases. Hesitancy was linked to safety concerns and use of social media as source of information. This research highlights the importance of advocating the role of vaccines to reduce the impact from disease spread or contraction and not only prevent infection even before a pandemic occurs.

Practical implications for future vaccination campaigns

There is much to learn from this study and the practical implications for future practice, including the engagement of trusted community sources such as pastors/religious leaders, teachers, nurses and physicians as part of the information dissemination campaign on all communication platforms and the use of one cohesive message by political representatives, irrespective of party allegiance. Another recommendation is for simplification of the vaccination campaign with the message that vaccines serve to reduce spread and decrease the impact of a disease, not just prevent the disease, using popular audience-friendly medium, such as cartoons and TikTok videos. It is recommended that the population be educated on the success of vaccines with the reduction in the morbidity and mortality associated with vaccine-preventable diseases, such as measles and polio, the advances in technology that allows for reduced production times for manufacturing, food production and development of medicines. The population should be advised on the safety of the vaccines using the low adverse incidence rates and high recovery rates of vaccinated patients. Education on the adaptive nature of viruses to mutate, making it necessary to create boosters, much in the same way as resistance develops to bacteria or tolerance develops to some medications could reduce some of the mistrust surrounding the need for booster shots and new vaccines.

Study limitations

This study was limited to persons with internet access and who were literate therefore reducing participation of marginalised populations. However, the results are informative and valid for use in vaccine policy and campaign development.

Author statements

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Ethical approval

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Competing interests

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.031.

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Original Research

Depression trajectories during the COVID-19 pandemic in the high-quality health care setting of Switzerland: the COVCO-Basel cohort

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ABSTRACT

Objectives: During the pandemic, Switzerland avoided stringent lockdowns and provided funds to stabilize the economy. To assess whether and in what subgroups the pandemic impacted on depressive symptoms in this specific Swiss context, we derived depression trajectories over an extended pandemic period in a Swiss cohort and related them to individuals' sociodemographic characteristics.
Study design: This was a population-based cohort study.
Methods: The population-based COVCO-Basel cohort in North-Western Switzerland invited 112,848 adult residents of whom 12,724 participated at baseline. Between July 2020 and December 2021, 6396 participants answered to additional 18 monthly online questionnaires. Depression symptoms were repeatedly measured by the DASS-21 scale. Group-based Trajectory Models methods were applied to identify clusters of similar depression trajectories. Trajectory clusters were characterized descriptively and with a Multinomial response model.
Results: Three distinct trajectories were identified. The ‘Highly affected’ trajectory (13%) had a larger presence of younger and female participants with lower average income, higher levels of past depression, and living alone. A majority of individuals in the ‘Unaffected’ trajectory (52%) were of medium or high average income, older average age, without previous depression symptoms, and not living alone. The ‘Moderately affected’ trajectory (35%) had a composition intermediate between the two opposite ‘extreme’ trajectories.
Conclusions: This study is among few studies investigating depression trajectories up to the time when COVID-19 vaccination was readily available to the entire population. During these 18 months of the pandemic, depressive symptoms increased in a substantial percentage of participants. Economic support, high-quality health care system, and moderate containment measures did not sufficiently protect all population subgroups from adverse, potentially long-term psychological pandemic impacts.

Introduction

As health is a state of complete physical, mental and social well-being, efforts to prevent SARS-CoV-2 infections must be parallelled by measures to maintain mental health.[1,2] Possible pathways from the pandemic to poor mental health include, but are not restricted to, fear of infection, a severe disease course, and vaccination; job loss and financial worries; work-life conflict; conflicts in family and social networks; social isolation; unhealthy or addictive behaviour; cultural and travel restrictions; a general loss of freedom; and feelings of uncertainty.[3,4] Inadequate utilization of, and access to, mental health care may have contributed to the increasing symptoms burden. The COVID-19 pandemic not only challenged the capacity of infection-related care, but also mental health care, which is in any case often marginalized compared to other health service domains.[1,5]

According to a recent meta-analysis of 43 repeated cross-sectional and longitudinal studies covering the first year of the pandemic, mental health including depression symptoms worsened on average during the first two months of the pandemic and increased in a dose-dependent manner with the number of COVID-19 cases and deaths

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and with the stringency of governmental lockdown measures. Past the first two pandemic months, the heterogeneity of mental health symptom trajectories was very high,[6] thereby questioning the meaning of overall trajectories reported in previous meta-analyses.[7,8] Evidence on substantial differences in longer-term mental reactions to the pandemic and the numerous pathways potentially affecting mental health during the pandemic point to the need for context- and subgroup-specific evidence on symptom trajectories obtained from longitudinally assessed individuals.

Understanding individual differences in longer-term mental health reactions to pandemic situations is of policy relevance for more precise predictions on the pandemic contribution to the future mental health burden,[8] and for future pandemic preparedness in targeting preventive interventions and in designing containment measures to protect the most susceptible groups from adverse mental health effects. It also supports clinicians in paying attention to patients at high risk for developing a clinically relevant mental disorder as a result of the pandemic.

Yet, the studies investigating the trajectories of mental health symptoms based on repeatedly interviewed participants in sufficiently sized adult general population studies are still limited and often cover the first pandemic months only.[2,9,10,11,12,13,14,15,16–18] These shorter-term trajectory studies inconsistently point to differences in mental health responses by age, sex, socio-economic status, or pre-existing mental and physical health conditions in the first phases of the pandemic. More recent longitudinal trajectory studies covering a period of at least one year after the start of the pandemic are evolving, covering different cultural contexts, and they confirm the existence of clusters of individuals with higher and lower mental health score trajectories (e.g. depression, anxiety, stress, post-traumatic stress disorder, or a combination thereof),[19–24] with scores seemingly worse during phases of lockdown, in young adults, in women, and in people with pre-existing physical and mental health conditions. Other factors associated with more severe mental health trajectories included social isolation, unhealthy lifestyles and sleep problems, lack of outdoor access, domestic violence, and financial problems.[19–24] Interestingly, in France where financial support was provided to affected occupational groups, financial difficulties were not associated with the level of mental health symptoms[19]

The aim of this study was, first, to identify clusters of similar depression trajectories over an extended period of the pandemic, and second, to relate these trajectories to individuals' sociodemographic characteristics. The study is based on longitudinal data from more than 10,000 randomly selected residents from North-Western Switzerland, an economically well-off country usually considered as a country with one of the worldwide most highly performing health care systems.[25] The country was evaluated to handle the pandemic comparatively well, both from a health[26] and from an economic (https://www.admin.ch/gov/en/start/documentation/media-releases.msg-id-86822.html) perspective, and avoided very stringent lockdowns.[27]

Methods

Study population

We analyzed the trajectories of the depression scores in the digital COVCO-Basel cohort implemented in July 2020 in North-Western Switzerland to investigate the long-term impact of the COVID-19 containment measures on broad health domains.[28]

Persons aged 18 years or older residing in Basel-Stadt or Basel-Landschaft for at least 5 years were eligible. Equally sized canton and age-stratified (18–49, 50–65, 65+ years) random samples of eligible individual residents were provided by the Federal Statistical Office. Study invitations were sent to the randomly sampled individuals in waves by surface mail. Of 112,848 people receiving an invitation, 12,724 participated at baseline and entered the study between July 2020 and April 2021. The COVCO-Basel study population is comparable to the total population in the two cantons in terms of publicly available sociodemographic factors including gender and marital status (see final COVCO-Basel report available in German only: https://www.swisstph.ch/fileadmin/user_upload/CoVCoBasel_Schlussbericht_20211028.pdf).

Women are overrepresented in the age group <65 years and underrepresented in the age group 65+ years. Foreign language–speaking residents are underrepresented as questionnaires were only provided in German in the absence of funds for multilingual translations.

Between July 2020 and December 2021, participants answered to a baseline and repeated monthly online questionnaires implemented in REDCap (Research Electronic Data Capture) data collection system (https://www.project-redcap.org/). The study period was divided into two-week periods (fortnights), and we included in the analysis 6396 participants with depression score recorded for at least eight fortnights, not necessarily in a row. Participants with segments of trajectories shorter than eight fortnights would excessively influence estimation of the parameters characterizing the clusters, since we fit polynomials of increasing degree to the observed trajectories (see below).

The study protocol was approved by the regional ethics committee (Ethikkommission Nordwest-und Zentralschweiz 2020-00927) and all participants provided informed consent before enrolment to the study.

Depressive symptom score

Depressive symptoms were measured using the Depressive Anxiety Stress Scale (DASS-21.)[29]

Each item (depression; anxiety; stress) is scored on a 0–3 scale: ‘never = 0, sometimes = 1, often = 2, and (almost) always = 3’. The score for each domain is calculated by summing up the scores for the corresponding seven items and multiplying the total by 2. The score can be divided, to aid interpretation, into the following categories (normal = 0–9, mild = 10–13, moderate = 14–20, severe = 21–27, and extremely severe = 28+) for each domain. But the present study *a priori* focused on the original quantitative discrete depression score, rather than on categories, as endpoint, with a possible score range from 0 to 42.

Descriptive characteristics of trajectories

Age in years and **sex** were self-reported. Non-binary sex was excluded because of its small sample size. Self-reported **household income** was classified into three categories: below 6000, 6000–15,000, and 15,000+ CHF/month (1 CHF is equivalent to approximately 1.05 US$). **Education** was classified into six levels: no school degree, compulsory school, vocational training, high school diploma, technical college/University of Applied Sciences, University (including Polytechnical University). **Canton of residence** distinguished Basel-Stadt (urban) and Basel-Landschaft (periurban/rural). **Living status** was dichotomised into ‘Alone’ vs ‘Not alone’.

Participants were asked to retrospectively report **past depressive symptoms** according to DASS-21 scale for the month of the baseline assessment in the year before the pandemic.

For sensitivity analysis, **time of study entry** was defined as the period of completing the baseline questionnaire, categorised as follows: July–Sep 2020; Oct–Dec 2020; Jan–April 2021.

Statistical analysis

In the first step, we applied Group-based Trajectory Models (GBTM) methods to identify clusters of similar trajectories. The approach by Nielsen et al. (2014)[30] estimates by maximum likelihood a finite mixture model where each individual belongs to a cluster with an unknown probability (to be estimated), and the response in each class is assumed to be distributed as a Zero-inflated Poisson with expected value varying polynomially with time. A Zero-inflated Poisson distribution is appropriate for the depression score, which has a discrete domain, ranging from 0 to 42, and a positively skewed distribution characterized by an excess of zeroes (see Supplementary Fig. S1). Although other approaches are present in the literature for this purpose, in particular models in the wide class of Structural Equation Models (like the Latent Growth Mixed Models – LGMM), we preferred the GBTM approach mainly for two reasons: i) GBTMs are somewhat more ‘exploratory’ than LGMMs, as they just ‘agnostically’ identify groups of similar trajectories in the population, leaving to further analyses the task to characterise such classes (see below, the description of the second step of analysis); ii) GBTMs are more flexible in the choice of the response distribution, and therefore more appropriate for our choice of assuming a Zero-inflated Poisson distribution for the depression score. For a non-technical comparison of the two approaches, see Frankfurt et al.[31]

After obtaining the clusters of similar trajectories, we estimated the average trajectories for each cluster and plotted them in Fig. 1.

In the second step, we characterised the clusters both in descriptive and model-based terms. The descriptive analysis is a simple graphical representation of the distribution of selected characteristics (specifically: age, gender, income, canton, education, living status, past depression) in the clusters of similar trajectories. The modelling approach consisted in treating cluster membership as a categorical polytomous response variable, specifying a multinomial response model and testing the statistical significance of the same characteristics used in the descriptive phase, as independent predictors of the cluster membership.

All statistical analyses were conducted using R 4.0.[32] The GBTM analysis used the code made available by Paul Schneider at the URL: https://raw.githubusercontent.com/bitowaqr/traj/master/raw_

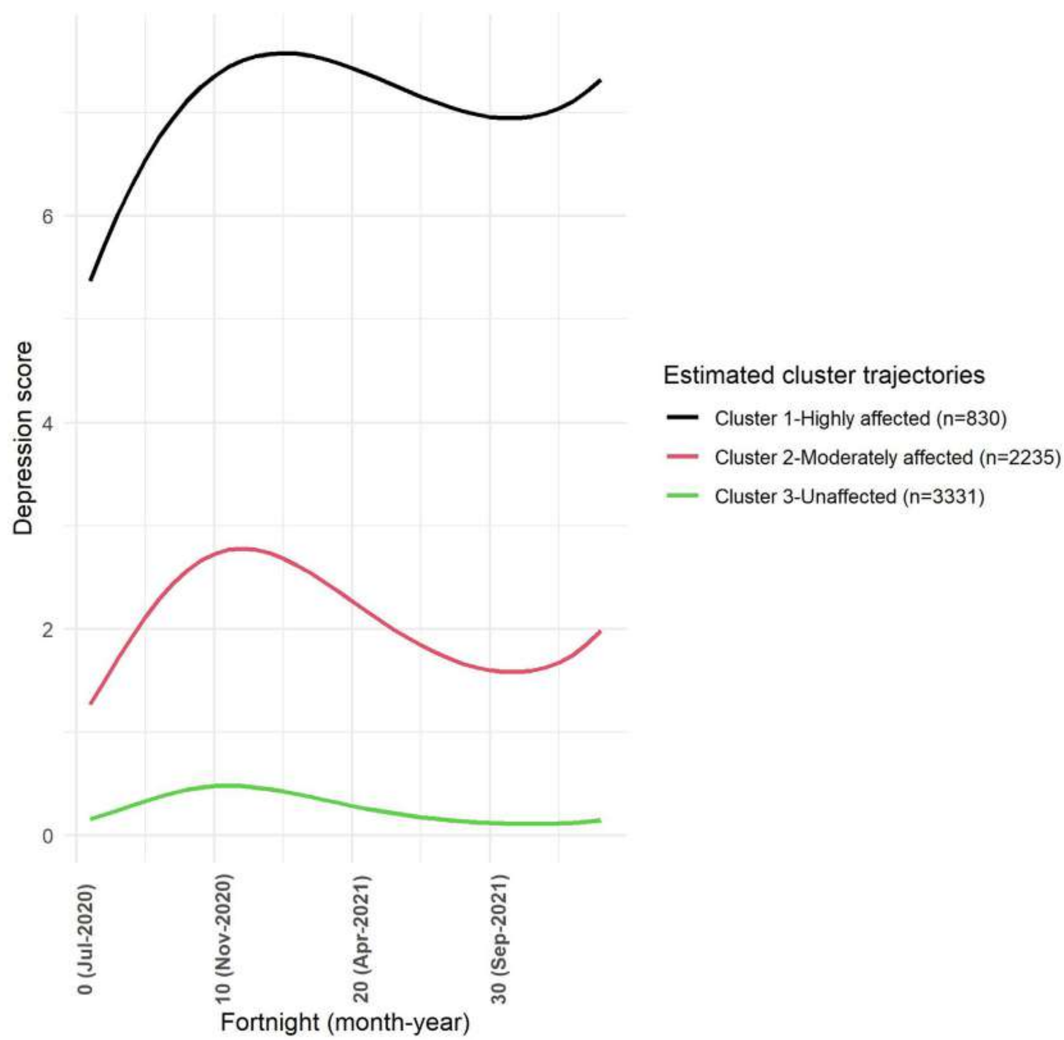

Fig. 1. Estimated trajectories of depression symptom scores for the three clusters ($n = 6396$, number of clusters $k = 3$, polynomial degree $P = 3$).

Table 1
Baseline characteristics[a] of COVCO-Basel participants, comparing participants included vs not-included in the current analysis.

		Participants included (≥8 occasions)	Participants excluded (<8 occasions)
N		6396	6328
Age [Years]		57.66 (14.17)	55.4 (15.3)
Sex	Female	3561 (55.68)	3430 (54.2)
	Male	2835 (44.32)	2898 (45.8)
Household income	<6000 CHF/month	1842 (28.80)	1830 (28.91)
	6000-15000 CHF/month	3610 (56.44)	3414 (53.95)
	15,000+ CHF/month	745 (11.65)	804 (12.70)
	NA	199 (3.11)	280 (4.43)
Canton	Basel-Stadt	3137 (49.05)	3160 (49.90)
	Basel-Landschaft	3259 (50.95)	3168 (50.10)
Education	No school degree	4 (0.06)	6 (0.10)
	Compulsory school	140 (2.19)	175 (2.77)
	Vocational training	2234 (34.93)	2058 (32.52)
	High school	383 (5.99)	402 (6.36)
	Technical college/University of Applied Sciences	1565 (24.47)	1537 (24.28)
	University (including Polytechnic)	2060 (32.21)	2076 (32.80)
	NA	10 (0.15)	74 (1.17)
Living status	Alone	1362 (21.29)	1316 (20.79)
	Not alone	4994 (78.08)	4910 (77.60)
	NA	40 (0.63)	102 (1.61)
Past depression (score 0–42)		2.62 (5.14)	2.66 (5.05)

[a] Data presented as mean (standard deviation) or count (percentage).

code.R. Multinomial logit models have been fitted using the library VGAM. The plots have been produced using the library ggplot2.

Results

Study population characteristics are summarized in Table 1. The sample has an overrepresentation of females. Participants are well educated with 32% having a University degree. The mean prevalence of moderate to severe depressive symptoms one year before entry into the study was 8.18% (age group 18–49 years), 3.47% (age group 50–65 years) and 2.31% (age group 65+ years). Participants answering to at least eight occasions did not differ from excluded participants.

Finding clusters of similar trajectories using GBTM

Based on computational stability, the degree of the polynomials used to estimate the average trajectories in the clusters has been fixed at $P = 3$ (i.e. cubic polynomials) and the number of clusters has been fixed at $k = 3$, using AIC and BIC as criteria. $k = 4$ clusters were slightly superior in terms of AIC and BIC, but posed problems in terms of convergence. Moreover, the four clusters obtained were not as well separated as the three clusters chosen for this paper: in particular, groups 3 and 4 differ on average only by about 1 point of depression score. This difference does not appear to be relevant in public health terms, and this led us to prefer the classification into 3 clusters over 4, notwithstanding the small gain in AIC and BIC. The 'typical' (average) trajectories of the three clusters of similar trajectories are graphically represented in Fig. 1. Cluster 1 (**'Highly affected'),** with an estimated prevalence of 13%, starts already at a higher average level of depression score, and follows markedly the waves the COVID-19 pandemic. Mental health, in terms of depression score, of members of this cluster is strongly influenced by the pandemic and stays elevated by December 2021 compared to the baseline depression score. On the contrary, Cluster 3 (**'Unaffected'),** with an estimated prevalence of 52%, starts at very low levels of depression and has a typical trajectory over time that is hardly influenced by the waves of the COVID-19 pandemic. Finally, Cluster 2 (**'Moderately affected'**), with an estimated prevalence of 35%, has an intermediate pattern, similar to Cluster 1, but with attenuated effects of the waves of the COVID-19 pandemic.

Exploratory analysis

Fig. 2 graphically displays the distribution of selected characteristics in the three clusters: (a) age, (b) sex, (c) income, (d) educational level, (e) canton, (f) living status, and (g) past depression. Visual inspection of Fig. 2(a–g) suggests that age, sex, income, living status, and past depression may play a role in explaining membership in the three clusters, and therefore different trajectories in mean depression. In Cluster 1 (the 'Highly affected'), there is a relatively larger presence, compared to the other two clusters, of participants who are younger, female, with lower average income, living alone, with higher levels of past depression. On the contrary, in Cluster 3 (the 'Unaffected'), there is a majority of individuals with medium or older average age, high average income, not living along, with no previous symptoms of depression, while sex seems to be balanced in this Cluster. Cluster 2 has a composition intermediate between the two opposite 'extreme' Clusters 1 and 3. Cantonal residency (urban vs periurban/rural setting) and educational level did not seem to play a significant role in characterizing the three clusters.

Model-based analysis

A selection procedure, starting from the full multinomial logit model with all covariates additively included and carried out using both AIC and BIC, has provided the following final model:

$$\log(\pi_1/\pi_3) = \beta_{01} + \beta_{11}Age + \beta_{21}Sex_2 + \beta_{31}Income_2 + \beta_{41}Income_3 + \beta_{61}LivingStatus_2 + \beta_{51}PastDepression$$

$$\log(\pi_2/\pi_3) = \beta_{02} + \beta_{12}Age + \beta_{22}Sex_2 + \beta_{32}Income_2 + \beta_{42}Income_3 + \beta_{62}LivingStatus_2 + \beta_{52}PastDepression$$

where: π_1 = Pr{belonging to Cluster 1}, π_2 = Pr{belonging to Cluster 2}, π_3 = Pr{belonging to Cluster 3}; Sex_2 = Male; $Income_2$ = CHF 6000 – 15,000; $Income_3$ = >CHF 15000; $LivingStatus_2$ = Not alone.

The estimated regression coefficients, their standard deviations and *P*-value of the Wald test statistics for testing their significance are summarized in Table 2. The most statistically significant determinants of cluster membership were age, sex, the highest category of income and the score on past depression. Living status appears to have a significant effect only on the logit of belonging to Cluster 1 vs belonging to

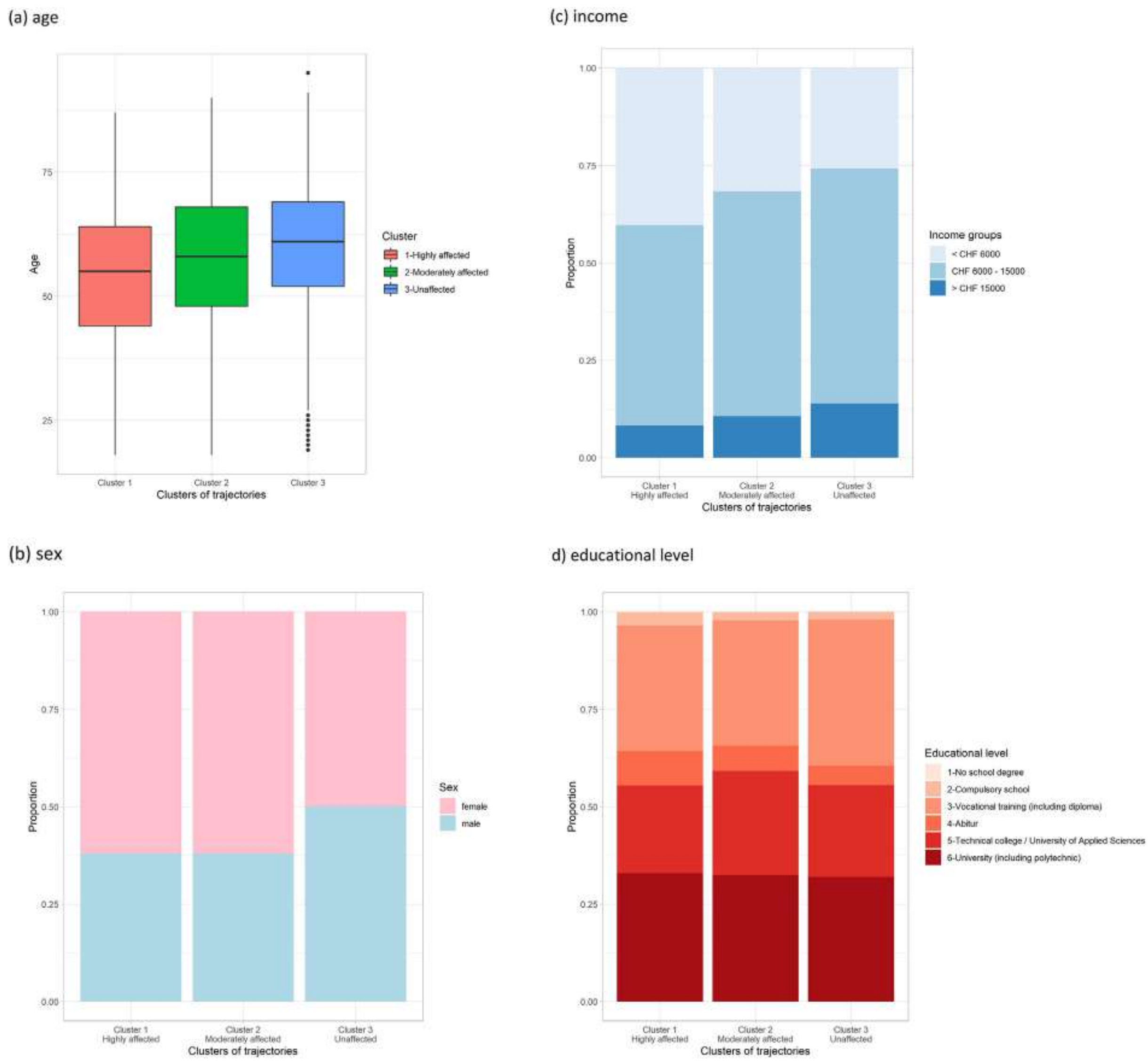

Fig. 2. Distribution of selected characteristics according to the three clusters of trajectories.

Cluster 3. Education level and canton were not statistically significant predictors and were thus excluded from the final model.

In Table 3, we report the predicted probability of cluster membership for three hypothetical individuals.

Petra is a young woman, aged 25 years, living alone, having an income in the lowest class (< CHF 6000 per month) and with a previous history of moderate depression symptoms. She has a very high probability of belonging to Cluster 'Highly affected'. Ursula is also a woman, but older than Petra (aged 60 years), living with her family, having an income in the intermediate class (CHF 6000–15,000 per month) and with only slight symptoms of depression in the past. The most probable cluster for Ursula is Cluster 'Moderately affected', although the probability of falling into Cluster 'Highly affected' is not negligible (0.247). Martin is a man, aged 70 years, living with his family, with an income in the highest class (>CHF 15,000) and no symptoms of depression in the past. By far the most probable cluster for Martin is Cluster 'Unaffected'.

Sensitivity analysis

Participants entered the study at different dates (from July 2020 up to April 2021) and hence at different phases of the COVID-19 pandemic. Supplement Fig. S2 displays the distribution of month of entry in the three clusters. The distribution is highly balanced. Furthermore, the distribution of the number of occasions answered did not differ by cluster (Supplementary Fig. S3).

Discussion

This is one of only few studies investigating depression trajectories in a large adult community sample over an extended period, up to the time when COVID-19 vaccination was readily available to the population. Depressive symptoms increased in a substantial percentage of this North-Western Switzerland study population, albeit at a rather low, and clinically not yet relevant, average depression score level, and mental health trajectories were similar to other regions in Europe and elsewhere.[19–24]

Compared to other European countries, Switzerland imposed less stringent containment measures.[33] Jobs and enterprises were protected and subsidized to avoid economic hardship. But like others, the country experienced substantial excess mortality, particularly during the second epidemic wave.[34] In-hospital mortality among COVID-19 patients decreased between February 2020 and March 2021, but deteriorated when national intensive care unit occupancy reached about 70%, suggesting that even in a high-

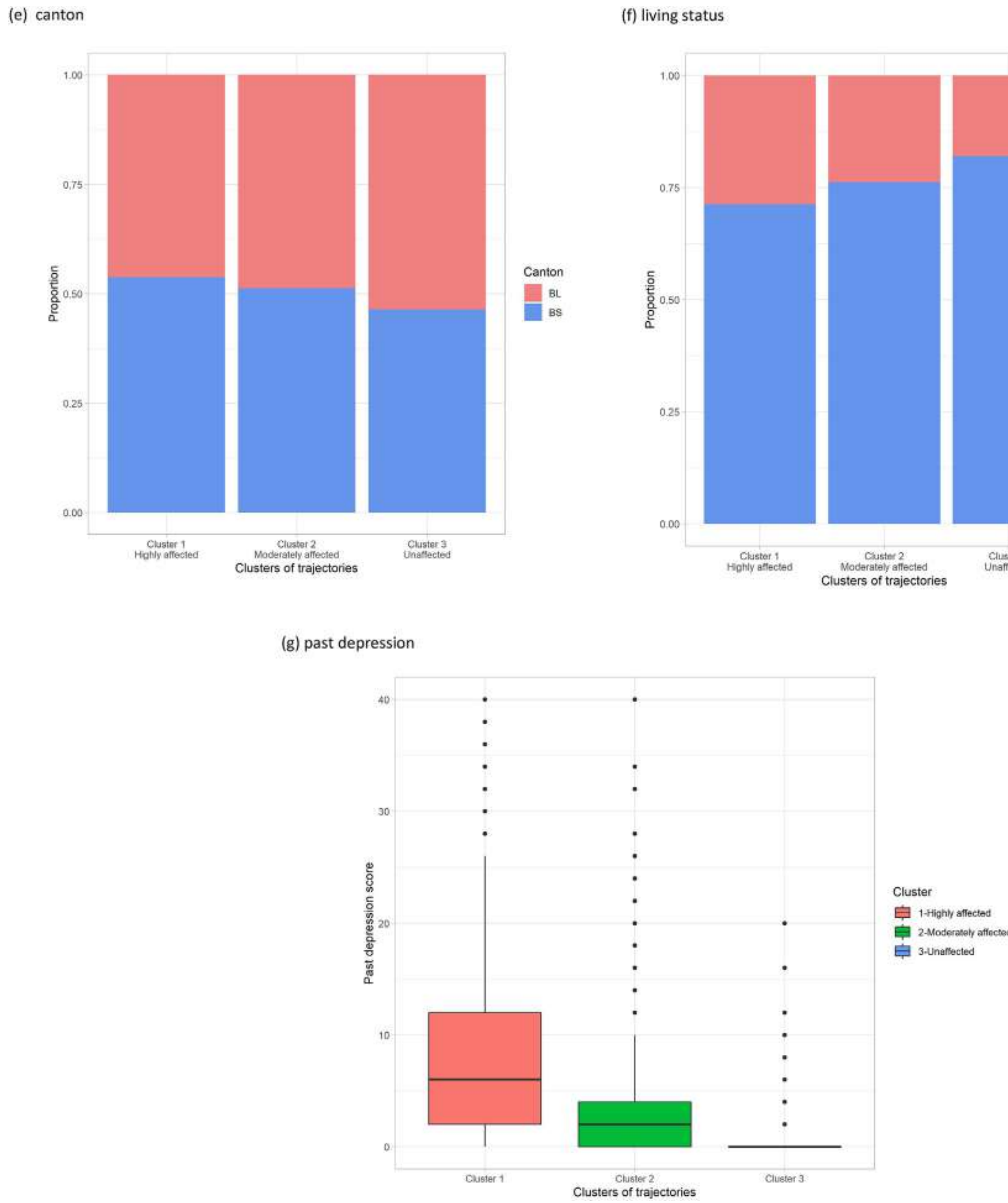

Fig. 2. (*continued*).

quality health care system operational pressures develop before triage becomes necessary.[35] In the first pandemic year, a survey among youth mental health professionals reported a large increase in treatment demand and waiting time and a worrisome overload of mental health services.[9,36]

The study was implemented after the most extreme lockdown spanning from March 2020 to June 2020 in Switzerland. The increase in depressive symptoms in the affected trajectories coincides with the second epidemic wave resulting in restrictions between October 2020 and April 2021, and the emergence of the Omicron

Table 2
Independent association of covariates[a] with depression trajectories according to the multinomial logit model.

		$log(\pi_1/\pi_3)$	S.Dev.	*P*-value	$log(\pi_2/\pi_3)$	S.Dev.	*P*-value
Intercept		−1.539	0.302	0.000	−0.083	0.207	0.689
Age		−0.010	0.004	0.023	−0.009	0.003	0.002
Sex	Male	−0.355	0.129	0.006	−0.476	0.083	0.000
Income	CHF 6000 − 15,000	−0.137	0.135	0.311	0.022	0.091	0.813
	>CHF 15,000	−0.639	0.240	0.008	−0.338	0.142	0.018
Living status	Not alone	−0.256	0.150	0.088	−0.120	0.104	0.246
Past depression score		1.082	0.048	0.000	0.791	0.044	0.000

[a] Education and Canton were not maintained in the model.

Table 3
Predicted probability of cluster membership for three hypothetical individuals.

Name	Age	Sex	Income	Living status	Past depres. score	Prob (Cluster1)	Prob (Cluster2)	Prob (Cluster3)
Petra	25	Female	< CHF 6000	Alone	11	0.848	0.152	0.000
Ursula	60	Female	CHF 6000–15,000	Not alone	3	0.247	0.631	0.121
Martin	70	Male	> CHF 15,000	Not alone	0	0.025	0.157	0.817

Sars-Cov-2 variant and associated restrictions towards the end of 2021. COVID-19 vaccine was provided to susceptible persons from December 2020 and made readily available to all population subgroups from Spring 2021 on.

Few studies identified longitudinal trajectories in an exploratory fashion. Two early longitudinal studies in the UK investigated psychological distress trajectories in community samples with a latent class approach.[9,17] In the period between April and May 2021, general health questionnaire (GHQ-12) derived psychological distress was higher than prepandemic. Trajectories also included at the one extreme end a subgroup of people whose likelihood of distress remained continuously close to zero up to May 2021 (53.2% of study participants) and at the other extreme two-fifths of all participants who experienced a severe elevation of distress throughout the observation period.[9] Another analysis of the same study population, but focusing on depressive symptoms, also found three latent trajectories similar to ours and to the psychological distress trajectories, including low (60%), moderate (29%) and severe (11%) depressive symptoms during the lockdown.[18] Longer-term trajectory studies confirmed the presence of clusters of mental health trajectories with different response levels to the pandemic.[19–24] Few quasi-experimental studies benefitted from the effect of the pandemic and associated lockdowns on mental health. For example, a quasi-experimental study in Australia demonstrated that mental health was slightly worse in the region affected by a lockdown.[37]

The observed characteristics of persons at risk of exhibiting mental health symptoms also closely follow results from shorter- and longer-term studies abroad,[19–24,38] although the findings are not entirely consistent.[7] But many, including longer-term studies, parallel early observations from UK exploratory trajectory approach studies, where the risk of belonging to a trajectory affected by psychological distress was greater for those who were younger, female, living without a partner, those who lost income or were living in poor neighbourhoods, and those who were reporting a previous mental illness. In addition, individuals with COVID-19–related symptoms and pre-existing at-risk health conditions for a severe COVID-19 course seemed more affected.[7,9,17] Trajectories and characteristics similar to ours were also observed in a smaller Argentinian community sample with less frequent questionnaires but covering the period from April 2020 to August 2021.[10] In the COVCO-Basel cohort, we observed a strong correlation between greenspace and life satisfaction that was restricted to persons with high income pointing to the complex role of the environment on psychological well-being during the pandemic.[28]

The population sub-groups exhibiting a continuously high level of mental distress during times of the pandemic are of concern. First, extended periods of elevated depression symptoms harbour a longer-term risk for developing mental illness.[39] Second, elevated depression is often associated with changes in sleeping and eating habits, themselves posing a risk for physical and mental disorders.[38,39] Third, depression and psychological distress are linked to altered immune system functioning and cardiovascular disease risk, both affecting infection susceptibility.[40] Fourth, differences in life expectancy of up to four years according to neighbourhood SES level were previously reported in Basel, the urban centre of North-Western Switzerland, and the pandemic may widen this gap.[41]

The strengths of the present study are the population-based sampling, the comparatively large sample size, that symptoms of depression were assessed on a monthly basis with a validated tool until months after the broad availability of an efficient COVID-19 vaccine, and that neither date of study entry nor extent of monthly participation confounded the results. Study limitations include, first, the low participation rate in the COVCO-Basel study. Second, the lack of generalizability of the results to all residents in the greater Basel region, as foreign language–speaking residents were underrepresented in the study sample. In the absence of a multilingual non-responder questionnaire, the present study cannot be evaluated for representativeness. In particular, the prevalence of the observed trajectories cannot be estimated for the general population. It is possible that additional trajectories exist in non-participants. Third, prepandemic depression levels were assessed retrospectively. If participants with high depression levels during the pandemic were more likely to overestimate prepandemic depression, the influence of prepandemic depression symptoms may be overestimated. Fourth, as in any cohort, attrition bias is of concern.

Conclusions

The results point out that a high level of economic support and a high-quality health care system in the light of moderate containment measures as applied in Switzerland do not sufficiently protect the entire population to the same extent from adverse psychological impacts of a pandemic. Ignoring adverse effects of a long-lasting pandemic on mental well-being may have negative repercussions in the life trajectories of specific vulnerable subgroups as well as potentially on the infection control. Poor mental health and associated unhealthy behaviours may well be the most important long-term sequelae of the pandemic.

Author statements

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Ethical approval

The study protocol was approved by the regional ethics committee (Ethikkommission Nordwest-und Zentralschweiz 2020-00927) and all participants provided informed consent before enrolment to the study

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Competing interests

The authors declare no conflict of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

Author contributions

Nicole Probst-Hensch: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition. **Ayoung Jeong:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Dirk Keidel:** Investigation, Data curation, Writing – review & editing, Project administration. **Medea Imboden:** Investigation, Writing – review & editing, Project administration. **Gianfranco Lovison:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.010.

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Environmental characteristics and disparities in adult asthma in north central Texas urban counties

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ABSTRACT

Objectives: Disparities in asthma prevalence present a persistent challenge to public health. The complex nature of the issue requires studies through a wide range of lenses. To date, little research has examined associations between asthma and multiple social and environmental factors simultaneously. This study aims to fill the gap with a focus on the impacts of multiple environmental characteristics and social determinants of health on asthma.
Study design: This study uses secondary analysis with data from a variety of sources to analyze the effects of environmental and social factors on adult asthma occurrence in North Central Texas.
Method: Hospital records and demographic and environmental data for four urban counties in North Central Texas (Collin, Dallas, Denton, and Tarrant) come from the Dallas/Fort Worth Hospital Council Foundation, the US census, the North Central Texas Council of Governments, and the Railroad Commission of Texas. The data were integrated using ArcGIS. A hotspot analysis was performed to inspect the spatial patterns of hospital visits for asthma exacerbations in 2014. The impacts of multiple environmental characteristics and social determinants of health were modeled using negative binomial regression.
Results: The results revealed spatial clusters of adult asthma prevalence and disparities by race, class, and education. The occurrence of asthma exacerbations was positively associated with exposure to traffic-related air pollution, energy-related drilling activities, and older housing stock and negatively linked to green space.
Conclusions: Associations between built environmental characteristics and asthma prevalence have implications for urban planners, healthcare professionals, and policy makers. Empirical evidence for the role of social determinants of health supports continuing efforts in policies and practices to improve education and reduce socio-economic inequities.

Introduction

Asthma is a well-known concern in public health. According to the World Health Organization, more than 262 million people around the world suffered from the disease in 2019.[1] In the United States, the number of asthma patients was more than 25 million in 2019, of whom more than 20 million were adults aged ≥18 years.[2] Statistics also show persistent disparities among adults with asthma. For example, the adult asthma prevalence rate in the United States was 8.1% for non-Hispanic Whites, 9.7% for non-Hispanic Blacks, and 6.1% for Hispanics. The rate was only 5.9% for those at 450% of poverty threshold or higher, but 11.8% for those at or under the federal poverty level in 2019.[2]

The literature suggests that there exist health inequalities, defined by McCartney et al.[3] as “the systematic, [observable], avoidable and unfair differences in health outcomes … [among] groups that share common characteristics.” The existing literature also suggests that the linkages between asthma and its attributes are multifaceted. Nevertheless, existing studies mostly focus on the effects of attributes along limited dimensions on asthma; thus, the complex relationships require further investigation.[4–8] Moreover, the bulk of asthma literature focuses on children, and evidence

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suggests that asthma triggering factors for adults may be different from those for children.[5,8–13]

Building on prior knowledge about asthma disparities, we investigate the relationships between environmental attributes and adult asthma occurance in four urban counties in North Central Texas. We contribute to the literature with a more complete set of measures along multi-environmental dimensions, Hotspot analysis for spatial patterns, negative binomial regression for count data, and the empirical evidence for an area known for domination by car culture, dispersed land use patterns, and continuing efforts to meet federal ozone standards. The findings of this study also add insights into the difference in asthma trigger factors between children and adults. In the following, we review the current research in asthma disparities, describe our analysis approach, and present our findings. We discuss the implications of the findings and conclude the paper at the end.

The literature on health and asthma disparities

The social determinants of health

Traditionally, epidemiological studies followed genetic and medical models, with a focus on genetic factors and medical treatments. Krieger[4] argued that traditional epidemiological studies paid little attention to the "web of causation" in health, a metaphor for the multiple causes of health outcomes. She called for a shift from the genetic/medical model to including broader socio-economic factors. Similarly, House and Williams[14] noted that biological variations only explain a small proportion of the health disparities among racial groups and suggested that racial health disparity should be examined through a broader sociopolitical lens.

Health studies since the late 1990s have focused on the social determinants of health. A well-known theory of health disparities is the income inequality hypothesis. The theory, by its name, attributes health inequalities to income inequality.[15–17] Although the income inequality hypothesis has contributed to the studies of health disparities by identifying a major contributor (through observations of income and health disparity patterns mostly across countries), more studies have extended the social determinants of health to include other social, economic, and contextual factors. Yen and Syme[18] noted the importance of socioenvironmental influences on disease and conceptualized social environment as physical and social dimensions of neighborhoods. Examples of such social environments range from dwelling density, access to health-related services, access to retail stores and parks, social problems such as crime and vandalism, as well as social structures such as discrimination, segregation, and social capital. Robert[19] conceptualized a framework for studying the linkage between community socio-economic context and individual health outcome. Similarly, Sampson et al.[20] suggested strategies and directions for studying the influence of neighborhood social interaction and the institutional process on individuals' health. Collectively, these studies contribute to the theoretical foundation for health disparity studies and suggest the need to study health inequality comprehensively from multiple social and environmental dimensions.

Empirical studies of asthma disparities

Asthma disparity studies generally consider variables in four dimensions, including socio-economic characteristics, air quality, built environment, and other miscellaneous factors. The most common measurements in the built environmental dimension can be further delineated into transportation, land use, and housing-related measurements. Some examples of other factors include family asthma history, behavior, and lifestyle.

Following the paradigm of social determinants of health, socio-economic characteristics have been at the center of many investigations, as these factors have directly or indirectly contributed to health disparities due to resource limitations or/and environmental risks rooted in structural inequalities, unjustified place-based and income-based local or federal policies. Common measurements are gender, race/ethnicity, income, and individual or parental/caregivers' level of educational attainment.[6,8,10,12,21,22] Some studies also investigate other socio-economic variables, such as financial hardship, marital status, etc. Although many studies found that males, Blacks, and individuals or households with low-income status or low level of educational attainment tend to be associated with high rates of asthma prevalence,[6,23] the findings were not always consistent.[7,12,24]

Similar discrepancies exist in research focusing on other dimensions. Air pollution has been identified as 'the single largest environmental health risk.'[25] As such, a large body of research has been devoted to the linkage between asthma and air pollutants. Due to the limits in air pollution data and the cost of data collection, studies have used a variety of approaches to estimate air pollution levels associated with asthma occurrences. Some studies used spatial interpolation techniques based on values observed at limited air pollution monitoring stations.[11,26,27] Other studies used transportation and/or land use parameters as predictors of air pollution.[6,28–30] Additional research applied direct measures of transportation and/or land use as the proxies for air pollution[5,8,9,29,31] because transportation and land use have been viewed as main sources of pollutants.[32] The results are quite mixed. Although some studies found that land use density, exposure to NO_2 are associated with the risk of asthma symptoms,[6,11,27,27] the results of other studies revealed insignificant association between asthma and NO_s along with $PM_{2.5}$, PM_{10}, or transportation-related factors, such as traffic load on major roads and traffic intensity.[12,29] Additional studies concluded that the relationships may vary by age or gender.[5,8,9,12,29]

A limited number of studies also investigated the impacts of housing characteristics on asthma. A common measure of housing characteristic is housing age, as older housing is likely to have issues with construction materials or utility systems. For example, Free et al.[33] investigated the relationship between heating methods and school absence due to asthma symptoms. Their results indicated that children living in homes with heating intervention experienced fewer absences from schools. Newcomb and Li[8] hypothesized that older housing stocks are less efficient in indoor air circulation and hence contribute to triggering asthma exacerbations. The results supported their hypotheses. Vesper et al.[34] found a positive relationship between asthma prevalence and older homes. Similarly, Piekarska et al.[35] observed a positive correlation between the occurrence of allergic rhinitis/asthma and housing age and a negative correlation between asthma and central heating. Although the last two studies indicate the effects of housing age and heating, they did not adjust for the effects of other confounding factors. The connection between green open space and air quality/health is well recognized, but research has mostly focused on the association between open space and air quality (e.g. see, Ebisu et al.[6]; Rao et al.[30]). The research on the relationship between open space and asthma is limited and inconclusive.[36]

In summary, significant efforts have been devoted to asthma disparity studies. The research to date has focused on the effects of variables along one or few dimensions. The results show complex relationships between the associated factors and asthma occurrence, as well as possible differentiation between children and adults. The discrepancies in the results of contemporary research call for more effort to use multivariable analytical techniques and comprehensive measurements.

Methods

Research scope

Building on the knowledge from existing asthma disparity studies, we investigated the complex relationships between neighborhood environmental characteristics and adult asthma exacerbations. We focused on the four urban counties in the Dallas/Fort Worth Metropolitan area, including Collin, Dallas, Denton, and Tarrant Counties. Data from these four counties are consistent and available. These counties have known patterns of land use and vehicle travel when compared with many metropolitan areas in the nation. The four counties are also the core areas crucial to air pollution attainment in this metropolitan area.

Measurements and hypotheses

The dependent variable is the count of asthma hospital visits in each census block group. Hospital records contain information related to specific hospital admissions, such as International Classification of Diseases, Ninth Revision, diagnostic codes, residential addresses, race, gender, and insurance. Records were selected according to International Classification of Diseases, Ninth Revision, diagnostic codes, admission type, year, and age. Specially, our data only included those admissions associated with International Classifications of Diseases asthma diagnostic codes in 2014. Records included cases admitted to the emergency department (ED) and cases admitted directly to an inpatient unit without ED admission. Inpatient admissions through the ED were excluded to avoid duplication. Only occurrences from patients aged between 18 and 65 years were included in the analysis.

We identified social and built environmental measurements, including socio-economic characteristics, transportation, housing conditions, and land use at the census block group level. Following the existing literature, the socio-economic characteristics included the number of adult males, number of Black population, number of people aged ≥25 years without high school diploma, and the median household income in census block groups. A density variable "Adult Density" was used to normalize the variation in size of census block groups to control for the impacts of population and land size. The median age was also used to measure the age difference in census block groups. In addition, we considered the potential influence of urban gas drilling, as it is an activity that affects air quality and potentially contributes to asthma occurrence. This gas drilling activity is measured by the aggregated counts of wells in each census block group. Moreover, proximity to highways is a dummy variable, in which a value of one is given if the centroid of a census block group is within a buffer zone of a quarter mile from a highway, and a value of 0 is assigned otherwise. This variable was used in the existing literature as a proxy to measure exposure to air pollution resulting from vehicle emissions. It enables the comparison between the results of this and previous studies. In addition to the average speed limits weighted by types of roads in census block groups and road density defined as miles per census block group, we also included several measures of exposure to transportation-related air pollution as suggested by Lindgren et al.,[31] such as average commute distance of workers, number of workers commuting by public transit, and number of workers working from home in census block groups. Measures of housing age and conditions, as well as several land use types that are beneficial for air quality, are also used to examine the complex relationships between asthma occurrence and potential attributes. All the variables, the explanation, measurements, and the expected relationships between the independent variables and the dependent variable are displayed in Table 1.

Data sources

Data on asthma ED and inpatient visits in 2014 were obtained from the Dallas/Fort Worth Hospital Council Foundation[37] after Institutional Review Board approval. Most socio-economic, housing, and commute data were extracted from the 2014 American Community Survey (ACS) data set.[38] Gas drilling data were obtained from the Railroad Commission of Texas. Road network, and land use data were collected from the North Central Texas Council of Governments.[39]

Data limitations

Limitations of data should be acknowledged. First, our data are limited at the census block group level. The 2014 ACS data are public use data at the block group level. Our asthma data are limited to the hospital visits for asthma treatment purposes in the year 2014. As there is no information on non-asthma hospital visits, it is impossible to conduct an individual-level analysis of asthma hospital visits vs non-asthma hospital visits. Hence, this study aggregates asthma hospital visits to the census block group level to match the ACS data. This data limitation also precludes us from doing a multilevel analysis. Second, because our data are cross-sectional, we cannot truly establish causal relationships but can only make inferences based on multifactorial associations. Despite these limitations, our assembled data are unique and can shed light on the associations between built environment and asthma occurrence.

Data integration and analytic techniques

A geographic information system program was used as a tool to geocode residential addresses of patients experiencing asthma hospital visits and spatially link the data from various sources into a geodatabase. About 94% of the original hospital records were geocoded. The other 6% were excluded because of unknown addresses. In addition, a descriptive analysis was conducted to identify the basic demographic characteristics of the asthma patients and to compare them with those of the general population in the study area. Moreover, the optimized hot spot analysis tool was used to analyze and display the spatial clusters of asthma hospital visits based on their residential locations. The main purpose of this analysis is to inspect where the patients resided and if they were concentrated in certain neighborhoods. The information provides the basis for the contextual analysis in later sections. The hot spot analysis is a spatial statistical tool based on the Getis-Ord Gi* statistics that can detect spatial clusters with statistical confidence.

A preliminary descriptive analysis indicated that the mean of asthma counts is smaller than the variance, an indication that the data are overdispersed, which suggests that negative binomial regression (NBR) is more suitable than Poisson regression for the data because the NBR model is more suitable for overdispersed count data.[28] The NBR model is preferred because it can not only control for as many confounding factors as possible but also has fewer restrictive assumptions than the Poisson regression model and therefore greater generality or applicability. The traditional NBR model, designated the NBR2 given by Hilbe,[40] is specified as the following:

$$\ln(\mu) = \beta 0 + \beta 1X1 + \beta 2X2 + \ldots + \beta nXn \quad (1)$$

where X1, X2, … Xn are predictors as listed in Table 1; β0, β1, β2 … βn are coefficients to be estimated. We started with a model that includes the commonly used socio-economic variables plus the gas drilling variable. In our second model, we supplemented

Table 1
Variables and hypotheses.

Variable name	Meaning	Measure	Predicted direction
Dependent variable			
Asthma count	Count of hospital visits	# per block group	
Independent variables			
Sociodemographic characteristics			
#Adult males	Adult males	# per block group	+
Median age	Median age	years in block group	+
#Black	Black population	# per block group	+
Md HH income	Median Household Income	$ in block group	−
#No HS diploma	Population aged 25+ without high school diploma	# per block group	+
Adult density	Density of adult population	#/Sq. Mile	+
Built environmental characteristics			
Well counts	Counts of drilling wells	# per block group	+
Proximity to HWY	A quarter mile buffer zone from highway	1 if within; 0 else	+
AVG speed	Average speed limit weighted by type of roads	Miles/hour	+
Road density	Road length density	Miles/Sq. Mile	+
AVG COM distance	Average commute distance	Miles	+
#Work at home	Workers working from home	# per block group	−
#Pubtransit users	Workers commute by public transit	# per block group	+
House before 1979	Housing units built before 1979	# per block group	+
Gas heating house	Housing units w/gas heating	# per block group	+
Elec heating house	Housing units w/electric heating	# per block group	−
Park/Rec density	Park or recreational land use density	#/Sq. Miles	−
Tim/farm density	Forest and farmland density	#/Sq. Miles	−

transportation variables, including commute variables measuring exposure to transportation-related air pollution. We added housing variables to model two in our third model. The final model included all the variables in model three and the land use variables.

Results

In the following, we first describe the characteristics of asthma patients in the hospital visit data set and compare them to the characteristics of the general population based on the 2014 ACS data. We then explain the spatial pattern of asthma clusters. The model results are presented after a brief report of the correlation analysis.

Characteristics of asthma hospital visits

Table 2 displays the characteristics of individuals in the data set of asthma hospital visits and the general population of ACS in the study area. The results indicate that most people were in the age groups between 20 and 54 years. This pattern of age distribution is in general consistent with that of the general population. Females were overrepresented, as females accounted for about 65% of the asthma hospital visits and compared to about 51% in the general population. Whites and Blacks were the majority, which were also consistent with the general population. However, the percentage of Blacks in our data was much higher than that in the general population, whereas Hispanic in our data was much lower. The percentage of uninsured adults in the data set of asthma hospital visits was 47%, which was significantly higher than the percentage of uninsured adults in the ACS data.

Spatial clusters of asthma hospital visits

The result of spatial analysis shows that there was a clear pattern of clusters in residential locations of asthma patients who visited hospitals during the study period (Fig. 1). The largest hotspots (red) of hospital visits appeared in areas from the center to the south of Dallas and Fort Worth, and extended further to areas in south Dallas and Tarrant Counties. Several small hotspots were also seen in the cities of Denton and McKinney at the center of Denton and Collin Counties, as well as scattered areas throughout Dallas and Tarrant Counties. These hotspots indicate that the concentrations of asthma hospital visits were statistically significant at the 0.10 or lower levels. In other words, the cluster patterns of asthma hospital visits were not the results of random chance with a confidence level of 90% or higher. On the other hand, the largest cold spots (blue) were in the southwest area of Collin County, south-center of Denton County, and north of Dallas and Tarrant Counties. These cold spots indicate the areas with few hospital visits at the confidence level of 90% or higher.

Table 2
Characteristics of asthma sample data and ACS.

Characteristics	Asthma	ACS (aged 18–64 years)[a]
Age group (years)		
18–19	5%	4%
20–24	13%	11%
25–29	13%	12%
30–34	12%	12%
35–39	10%	12%
40–44	10%	12%
45–49	11%	11%
50–54	10%	11%
55–59	8%	9%
60–64	6%	7%
65	1%	
Total	100%	100%
Gender		
Female	65%	51%
Male	35%	49%
Race		
White	41%	67%
Black	44%	17%
Other	15%	16%
Ethnicity		
Hispanic	13%	28%
Non-Hispanic	87%	72%
Insurance		
Private	30%	63%
Public	22%	25%
Uninsured	47%	12%

[a] ACS Insurance data were extracted from Tables K202701, K202702, and K202703. The percentage data were calculated using the total population in the 2014 ACS 1 Year estimates.

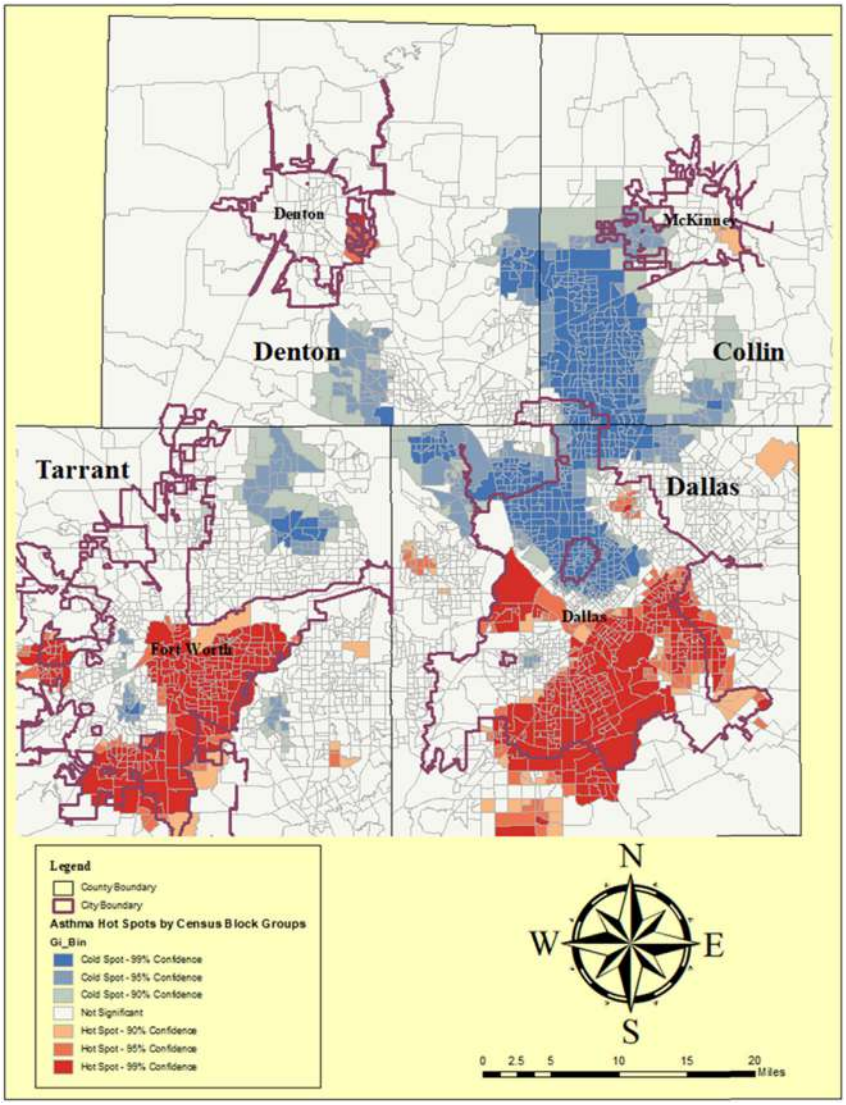

Fig. 1. Hot spots of adult asthma hospital visits.

The spatial patterns are further examined by type of insurance and race groups. Overall, those with private insurance are found more in cold spot areas. Those with public or no insurance are concentrated in hot spot areas. For example, Table 3 indicates that only about 26% of those with private insurance are in hot spot areas, compared with about 45% of those with public insurance and 36% of those without insurance are in hot spot areas. These patterns are not surprising as insurance is highly correlated to household income. The same is true for White and other race groups. Compared with other race groups, Blacks are highly concentrated in hotspot areas (about 53% compared with about 18% for White and 27% for other race groups). The differences among insurance and race groups are statistically significant at the 0.001 level.

Table 3
Clusters by type of insurance and race groups.

Groups	Cold	Hot	Other	Total
Insurance				
Private	13.3%	26.0%	60.7%	100.0%
Public	7.6%	45.1%	47.3%	100.0%
Uninsured	10.4%	35.9%	53.7%	100.0%
Total	10.6%	35.0%	54.4%	100.0%
Race				
Black	7.0%	52.8%	40.2%	100.0%
Other	12.0%	27.3%	60.7%	100.0%
White	14.1%	18.4%	67.5%	100.0%
Total	10.6%	35.0%	54.4%	100.0%

Negative binomial regression analysis

The results of pair-wise correlation analysis indicated that no multicollinearity exists among the independent variables. The highest correlation coefficient among the independent variables is .45. We tested four models. Following the social determinants of health theory, Model one contains only socio-economic variables. Model two adds measures of transportation characteristics to Model one to inspect the effects of transportation on asthma. Additional housing variables are included in Model 3. Following our hypotheses, we included all the regressors along the socio-economic, transportation, housing, and land use dimensions in Model 4. This incremental approach allows us to observe the changes when additional characteristics are considered. The results

Table 4
The goodness-of-fit statistics of models.

Goodness-of-fit statistics	Model 1	Model 2	Model 3	Model 4
Wald Chi-square	724.08***	819.88***	1014.12***	1033.29***
Log pseudo likelihood	−7017.948	−6982.307	−6956.796	−6953.519
Pseudo R2	0.0708	0.0742	0.0776	0.0781
AIC	14,053.9	13,994.61	13,949.59	13,947.04
N	2931	2926	2926	2926

AIC, Akaike information criterion.
***p < .001.

of the NBR model fit statistics are presented in Table 4. The Wald Chi-squared value increases from 724 for Model one to 1033 for Model 4, which indicates better predictive power, as we increase the comprehensiveness of the models. Akaike information criterion, a statistical measure of model goodness-of-fit, also indicates that Model four is the best model; thus, the results of Model four are the focus of our presentation below.

The results of model four reveal a number of observations (Table 5). Race, income, and educational attainment are significantly associated with adult asthma exacerbation at the 0.001 level after controlling for all the other variables. Specifically, the incidence rate ratio (IRR) of the variable "Black" in model four is about 1.0005, indicating that for each additional member of the Black population per census block group, the rate for asthma hospital visits per block group is expected to increase by a factor of 1.0005 while holding all other variables in the model constant. Similarly, the IRR for the education variable is 1.0022, which suggests that for each additional person in the population aged ≥25 years without a high school diploma per census block group, the rate for asthma hospital visits per block group is predicted to increase by a factor of 1.0022, all else being equal. On the other hand, the IRR for the median household income variable is .99,999, which signifies that for each dollar increase in median household income in a census block group, the rate for asthma hospital visits per block group is expected to decrease by a factor of 0.9999, all else being equal. Although the coefficients for the variable "Adult Males" are significant after controlling for socio-economic and transportation characteristics, the gender effect is not significant at the 0.05 level after adding the housing and land use variables. The results of "Adult Density" and "Median Age" are significant at the 0.01 level or better after controlling for housing and open space factors. On the other hand, the association between the number of adult males and hospital visit counts becomes insignificant after controlling for housing and open space factors.

Table 5
Negative binomial regression model predicting asthma hospital visits.

Variable name	IRR (standard error)	95% confidence interval	
#Adult males	0.9999 (0.0001)	0.9997	1.0003
#Black	1.0005*** (0.0000)	1.0005	1.0006
Median HH income	0.9999*** (0.0000)	0.9999	0.9999
#No HS diploma	1.0022*** (0.0006)	1.0009	1.0034
Adult density	0.9999*** (0.0000)	0.9999	0.9999
Median age	0.9946** (0.0021)	0.9904	0.9988
Well counts	1.0008* (0.0004)	1.0000	1.0016
Proximity to HWY	1.0426 (0.0329)	0.9801	1.1092
AVG speed	0.9937 (0.0042)	0.9855	1.0021
Road density	1.0045* (0.0022)	1.0003	1.0087
AVG COM distance	1.0234*** (0.0057)	1.0124	1.0346
#Work at home	0.9987** (0.0005)	0.9978	0.9997
#Pub transit users	1.0019** (0.0006)	1.0006	1.0031
House before 1979	1.0025*** (0.0007)	1.0011	1.0039
Gas heating house	1.0005* (0.0002)	1.00009	1.000835
Elec heating house	1.0007*** (0.0001)	1.0004	1.0009
Park/Rec density	0.9996 (0.0003)	0.9989	1.0002
Tim/farm density	0.9946** (0.0019)	0.9907	0.9985
_cons	3.9817*** (0.9352)	2.5127	6.3096
/lnalpha	−1.1587 (0.0504)	−1.2574	−1.0601
alpha	0.3139 (0.0158)	0.2844	0.3464

IRR = incidence rate ratio.
****P* < 0.001 =; ***P* < 0.01; * *P* < 0.05.

The effect of drilling activities on adult asthma occurrence is also significant at the .05 level when socio-economic, transportation, housing characteristics, and land use variables are considered. In general, higher rates of drilling activities are associated with higher rates of hospital visits. Specifically, the IRR for the variable is 1.0008 in model 4, meaning that for each additional drilling well per census block group, the rate for asthma hospital visits per block group is expected to increase by a factor of 1.0008, holding other variables constant. The same interpretation can be applied to other transportation, housing, and land use variables.

Most commute-related variables are significantly associated with the dependent variable. For example, the IRR in model four is 1.0234 for average distance to work, 1.0018 for public transit, .9987 for working at home, and 1.0045 for road density, respectively. All are significant at the .05 level or better. The associations between other transportation-related built environmental measures and asthma are insignificant. For example, the IRRs for the variables of proximity to highways and the weighted average speed limits are 1.0426 and .9937, respectively, but insignificant. Nevertheless, the sign of the proximity variable is consistent with the hypothesis and the literature. The results for the variable of the weighted average speed limit are consistently insignificant in the relevant models. Consistent with the existing literature, older housing stock is found to be associated with a higher rate of asthma hospital visits. The relationship is significant at the 0.001 level with or without land use variables. The model results also signify the effects of gas or electrical heating in housing units on asthma as demonstrated by Free et al.,[33] Vesper et al.,[34] and Piekarska et al.[35] though the results vary.

It is expected that green space, measured by land use for parks or other recreation purpose and timberland/farmland, would absorb pollution and be beneficial to health. The results in model four show the significant effect of timber land/farmland density but not parks or recreation land use density. The findings require further investigation.

Discussion

The results of this study show significant influences of neighborhood-level transportation, built environment, and social characteristics on asthma exacerbation among adults. Neighborhoods where residents on average experience longer commute distance and use of public transit are likely to have more asthma hospital visits as residents in those neighborhoods have more exposure to traffic-related air pollution. Major sources of traffic-related air pollution for commuters are from vehicle emissions, especially buses, because most transit vehicles are powered by diesel. In contrast, neighborhoods with more residents working at home show fewer hospital visits as working at home can reduce the time and the magnitude of exposure to harmful air pollution. The results also suggest that higher road density in neighborhoods is associated with more asthma hospital visits. Drilling construction activity during the study period was active; thus, the significant association between urban drilling and asthma symptoms may be due to airborne dust resulting from disruption of surface areas in neighborhood. Further research should validate this speculation. Consistent with previous research, race, income, and education are significantly associated with asthma exacerbation.

The findings regarding the effects of average commute distance, workers working from home, and public transit users have implications for transportation planners and policy makers. With the advancement in communication and transportation technologies and the experience with virtual activities due to COVID, working from home seems to have become an established part of our daily lives. It may also have other economic and environmental benefits, such as reduced business rental, utility, and maintenance costs, reduced travel time, improved productivity, ease of traffic congestion, and lower traffic-related air pollution. Transportation planners have already advocated travel demand management solutions, such as telecommuting, congestion pricing, and parking management to reduce traffic congestion. Our results lend support for these solutions. Additional innovative policies are required to further facilitate the new work at home trend and virtual activities while maintaining productivity. The finding that public transit is associated with asthma occurrence calls for urgent improvement in technologies for clean fuel for buses and trains. Similarly, the finding of a drilling effect on asthma suggests the need for policies to promote alternative clean fuels for drilling activities. In short, the knowledge about the link between asthma exacerbations and commuting/drilling activities not only lends support for transportation management solutions but also informs public administrators and policy makers in the energy production and technologies sectors to search for innovative policies and to speed up the production and adoption of green energy and transportation to improve air quality.

The findings on the linkages between asthma exacerbations and housing/land use characteristics provide support for evidence from the previous studies in these dimensions. For instance, similar to some previous studies (e.g. Newcomb and Li[8]; Piekarska et al.[35]; Vesper et al.[34]; Wang et al.[41]), this study found a positive relationship between asthma occurances and housing age, as well as heating systems. These findings call for policies related to housing construction and technologies improving housing conditions. The result of forest and farmland density provides empirical evidence to the limited research on the relationship between green open space and asthma.

The findings about the relationships among asthma, race, class, and education attainment reinforce the notions of disparities in public health and the need for policies and practices with a focus on equity and commitment to help poor and less-educated populations. Greener alternatives are emerging, but the individuals most vulnerable to asthma exacerbations are those who will be least able to benefit from green transportation and fuel technology alternatives in the near term. Likewise, policies promoting urban green space and retrofitting of older housing stocks will face the same equity challenges. Those individuals most likely to be vulnerable to the loss of asthma control are those least likely to live near substantial urban green space or to live in newer housing. Therefore, attention to equity should be addressed in all policies and practices.

Relevant local, regional, and federal policies and resources will be critical for urban planners, public healthcare professionals, and government officials. The internet will be the asthma advocate's best friend in this respect. For instance, an easy place to start for municipalities interested in green space is the Municipal Handbook published by the US Environmental Protection Agency. This publication is a 'how-to' guide for local governments that describe programs and policies related to funding and incentives, retrofit policies, rainwater harvesting, and green streets.[42] Another example for municipalities interested in housing is the American Lung Association's discussion of code ordinances, code enforcement, multiunit housing, and new and remodeled housing.[43]

Although the results of several environmental variables, such as highway proximity, average speed limit weighted by type of roads, and parks/recreation density show, the expected signs as hypothesized, the effects of these variables on asthma cannot be demonstrated with great statistical confidence. Other measurements, such as continuous numbers of meters from residential address to highways and other types of roadways, are less informative than direct measures of vehicle emission for measuring the effects of transportation-induced pollution on asthma. Likewise, alternative measurement of green space, such as tree canopy, may be a better predictor than the measurements used in this study. In addition, this study is limited to urban counties in the Dallas-Fort Worth (DFW) area. The discussion on policy implications should be taken with cautions.

Conclusions

In general, neighborhood characteristics continue to be determined by race and socio-economic status through place-based and income-based local or federal policies. This legacy reflects historical patterns of discrimination institutionalized in the United States since its inception and is well documented. From redlining, which began in the 1930s, to contemporary zoning and the alike, unfair private actions and governmental policies or practices espouse that segregation of the poor and people of color remains in place (Anderson[44]; Swope[45]). Historical and contemporary racism differentially exposes people of color to lifelong conditions harmful to health (Bravo[46]; Rothstein[47]), whereas poverty has the same effect (Wodtke[48]). The health effects of racism and discrimination on the basis of wealth are sweeping, detectable in almost every branch of medicine and health service, including such diverse areas as transplants, cancer, maternity outcomes, obesity, and access to medical providers. Asthma is not exceptional. Revolutions have failed to eradicate structural inequality, leaving incremental change as the most likely option. The role of observational studies, such as this one, is to provide an accumulation of evidence to be used to guide policy both grand and small. Empirical evidence should be taken into account in policy making, given that each factor identified as contributing to asthma exacerbations in studies like this is amplified in neighborhoods of the poor and people of color.

Social, epidemiologic, and public health scholars have advocated for studying the causes of health disparities from multiple perspectives. Asthma provides an exceptionally relevant condition for such scholarship as disparities in outcomes, treatment, and access to health care have been demonstrated repeatedly among patients with this condition. Asthma exacerbations affect the life of millions every year. The triggers for asthma exacerbations are multiple and diverse, including physiological, environmental, and social factors. Although scholars from various fields in the past several decades have investigated factors responsible for triggering asthma, fewer have approached the issue comprehensively and simultaneously from multiple social/community directions. This research helps fill that gap using data from four urban counties in North Central Texas.

The results from this study provide additional empirical evidence for the effects of social and environmental determinants of health on asthma control. The results of this research under a comprehensive framework by and large reinforce the notions in the previous studies that are limited to examining fewer variables. Drilling activity is rarely considered in the previous studies, but its effect on adult asthma is demonstrated in this study. The research also observes the change in significance of gender-related effect, measured by number of adult males, after controlling for housing and green open space variables. In addition, the research cannot determine the effects of proximity to highways and the weighted average speed limit of roadways, despite the expected signs as hypothesized. The effect of green open space is partially observed. The results of social determinants support continuing efforts, either through policies or practices, to improve education and socio-economic equities. The results also support existing transportation demand management solutions and disease management practices, as well as calls for innovative policies and strategies to promote clean fuel and technologies for public health. The study builds upon theories established by the existing literature, and the results could infer causal relationships and contribute to the current knowledge about the complex relationships between asthma exacerbations and possible triggering factors. Further research can extend the research scope, use more suitable measurements and panel data, as well as apply longitudinal research designs to advance the current understanding of asthma disparities.

Author statements

Ethical approval

The study was conducted according to the guidelines of the Declaration of Helsinki and determined by the University of Texas Southwestern Medical Center/Texas Health Resources IRB to be not human subjects research, and thus exempt from IRB oversight.

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Competing interests

None declared.

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Themed Paper – Original Research

Generating data to facilitate more equitable distribution of health resources: an illustration of how local health surveys can identify probable need in mixed socio-economic regions

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ABSTRACT

Objectives: This study aimed to (1) encourage allocation of governmental and grant funds to the administration of local area health surveys and (2) illustrate the predictive impact of socio-economic resources on adult health status at the local area level to provide an example of how health surveys can identify residents with the greatest health needs.
Study design: Randomly sampled and weight-adjusted regional household health survey (7501 respondents) analyzed with categorical bivariate and multivariate statistics, combined with Census data. Survey sample consists of the lowest, highest, and near highest ranked counties in the County Health Rankings and Roadmaps for Pennsylvania.
Methods: Socio-economic status (SES) is measured regionally with Census data consisting of seven indicators and individually with Health Survey data consisting of five indicators based on poverty level, overall household income, and education. Both of these composite measures are examined jointly for their predictive effects on a validated health status measure using binary logistic regression.
Results: Once county-level measures of SES and health status are broken down into smaller areas, better identification of pockets of health need is possible. This was most strongly revealed in an urban county, Philadelphia, which is ranked lowest of 67 counties on health measures in the state of Pennsylvania, yet when broken down into 'neighborhood clusters' contained both the highest- and lowest-ranked local area in a five-county region. Overall, regardless of the SES level of the County subdivision one lives in, a low-SES adult has close to six times greater odds of reporting 'fair or poor health status' than does a high-SES adult.
Conclusion: Local health survey analysis can lead to a more precise identification of health needs than surveys attempting to cover broad areas. Low-SES communities within counties, and low-SES individuals, regardless of the community they live in, are substantially more likely to experience fair to poor health. This adds urgency to the need to implement and investigate socio-economic interventions, which can hopefully improve health and save healthcare costs. Novel local area research can identify the impact of intervening variables such as race in addition to SES to add more specificity in identifying populations with the greatest health needs.

Introduction

In recent years, policymakers have relied on data that rank fairly broad geographical areas, such as states and counties in the United States, to identify public health needs and prioritize resources to address health disparities.[1,2] This is the case with the most detailed annual report for each state, known as the County Health Rankings and Roadmaps (CHR&R), which is conducted by the University of Wisconsin Population Health Institute and funded by the Robert Wood Johnson Foundation.[3] CHR&R opens its 2022 County Health Rankings National Findings report with an Executive Summary that outlines the purpose of the County Health Rankings (https://www.countyhealthrankings.org/reports/2022-county-health-rankings-national-findings-report). The first sentence sums up their mission:

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Table 1
Neighborhood cluster characteristics for SES index.

Neighborhood cluster	SES rank	Income ($)		% Families under poverty line		Education		Employment
		Median household	Per capita	All	With children	% Less than HS degree	% Less than college degree	% Unemployed
Center City	**24**	83,646	73,288	6.6	9.4	4.9	23.6	4.3
South Phila	**12**	60,420	36,678	14.9	24.5	16.0	64.2	8.9
Southwest Phila	**3**	35,981	18,788	26.1	37.1	18.0	82.1	16.0
West Phila	**5**	32,922	19,046	26.0	36.4	14.7	74.5	11.7
Lower N Phila	**7**	54,111	31,179	25.0	36.1	15.8	60.0	9.9
Upper N Phila	**1**	24,787	13,375	38.4	51.6	29.0	93.0	20.1
Kensington–Richmond	**2**	40,394	20,136	31.8	48.6	27.3	82.7	16.9
Roxborough–Manayunk	**18**	74,051	43,370	6.7	11.2	6.0	50.9	4.8
Germantown Chestnut Hill	**10**	51,710	34,465	15.5	25.2	11.6	59.7	10.1
Olney Oak Lane	**4**	41,151	19,959	21.9	31.2	20.3	83.5	16.1
Lower Northeast	**6**	45,080	20,581	19.8	28.1	20.0	83.3	12.1
Upper Northeast	**9**	57,711	28,685	8.9	13.6	12.2	76.5	7.4
Bucks South	**13**	81,791	40,169	3.6	6.7	7.7	66.6	5.6
Bucks Central-South	**25**	116,750	57,374	3.4	5.3	3.6	46.9	4.3
Bucks Central	**27**	107,860	55,104	2.7	4.3	5.0	51.7	5.7
Bucks North	**16**	71,429	34,213	5.9	9.0	8.7	74.9	6.9
Chester Central-East	**28**	130,159	71,295	3.0	4.9	3.2	30.7	3.4
Chester South	**19**	90,631	42,563	5.4	9.1	8.8	61.6	5.8
Chester North-Northwest	**14**	91,945	40,547	4.8	8.2	14.9	62.6	4.1
Chester Northeast	**30**	100,227	51,168	2.8	3.3	4.4	43.8	4.2
Delaware West	**29**	64,227	29,177	11.6	19.3	11.6	76.7	9.8
Delaware North	**26**	85,240	39,678	5.0	7.5	6.6	67.4	5.8
Delaware Northeast	**11**	58,135	27,945	11.8	17.8	9.7	73.9	7.7
Delaware Central-East	**15**	103,502	51,191	2.7	4.1	4.4	51.0	4.7
Delaware South	**8**	107,793	55,020	2.6	4.4	4.0	44.4	4.2
Montgomery West	**20**	89,702	47,160	3.7	5.4	5.2	51.1	5.6
Montgomery North	**17**	129,089	69,951	2.6	2.5	2.8	26.0	4.6
Montgomery Northeast	**23**	93,020	50,447	5.8	9.4	6.9	49.9	5.8
Montgomery Central-South	**21**	89,122	45,640	3.3	4.9	6.3	54.7	4.9
Montgomery Southeast	**31**	83,102	36,644	3.1	4.7	8.1	70.2	5.5
Montgomery East	**22**	88,163	43,285	5.0	7.3	6.3	56.6	5.7

HS, high school; SES, socio-economic status.
Source: Claritas 2018 Pop-Facts Database. Notes: Rankings of these seven items were averaged to form the SES ranks portrayed in Figs. 1 and 2. For Fig. 3, neighborhood ranks were grouped as follows: 1–11 = Low, 12–21 = Middle, 22–31 = High. Their proportional distribution was closely matched by grouping individual SES levels into these three categories based on the 5-item SES index created from the 2018 Household Health Survey (see Measures).

'County Health Rankings and Roadmaps (CHR&R) brings actionable data, evidence, guidance, and stories to diverse leaders and residents so people and communities can be healthier.' The reports focus on the various hardships minorities and people with low-income face, and the Executive Summary proclaims that the reports are designed to 'help allocate resources where they are most needed.'[c]

The authors of this article laud the ambitious goals of CHR&R and health planners who want to locate and serve people in need in the most effective way. We contend, however, that the county level is often not precise enough for identifying those with the most health needs, particularly larger suburban and urban counties, and that health survey data could be more effectively used if there was a greater availability of local-based health survey analyses. This would ideally be of the local areas that health planners are focused on, but when not possible, incorporating results from small areas that were intensively surveyed. Simply expressing in an interview or questionnaire that one has fair or poor health is a good indication that the individual is more in need of public health interventions, which if properly targeted and effective, could lower the number of hospital admissions for more serious health problems.

We provide an example of how sufficient sample sizes for areas within counties can add additional insights to locating and assessing health needs. By relying on a general measure of health (self-assessed health status), we show how county data alone can be insufficient in locating pockets of greater health needs. We also show how a key predictive measure of health status can be measured using a questionnaire format that adds insight to identifying people with health problems that can complement Health Ranking reports relying on aggregated data sources.

We focus on one key type of Health Outcome measured in the County Ranking Reports (Health Status) and one key index of health factors (socio-economic status [SES]). There are many choices for identifying county subregions, but because they were created by combining several neighborhoods together, which are a mix of community and professional identifications, we opted for the term 'neighborhood cluster' (NC).[4] As one can see from a Google search of maps of Philadelphia, the term neighborhood by itself has been used to refer to anywhere from 12 to 150 subdivisions.

The most complete source of individual health data at a state and national level is the Center For Disease Control's (CDC's) Behavioural Risk Factor Surveillance System (BRFSS) health survey, which is used by CHR&R for several of its health measures.[5] BRFSS is conducted annually within each state, where each state has some flexibility in tailoring the survey to their particular needs. Because of the nature of this survey, sample size per county can be small. Pennsylvania is typical of other states in that the majority of counties have annual sample sizes less than 100.[6]

[c] The methodology to accomplish this consists of measures with weighted items to form two scales at the county level: health outcomes and health factors. The Outcome Scale includes vital statistics and health survey measures, whereas the more complex Factors Scale includes four dimensions: Health Behaviours, Clinical Care, the Physical Environment, and Social and Economic Factors.

For this reason, in Pennsylvania, BRFSS data are broken down into only six districts and two large counties (Philadelphia and Allegheny) for annual County Ranking Reports.[d]

Similar to the rankings of counties in the County Health Ranking and Roadmaps reports, we focus on rankings of the Public Health Management Corporation Southeastern Pennsylvania Household Health Survey data broken down into 31 'NCs' within five counties in Pennsylvania. Among these five counties is one that currently ranks highest in the state on both health factors and outcomes in the CHR&R reports, followed by the second highest on Health Factors. It also includes the lowest-ranked county in the state, Philadelphia (67th out of 67).[e] This variability at the county level implies that residents of the highest ranked counties have better health than residents of the lowest-ranked county. The aim of this study is to show how a health survey with sufficient sample sizes for county subdivisions can reveal a more complex pattern of health variability in both highly and lowly ranked counties.

Methods

This analysis draws on the 2018–2019 Southeastern Pennsylvania Household Health Survey collected by Public Health Management Corporation (PHMC HHS) and funded by hospitals and non-profit organizations that received data files, reports, and navigation tools. It includes more than 7500 health surveys within five counties of Southeastern Pennsylvania, which actually exceeded BRFSS state totals that fell below 7000 both in 2018 and 2019. The 2018–2019 survey is the 17th administration of the health survey conducted by PHMC since 1983, with 13 of the surveys exceeding 10,000 adult samples. The PHMC HHS has been used primarily for proposals to implement health centers and various health interventions, hospital assessments of their service area's needs, and newspaper articles detailing local health issues to spread awareness and health education.[7] Details regarding the PHMC HHS methods, including a more detailed description of response rates and weights, are available at https://research.phmc.org/products/community-health-database.

The 31 NCs are ZIP code based and derive from a longstanding division of Philadelphia into 12 Planning Analysis Sections, and for the four suburban counties, we carved 19 boundaries based on consultations with county and hospital planners. The total 31 NCs average 242 respondents apiece.

We focus on SES, a measure of a person's social and economic status, which is based on income, education, and occupation. SES is a key component of CHR&R's list of health factors. The PHMC HHS contains several questions to ascertain income cutoffs enabling the creation of two poverty-level variables.[f] These are a major component of our 5-item SES index consisting of (1) Above the Poverty line, (2) Above 200% of the Poverty Line, (3) Above $100,000 Household Income, (4) High School Graduation, and (5) College Graduation. If a respondent met all five criteria, they were categorized as high SES, if 3–4, middle SES, and 0–2, low SES.

Table 2
Neighborhood cluster legend and health status/SES rankings for the 31 neighborhood clusters in five counties.

Cluster ID	Neighborhood cluster	Health rank	% fair/poor health	SES rank
P1	Center City	31	7.7	24
P2	South Phila	10	21.5	12
P3	Southwest Phila	9	21.8	3
P4	West Phila	2	29.9	5
P5	Lower N Phila	8	21.8	7
P6	Upper N Phila	1	55.2	1
P7	Kensington–Richmond	16	17.7	2
P8	Roxborough–Manayunk	13	19.7	18
P9	German Chestnut Hill	14	18.8	10
P10	Olney Oak Lane	5	23.9	4
P11	Lower Northeast	3	29.4	6
P12	Upper Northeast	6	23.5	9
B4	Bucks South	11	21.5	13
B3	Bucks Central-South	26	12.9	25
B2	Bucks Central	28	9.6	27
B1	Bucks North	17	17.5	16
C4	Chester Central-East	20	14.6	28
C3	Chester South	19	15.9	19
C2	Chester North-Northwest	18	16.2	14
C1	Chester Northeast	30	8.1	30
D5	Delaware West	27	10.6	29
D4	Delaware North	21	14.6	26
D3	Delaware Northeast	4	23.9	11
D2	Delaware Central-East	15	18.0	15
D1	Delaware South	7	21.8	8
M6	Montgomery West	23	14.4	20
M5	Montgomery North	12	21.2	17
M4	Montgomery Northeast	22	14.5	23
M3	Montgomery Central-South	25	13.0	21
M2	Montgomery Southeast	29	8.3	31
M1	Montgomery East	24	14.4	22

SES, socio-economic status.
Rankings of each of the seven Census estimate items (median hh income, per capita income, % families below poverty, % families with children below poverty, % less than HS graduation, % less than college graduation, and % unemployed) were averaged to form the overall SES ranks used for Fig. 1.
To be consistent with the figure, ranks that start at 1 represent the lowest score and 31 the highest score, despite the more common practice of ranking the highest SES area as 1.
Source: Claritas 2018 Pop-Facts Database and PHMC 2018 Household Health Survey.

The methodology to create similar categories for the NC in which the respondents lived entailed a different approach due to the aggregate nature of Census data.

We developed an NC SES variable based on seven indicators. Instead of relying on 5-year averages provided by the US Census, we used a proprietary database, which provided specific ZIP Code estimates for the 2018 survey year by supplementing prior available US Census data with other current data sources, such as utility bills and home sales data.[8] Each of the 31 NCs received a rank for each of the seven SES items and then the average ranked score was created to provide one overall rank. Then the ranks were divided into low, medium, and high categories, which closely matched the individual SES proportional distribution.

If NCs were near perfectly matched so that high SES segregation existed (i.e. low-SES residents only lived in low-SES NCs, middle in middle, and high in high), it would be pointless to analyze the combination of the SES of an individual respondent with the SES of their geographical surroundings. There was much heterogeneity in individual SES and the SES of the individual's NC, providing us with sufficient sample sizes for all nine possible combinations of the

[d] BRFSS reports have also reduced the 67 counties in Pennsylvania to 25 regions when three years of data are combined, with only nine counties standing alone with sufficient sample size for county-level health measures based on the rule of not reporting a percentage with a denominator under 50 or 95% confidence interval half-width greater than 10.[29]

[e] Philadelphia County is geographically the same as the city of Philadelphia City and is almost as large as the other four counties combined. It contains 12 of the 31 neighborhood clusters. Even with this great disparity in ranks, we discovered 'neighborhood clusters' in Philadelphia, which are in good shape (Center City in particular) and some in the suburban counties that are not in such good shape.

[f] Income was collected using ranges that very closely matched US Department of Health and Human Services Poverty Guidelines for given family sizes based on 2017 and 2018 income.[30] The survey contains more categories than BRFSS and enables the creation of different poverty levels such as extreme poverty (50% of poverty level) and near poverty (200% of poverty level) by adjusting the ranges. For example, there are six ranges of income between $33,000 and $57,000 to meet poverty-level endpoints compared to $25,000–$35,000 and $35,000–$50,000 asked in each BRFSS survey for the past decade.[10]

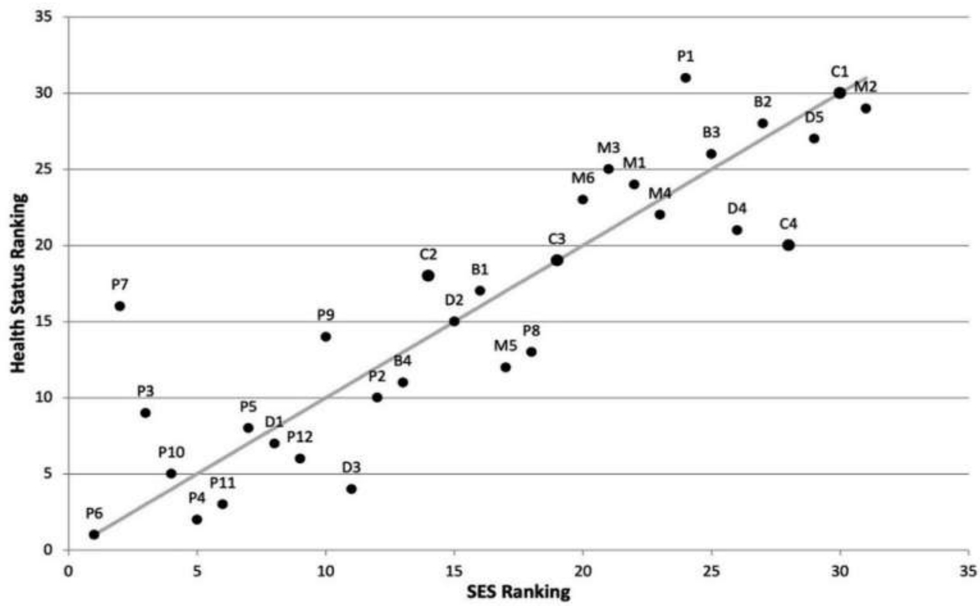

Fig. 1. Scattergram of low to high rankings of SES based on Census data and of health status based on survey data for 31 neighborhood clusters in five counties*. *B=Bucks County, C=Chester County, D=Delaware County, M=Montgomery County, P=Philadelphia County (Spearman's Rank Correlation = .88). SES, socio-economic status.

two, with the least likely combination being high-SES residents living in low-SES NCs ($n = 147$). This enables us to address the question of the relative importance of an individual's SES and the SES of their NC in impacting health, with the implication that to the extent geographical surroundings, as measured by NCs in this article, are influential, health needs will be more geographically concentrated. This question was addressed by appropriate bivariate and multivariate procedures.[g,h,i]

Self-assessed health, a commonly used measure of general health status, asks adults to rate their health on a five-point Likert scale, varying from excellent to poor.[9] Analyses commonly dichotomize the variable between good or better health compared with fair or worse health. This measure has been found to be predictive of multiple dimensions of health[10] and mortality[11] and has passed multiple reliability and validity tests.[12–14]

Results

Examining SES at an NC level compared with the county level reveals substantial intra-county variation, as revealed in the Census-based items measuring SES in Table 1, and their overall ranks alongside of health status ranks in Table 2 and graphically illustrated in Fig. 1. The relationship between the 31 NC ranks on SES and health status was tested with Spearman's rank order correlation coefficient, producing a strongly predictive coefficient of .88.

The most notable variation between NCs lies within the county/city of Philadelphia, which is the poorest- and lowest-ranked county on social factors among Pennsylvania's 67 counties (County Health Rankings, 2019). Nonetheless, we can see in these tables and figure that the SES of one Philadelphia NC—Center City (P1 in Fig. 1)—ranks close to the wealthiest NCs in the surrounding suburban counties and highest in health status among all 31 NCs. Only 7.7% of Center City adults declared their overall health as fair or poor, compared to 55.2% of adults in the NC with the lowest SES and health status rank—Upper North Philadelphia (P6 in Fig. 1). Even the highest SES counties in the top 10 of Pennsylvania (Chester, Montgomery, and Bucks) have at least one NC that is lower to middle SES. In fact, Montgomery North and Bucks South are surpassed by two of the 12 Philadelphia NCs on both SES and health status.[j]

Wide variations in health status occur between the NCs ranked highest and lowest in SES within each county, as illustrated in Fig. 2. The solid horizontal lines connect the rank order points of the highest and lowest SES-ranked NC in each county, and the dotted lines connect the rank points of their corresponding health status level. The most extreme difference in NC SES lies in Philadelphia, as just mentioned, but large gaps are evident between the highest and lowest SES-ranked NC within each county and their concomitant health status ranking. Only Montgomery County contains a partial outlier for its highest SES NC, whose health status ranked twelfth of 31 clusters.

[g] For our multivariate analysis, we excluded cases without income and/or education data rather than allow for imperfect missing values imputation of these variables. Those excluded were primarily respondents who did not provide their income, who averaged slightly lower on high school and college graduation rates. As a result, our multivariate analysis is based on 5110 interviews with non-missing data on each SES item, weight-adjusted to regional demographics (age, sex, race, poverty level) and to adult household size (https://research.phmc.org/products/community-health-database).

[h] Among this subsample with complete income and education data, the five SES items have a Cronbach alpha coefficient of 0.72, with no independent correlation greater than 0.64 or less than 0.15, which is good, as no items are duplicates but capture the same concept.

[i] By using a stepwise approach of introducing 'blocks of predictor variables' one at a time into our regression model, we avoid problems of multicollinearity in being able to determine the effects of county before seeing if they had any independent effects after controlling for neighborhood cluster effects, where high collinearity reduces the effects and similarly when introducing the respondents' own SES levels into the final model.

[j] The most outstanding outlier, Kensington–Richmond (P7), was largely due to weighting adjustments due to a preponderance of older adults being interviewed who tend to be less healthy. This resulted in an unweighted percent of 30.1% in fair/poor health that was weight adjusted to only 17.8% due to a small selection of younger respondents who may not be representative of their cohort.

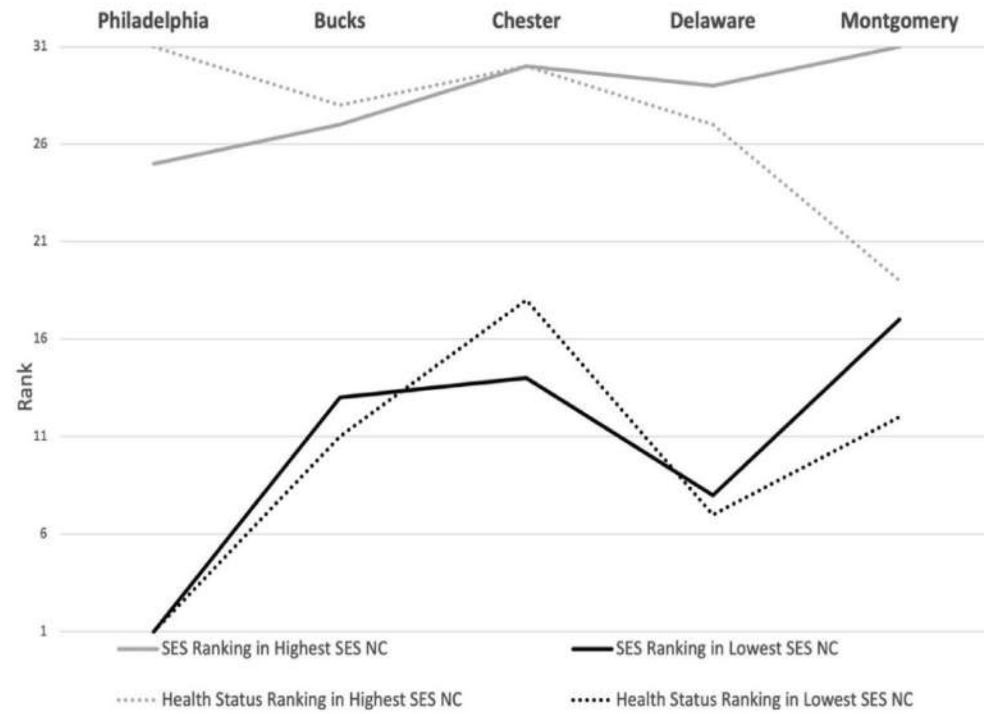

Fig. 2. Correspondence of SES and health status in the highest and lowest SES 'Neighborhood Cluster' within each county. SES, socio-economic status.

SES also varies 'within' each NC. By using the PHMC HHS to look at the health status of individuals who differ from their NC level, we can better assess the extent to which higher or lower household SES measures are important predictors of health, independent of geographic location. We can see at the top of Fig. 3 that NCs are not entirely homogenous in internal SES levels, where slightly less than half of respondents residing in lower SES NCs have low SES, with most of the remainder having middle SES. About one-half of respondents in middle-SES NCs have middle SES, with the remainder closely divided between high and low SES. One-third who reside in higher SES NCs have high SES, with most of the remainder having middle SES. At the bottom of Fig. 3, the graph displays the variations in health status level for the nine combinations of individual and NC SES. The most marked difference is approximately 40% of low-SES adult residents of low-SES NCs have fair or poor self-reported health compared with only 6.6% of high-SES residents of low-SES NCs ($P < 0.001$, RR = 6.08). The best health status outcome for low-SES adults is residence in high-SES NCs (23.2% with fair or poor health).[k] Nonetheless, there still remains a large gap between their health status and the health status of middle-SES ($P < 0.001$, RR = 1.98) and high-SES ($P < 0.001$, RR = 2.49) adult residents of high-SES NCs.

The findings from the multivariate binary logistic regression model add further precision to the direction of the results above. Table 3 consists of a multivariate analysis of county, NC, and individual-level predictors of health status, broken down into three corresponding blocks of predictor variables. Block 1 contains county only, with the highest ranked Pennsylvania county in recent ranking reports, Chester, serving as the reference category. Block 2 consists of county plus the inclusion of SES level of the respondent's NC (with high SES serving as the reference category), and Block 3 consists of county, SES level of the respondent's NC, and SES level of the individual respondent (with high-SES individuals serving as the reference category). The fourth column of adjusted odds ratios is a separate insertion of a block of the nine combinations of respondent and NC SES levels after inserting the county block.

In Block 1, Philadelphia is shown to report significantly lower health than suburban counties, with Delaware County reporting only mildly better health. Since no variables are being controlled for, the odds ratios for Block 1 are unadjusted. Block 2 shows that once the SES level of a respondent's NC is included in the model, most of the county effect is removed based on their no longer significant adjusted odds ratios coupled with highly significant odds ratios (AOR) for middle- vs. high-SES NC residence and most strongly for low- vs. high-SES NC residence, where living in low SES residence NCs doubles the odds of being in fair or poor health irrespective of county residence.

Block 3 contains the full set of variables, where county becomes irrelevant in having no additional predictive power, NC SES level is somewhat, but less significant, and individual SES, regardless of county or NC resided in, is highly significant and most strongly predictive (up to six times greater odds of fair or poor health when comparing low to high-SES individuals, regardless of geographical location). Each of the five SES scale items is also highly significant when substituting each one in place of the combined scale, with being below or above 200% poverty having the highest predictive value of the likelihood of fair or poor health (AOR = 2.1).

The interaction between the trichotomized NC SES level and respondent SES level measures can best be grasped by examining the combination of categories from Blocks 2 and 3, without controlling for them. Of the nine combinations of low/middle/high NC SES and individual SES, the higher the SES level of the individual respondent, regardless of county of residence or NC

[k] This improvement in health for the low SES in higher SES environments can only be partially attributed to having an initial higher SES score when grouped with other respondents with 0–2 checks of the five-item SES index, in their having a mean of 1.49 items checked compared with 1.31 for the low-SES residents of low SES neighborhood clusters and 1.44 for the low SES residents of middle SES neighborhood clusters.

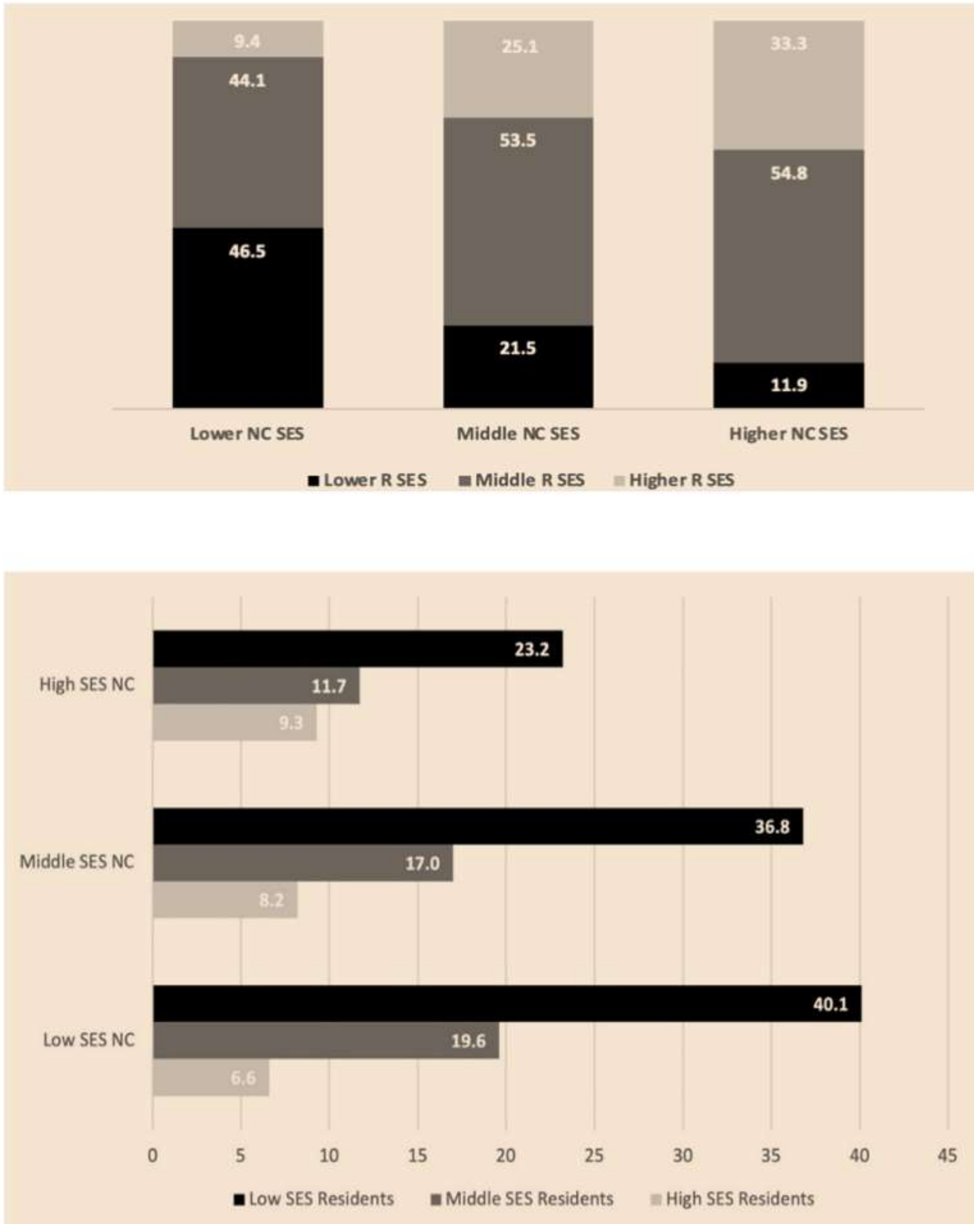

Fig. 3. Percentage of low, middle, and high SES interview respondents (R) who live in low, middle, and high SES neighborhood clusters (NC) followed by the percentage of each group with fair/poor health. SES, socio-economic status.

SES, the stronger the predictive effects of not having fair or poor health. There is one modification of the intensity of prediction, where the odds of low-SES residents living in high SES clusters are 3.5 times greater than the odds of high-SES residents of high SES clusters in assessing their health as fair to poor health, which is less than the odds of their living in low or middle SES clusters, where residents are over six times greater than high-SES residents of high SES clusters in assessing their health as fair to poor. This is the only interaction effect revealed, reinforcing the importance of individual SES vs. the SES of one's NC when the two differ.

To further enhance the relationship between SES and health outcomes, we can incorporate intervening variables such as gender, race, ethnicity, and age as SES may not have the same predictive impact for particular groups. We have started this process, and the initial results lead to promising insights. Racial discrimination has had hurtful impacts on health,[15–17] and African American and Latinx minorities are more likely to be stuck in lower SES levels. Nonetheless, some minority members have attained higher SES status, and we had sufficient sample sizes of African Americans at each of the three SES levels to compare to Whites.[1] Our early exploratory analyses suggest that low SES is hurtful to health status about equally for both race groups and high SES is equally helpful. The middle-level SES group, however, showed significantly lower

[1] There was an insufficient Latinx sample at the higher SES level, but their health status was also lower than White non-Hispanics in the middle SES level and lower than both White non-Hispanics and African Americans at the low SES level, with 44.8% in fair/poor health compared with 36.0% of African Americans and 34.9% of White non-Hispanics. Overall, SES is far more predictive of health status as neither race group with high SES surpassed 10% in fair/poor health.

Table 3
Binary logistic regression analysis of the predictive impact of SES on fair to poor health status incorporating three block levels of geographical specificity and the impact of individual SES when it does not conform to neighborhood cluster SES ($n = 5110$).

Breakdown of Residential County, and of SES Levels of Neighborhood Clusters and of Individual Respondent	Block One		Block Two		Block Three		Combination of Blocks Two and Three	
	County		County + Neigh Cluster (NC) SES		County+NC +Individual SES		County+Interaction of NC and Individual SES	
Block Items	Un-adj OR	*P*-value (Wald)	Adjusted OR	*P*-value (Wald)	Adjusted OR	*P*-value (Wald)	Adjusted OR	*P*-value (Wald)
County								
Philadelphia	1.78	***	1.21	ns	.95	ns	1.05	ns
Bucks	1.05		1.03	ns	.92	ns	1.08	ns
Delaware	1.40	*	1.21	ns	1.17	ns	.85	ns
Montgomery	.88		.91	ns	.88	ns	1.13	ns
Chester	–	–	–	–	–	–	–	–
Neighborhood cluster SES								
High SES			–	–	–	–		
Middle SES			1.50	***	1.29	*		
Low SES			2.11	***	1.34	*		
Individual SES								
High SES					–	–		
Middle SES					1.94	***		
Low SES					6.17	***		
Neighborhood SES * individual SES								
Low/low							6.62	***
Low/middle							1.99	***
Low/high							.67	ns
Middle/low							6.36	***
Middle/middle							2.01	***
Middle/high							.86	ns
High/low							3.55	***
High/middle							1.37	ns
High/high							–	–

OR, odds ratio; SES, socio-economic status.ns: $P > .05$ (not significant); *: $P \leq .05$ (significant); **: $P \leq .01$ (highly significant); ***: $P \leq .001$ (very highly significant).
Double dashes (–) represent the comparison group, where the unadjusted and adjusted odds ratios are likelihoods of fair to poor health compared to the comparison group.

health status for African Americans than for Whites (data not provided).

Conclusion

This article's findings follow the lead of studies that combine regional and individual SES measures.[18–20] To date, based on this literature, it is still unclear whether low SES individuals living in higher SES neighborhoods are healthier or not, as these studies have mixed results. We found a very modest improvement of living in higher SES NCs.

One way to increase funding for small area health survey research, without taking funds away from actual programs that lead to greater health equity, is to have the national BRFSS phone survey conducted every other year instead of annually. Broad area health estimates, such as at the state and county level, change little year by year, so there may be less urgency for annual health survey data. County ranking reports and the like will still have access to administrative data for each year and can use imputation methods based on the BRFSS data available and perhaps piggyback off of the findings of small area research studies to sharpen the imputation equations. The added problem of relying on telephone interviewing exclusively at a time when response rates are dropping and more interview calls are automatically blocked begs for more innovative survey methodology.[21,22] Small area studies that focus on local areas, whether they be NCs, neighborhoods, Census tracts, or Census block groups, are easier to advertise. This is because flyers and announcements in community centers and the like can be more concentrated, and the study can train local residents as interviewers and ambassadors for the survey because they know the area and can make face-to-face contacts with the knowledge that many, if not most or even all, households are potential health survey participants. To obtain a more closely representative sample than telephone interviews which can necessitate weighting adjustments for under-represented groups such as low-income males, non-random procedures such as snowball sampling that require finding local residents such as prior survey participants to recruit members of under-represented groups can be accomplished within small areas.[22] A combination of non-telephone-based sampling methods has been fruitfully applied in a just completed study commissioned by the Pottstown Area Health and Wellness Foundation.[m]

Focus on smaller areas that enable intra-county analyses would not only be informative of the unique aspects of the studied areas; they could improve the statistically intensive methodology called ‘Small Area Analysis,’ which attempts to impute health outcomes that are not heavily surveyed by relying on known demographic and environmental predictors.[23–25] Without actual data on small areas themselves, there is little verification or refinement of these models to enhance predictive accuracy. By gathering more data on distinctive neighborhoods and revealing more complex associations between neighborhood composition, demographics, and

[m] This study's methodology and findings will be available in spring 2023; one can contact the lead author of this article for access to it. In brief, this study is unique in that every household in a lower-income neighborhood consisting of approximately 3500 households was contacted via a letter containing a $2 bill in the window and other incentives to complete the interview online, by phone, or in the library, along with a second wave of follow-up postcards and snowball sampling of under-represented males and African Americans. Response rates exceeded other recent large health surveys, and weighting adjustments resulted in a Design Effect well under that of most surveys, including the PHMC HHS survey used for this article.

health, this methodology will improve its ability to generalize to other similar small areas.

SES should be measured with sufficient indicators and looked at by breaking down its components, as it has repeatedly shown strong predictive qualities. In our research, both education and income were highly significantly predictive, with the strongest predictive indicator being above or below 200% of the poverty level. Further research can compare the impacts of education and income on different health outcomes, as they may have distinctive effects on health. For example, one study found mental health to be more strongly impacted by income in a richer country and by education in a poorer country.[26]

SES factors may have a more or less pronounced impact on certain health conditions based on race, gender, and age, such as has been shown on health outcomes such as cardiovascular health, but with its impact varying by gender and race (lower SES males and lower SES Whites more likely to have cardiovascular problems).[27] Further predictive analysis on health data warrants the inclusion of intervening variables to enable more precise predictive identification of those who are most in need of assistance at an early stage of experiencing health problems.

One finding that the gap in health status between low and high SES residents of lower, middle, and upper SES NCs suggests a need for further investigation to facilitate greater health equity. Although when we went below the county-level predictions of health status greatly improved, there was still much socio-economic and health variation within these areas. One methodological option is to make areas studied even smaller in size. For example, regional prediction of health seems of less value during periods of gentrification, such as is currently underway in many Philadelphia neighborhoods[28] than it was when neighborhoods were more homogenous in housing stock and assets held. One may be aware, without needing more research to verify this, that the SES resources one has supersede where one lives in impacting health, but nonetheless, our findings on the great distance between low, middle, and high SES respondents were surprising. An adjusted odds ratio above 6 when comparing low-SES respondents to high SES respondents in having fair or poor health is quite high. Such results could not be attained with county-level data because of the mix of socio-economic levels in each county we studied.

Our hope is that this article inspires additional analyses to better understand and target local areas with the greatest health needs and that public and private organizations see the value of local-based health surveys in accomplishing this goal and provide funding to support them. We also hope that our results lend support and inspiration to novel efforts to implement and investigate socio-economic interventions among people with low SES.

Author statements

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Ethical approval

On February 16, 2018, the PHMC Institutional Review Board (IRB) reviewed '2018–2019 Southeastern Pennsylvania Household Health Survey' in accordance with 45 CFR 46.102 and determined that the study is not human subjects research (NHSR) for the following reason(s): Public health surveillance.

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None declared.

Author contributions

G.K. and E.B. contributed to conceptual/theoretical development. G.K. contributed to research/methodological design and managing/supervising the project. G.K. and M.H.S. contributed to data collection/coding/analysis and securing external funding for data set. G.K., E.B., and M.H.S. contributed to manuscript drafting and critical analytical/writing revisions.

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Original Research

How well do area-based deprivation indices identify income- and employment-deprived individuals across Great Britain today?

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ABSTRACT

Background: Area-based deprivation indices are used in many countries to target interventions and policies to populations with the greatest needs. Analyses of the Carstairs deprivation index applied to postcode sectors in 2001 identified that less than half of all deprived individuals lived in the most deprived areas.
Objective: This article examines the specificity and sensitivity of deprivation indices across Great Britain in identifying individuals claiming income- and employment-related social security benefits.
Study design: This was a descriptive analysis of cross-sectional administrative data.
Methods: The data sets for the 2020 Scottish Index of Multiple Deprivation, Scottish Income and Employment Index, the 2019 English Index of Multiple Deprivation and the 2019 Welsh Index of Multiple Deprivation were obtained. For each data set, small areas were ranked by increasing overall deprivation, and the cumulative proportions of individuals who were income and employment deprived were calculated. Receiver operating characteristic curves were plotted to show the sensitivity and specificity of each index, and the percentages of income- and employment-deprived individuals captured at different overall deprivation thresholds were calculated.
Results: Across all indices, the sensitivity and specificity for detecting income- and employment-deprived individuals were low, with less than half living in the most deprived 20% of areas. Between 55% and 62% of income-deprived people and between 56% and 63% of employment-deprived people were missed across the indices at the 20% deprivation threshold. The sensitivity and specificity were slightly higher for income deprivation than employment deprivation across indices and slightly higher for the Scottish Index of Multiple Deprivation and Scottish Income and Employment Index than for the English Index of Multiple Deprivation and Welsh Index of Multiple Deprivation.
Conclusion: Area-based deprivation measures in Great Britain have limited sensitivity and specificity for identifying individuals who are income or employment deprived. Place-based policies and interventions are unlikely to be effective at reducing inequalities as a result. Creation of individually linked data sets and interventions that recognise the social and economic relationships between social groups are likely to be more effective.

Background

Health inequalities, defined as the “systematic, avoidable and unfair differences in health outcomes that can be observed between populations, between social groups within the same population or as a gradient across a population ranked by social position”,[1] remain one of the greatest public health challenges today.[2] Despite there being substantial evidence describing the effective actions to reduce health inequalities,[3–7] they have remained stubbornly wide across most countries where they have been monitored.[8]

In contrast to many European countries, where individually linked socio-economic position and mortality data are routinely available, monitoring of health inequalities in the United Kingdom

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has relied on area-based deprivation indices to rank the population.[9–12] The use of a comprehensive range of indicators and statistical analyses to monitor health inequalities has been commended,[13,14] but there are three key limitations to the use of area-based indices for this purpose. First, it misallocates individuals to the average deprivation level of local areas, which reduces the scale of inequalities towards the null. Second, it can be misused to accord individuals the risk and deprivation of the area (and population average) in which they live (i.e. the ecological fallacy). This is exacerbated when the area unit size is larger (e.g. local authorities compared with data zones or Lower Super Output Areas). Third, some deprivation indices include health outcomes in their weightings, and this leads to a circular logic in the use of the indices for ranking health outcomes (which has led to the creation and use of subindices such as the Index of Employment and Income [IEI] deprivation in Scotland, which do not include health outcomes).

Despite these limitations, the use of area deprivation indices has the key advantage of identifying spatial concentrations of need, which can assist in the planning of services and interventions. This has allowed targeting of health, social and economic interventions and funding to the areas of greatest risk and needs.[15] However, identifying the most deprived areas may not identify the most deprived 'highest risk' individuals. Furthermore, area-based strategies ignore the social and economic *relationships* that underlie inequalities between social groups (e.g. they do not address the income flows between landlords and renters, which maintain or exacerbate economic inequalities).[16,17]

The analysis of the Carstairs deprivation index in 2001 in Scotland demonstrated that targeting the most deprived 20% of postcode sector areas would miss more than half of the most deprived individuals because most did not live in the most deprived areas.[18] This article updates that analysis using the smaller area data and the most commonly used deprivation indices in Scotland, England and Wales (the Scottish Index of Multiple Deprivation [SIMD], the IEI, the English Index of Multiple Deprivation [IMD], and the Welsh Index of Multiple Deprivation [WIMD]) by considering how sensitive these indices are at identifying income- and employment-deprived individuals at different thresholds.

Methods

Data sources

The 2020 SIMD and IEI data sets were obtained from the Scottish Government Web site and by personal correspondence.[19] The 2019 English IMD and WIMD data sets were obtained from the UK Government and Welsh Government, respectively.[20,21] Although the IEI data set is less commonly used, nor routinely available, it was included because of its value for health inequality analyses because it does not include health measures in the index and thereby avoids the circular logic of using SIMD as a health ranking measure. The data sets included the deprivation ranking, the crude number of individuals claiming unemployment-related social security benefits and the crude number of individuals claiming income-related benefits in each small area. The data relating to individuals are allocated to each small area using their addresses and associated postcodes. These are unique identifiers that avoid misallocation on the basis of imprecise georeferencing, although misallocation could occur as a result of incorrect or out-of-date addresses within administrative records.

Analytical approach

Each data set was first ranked by the overall relevant deprivation index. The cumulative proportion of income- and employment-deprived individuals was then calculated and graphed as a receiver operating characteristic curve to compare sensitivity and specificity across all possible deprivation thresholds. The percentage of income- and employment-deprived individuals resident within the most deprived 5%, 10%, 15%, 20%, 25% and 30% of small areas for each of the deprivation indices were calculated.

Results

The receiver operating characteristic curve for the cumulative percentage of income- and employment-deprived individuals across areas ranked by overall SIMD deprivation in Scotland is shown in Fig. 1. As expected, more deprived areas contain a higher proportion of people who are individually deprived than less deprived areas, but the curve is not steep, indicating a low sensitivity and specificity. Almost identical results were found when the IEI was used to rank Scottish areas instead of SIMD. The IMD for England and the WIMD for Wales are slightly less sensitive than both of the Scottish indices (Table 1).

Taking the 20% most deprived areas as the threshold, only 45% of income-deprived individuals were identified using both of the Scottish indices, with 43% identified using the English IMD and 38% using WIMD. The percentage of employment-deprived individuals identified at the 20% most deprived threshold was slightly lower for all indices, with 44% of people identified with both the SIMD and IEI, 42% with the English IMD and 37% with the WIMD.

Discussion

The sensitivity and specificity of area-based deprivation indices in Great Britain in terms of identifying individuals who are income or employment deprived are low. If the standard threshold of the most deprived 20% of areas is used to identify people at risk or with higher needs, some 55–62% of income-deprived people and 56–63% of employment-deprived people will be missed.

The strengths of the approach taken in this article include the simplicity of the analysis, the triangulation of findings across four deprivation indices and three national populations, and the use of commonly used administrative data that are the most common basis for identifying populations at greatest need across Great Britain. The extent to which this applies beyond Great Britain, to other area-based indices and to other outcomes has not been covered here.

The findings in this article show that the SIMD, IEI, English IMD and WIMD are more sensitive than the Carstairs index as applied to postcode sectors in Scotland in 2001, when only 34% of all income-deprived households and 41% of all employment-deprived individuals were found to live in the most deprived 20% of areas. This is likely to reflect the larger area unit size of postcode sectors compared with the data zones and Lower Super Output Areas used for deprivation indices now.

There are numerous implications of this study across policy, practice and academia. First, as much as area-based indices of deprivation are useful tools for identifying spatial areas with greater needs, they are limited in their sensitivity (i.e. they miss many people experiencing deprivation) and specificity (i.e. they include many people within deprived areas who are not experiencing deprivation). Using area deprivation to identify people at higher risk to plan and target interventions is likely to only have very muted impacts as a result. This compounds the problem of missing the crucial importance of economic and social relationships between social groups (e.g. between renters and landlords, company owners and workers, savers and borrowers), which underpin trends in social, economic and health inequalities.[16,17,22] Place-based strategies, which have become increasingly popular

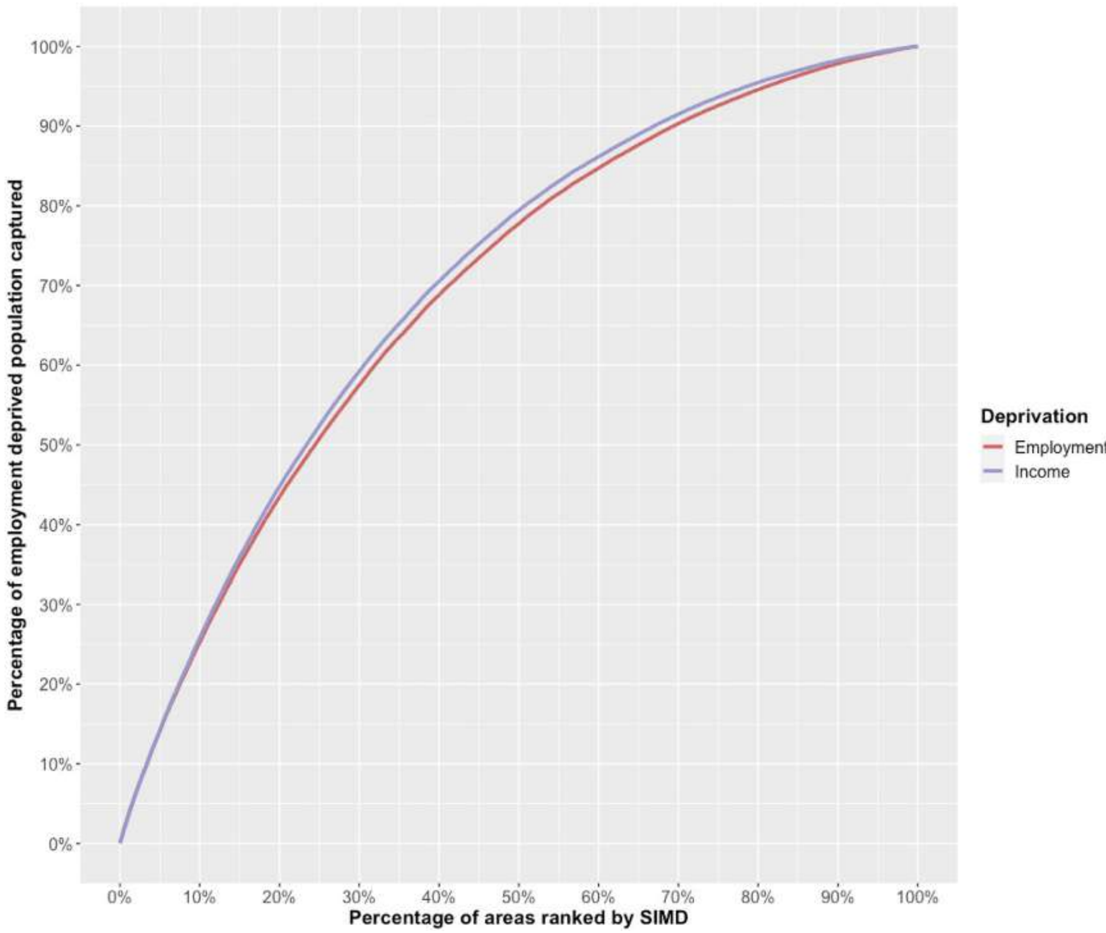

Fig. 1. The cumulative percentage of individuals who are income and employment deprived across data zones ranked by SIMD.

Table 1
Percentage of income- and employment-deprived individuals found within the most deprived areas using the Scottish IMD and IEI ranks, 2020, Scotland, English IMD ranks, 2019, England and Welsh IMD rank, 2019, Wales.

Individual deprivation outcome	Nation	Deprivation index	Deprivation threshold (i.e. the percentage of areas included in the most deprived group)					
			5%	10%	15%	20%	25%	30%
Income deprived	Scotland	SIMD	14.2%	25.8%	36.0%	44.8%	52.4%	59.2%
	Scotland	IEI	14.2%	25.8%	35.6%	44.8%	52.5%	59.3%
	England	IMD	13.9%	25.3%	34.9%	43.4%	50.9%	57.6%
	Wales	WIMD	12.0%	21.5%	29.9%	37.9%	44.9%	51.2%
Employment deprived	Scotland	SIMD	14.1%	25.2%	35.1%	43.5%	55.1%	57.5%
	Scotland	IEI	14.2%	25.3%	35.1%	43.5%	50.8%	57.6%
	England	IMD	13.5%	24.3%	33.5%	41.6%	48.9%	55.4%
	Wales	WIMD	11.3%	20.5%	28.9%	36.8%	43.8%	50.3%

IEI, Scottish Income and Employment Index; IMD, the 2019 English Index of Multiple Deprivation; SIMD, Scottish Index of Multiple Deprivation; WIMD, the 2019 Welsh Index of Multiple Deprivation.

amongst policymakers in recent years, are likely to have very limited impacts on inequalities as a result.[15]

However, in the absence of individual-level data on socio-economic position being routinely linked, in particular to health data, area deprivation indices provide an important and useful means of monitoring health inequality trends and identifying areas with greater needs for service planning. However, facilitating and funding a sustained linkage of individual socio-economic position (e.g. from the census, Her Majesty's Revenue and Customs and the Department for Work and Pensions) and health, mortality and other outcome data would vastly improve the understanding of inequality trends, make higher quality evaluations possible and allow for much better targeting of policies and interventions.

Conclusion

Area-based multiple deprivation measures, including SIMD and IEI, English IMD and WIMD, are not sensitive or specific at identifying income- or employment-deprived individuals. The use of area-based deprivation indices and place-based approaches risks misunderstanding the extent of need across spatial areas and might misdirect attention away from the economic and social relationships between social groups that underlie inequality trends.

Author statements

Ethical approval

No ethical approval was sought, as this study was restricted to analysis of secondary data.

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Competing interests

We declare that no author has any conflicts of interest.

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Original Research

How well does the Scottish Index of Multiple Deprivation identify income and employment deprived individuals across the urban-rural spectrum and between local authorities?

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ABSTRACT

Background: Area-based indices of deprivation are used to identify populations at need, to inform service planning and policy, to rank populations for monitoring trends in inequalities, and to evaluate the impacts of interventions. There is scepticism of the utility of area deprivation indices in rural areas because of the spatial heterogeneity of their populations.
Objective: To compare the sensitivity of the Scottish Index of Multiple Deprivation (SIMD) for detecting income and employment deprived individuals by urban-rural classification and across local authorities.
Study design: Descriptive analysis of cross-sectional data.
Methods: Data from the 2020 Scottish Index of Multiple Deprivation (SIMD) were used to calculate the number and percentage of income and employment deprived people missed within each of the six-fold urban-rural classification strata and each local authority using areas ranked by the national SIMD, within local authority rankings, and within urban-rural strata rankings, for deprivation thresholds between the 5% most deprived areas and the 30% most deprived areas. The Slope Index of Inequality (SII) and Relative Index of Inequality (RII) were calculated within local authorities and urban-rural classification strata to estimate the concentration of deprivation within ranked data zones.
Results: The number and percentage of income and employment deprived people is higher in urban than rural areas. However, using the national, local authority, and within urban-rural classification strata rankings of SIMD, and under all deprivation thresholds (from the 5%–30% most deprived areas), the percentage of income and employment deprived people missed by targeting the most deprived areas within urban-rural strata is higher in more remote and rural areas, and in island local authorities. The absolute number of income and employment deprived individuals is greater in urban areas across rankings and thresholds.
Conclusion: The SIMD misses a higher percentage of income and employment deprived people in remote, rural and island areas across deprivation thresholds and irrespective of whether national, local or within urban-rural classification strata are used. However, the absolute number of people missed is higher in urban areas.

Background

Socio-economic deprivation is an important determinant of population health.[1] Many countries have developed area-based indices of multiple deprivation to serve several purposes.[2] First, the indices can be used to identify populations with different needs for services or policy interventions based on their experience of deprivation.[3] Second, the indices can be used to rank the population to monitor the extent of inequalities.[4,5] Third, the indices can be used as a data source for evaluation and monitoring of policy interventions.[6]

Deprivation indices are constructed at small area level to make use of routinely available administrative data for standard geographies.[2] This facilitates regular updating of data and avoids the challenges of individual data linkage or the need to suppress small

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numbers to avoid inadvertent disclosure. A perceived limitation of area-based deprivation indices is the extent to which their sensitivity at identifying people in deprived circumstances varies according to how urban or rural the context is.[7] This has led to some scepticism amongst service managers and planners about the utility of such deprivation indices in rural and island areas. This is not unique to rural areas given that most deprived individuals do not live in the most deprived areas,[8] and the use of area-based deprivation scores to infer the characteristics of individuals or households falls foul of the ecological fallacy.[9]

The Scottish Government's official tool for identifying the concentration of deprivation across Scotland is the Scottish Index of Multiple Deprivation (SIMD). The SIMD is derived from a weighted score of data across seven domains (Income, Employment, Education, Health, Access to Services, Crime and Housing).[10] The 'access to services' domain captures some aspects of rural deprivation, but the 'income' and 'employment' domains which make up the Income Employment Index (IEI), a sub-index of SIMD used to monitor health inequalities, does not. The experience of deprivation differs between urban and rural areas. In addition to service access issues, people living in rural areas may face higher costs (e.g. for fuel, transport and food), a lack of employment opportunities, and a reliance on part-time and seasonal work.[11]

It has been suggested that SIMD, "tend[s] to privilege urban concentrations of deprivation to the detriment of deprived people in more rural areas",[12] on the basis that individuals experiencing deprivation may be more dispersed in rural areas, leading to greater heterogeneity in their populations.[6]

Given the perception that the commonly used area-based deprivation index (SIMD) in Scotland is not as sensitive for identifying deprived individuals in rural areas, this paper aims to compare the sensitivity of the SIMD in detecting income and employment deprived individuals between urban-rural categories and across local authorities.

Methods

The 2020 version of the SIMD data set was obtained from the Scottish Government for this analysis. The smallest unit of analysis for SIMD are data zones. There are 6796 data zones in Scotland (in the revision used for calculation of the 2020 SIMD) defined to follow natural and social boundaries where possible. The mean population size of a data zone is 778 people, the median 755, but with a range of 0–3847 reflecting that there are three data zones that have become completely depopulated since the definition of the data zone (due to the demolition of housing in those areas) and there are several areas whose population has grown substantially due to new house building since the last revision of boundaries.

The data set obtained had data for each data zone on: the SIMD ranking; number of individuals within each data zone classified as income deprived; the number of individuals within each data zone classified as employment deprived; the local authority; and the stratum of the six-fold urban-rural classification.[13,14]

For Scotland overall, within each of the six-fold urban-rural categories, and within each local authority, data zones were ranked by the SIMD, and the cumulative numbers and percentages of income and employment deprived individuals calculated. The sensitivity and specificity of the SIMD was then assessed by calculating the percentage of income and employment deprived individuals for Scotland overall, within each urban-rural category, and within each local authority, captured below different deprivation thresholds (the 5%, 10%, 15%, 20%, 25% and 30% most deprived areas) and within deprivation fifths. These deprivation fifths were defined within categories (i.e. ranked fifths within Scotland, within each urban-rural category, and within each local authority). In other words, the crude number, and % of the total number of income deprived individuals in Scotland, included within the most deprived 5% of areas, the most deprived 10% of areas, etc. were calculated. This was then repeated within each urban-rural strata, and within each deprivation fifth. As well as the total number and % captured within each of these, the reverse (the total number and % missed), were also calculated. The results were then tabulated and graphed to identify patterns.

The distribution of income deprived individuals across locally ranked data zones (within local authorities and urban-rural classification strata) was additionally explored through calculation of the Slope Index of Inequality (SII) and Relative Index of Inequality (RII) using weighted linear regressions as described by Pamuk.[15]

Results

Scotland-level deprivation strata

Although the majority of Scotland's population live in urban areas (71%), a significant minority live in remote (10%) and/or rural (17%) areas (Figure S1). Across the urban-rural classification system, the prevalence of income and employment deprivation is generally higher in urban than in remote or rural areas (Figure S2). Furthermore, the most deprived SIMD areas are heavily skewed towards urban areas, with 55.0% of the most deprived tenth of the population residing in 'Large Urban Areas', 38.8% in 'Other Urban Areas', 2.5% in 'Accessible Small Towns', 1.9% in 'Remote Small Towns', 1% in 'Accessible Rural' areas, and only 0.8% in 'Remote Rural' areas.

When Scottish areas are ranked by SIMD deprivation and divided by quintiles into fifths, 40% of income deprived individuals reside in the most deprived fifth, 27% in the second most deprived fifth, 18% in the middle fifth, 11% in the second least deprived fifth, and 5% in the least deprived fifth.

When the sensitivity of SIMD in detecting income deprivation is compared across the strata of the urban-rural classification system, clear differences can be seen (Fig. 1). Using the lowest ranked 20% of SIMD data zones across Scotland to identify people on low incomes, 55% of income deprived people are missed (and 45% of income deprived individuals are identified). However, fully 90% of low-income individuals living within remote rural areas are missed using this approach, with a stepwise gradient down to 43% of low-income individuals being missed in large urban areas. This gradient is seen across the urban-rural spectrum most clearly when a larger percentage of the most deprived SIMD data zones are included (e.g. when the 30% most deprived areas is used as the threshold).

Although the percentage of income deprived individuals missed by targeting deprived areas within remote and rural area strata is much higher than in urban areas irrespective of the deprivation threshold used, the absolute number of individuals missed is much higher in the urban areas because of the greater number of people in these areas and the overall higher prevalence (Fig. 2). The patterning and percentages are almost identical when employment deprivation is the outcome of interest instead of income deprivation (Figures S3 and S4).

Intra-local authority deprivation strata

The percentage of the population in each local authority area who are income deprived ranges from 5% in Shetland to 19% in Glasgow City (Figure S5). Using intra-local authority deprivation rankings to attempt to better identify income deprived individuals, the varying sensitivity of the SIMD measure can be seen. This ranking performs worst in the Orkney Islands, Shetland Islands, and Na-h-Eileanan Siar, with the most deprived fifth of locally ranked areas identifying only 24%, 29% and 25% of income

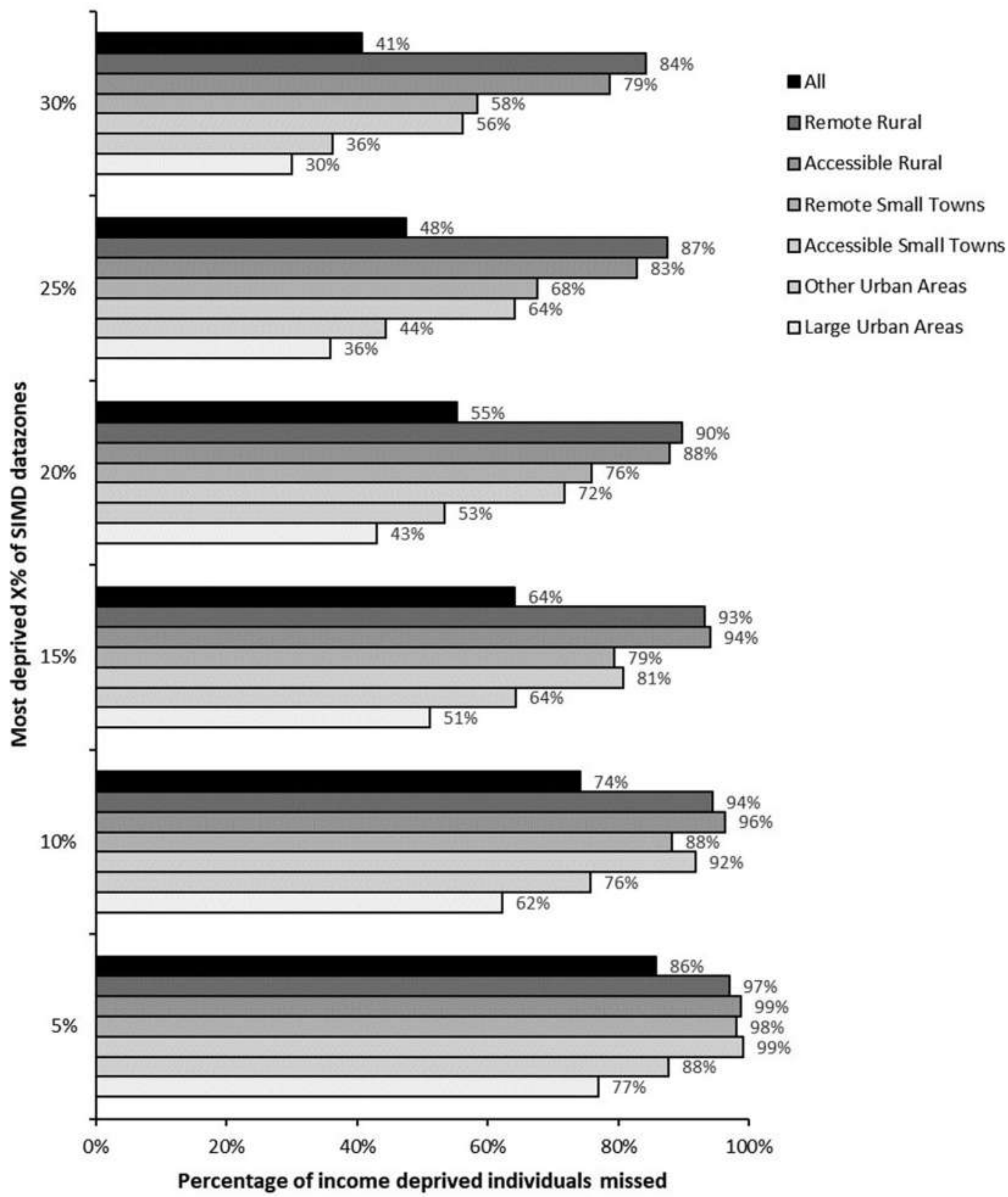

Fig. 1. Percentage of all low-income individuals missed within each of the six-fold urban-rural strata using a range of SIMD deprivation thresholds (from the 5% most deprived to the 30% most deprived).

deprived individuals within each local authority, respectively. In contrast, several relatively affluent local authorities (e.g. East Dunbartonshire and East Renfrewshire) have more sensitive local rankings, with 54% and 53% of income deprived individuals in East Dunbartonshire and East Renfrewshire, respectively, living in the locally defined most deprived fifth of locally ranked areas (Fig. 3). The sensitivity of the local rankings for these affluent local authorities are similar to that of the whole-Scotland SIMD ranking (in which 55% of income deprived people lived outside the most deprived fifth of Scottish areas, Fig. 1), but for all other areas the local rankings is less sensitive. Using the SII and RII to investigate the clustering of income deprivation in locally ranked data zones across the whole data zone distribution (i.e. not just using the 20% most deprived areas) shows that Na-h-Eileanan Siar has the flattest distributions using both absolute and relative measures (Figures S6 and S7), meaning that income deprivation is distributed widely across SIMD ranked data zones within that local authority. Using the RII, there are a small number of local authorities which have substantially steeper gradients, representing greater spatial clustering of income deprivation and a lower overall prevalence (as the SII is then divided by a smaller number [the prevalence] to produce the RII), including East Dunbartonshire, East Renfrewshire, Aberdeenshire, City of Edinburgh, Aberdeen City and Stirling (Figure S7).

Intra-urban-rural classification strata

Ranking data zones within urban-rural classification strata is another potential means of better identifying people who are income deprived. Using this approach to ranking, the percentage of

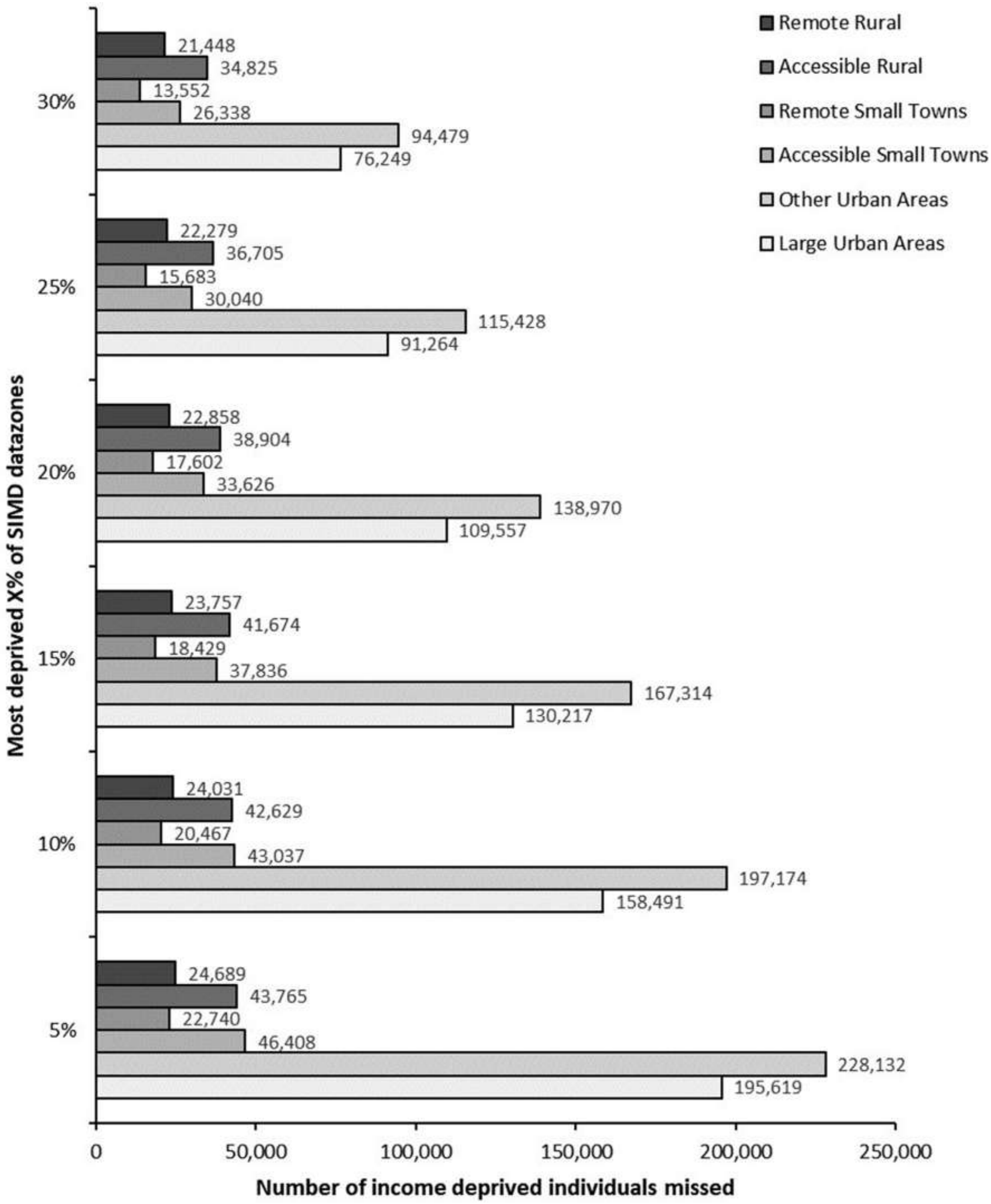

Fig. 2. Number of all income deprived individuals missed within each of the six-fold urban-rural categories, using deprivation thresholds from 5% to 30% of most deprived SIMD-ranked data zones.

income deprived people who live in the most deprived 20% of areas within each urban-rural classification strata ranges from 45% in large urban areas to 35% in remote small towns and in remote rural areas (Fig. 4). When the distribution of income deprivation is measured using the SII, the concentration is greatest in large urban areas (Figure S8), but is greater in accessible rural areas using the RII (Figure S9).

Discussion

The prevalence of income and employment deprivation is higher in urban areas than in rural areas, although the prevalence in remote small towns is only slightly lower than in urban areas. The Scottish level SIMD ranking is more sensitive at detecting income and employment deprived people in urban areas than in rural areas, with 57% of income deprived people in large urban areas also living in the most deprived fifth of Scottish SIMD areas, compared to only 10% of the income deprived people living in remote rural areas. However, the absolute number of income and employment deprived people living in remote and rural areas is much smaller, and so the number of people missed by the SIMD is higher in urban areas than rural areas at all deprivation thresholds.

When data zones are ranked by the SIMD *within* local authorities, the sensitivity for detecting income-deprived people is lowest

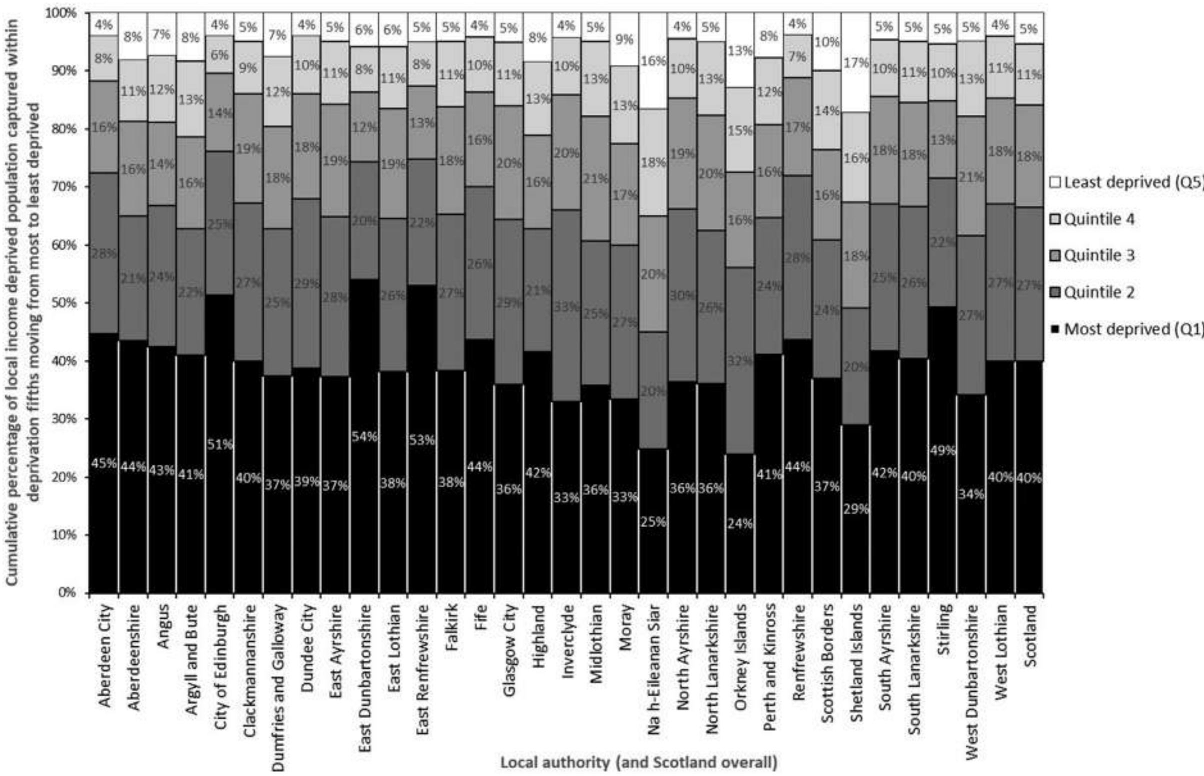

Fig. 3. The distribution of the income deprived individuals across intra-local authority deprivation rankings.

in the island local authorities, and highest in the more affluent urban local authorities such as East Dunbartonshire and East Renfrewshire. Finally, when data zones are ranked by the SIMD *within* urban-rural classification strata, the percentage of income deprived people who live in the most deprived 20% of areas within each urban-rural classification strata ranges from 45% in large urban areas to 35% in remote small towns and in remote rural areas. Although the sensitivity of all three rankings of SIMD (using Scottish rankings, within local authority rankings, and within urban-rural classification rankings) is lower in remote and rural areas and island local authorities, the number of income and employment deprived people missed remains greater in urban areas because of the higher prevalence and larger populations.

The key limitation in the approach taken in this paper is that the focus is on income and employment deprivation as an outcome. By definition, this misses the potentially compounding effects of rurality (e.g. higher costs, seasonal employment, etc.) on the experience of deprivation, and as a result may underestimate the limitations of SIMD in identifying deprivation in remote and rural areas. Income and employment deprivation within the SIMD are based on individuals being in receipt of income support or other benefits. There are studies that have suggested that a culture of self-reliance, or indeed stigma, may discourage individuals in rural areas from accessing income support to which they are entitled which could differentially underestimate the number of people actually income or employment deprived within rural areas compared to urban areas.[16]

Despite these limitations, this paper addresses a key question for policymakers in relation to the utility of SIMD in remote and rural areas in Scotland. Across all areas the sensitivity and specificity of SIMD in identifying income and employment deprived individuals is relatively low, and in percentage terms performs worse in remote and rural areas, and in island local authorities. However, the total number of people missed by SIMD at each threshold is much higher in urban areas. The implication is that the use of SIMD rankings, even within local strata or urban-rural strata, is a weak means of identifying people at high risk of income and employment deprivation (and likely other health and social problems), and this is worse in remote and rural areas. However, for resource allocation and identifying the degree of need across populations, more income and employment deprived people are missed in urban areas. Of course, rurality can be considered as an aspect of deprivation – especially in terms of the potentially greater difficulties in service access and through the range of higher costs faced by rural populations. Our results which consider the identification of income deprived individuals without accounting for these issues have to therefore be considered in that context.

Although much has been written about the limited ability of area-based deprivation measures to identify deprived individuals and households[8,9,17] there is less known about whether the operation of this ecological fallacy varies across the urban-rural spectrum. Of those studies that have considered this question, and in contrast to this study, they find limited evidence to support a clear pattern in the sensitivity and specificity of deprivation measures across the urban-rural spectrum.[18] There is a much more extensive literature on the relationship between rurality and health. For example, the likelihood of reporting a mental health condition was lower in rural (and especially island rural) areas, even after adjusting for markers of socio-economic position.[18] However, for other diagnoses, such as prostate cancer, no relationship with rurality was identified across the UK.[17]

There are several implications from this study. First, there is a need for linkage between individual and household level socio-economic position data and other data sets to address the issues identified here. Routine linkage of data from the Census, Her Majesty's Revenue and Customs (HMRC) and the Department for Work

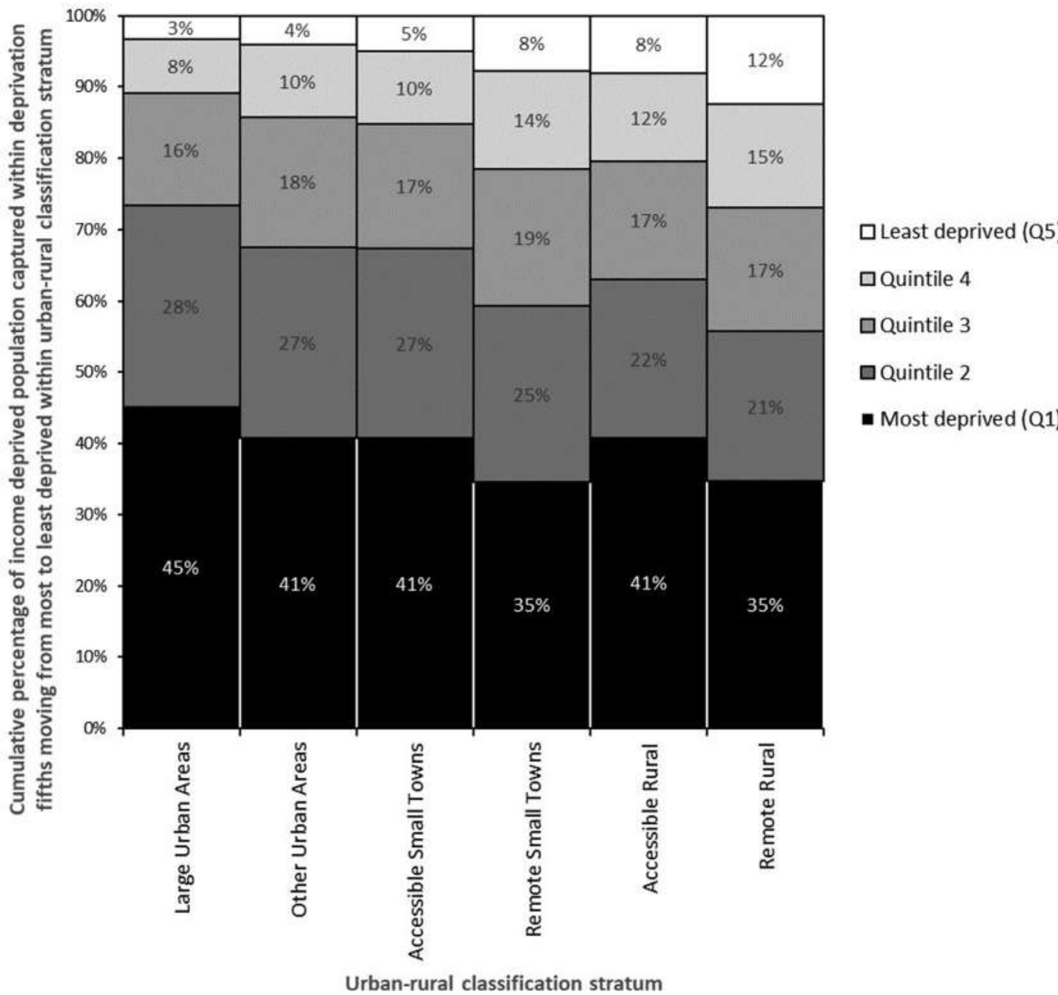

Fig. 4. The distribution of the income deprived individuals across intra-local authority deprivation rankings.

and Pensions (DWP), with other data sets (including health and mortality data sets) would be an obvious approach. Second, increasing the availability of data on wider aspects of deprivation (including differential costs, employment experiences, etc.) across areas, would allow for a much more nuanced understanding of the lived reality of deprivation between populations. Both of these would enhance the ability of service planners and policymakers at all levels to better assess the levels of need, and how to better target interventions. Service managers and policymakers working at local level should only use SIMD cautiously for assessing the needs of populations, and particularly in remote, rural and island areas. Place-based approaches to reducing inequalities are likely to have very limited impacts because of the wide spatial distribution of people across areas, and approaches that recognise socio-economic relationships between social groups'[19,20] rather than people classified by their place of residence may be more effective.

Conclusion

The sensitivity of SIMD for detecting income and employment deprived people is lower in remote and rural areas, and in island local authorities, no matter whether the Scottish ranking, within local authority ranking, or within urban-rural classification strata ranking, is used. Across deprivation thresholds and rankings derived at Scotland, local or within urban-rural strata, the percentage of local income and employment deprived people missed is greater in remote, rural and island areas, but the absolute number of people missed is higher in urban areas because the levels of deprivation are higher.

Author statements

Ethical approval

No ethical approval was sought for this study as it was restricted to the analysis of secondary data.

Funding

No funding was received for this study. GM is salaried by the University of Glasgow, RH is salaried by the NHS.

Competing interests

We declare that we have no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.009.

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Original Research

Impact of lockdown on cardiovascular disease hospitalizations in a Zero-COVID-19 country

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A R T I C L E I N F O

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A B S T R A C T

Objectives: There are concerns about the potential effect of social distancing used to control COVID-19 on the incidence of cardiovascular diseases (CVD).
Study design: Retrospective cohort study.
Methods: We examined the association between lockdown and CVD incidence in a Zero-COVID country, New Caledonia. Inclusion criteria were defined by a positive troponin sample during hospitalization. The study period lasted for 2 months, starting March 20, 2020 (strict lockdown: first month; loose lockdown: second month) compared with the same period of the three previous years to calculate incidence ratio (IR). Demographic characteristics and main CVD diagnoses were collected. The primary endpoint was the change in incidence of hospital admission with CVD during lockdown compared with the historical counterpart. The secondary endpoint included influence of strict lockdown, change in incidence of the primary endpoint by disease, and outcome incidences (intubation or death) analyzed with inverse probability weighting method.
Results: A total of 1215 patients were included: 264 in 2020 vs 317 (average of the historical period). CVD hospitalizations were reduced during strict lockdown (IR 0.71 [0.58–0.88]), but not during loose lockdown (IR 0.94 [0.78–1.12]). The incidence of acute coronary syndromes was similar in both periods. The incidence of acute decompensated heart failure was reduced during strict lockdown (IR 0.42 [0.24–0.73]), followed by a rebound (IR 1.42 [1–1.98]). There was no association between lockdown and short-term outcomes.
Conclusions: Our study showed that lockdown was associated with a striking reduction in CVD hospitalizations, independently from viral spread, and a rebound of acute decompensated heart failure hospitalizations during looser lockdown.

Introduction

Since the beginning of the SARS-CoV-2 pandemic, strict social distancing and healthcare reorganization measures have been adopted worldwide to contain transmission and address the surge

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of critically ill patients in acute care settings.[1] These measures along with border closing and contact tracing contributed to an efficient control of the spread of SARS-CoV-2 in certain isolated territories such as New Caledonia.[2–4] Restrictions related to COVID-19 remain debatable because of their social and economic consequences. Consequently, elimination strategies, which aim to fully prevent any viral circulation, represent a high level of social restrictions. Their impact on healthcare systems and diseases unrelated to COVID-19 remains to be elucidated.[5,6]

New Caledonia, a territory of the French Republic in the Pacific region, has a multicultural and inclusive population with Melanesian, Oceanian, Asian, and European cultures characterized by a high incidence of obesity.[7] New Caledonia benefits from a health system and medical infrastructure that meet the highest international standards, guaranteeing safe and efficient care. Early in the COVID-19 pandemic, New Caledonia issued a Zero-COVID strategy starting with complete border closure.[4] Indeed, after the detection of a first local case of COVID-19 in March 2020, a strict 1-month lockdown was applied. During this period, no local COVID-19 cases were detected. The strict lockdown was followed by a second month of looser restrictions and social distancing strategies.[4] Eventually, New Caledonia was declared a Zero-COVID country by the end of May 2020 and maintained this status until March 2021.[8]

After the introduction of the first lockdown measures, local healthcare workers in New Caledonia soon reported changes in hospitalization patterns with a specific signal on acute decompensated heart failure (AHF), acute coronary syndrome (ACS), and acute heart rhythm and conduction disorders as observed elsewhere in the world.[9] Few data on lockdown-related healthcare consequences and patient outcomes have been published despite the fact that it represents the untold toll of the pandemic. The unique setting of New Caledonia during the first lockdown in the absence of viral spread of SARS-CoV-2 represents an exceptional opportunity to analyze the consequences of this healthcare policy. Therefore, we studied the impact of lockdown on the incidence of cardiovascular hospitalizations.[10]

Methods

We conducted this study at the regional hospital of New Caledonia Centre-Hospitalier-Territorial Gaston-Bourret (CHT), the only tertiary hospital in New Caledonia. Unscheduled hospitalizations represented the nearly unique reason for hospital admissions in 2020 in the CHT, which is the referral hospital for major surgeries and life-threatening emergencies in non-pandemic time. In the present analysis, all adult patients with a positive troponin plasma sample at hospital admission were included. The threshold was >15.6 pg/mL for women and >32.4 pg/mL for men (Alinity I STAT high-sensitive troponin I kit, Abbott, Chicago, USA).[10] Patients who underwent cardiac surgery during the index hospitalization, imported COVID-19-related myocarditis, patients presenting with post-traumatic myocardial injury, as well as patients admitted for a scheduled dialysis or ambulatory care facilities were excluded. To limit bias due to migration and tourism in the historical group, residents from outside of New Caledonia were excluded because of the border closure during lockdown. The study period lasted from March 20, which was the day of the international border closure, to May 20, 2020. The lockdown period was compared with the same period of the three previous years (i.e. historical period) to minimize a potential seasonal epidemic effect.

Sensitivity analyses were also conducted. First, time effect was assessed by comparing the two lockdown periods vs the historical period. Period A comprised the 4 weeks when **strict lockdown** policies were enforced in New Caledonia and period B, the following month, when **loose lockdown** and social distancing policies were implemented. Second, the incidence of different cardiovascular diseases during lockdown was compared with their incidence during the historical period, such as the hospitalizations for AHF, ACS, acute rhythm and conduction disorders, sepsis, and surgical emergencies. Third, an analysis was conducted in the subgroup of intensive care unit (ICU) admissions. Finally, we analyzed the association of lockdown to a composite outcome (intubation and all-cause in-hospital death).

This study was approved by the local ethics committee (identification number 2020-001) and performed in accordance with the declaration of Helsinki.

Data on hospitalizations in ICU, specialty wards, and emergency department visits were collected. Chronic and acute diagnosis associated with the index hospitalization were collected according to the French coding system (CIM-10). Demographic data were recorded on age, gender, billing address, medical history of cancer, neurovascular disease, arterial hypertension, coronary artery disease, chronic heart failure, and chronic kidney failure. Clinical characteristics and biological data were extracted from the CHT clinical database (DX Care). ZIP codes were used to define two types of urbanicity (see supplementary materials).

Outcome variables included all-cause in-hospital death, the need for mechanical ventilation, a coronary angiography, ICU admission, and Simplified Acute Physiology Score 2 (SAPS2) score. The main diagnosis of cardiovascular disease included type 1 myocardial infarction (MI; ACS with and without ST-elevation [ST-segment elevation myocardial infarction (STEMI) and ST-segment elevation myocardial infarction (NSTEMI)]), AHF, as well as acute rhythm and conduction disorders. Data on myocardial injury were also collected, as defined by type 2 MI due to sepsis, acute neurovascular disease, or surgery.

The maximal troponin measured on plasma sample and the time from admittance to the troponin peak were noted.

The primary endpoint was the incidence of hospital admissions with a positive troponin sample during the 2020 lockdown compared with previous years and the incidence of the main CVD diagnoses, including ACS, AHF, and acute rhythm and conduction disorders.

The secondary endpoints included the effects of strict and loose lockdown on primary endpoint, change in incidence of hospitalization for each cardiovascular diagnosis, and effects of lockdown on the occurrence of the composite outcome of all-cause in-hospital death and the need of invasive ventilation.

We calculated bivariate frequencies of hospitalization rates, main diagnoses, outcome, and preadmission characteristics. Categorical variables are presented as number and percentage. Continuous variables are presented as means and 95% confidence interval (CI). The ZIP codes were used to provide a mapping of patients included in the analysis and to adjust the statistics according to the geographical localization.

The incidence ratios (IRs) were calculated as the proportion of related events from the study period in 2020 to the historical period. The incidence of events in the population of New Caledonia was calculated as the proportion of disease for 100,000 inhabitants. The interaction between periods A and B was also tested.

Data for patients' outcome were censored on September 1, 2020. We conducted a multivariable logistic regression analysis to estimate the association between the lockdown and the composite endpoint (all-cause in-hospital death or invasive ventilation). We conducted a propensity score–matched analysis to reduce the bias of confounding factors in the analysis. The individual propensities to be hospitalized with a positive troponin sample in 2020 were calculated with a multiple regression model using the same covariates as previously described. The association between the lockdown period and outcomes was first assessed by a logistic regression analysis (i.e. crude analysis), then by three different analyses using a propensity score. First, we used the propensity score as an additional covariate in the multiple logistic regression analysis with all potential cofounders as covariates. Second, we applied the nearest neighbor propensity score matching. Caliper value was 0.25 of the standard deviation of the logit of the propensity score. Finally, we used inverse probability weighting (IPW). Death and mechanical ventilation were studied as separate outcomes with the same methodology. Odds ratios (ORs) and their 95% CIs were calculated.

The subgroup analysis included ICU admissions. Patients with missing data on SAPS2 were considered random and excluded from the analysis.

Results

A total of 1399 patients were admitted with a positive troponin sample during the 2-month period from March 20 to May 20 in 2017, 2018, 2019, and 2020. Thirty-two patients were excluded because they underwent cardiac surgery, 104 for non-admittance to hospitalization, 19 for traumatic injuries, 17 because they were not New Caledonia residents, eight patients for chronic dialysis, and three due to missing ZIP codes. The final study cohort included 1215 patients (an average of 152 patients per month). The evolution of emergency department visits, as well as hospitalizations in ICU and non-ICU ward, are described in Fig. 1. The median troponin concentration on inclusion was 142 pg/mL (52–1078) and observed at the median day 1 after admission (0–2).

Baseline characteristics of the study population are presented in Table 1. The median age of patients included in the study during the 2020 lockdown was 67 years. Compared with the historic cohort, patients included in 2020 had more comorbidities, including neurovascular disease (10.2% vs 5.4%, $P = 0.01$) and chronic kidney disease (32.2% vs 23.6%, $P = 0.01$).

Concerning the primary endpoint, there were 264 hospitalizations with a positive troponin sample in 2020 vs 951 during the historical period (mean value of 317 patients over 2 months). This amounted to an 18% absolute reduction in hospitalizations in 2020 (see Fig. 1), with an IR of 0.83 (0.72–0.95). This reduction in the incidence was exclusively seen during the first month with strict lockdown (IR 0.72 [0.58–0.88]) and not during the second month of loose lockdown (IR 0.93 [0.78–1.12]), $P = 0.005$.

The incidence of hospitalization according to urbanicity is illustrated in Supplementary Fig. 1.

The incidence of main cardiovascular diagnoses during the study period is described in Supplementary Fig. 2. The number of hospitalizations for Type 1 MI did not vary significantly during periods A and B whether it was for an STEMI or an NSTEMI (*P* interaction 0.5; Fig. 2). However, the incidence of hospitalizations for AHF dropped significantly during the period A with a decrease of −42% compared with previous years and increased during period B at +41% above the usual rate (Supplementary Fig. 3; *P* interaction <0.001). Similarly, the hospitalizations for acute rhythm and conduction disorders decreased during period A and nearly doubled during period B (*P* interaction 0.002).

Concerning the diagnosis associated with type 2 MI, the number of hospitalizations for acute neurovascular events, sepsis, or surgical emergencies with a positive troponin sample did not vary over time.

During the period A, defined as the month of March 2020 when the strict lockdown measures were implemented, a 28.3% decrease in hospital admissions was observed, with 109 hospitalizations compared with a mean of 152 hospitalizations per month during the historical period of the three previous years, with an IR of 0.72 (0.58–0.88), $P = 0.002$. During the period B, defined as the second month of lockdown (April 2020) when restrictions were loosened and social distancing policies were applied, a 6.5% decrease in admissions was observed, with 155 patients hospitalized vs an average of 165 patients during the same month of previous years, with unchanged IR of 0.93 (0.78–1.12), $P = 0.452$.

During the inclusion period in 2020, the composite outcome of all-cause in-hospital death and mechanical ventilation was observed in 19.3% of patients vs 18.4% of patients of the historical cohort ($P = 0.74$).

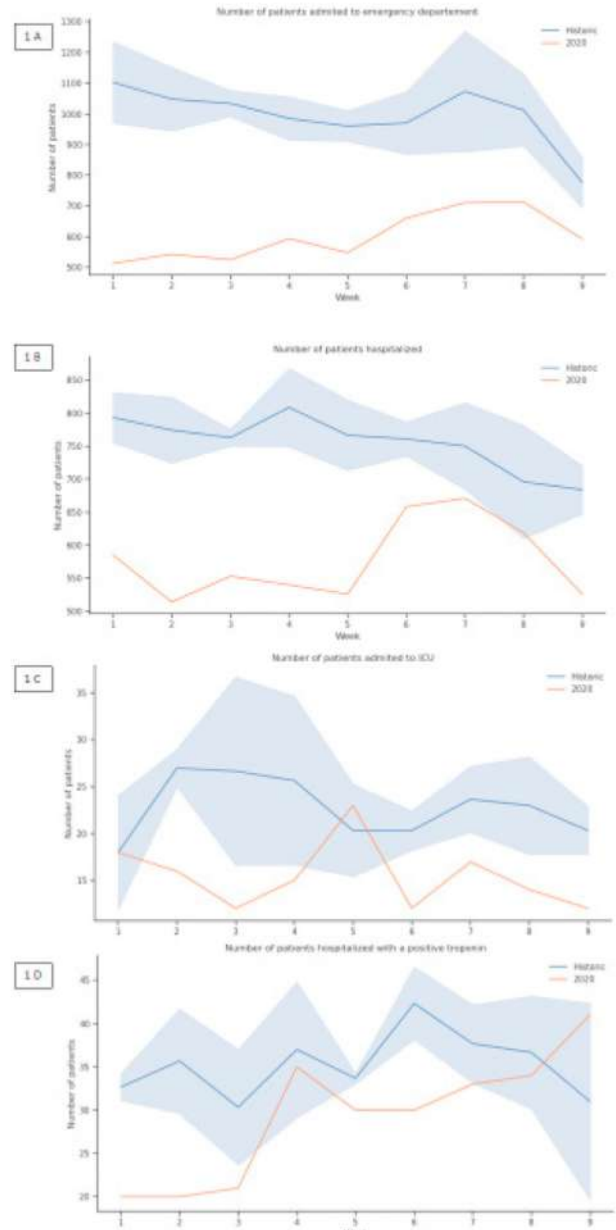

Fig. 1. Number of hospital admissions in Centre-Hospitalier-Territorial according to the study period and the historical cohort. (A) Emergency department admissions. (B) The number of hospital admissions. (C) Intensive care unit (ICU) admissions. (D) The number of patients with a positive troponin sample included in the study. Data were collected from the March 20 till May 20, 2020, and were compared with the same period of the three previous years (i.e. historical period).

Table 1
Patient characteristics and outcomes according to the period of inclusion.

Characteristics	Unmatched patients		*P*-value	Matched patients		*P*-value
	2020 ($N = 264$)	Historical period ($N = 951$)		2020 ($N = 261$)	Historical period ($N = 261$)	
Age (years)	66 (15)	66 (16)	0.89	66 (15)	65 (15)	0.70
<40	16 (6.1)	70 (7.4)	0.55	16 (6.1)	13 (5.0)	0.70
40–59	80 (30.3)	229 (24.1)	0.05	77 (29.5)	81 (31)	0.78
60–79	113 (42.8)	479 (50.4)	0.04	113 (43.3)	119 (45.6)	0.66
≥80	55 (20.8)	173 (18.2)	0.38	55 (21.1)	48 (18.4)	0.51
Female sex	128 (48.5)	453 (47.6)	0.86	126 (48.3)	116 (44.4)	0.43
Geographical region						
Grand Noumea	179 (67.8)	637 (67.0)	0.86	176 (67.4)	176 (67.4)	1.0
Medical history						
Oncology	29 (11.0)	103 (10.8)	0.97	29 (11.1)	34 (13)	0.59
Neurovascular	27 (10.2)	51 (5.4)	0.01	26 (10)	31 (11.9)	0.57
Cardiovascular	186 (70.5)	646 (67.9)	0.48	183 (70.1)	173 (66.3)	0.40
Hypertension	134 (50.8)	464 (48.8)	0.62	131 (50.2)	132 (50.6)	1.00
Coronary artery disease	85 (32.2)	253 (26.6)	0.09	83 (31.8)	71 (27.2)	0.29
Chronic heart failure	68 (25.8)	228 (24.0)	0.61	68 (26.1)	61 (23.4)	0.54
Chronic respiratory diseases	9 (3.4)	59 (6.2)	0.11	9 (3.4)	12 (4.6)	0.66
Chronic kidney disease	85 (32.2)	224 (23.6)	0.01	82 (31.4)	90 (34.5)	0.52
Active smoking	50 (18.9)	212 (22.3)	0.28	50 (19.2)	60 (23)	0.33
Metabolic syndrome	125 (47.3)	443 (46.6)	0.88	122 (46.7)	120 (46)	0.93
Associated diagnoses and procedures, *n* (%)						
STEMI	29 (11.0)	77 (8.1)	0.18	27 (10.3)	33 (12.6)	−0.49
NSTEMI	26 (9.8)	86 (9.0)	0.78	26 (10)	25 (9.6)	1.00
Acute heart failure	63 (23.9)	204 (21.5)	0.45	63 (24.1)	57 (21.8)	0.60
Acute neurovascular disease	33 (12.5)	80 (8.4)	0.06	32 (12.3)	29 (11.1)	0.79
Acute arrhythmia and conduction disorders	91 (34.5)	262 (27.5)	0.03	91 (34.9)	92 (35.2)	−1.00
Sepsis	44 (16.7)	128 (13.5)	0.22	44 (16.9)	44 (16.9)	1.00
Coronary angiography	70(26.5)	260(27.3)	0.85	70 (26.8)	71 (27.2)	1.00
Surgery	34 (12.9)	99 (10.4)	0.31	33(12.6)	30 (11.5)	0.79
ICU admission	68 (25.8)	256 (26.9)	0.77	68 (26.1)	71 (27.2)	0.84
Outcome						
Composite outcome	51 (19.3)	175 (18.4)	0.8	51 (19.5)	46 (17.6)	0.65
All-cause death	36 (13.6)	115 (12.1)	0.57	36 (13.8)	27 (10.3)	0.28
Mechanical ventilation	32 (12.1)	109 (11.5)	0.85	32 (12.3)	32 (12.3)	1.0

ICU, intensive care unit; NSTEMI, non-ST-segment elevation myocardial infarction; STEMI, ST-segment elevation myocardial infarction.
The composite outcome is defined as the occurrence of death or mechanical ventilation. The results are expressed as mean and standard deviation or number and percentage.

The OR and 95% CI for the outcome endpoint and its two determinants (i.e. death and mechanical ventilation) were calculated for each characteristic studied (Supplementary Table 1). In the crude unadjusted analysis, there was no difference in the composite outcome of all-cause in-hospital death or mechanical ventilation during the lockdown period compared with the historical cohort (OR 1.01 [0.96–1.06]). No influence was found for the strict vs loose lockdown (*P* interaction 0.888). No significant differences in the composite outcome were observed after adjustment for propensity score (OR 1.01 [0.97–1.05]), neither after propensity score matching (OR 1.02 [0.97–1.08]) or after inverse probability weighting (OR 1.01 [0.97–1.05]), with no significant interaction of strict vs loose lockdown. No significant differences were observed when analyzing each outcome separately (see Table 2).

Additional sensitivity analysis comparing the influence of the strict lockdown month vs looser lockdown month demonstrated that neither strict nor loose lockdown was associated with an increased rate of in-hospital death or mechanical ventilation (see Supplementary Table 2).

The subgroup analysis of ICU admissions during lockdown showed that there was no significant impact on the composite outcome (see Supplementary Table 3). Interestingly, patients who were admitted to the ICU during the lockdown period had a higher SAPS2 score when compared with the previous years (median 55 [24–96] vs 44 [19–95], $P = 0.01$).

Sensitivity analyses according to the admission diagnosis (ACS, AHF, acute rhythm and conductions disorders, acute neurovascular diseases, sepsis, and surgical emergencies) and ubranicity were also conducted according to the outcome (Supplementary Table 4). No associations were detected between the diagnosis on admission and the composite outcome.

Discussion

This study describes the incidence of cardiovascular hospitalizations and their outcomes during a lockdown period in a territory where implemented restrictions successfully prevented the spread of SARS-CoV-2. The overall incidence of hospitalizations for CVD with increased myocardial injury biomarkers was lower during lockdown, especially during the first month of strict lockdown when compared with the following month of looser restrictions. However, although the admissions for ACS remained similar during lockdown when compared with a historical cohort, the admissions for AHF decreased during the period of strict lockdown and rebounded with a dramatic increase during the period of looser lockdown. Interestingly, there was no association of the composite endpoint (all-cause in-hospital mortality and intubation) in patients hospitalized during lockdown.

Our study is unique, given the specific setting of New Caledonia, where early border closure and an implementation of strict lockdown resulted in a total control of the outbreak. No COVID-19 cases were detected in the population during the first wave of the SARS-CoV-2 pandemic. Our results provide a valuable insight into the impact of lockdown *per se*, without the confounding of direct effects of SARS-CoV-2. Until March 2021, all COVID-19 cases were diagnosed during quarantine with no local transmission.[8] Analysis of the hidden toll of lockdown is critical to identify patients at risk and to prevent any malfunction of the healthcare system.

	IR [95%CI] Strict Lockdown	IR [95%CI] Loose Lockdown	p-value
Hospitalization	0.71 [0.58 - 0.88]	0.93 [0.78 - 1.12]	0.06
Heart Failure	0.42 [0.24 - 0.73]	1.41 [1.00 - 1.98]	<0.001
Acute Coronary Syndrome	1.26 [0.82 - 1.93]	0.81 [0.52 - 1.26]	0.17
STEMI	1.39 [0.72 - 2.68]	0.98 [0.55 - 1.71]	0.43
NSTEMI	1.18 [0.67 - 2.07]	0.63 [0.30 - 1.28]	0.17
Acute Neurovascular event	0.97 [0.51 - 1.86]	1.46 [0.87 - 2.46]	0.34
Arrhytmias & Conduction diseases	0.74 [0.50 - 1.10]	1.31 [0.97 - 1.77]	0.002
Sepsis	0.83 [0.49 - 1.39]	1.23 [0.78 - 1.95]	0.26
Surgery	1.18 [0.65 - 2.14]	0.92 [0.55 - 1.53]	0.56
Coronarography	0.77 [0.52 - 1.14]	0.84 [0.59 - 1.20]	0.74
ICU admission	0.68 [0.46 - 1.02]	0.90 [0.63 - 1.29]	0.31

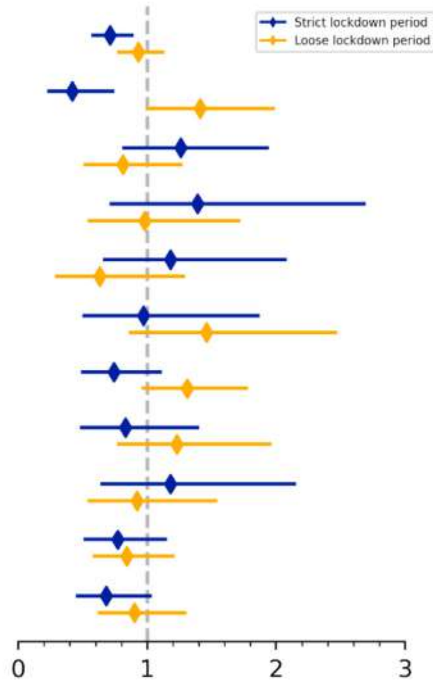

Fig. 2. Incidence of hospitalizations with a positive troponin sample and associate diagnosis during the strict lockdown month of the study period in 2020 (blue line) and during the looser lockdown (yellow line) compared with their historical counterpart of the three previous years. The results are expressed as incidence ratios (IRs) and 95% confidence interval. A *P*-value of interaction between the strict lockdown and the loose lockdown period was considered as significant when <0.05. ICU, intensive care unit; IR, incidence ratio; NSTEMI, non-ST-segment elevation myocardial infarction; STEMI, ST-segment elevation myocardial infarction; 95% CI, 95% confidence interval. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Association between lockdown and patient outcomes.

Outcomes	*N*	Odds ratio	95% CI	P-value
Composite endpoint of death and mechanical ventilation				
Crude analysis	1215	1.06	[0.75−1.49]	0.87
Adjusted for propensity score	1215	1.07	[0.66−1.72]	0.83
Matched on propensity score	322	1.29	[0.69−2.41]	0.58
IPW stabilized	1215	1.07	[0.66−1.72]	0.87
Death				
Crude analysis	1215	1.15	[0.76−1.70]	0.29
Adjusted for propensity score	1215	1.15	[0.71−1.85]	0.38
Matched on propensity score	322	1.70	[0.88−3.26]	0.99
IPW stabilized	1215	1.16	[0.71−1.86]	0.35
Mechanical ventilation				
Crude analysis	1215	1.07	[0.69−1.60]	0.96
Adjusted for propensity score	1215	1.11	[0.60−2.03]	0.60
Matched on propensity score	322	1.18	[0.52−2.70]	0.99
IPW stabilized	1215	1.11	[0.60−2.03]	0.63

CI, confidence interval; IPW, inverse-probability-weighted.
Data are presented as odds ratio (95% confidence interval).

In other regions of the world, the effect of lockdown on diseases unrelated to COVID-19 is difficult to interpret because of the confounding factors caused by the viral spread in the population.[11] Our findings confirm a decrease in admissions for cardiovascular disease during lockdown, which was comparable to those observed in countries with an active spread of SARS-CoV-2, including Italy, United Kingdom, and France.[9,12,13]

Most of the included patients were at risk of severe COVID-19. They presented a number of cardiovascular risk factors, such as metabolic syndrome and hypertension.[22,23] Also, patients hospitalized during lockdown had more comorbidities when compared with a historical cohort. Having in mind the reduced incidence of hospitalizations, higher rates of comorbidities demonstrate that only the most severely ill patients presented to the hospital during lockdown. This finding also emphasizes the importance of prevention policies for community medicine and continuity of essential health care for patients with chronic illnesses.[14]

Further key insights can be highlighted when looking closely at the admission diagnosis.[15] We hypothesized that specific factors might have had an influence on CVD presentation, such as a decrease in ACS admissions during lockdown, possibly due to a change in lifestyle or reluctance to seek medical help. A previous study reported significant lifestyle changes during lockdown in relation to NSTEMI incidence.[17] On the contrary, the hospitalizations for ACS during the lockdown period in New Caledonia did not change significantly when compared with other countries where the spread of SARS-CoV-2 was high.[12,16] ACS patients may have been compelled to consult hospitals because of the severity of their symptoms. Our data support the hypothesis that ACS rates were not influenced by the lower degree of physical exertion and other lifestyle changes during lockdown.[13] Furthermore, there was no increase in hospital workload related to COVID-19, so ACS patients were not underdiagnosed or undertreated, in contrast to countries with active viral spread.[18] Our study shows that there were no negative effects of early lockdown on the incidence of hospitalizations for ACS.

The incidence of hospitalizations of patients presenting with type 2 MI was not influenced by lockdown, in accordance to previous studies.[19] No significant difference was found in outcomes associated with type 2 MI in patients hospitalized during lockdown vs the historical period.

Acute heart failure patients with a positive troponin sample are considered as high risk because of the increased risk of in-hospital mortality. Our study demonstrated a dramatic decrease in AHF hospitalizations during lockdown, with a rebound phenomenon after the restrictions were lifted. Our results are consistent with previously published findings in countries with active SARS-CoV-2 circulation.[20–22] Our study was underpowered to analyze the specific reasons why heart failure patients did not present to the hospital or if they avoided preventive care. Notably, the New Caledonia residents strongly believed in the active circulation of SARS-CoV-2. We may thus hypothesize that the psychological aspect of lockdown was a prominent factor that prevented heart failure patients from seeking medical care during the initial phase of the pandemic. The rebound phenomenon that was observed during the looser lockdown illustrates the importance of ambulatory management of chronic heart failure.

It is challenging to identify the direct effect of healthcare policies, such as early strict lockdown in the setting of a pandemic. However, in our study, we were able to control for bias from the confounding factors, as our results are free from the influence of the direct effects of SARS-CoV-2. Other strengths of this study include an extensive overview of different causes of myocardial injury during lockdown. We used a composite outcome of all-cause in-hospital death and intubation clinically relevant during the pandemic.[23,24] We acknowledged that these outcomes can be unevenly affected by both the severity of underlying conditions and quality of care. Our results confirmed a preserved quality of care in the acute setting, as although the incidence of hospital admissions decreased, short-term outcomes remained unaffected. Therefore, the study provides information on the resilience of healthcare system rather than disease-specific factors.[25] It was important to verify this hypothesis when considering the restrictions initially applied to curb the spread of SARS-CoV-2 down to zero detection. Border closure might negatively affect patient care delivery in New Caledonia, as the healthcare system relies on medical evacuations to France or Australia as well as specialized visiting medical or surgical missions. Aside from hospital overload, Pacific islands as well as other remote territories had to face specific challenges in their healthcare systems due to the SARS-CoV-2 pandemic.

Several limitations of the present study must be acknowledged. First of all, the retrospective design of the study accounted to a small amount of missing data due to the potential inaccuracy of electronic medical records. Second, due to lack of randomization, there might be residual bias of the outcome analysis. However, the propensity score matching and the inverse probability weighting (IPW) method allowed us to minimize selection bias and provided consistent in line with a recent meta-analysis focused on the incidence of STEMI during lockdown.[26] Furthermore, our study included both unscheduled and planned hospitalizations, only outpatients were excluded to minimize the selection bias. Third, the results are based only on in-hospital outcomes without extended follow-up. On the one hand, the Zero-COVID-19 strategy with complete border closure might have direct implications on the incidence of COVID-19–related myocarditis. On the other hand, general stress and lack of medical care in patients with chronic diseases could have led to an increase in morbidity and mortality in the long term. Unfortunately, our study was underpowered to assess the long-term effects of Zero-COVID strategy. Finally, our study relies on data from a single center, which could limit the generalizability of the findings. However, the studied site has the only ICU, cardiology ward, and angiography facilities for the whole territory.

We feel that it is important to emphasize that the results of this study should not lead to a conclusion that the lockdown had no negative consequences. The fall in the incidence of hospitalization leads to the hypothesis that a significant number of patients did not consult and stayed home with a myocardial injury. Further studies should focus on the sociological and psychological aspects of the reluctance to seek medical care during the pandemic. Moreover, the rebound phenomenon of AHF hospitalizations emphasizes a major public health issue. At the time of study completion, New Caledonia succeeded in a Zero-COVID-19 strategy, but the pandemic consequences such as anxiety or other psychological aspects were most likely present. Policy makers should consider these aspects to enhance outpatient care during lockdown periods.

Author statements

Acknowledgments

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Ethical approval

This study was approved by the local ethics committee (identification number 2020-001) and performed in accordance with the declaration of Helsinki.

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Competing interests

A.M. received honorarium for lectures from Novartis, Roche, Abbott, Orion, Servier, consultation fees from Corteria and Windtree, and research grant from 4TEEN4, Adrenomed, Roche, Abbott.

Author contributions

P.H.M., J.B.B., and M.D.R. conceived the study and its design, had full access to the data, and take responsibility for the integrity of the data and accuracy of the analysis. P.H.M., V.C., and S.G. organized and entered data. P.H.M., N.O., and M.M. contributed to data analyses. P.H.M., V.C., M.S., E.C., and A.M. contributed to data interpretation. P.H.M. and N.O. drafted the article. All authors critically revised the drafted article and approve of the submitted manuscript.

Disclosure

None.

Data sharing

The authors are prepared to share their data according to French and New Caledonian laws on health data on specific request to P.H.M.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.029.

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Original Research

Impact of policy response on health protection and economic recovery in OECD and BRIICS countries during the early stages of the COVID-19 pandemic

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A B S T R A C T

Objectives: During the early stages of the COVID-19 pandemic, the full reopening of the economy typically accelerated viral transmission. This study aims to determine whether policy response could contribute to the dual objective of both reducing the spread of the epidemic and revitalising economic activities.
Study design: This is a longitudinal study of Organization for Economic Cooperation and Development (OECD) and Brazil, Russia, India, Indonesia, China, and South Africa (BRIICS) from the first quarter (Q1) of 2020 to the same period of 2021.
Methods: From a health-economic perspective, this study established a framework to illustrate the following outcomes: suppression-prosperity, outbreak-stagnancy, outbreak-prosperity and suppression-stagnancy scenarios. Multinomial logistic models were used to analyse the associations between policy response with both the pandemic and the economy. The study further examined two subtypes of policy response, stringency/health measures and economic support measures, separately. The probabilities of the different scenarios were estimated.
Results: Economic prosperity and epidemic suppression were significantly associated with policy response. The effects of policy response on health-economic scenarios took the form of inverse U-shapes with the increase in intensity. 'Leptokurtic', 'bimodal' and 'long-tailed' curves demonstrated the estimated possibilities of suppression-prosperity, outbreak-prosperity and suppression-stagnancy scenarios, respectively. In addition, stringency/health policies followed the inverted U-shaped pattern, whereas economic support policies showed a linear pattern.
Conclusions: It was possible to achieve the dual objective of economic growth and epidemic control simultaneously, and the effects of policy response were shaped like an inverse U. These findings provide a new perspective for balancing the economy with public health during the early stages of the pandemic.

Introduction

The COVID-19 pandemic has caused the most severe damage to the socio-economic system in the last 80 years and has led to global recession and intense conflicts.[1] Over the last 2 years, governments around the world have been trying to revitalise the socio-economic structure.[2] However, the full reopening and recovery of the socio-economic system relied on the mobility of people to consume and produce, which accelerated the spread of the virus, especially during the early stages of the outbreak.[3–5] Thus, the pandemic and the economy seemed to be coupled and bound together under the bridging effects of mobility, resulting in conflicts between protecting public health and revitalising the economy at the same time.[6–8]

Previous studies generally agreed that both the needs of public health and the economy were important,[9,10] but the logistics for achieving these two goals were different. Some studies demonstrated that only when the epidemic was under control could the economy develop.[11] It was highlighted that 'active' policy interventions were useful to curb transmission, reduce mortality, prevent medical systems from being overwhelmed and promote safe and sustained recovery of the socio-economic system.[12–16]

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Other studies stressed that society had the capacity for epidemic prevention only when sustainable economic growth was maintained.[17] These studies suggested that an open and liberal approach was required, where governments should assume a 'passive' role and phase out segregation, virus testing and vaccination orders to avoid substantial economic damage.[17–21]

All these studies, both those considering epidemic control before economic revitalisation or the reverse, still regarded the pandemic and the economy as absolute antagonists in the short term. Moreover, both 'active' and 'passive' responses, based on this antagonistic relationship, provided limited suggestions for the dual objective of developing the economy and controlling viral transmission concurrently. For this reason, this study defined the economy and the health as a coupled/decoupled system to eliminate the antagonistic perspective. Instead of debating 'active' or 'passive', this study analysed what level of intensity and what kind of policy response could decouple economic recovery from pandemics and achieve the dual objective.

Accordingly, 38 OECD (Organization for Economic Cooperation and Development) and BRIICS (Brazil, Russia, India, Indonesia, China and South Africa) countries, representing the major global economies, were included in this study. First, a four-quadrant framework was provided to depict four scenarios addressing both the economy and the pandemic. Second, it was found that the effects of policy response were lagged and showed an inverted U-shape, and the probabilities of the scenarios of interest corresponded to three different U-shaped curves, which could be described as 'leptokurtic', 'bimodal' and 'long-tailed'. Moreover, 20 policies were classified into stringency/health measures or economic support measures, and heterogeneity analyses took place.

Methods

Data from Q1 2020 to Q1 2021 were used in the analyses. Data came from OECD and BRIICS countries (see Table S1 in the supplementary material). The longitudinal design of the study and the lagged outcomes strengthened confidence in making causal inference.

Outcomes

A framework was established with decoupling theory and defined outcomes[22] (see Table S2 in the supplementary material). The ratio between the relative economic recovery index (ΔERI) and the relative number of new cases (ΔNC) was used to describe the decoupling relationship between the economy and the pandemic (see Equation S1 and Table S2 in the supplementary material). In particular, the ΔERI could be obtained by global principal component analysis of seven core economic indicators (e.g. the change rate of gross domestic product and the change rate of purchase management index on year-on-year basis).[23–25] Quarters in 2019 were set as the common base periods, and data details can be found in Tables S3 and S4 in the supplementary material. The relative number of new cases referred to the difference between the number of newly reported cases per million in each nation and worldwide over a specific period,[26,27] which was available in current data series and could serve directly as the indicator for cross-country comparisons.[28] Pandemic data were collected from the World Health Organisation database.

Four logical relationships, calculated as positive decoupled (ΔERI > 0, ΔNC < 0), negative decoupled (ΔERI < 0, ΔNC > 0), positive coupled (ΔERI > 0, ΔNC > 0) and negative coupled (ΔERI < 0, ΔNC < 0), were used to demonstrate the following four health-economic scenarios: suppression-prosperity, outbreak-stagnancy, outbreak-prosperity and suppression-stagnancy (Fig. S1 in the supplementary material). The suppression-prosperity scenario was the optimal state, where public health and economic development were both promoted. The outbreak-prosperity and suppression-stagnancy scenarios were suboptimal conditions. In the outbreak-prosperity scenario, the economy kept growing while the virus swept over the country. Conversely, suppression-stagnancy referred to the scenario where the proportion of confirmed cases was lower than in other countries, but the economy was seriously damaged. Both scenarios were temporary, and occasionally, they might transition into one another. Finally, the rising number of confirmed cases and sluggish economy appeared at the same time in the outbreak-stagnancy scenario. All outcomes were lagged to establish temporality.

Independent variables

The core explanatory variable, policy response index (PRI), was made up of 20 policies to measure the strength of the government's response.[29] These data were drawn from the Oxford COVID-19 Government Response Tracker (OxCGRT; see Table S5 in the supplementary material). In addition, public health measures and economic measures were assessed using the stringency/health policy index (SHI) and the economic support policy index (ESI), respectively. These indicators were set as the average of daily indices in the quarter.

National and digital features were adjusted for in the data, as previous studies reported this to be crucial for economic development models during the epidemic.[30–34] Adjusted covariates included the population, digital services and online education. The digital services came from the search quantification points with 'Amazon', 'eBay', 'Taobao' and 'Tmall' as the keywords in Google trends; online education was from the search quantification points with 'Coursera', 'Google Classroom', 'Udemy' and 'Zoom'; and population data were derived from the OECD database. Descriptive statistics for all variables are shown in Table S6 in the supplementary material.

Statistical analyses

Multinomial logistic models with random effects were used to analyse the impact of policy response. The standard form of multinomial logistic model was as follows (equation (1)):

$$\ln\left(\frac{\pi_{ij}}{\pi_{ij^*}}\right) = \alpha_j + \beta_j x \quad (j \neq j^*) \tag{1}$$

where π_{ij} was the probability that sample i fell into result j, and j* was the base category; each result had its own slope item; $\frac{\pi_{ij}}{\pi_{ij^*}}$ was known as relative risk. In this study, the dependent variable included four scenarios: suppression-prosperity, outbreak-prosperity, suppression-stagnancy and outbreak-stagnancy. Outbreak-stagnancy scenario was set as the base category. Due to the correlations between data within each sample, random effects calculations were used on the assumption that different nations had unique intercept terms in the regression, which could account for depended observations.

Overall PRI and its subset SHI and ESI, as core independent variables, were placed in the regression models. Models with squared terms of the variable indicated parabolic impacts of the policy response, whereas models without squared terms indicated linear effects. Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used to determine whether to include squared terms. The policy mix of stringency/health measures and economic support measures were also analysed.

When estimating the probability of each health-economic scenario, equation (1) could be written as follows:

$$P(y_i = j|x_i) = \frac{\exp\left(x_i'\beta_j\right)}{\sum_{k=1}^{J} \exp\left(x_i'\beta_k\right)} \tag{2}$$

Obviously,

$$\sum_{k=1}^{J} \exp\left(x_i'\beta_k\right) = 1 \tag{3}$$

The coefficient of the base category was set as 0. Thus, the probability of scenario j was as follows:

$$P(y_i = j|x_i) = \begin{cases} \dfrac{1}{1 + \sum_{k=2}^{J} \exp(x_i'\beta_k)} & (j = 1) \\ \dfrac{\exp(x_i'\beta_j)}{1 + \sum_{k=2}^{J} \exp(x_i'\beta_k)} & (j = 2, \ldots, J) \end{cases} \tag{4}$$

where the base category, outbreak-stagnancy scenario, was corresponding to j = 1.

Adjusted variables and models were used for sensitivity analyses. First, fixed effects models were used for comparison with the main analyses and Hausman tests were performed. Second, the outbreak-stagnancy scenario was set as the base category (x = 0) and the others as 1; and, separately, the suppression-prosperity scenario was also set as the base category and the others as 1. A series of logistic regressions was performed. STATA (version 17) was used for statistical analyses.

Results

Health-economic scenarios and coupled correlation during the early stage of the pandemic

Fig. 1 shows the coupled relationship between economic expansion and virus spread caused by the outbreak. Many countries entered a paradigm of suppression-stagnancy or even outbreak-stagnancy by Q2 2020 (Fig. 1A). Data from Q3 2020 indicated that a recovery of the health-economic system might be imminent (Fig. 1B). However, only a small number of nations, such as South Korea and China, remained in the suppression-prosperity scenario in Q4 2020 and Q1 2021 (Fig. 1C and D). On the other hand, for example, the United States experienced a high rate of economic

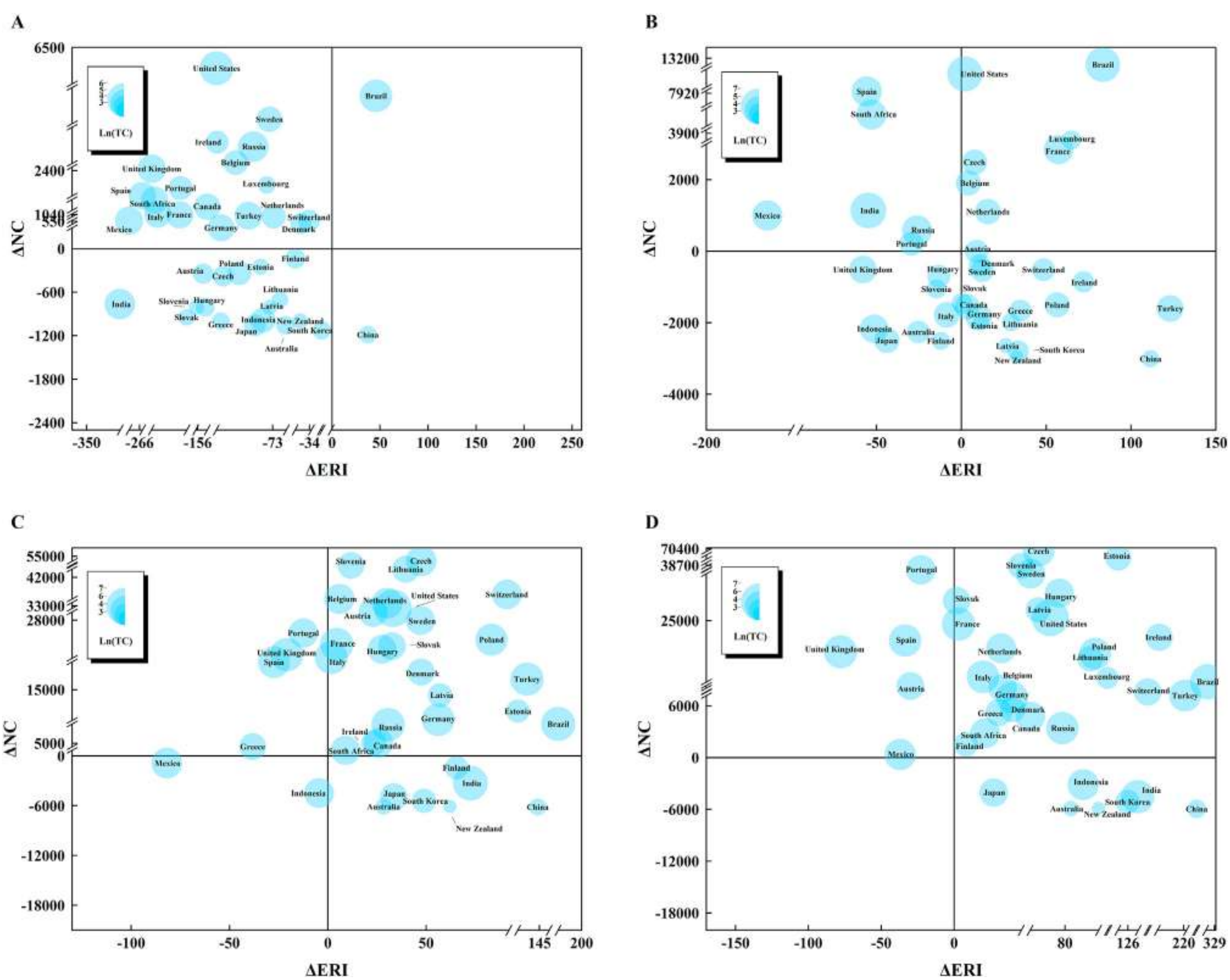

Fig. 1. A schematic framework of the health-economic scenarios in Q2 2020 – Q1 2021 (A–D). Outbreak-prosperity scenario is the first quadrant, outbreak-stagnancy scenario is the second quadrant, suppression-stagnancy scenario is the third quadrant, and suppression-prosperity scenario is the fourth quadrant. ΔERI, relative economic recovery index; ΔNC, relative number of new cases.

Table 1
Results for multinomial logistic models.

Scenario		Model Total	(For reference)	Model Subtype-stringency/ health policies	(For reference)	Model Subtype-economic-policies	(For reference)	Model Subtype
		β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Outbreak-stagnancy scenario	Base category	/	/	/	/	/	/	/
Suppression-prosperity scenario	L_PRI	**0.970*** (0.271, 1.668)**	0.082*** (0.028, 0.136)	/ /	/ /	/ /	/ /	/ /
	L_PRI_squ	**−0.009*** (−0.015, −0.003)**	/ /	/ /	/ /	/ /	/ /	/ /
	L-SHI	/ /	/ /	0.750*** (0.271, 1.229)	0.073*** (0.020, 0.126)	/ /	/ /	**0.799*** (0.280, 1.318)**
	L-SHI_squ	/ /	/ /	−0.007*** (−0.012, −0.002)	/ /	/ /	/ /	**−0.008*** (−0.012, −0.003)**
	L-ESI	/ /	/ /	/ /	/ /	0.092* (−0.014, 0.198)	0.027* (−0.002, 0.056)	**0.021 (−0.013, 0.054)**
	L-ESI_squ	/ /	/ /	/ /	/ /	−0.001 (−0.001, 0.0003)	/	/
Outbreak-prosperity scenario	L_PRI	**0.564*** (0.237, 0.892)**	0.086*** (0.042, 0.131)	/ /	/ /	/ /	/ /	/ /
	L_PRI_squ	**−0.005*** (−0.008, −0.002)**	/ /	/ /	/ /	/ /	/ /	/ /
	L-SHI	/ /	/ /	0.632*** (0.280, 0.983)	0.077*** (0.034, 0.120)	/ /	/ /	**0.629*** (0.268, 0.991)**
	L-SHI_squ	/ /	/ /	−0.006*** (−0.010, −0.002)	/ /	/ /	/ /	**−0.006*** (−0.010, −0.002)**
	L-ESI	/ /	/ /	/ /	/ /	0.085 (−0.022, 0.193)	0.039** (0.007, 0.071)	**0.023 (−0.015, 0.061)**
	L-ESI_squ	/ /	/ /	/ /	/ /	−0.0004 (−0.001, 0.0005)	/ /	/ /
Suppression-stagnancy scenario	L_PRI	**0.205* (−0.003, 0.412)**	−0.019 (−0.051, 0.014)	/ /	/ /	/ /	/ /	/ /
	L_PRI_squ	**−0.003** (−0.005, −0.0002)**	/ /	/ /	/ /	/ /	/ /	/ /
	L-SHI	/ /	/ /	0.219* (−0.007, 0.444)	−0.018 (−0.051, 0.016)	/ /	/ /	**0.245** (0.014, 0.477)**
	L-SHI_squ	/ /	/ /	−0.003** (−0.005, −0.0001)	/ /	/ /	/ /	**−0.003** (−0.006, −0.0002)**
	L-ESI	/ /	/ /	/ /	/ /	0.051 (−0.024, 0.125)	−0.019 (−0.048, 0.011)	**−0.0156 (−0.041, 0.010)**
	L-ESI_squ	/ /	/ /	/ /	/ /	−0.001* (−0.001, 0.0001)	/ /	/ /
	AIC	**328.9147**	**347.6178**	**336.7429**	**355.4985**	**369.6402**	**368.5781**	**336.877**
	BIC	**392.4162**	**402.0476**	**400.2444**	**409.9284**	**433.1417**	**423.008**	**409.4501**

AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; CI, confidence interval.
*$P < 0.1$; **$P < 0.05$; ***$P < 0.01$.
Model Total focused on the impact of overall policy response index (with the squared terms). Model Subtype-stringency/health policies and Model Subtype-economic-policies included stringency/health policy index (with its squared terms) and economic support policy index (with its squared terms), respectively. Models For reference were provided without squared terms. Model Subtype was the comprehensive model with the policy mix. L_PRI was policy response index. L-SHI and L-ESI referred to stringency/health policy index and economic support policy index. These Models all controlled for covariates. Bold models fitted the data better and were used to estimated probabilities for health-economic scenarios.

expansion in Q1 2021 along with a reported case count of more than 10 million people, resulting in the outbreak-prosperity scenario. In addition, Indonesia was in suppression-stagnancy in Q4 2020. The blockade for virus control kept economic growth low for a significant amount of time, with imports and exports greatly reduced (Fig. 1C and D). It was worth noting that the outbreak-stagnancy scenario logically followed from the coupled relationship, such as the increase in the number of confirmed cases from Q2 to Q3 of 2020 after the slow growth of the Indian economy, which brought India from the suppression-stagnancy to the outbreak-stagnancy scenario (Fig. 1A and B).

Associations between policy response and health-economic scenarios

Since Q1 2020, all countries adopted either strong or weak policies (for more details, see Figs. S2 and S3 in the supplementary material).

Table 1 shows the results of multinomial logistic regression with random effects. From Model Total, PRI and its squared terms were found to be statistically significant, and the coefficients of squared term were less than 0. The coefficients of PRI and its squared terms were 0.970 (0.271, 1.668) and −0.009 (−0.015, −0.003) for suppression-prosperity scenario; 0.564 (0.237, 0.892) and −0.005 (−0.008, −0.002) for outbreak-prosperity scenario; and 0.205 (−0.003, 0.412) and −0.003 (−0.005, −0.0002) for suppression-stagnancy scenario, respectively. Because AIC and BIC of Model Total were lower than the reference, the quadratic form may fit the data better. The results validated that the effects of policy response on health-economic scenarios were marginal diminishing. Inverse U-shapes can be seen in Fig. S4 in the supplementary material.

Stringency/health policies and economic support policies were analysed in Model Subtypes separately (Table 1). According to comparisons of AIC, BIC and the significance of the squared terms among these models, the effects of SHI were found to be inverted U-shaped (AIC and BIC in Model Subtype-stringency/health policies were lower than the reference, and the coefficients of the squared terms were mostly significant), whereas the effects of ESI were linear (AIC and BIC in Model Subtype-economic-policies were higher than the reference, and the coefficients of the squared terms were not significant). The regression was further performed on SHI, SHI's squared terms and ESI in Model Subtype. The coefficients of SHI and its squared terms remained significant, whereas the significance of ESI coefficients became lower.

For sensitivity analyses, a fixed effects multinomial logistic regression was first performed for comparison (see Table S7 in the supplementary material). Inverted U-shaped relationships continued to exist and were mainly significant; hence, the substantive findings remained unaltered. According to the results of Hausman tests, random effects models were shown as main analyses (see Table S8 in the supplementary material). Second, a logistic regression was performed after recoding the outcomes by setting the outbreak-stagnancy scenario and suppression-prosperity scenario as the base category separately. Analyses showed that most of the effects of policies followed the same patterns (see Table S9 in the supplementary material).

Estimated curves of policy response with health-economic scenarios

Model Total and Model Subtype (best-fitted) were used to estimate probabilities for health-economic scenarios (see Fig. 2). The outbreak-stagnancy scenario was almost certain when there was no policy at all. With increasing policy response, the probabilities of the other three scenarios increased. At medium-low intensity (around 30 score), the suppression-stagnancy scenario peaked for 42.80% (22.79%, 62.82%). A higher intensity of late policy response was likely to lead to outbreak-prosperity or suppression-prosperity scenarios. At medium-high intensity (about 57 score), the probability of suppression-prosperity reached the highest for 40.27% (25.14%, 55.40%); and outbreak-prosperity scenario reached the peak for 43.48% (27.40%, 59.56%) at the turning point of 66 score (see Table S10 in the supplementary material). The likelihood of these three eventualities decreased considerably when the policy intensity rose above a 70-score threshold.

Separately, the curves of suppression-prosperity, outbreak-prosperity and suppression-stagnancy scenarios corresponded to three different inverted U-shapes, which could be described as ‘leptokurtic’, ‘bimodal’ and ‘long-tailed’ (Fig. 2B–D). A leptokurtic shape indicated that the curvature of the policy response curve was larger, and marginal effects were more distinct and sensitive in the suppression-prosperity scenario. The bimodal shape demonstrated that the probability curve of the outbreak-prosperity scenario had a length of ‘plateau’ after increasing to a certain level and showed signs of relatively obvious twin-peak characteristics. The probability of the suppression-stagnancy scenario swiftly reached its peak and then rapidly declined with the increase of policy intensity, as it was long-tailed.

The three-dimensional figures of stringency/health and economic policy mix are shown in Fig. 2E–G. It was shown that moderate intensity of stringency/health policies and high intensity of economic support policies were the optimal policy mix. Positive incentives from SHI attained maximum at medium policy intensity. Yet, the impacts from ESI continued while enhancing policies.

Discussion

Data from OECD and BRIICS countries were used to analyse the impacts of policy response on the pandemic and the economy. The results showed that (1) both economic development and epidemic suppression might be achieved, namely, decoupled, with the intervention of policy response; (2) the impacts of policy response were lagged and showed an inverted U-shape, meaning that the benefits of policy response on the health-economic system would be overweighed by the incremental distortive effects after the turning point; (3) the effects of stringency/health policies resembled inverted U-shapes compared with economic support policies; and (4) estimated curves of suppression-prosperity, outbreak-prosperity and suppression-stagnancy scenarios presented ‘leptokurtic’, ‘bimodal’ and ‘long-tailed’ characteristics. These findings might help to keep the epidemic controlled while not sacrificing economy recovery in the early pandemic period.

It was often assumed that stimulating the economy and controlling the pandemic were in conflict.[35] However, the current analyses based on OECD and BRIICS countries offered a different story. This study emphasised that the dual objective, by decoupling the epidemic and the economy, was more important when facing complex, uncertain and ambiguous risks. It was possible to keep the epidemic controlled while not sacrificing the recovery of the economy. In addition, this study focused on the perspective of policy intensity and put forward the inverted U-shaped pattern of policy effects, indicating that it was advisable to adopt medium-intensity (around 57 score) public policies in the early COVID-19 period (see Table S10 in the supplementary material). This U-shaped pattern is consistent with several previous studies on pandemic policy analyses.[9,36] In total, 20 different policies and 38 countries were included in the current analyses, which enhanced the general significance of the research results. The study findings are complementary to the previous literature.

From a theoretical perspective, the inverted U-shaped curves of stringency/health policies may be caused by the interaction of two latent but opposite functions.[37] Because these functions are asymmetric in two aspects, an inverted U emerges. The first stems from the asymmetry between the effects of blockade policies on health and economic activities. Lockdowns are detrimental to the economy but are beneficial for viral containment. However, panic and irrational behaviour responses as a result of lockdowns often result in extensive damage to economic systems, which is greater than the protective effect provided by lockdowns to susceptible people.[38] The second stems from the asymmetry between the effects of health support policies on the contact rate and the probability of infection. Scholars often believe that health support policies can separate the contact rate and the probability of infection, which should both be dependent on social mobility.[39,40] In terms of the probability of infection, the initial effect of health policies is obvious, but higher levels of intensity may not continue to decrease this variable.[5,41] For example, more extensive tests sometimes have no greater effect than tests for high-risk populations. In terms of the contact rate, the incremental policies may

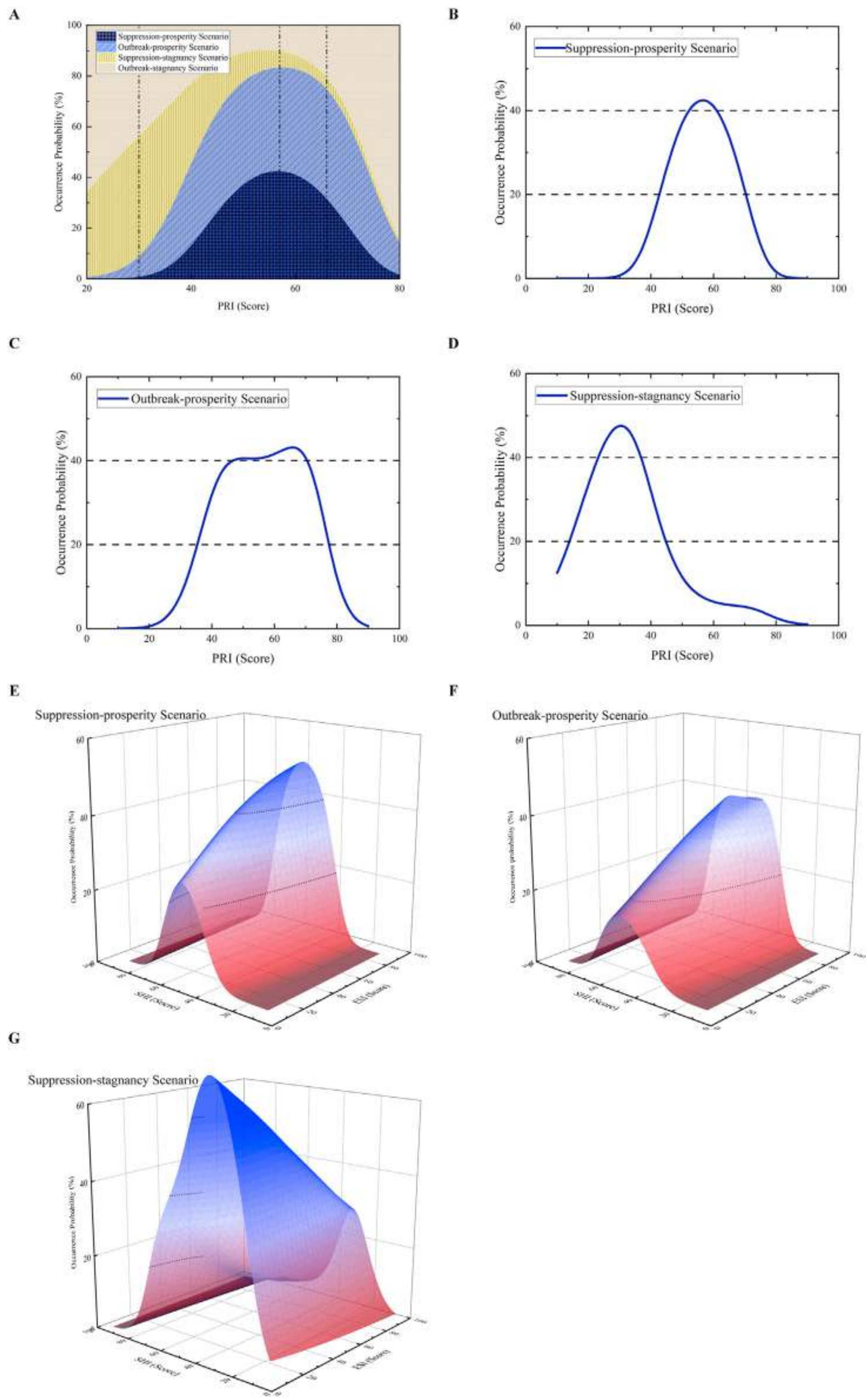

Fig. 2. Estimated curves of policy response and marginal effects. Panel A indicates the probabilities of four scenarios; Panels B–D represents the probability curves of three interest scenarios as PRI changed; Panels E–G were probability curves under the impact of stringency/health policies and economic support policies. PRI, policy response index.

make people overtrust the government's ability and become more relaxed about self-protection and movement restrictions, both psychologically and behaviourally.[42] When the promotion of the contact rate outpaces the inhibition of the probability of infection, negative incentives outweigh positive ones. From these two perspectives, the effects of stringency/health policies show inverted U-shapes.

This study identified 'leptokurtic', 'bimodal' and 'long-tailed' inverted U-shapes for the scenarios of interest. In probability theory, leptokurtic shapes are curves with larger positive kurtosis, bimodal shapes refer to curves with two peaks that indicate two local maximums and long-tailed shapes have heavier tails than the typical.[43] Disparities among the three scenarios were caused by the dissimilar policy thresholds and unequal widths of effective policy intervals. The probabilities of scenarios were affected by each other, and the dominant scenario was different under different policy intensity. Suppression-prosperity scenario was the optimal outcome, but the most difficult to achieve during the pandemic. The kurtosis of the curve of suppression-prosperity scenario was relatively large, where even a slight intensity score deviation from the turning point could result in a considerable decrease in probability. Moreover, the effective policy interval for the suppression-prosperity scenario was smaller than that in the outbreak-prosperity scenario. Hence, the effective interval of policy intensity for suppression-prosperity scenario was very narrow. In a sense, 'moderate' policy measures are the key to good governance. To be specific, too-strong or too-weak policy responses were detrimental to achieve the suppression-prosperity scenario, and precise intensity of policy implementation was essential.[44]

Although this study has demonstrated the effectiveness of some policy response, the possibility of action is limited by the constantly changing virus, and thus, policymakers must be prudent. Policy instruments are more likely to be implemented when institutional and social infrastructures support management actions.[45] However, in some decentralised systems, governments face higher thresholds to justify intervention.[12] In addition, China's recent experience revealed that the ever-increasing 'ultra-long isolation' did not benefit the dual objective and increased the cost of controlling the epidemic. Policymakers should be cautious to maximise the effectiveness of policy implementation by ensuring that the reaction offers positive rather than negative incentives.

This study has some limitations. First, treating only the strength of policy response might fail to consider some crucial concerns pertaining to policy contents. In addition, to perform country-based comparison, the set outcomes might overlook some contexts in this study. For example, over the study period, different countries were dealing with different COVID-19 variants and conducted testing at different rates. Quarterly variations could also make the current data less comparable. Moreover, the inverted U-shaped curves identified did not emphasise predictive functions but rather illustrated the tendency for policy intensity to affect health-economic scenarios. In addition, the temporality of the data in the early pandemic phase also limited the study. Only the early stages of the pandemic were considered in the assessments that were given in the present study. Future research could consider the contents of policy instruments, as well as the difference of testing rates and viral variants.

In conclusion, it was possible to achieve the dual objective of economic growth and epidemic control simultaneously, and the effects of policy response were shaped like an inverse U. These findings provide a new perspective for balancing the economy with public health during the early stages of pandemics.

Author statements

Ethical approval

The study used publicly available and country-level data with no identifiable personal information; thus, ethical approval was not required.

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Competing interests

None declared.

Data availability

The data underlying this article are available in WHO, OECD, OxCGRT and Wind databases.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.012.

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Original Research

Influence of family structure on adolescent deviant behavior and depression: the mediation roles of parental monitoring and school connectedness

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ABSTRACT

Objectives: This study aimed to explore the specific pathway of family structure on adolescent health.
Study design: This was a cross-sectional study.
Methods: We examined the influence of family structure on adolescent deviant behavior and depression, as well as the mediation roles of parental monitoring and school connectedness, using the multivariate regression and Karlson-Holm-Breen mediation models.
Results: Compared with adolescents in intact families, those in non-intact families showed more deviant behaviors and depression. Parental monitoring and school connectedness appeared to be two important pathways from family structure to deviant behavior and depression. In addition, urban and female adolescents in non-intact families showed more deviant behaviors and depression than their rural and male counterparts, respectively. Furthermore, adolescents in reconstituted families showed more deviant behaviors than those in single-parent families.
Conclusions: The behavioral and mental health of adolescents in single-parent or reconstituted families deserves more attention, and interventions should be actively conducted at both family and school level to improve adolescent health.

Introduction

The healthy growth and development of adolescents are crucial to the quality of population and social development. However, with a rapid social transition, adolescent health is challenged by various risk factors. In this context, adolescent deviant behavior in China shows an upward trend, and their psychological disorders such as depression and anxiety are also becoming increasingly popular.[1–3] Numerous studies have suggested the rapid transition in culture and social structure is a fundamental factor leading to the deterioration of adolescent behavioral and mental health.[4] Huge structural changes in family, school, community, and labor market in the process of modernization and social transition are crucial forces influencing adolescent behavioral and mental health. As the first growth place of children, family plays an extremely important role in adolescent healthy growth.

The *double-parents rearing theory* holds that a perfect child rearing process consists of participation of both parents. The father mainly takes the social parenting responsibility, whereas the mother takes the emotional parenting responsibility. Both parties follow established family gender division system and sociocultural rules to play the role, and their parenting practices have different but indispensable functions, and they complement mutually and work together.[5,6] Thus, living in a native family environment is of great significance for the healthy growth and development of adolescents, and an intact two-parent family structure is conducive to adolescent behavioral and mental health.[7,8] However, in the process of China's social transition, parental divorce continues rising, so more and more adolescents have to grow up in non-intact families, which brings about many negative consequences for their healthy growth.[6,9] However, it is unclear whether non-intact family structure exerts significant negative effects on adolescent health in different subgroups, whether different forms of non-intact family structure can lead to distinct negative consequences,

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and the underlying pathways in this relationship. Therefore, this study aimed to analyze the impact of family structure on adolescent deviant behavior and depression, as well as potential pathways and group heterogeneities.

Literature review and hypotheses

Influence of family structure on adolescent deviant behavior and depression

Parental divorce is the most important reason for adolescents to grow up in non-intact families. The *serious influence theory* believes that the breakdown of family relationship caused by parental divorce exerts serious and irreversible negative effects on the mental health and behavioral development of adolescents.[10] The *limited influence theory*, by contrast, puts that the negative consequences of parental divorce are not irreversible, and most adolescents can gradually adapt to their new family environments in the process of family–society interactions.[11,12] Anyway, both of the abovementioned theories note that broken or non-intact family structure will have negative impacts on the healthy growth of adolescents.

Studies in most countries have shown that non-intact family structure caused by parental divorce has negative effects on the behavioral and psychological health of adolescents.[13–15] Studies from South Korea report that middle school students from single-parent families are more likely to skip classes,[16] use drugs, and report depressive symptoms.[15] Studies from Italy and Denmark indicate that adolescents from non-intact families are more prone to smoke and drink[13] and be charged with a criminal offense and disconnected from education.[17] Two Canadian studies report that parental divorce is associated with more deviant behaviors and poorer mental health among children.[18,19] Studies from India and Ghana find that adolescents in single-parent families show more mental health problems, especially for female adolescents.[20,21] The impact of non-intact family structure caused by parental divorce on adolescent behavior and psychology is long-lasting, and numerous adolescents with divorced parents are even at a behavioral and mental health disadvantage in their adulthood.[22]

Evidence from China suggests that the impact of family structure on adolescent psychological and behavioral development is complex. Living in an environment where parents are absent for a long time can significantly impair adolescent mental health.[23,24] Parental divorce can lead to more adolescent mental health problems and deviant behaviors, but it can also help them grow up faster and become mature earlier.[25] Recent evidence shows that the influences of different family structures may differ; compared with adolescents in intact families, those in single-parent families are more prone to report deviant behaviors.[9] However, due to the reintegration of family structure, adolescents in reconstituted families have similar self-consciousness and self-control compared with those in intact families.[9] By contrast, some scholars find that single-parent and orphans family structures exert a negative effect on adolescent psychosocial health compared with intact family structure,[6,26] and the negative effect of single-mother family on adolescent psychosocial health is stronger than that of single-father family.[6] Accordingly, we proposed the following hypothesis.

Hypothesis 1: Non-intact family structure increases adolescent deviant behavior and depression.

Mediation of parental monitoring and school connectedness

Family and school constitute two vital growth environments for children and adolescents. Non-intact family structure will lead to insufficient resource input in the process of child rearing, including not only material resource input but also social capital, time, and emotional input.[26] Empirical evidence suggests that the time and affection that parents devote to their children play important roles in adolescent healthy growth, and the lack of parental monitoring and parent–child interaction will worsen adolescents' mental health[6,27,28] and lead to deviant behaviors such as truancy, fighting, and substance abuse.[29,30] Because of the absence of biological father or mother in single-parent and restructured families, non-intact family structure may lead to limited time and emotional investment of parents in rearing and supervision on adolescents; meanwhile, the breakdown or reconstitution process of family will have huge negative influences on parent–child relationship.[28,31] The abovementioned phenomena weaken family constraints and parental monitoring, increase adolescent deviant behaviors, and damage their mental health.

School connectedness also fundamentally shapes adolescent behavioral and mental health. Previous evidence shows that school connectedness can effectively reduce adolescent depression and anxiety.[32–35] School connectedness may be an important channel through which family structure influences adolescent behavioral and mental health. On the one hand, the school education of Chinese children is deeply bound to family education, and most of the extracurricular tasks assigned by school require the participation of both children and parents.[36] Thus, the non-intact family structure will lead to the absence of parents in the above process, making it difficult for children to complete their learning tasks. This will result in elevated academic stress, disharmonious relationship with teachers and classmates, and decreased school connectedness, which ultimately hinder their behavioral and mental health development.[7,30] On the other hand, the influence of non-intact family structure on adolescent behavioral and mental health mediated by school connectedness may be cyclic and continuously enhanced. Non-intact family structure will lead to psychological problems, such as autism, inferiority, and depression among adolescents,[6,18] which further affects their active integration into campus life and makes it hard to gain a sense of belonging in the school. The above decline in school connectedness may further enhance adolescent rebellious psychology and lead to more serious deviant behaviors and psychological disorders. Accordingly, we proposed the following two hypotheses.

Hypothesis 2: The influence of family structure on adolescent deviant behavior and depression is mediated by parental monitoring.

Hypothesis 3: The influence of family structure on adolescent deviant behavior and depression is mediated by school connectedness.

Moderation of sex and urban-rural residence

There are potential sex and urban-rural heterogeneities in the influence of family structure on adolescent behavioral and mental health. Chinese families have long had different parenting strategies for boys and girls. A fair amount of families still have the son preference value, which makes boys get more family resources input when family resources are insufficient.[37] Thus, the negative effect of non-intact family structure on girls' behavioral and mental health may be stronger. On the other hand, boys and girls also differ significantly in behavioral styles and traits. Girls are more susceptible to puberty and bear more stress from physiological development, school adaptation, and social norms than boys,[38,39] which may make the negative effect of non-intact family on girls' behavioral and mental health stronger.[20]

There are huge differences in the socio-economic development of urban and rural China, so the growth environment of urban and rural children is significantly different. In this context, compared with urban adolescents, rural adolescents are more resilient and psychologically mature,[40] so their behavioral and mental health may be less affected by family structure. By contrast, the absence of parents in urban families is more likely to be caused by parental divorce,[41] and urban adolescents have weaker psychological resilience and less psychological maturity than their rural counterparts.[40] Therefore, non-intact family structure may be more destructive to the healthy growth of urban adolescent. Accordingly, we proposed the following two hypotheses.

Hypothesis 4: The negative influence of non-intact family structure on deviant behavior and depression is stronger in boys than in girls.

Hypothesis 5: The negative influence of non-intact family structure on deviant behavior and depression is stronger in urban adolescents than in their rural counterparts.

Methods

Participants

Data came from a survey conducted among Chinese high school students from May to June 2021. Four senior schools (one private and three public) were chosen to recruit participants in Henan Province, central China. Four or five classes were randomly sampled from grades 10 and 11 at each school site. All students in selected classes were invited to complete an anonymous questionnaire. A total of 1650 students from 33 classes were interviewed, and 1607 respondents were eligible for data analysis.

Measures

Family structure

We dichotomized family structure into intact family (two-parent family) and non-intact family (single-parent family, restructured family, and other family types). In addition, to analyze the separate effects of single-parent and reconstituted family, a three-category variable (intact family, single-parent family, and reconstituted family) was also used in this study. Because the option 'other family types' only includes five samples, we consider it as missing data in the three-category family intactness variable, given statistical power.

Deviant behavior

Ten dichotomous questions were used to measure common deviant behaviors among Chinese adolescents, including skipping school, carrying weapons, fighting, smoking, drinking, cheating in tests, running away from home, vandalism, and sexual behavior (Cronbach's alpha = 0.702). All items were summed to yield a continuous variable, and larger scores meant more deviant behaviors.

Depression

Depression was measured using the 20-item Center for Epidemiologic Studies Depression Scale,[42,43] and all items were assessed on a 4-point Likert scale. All items were summed to yield a continuous variable, with larger scores representing more depression (Cronbach's alpha = 0.889). Furthermore, score of 21 was used as the cut-off point of depressive symptoms.[42]

Parental monitoring

Parental monitoring was measured using the 8-item Parental Monitoring Scale developed by Small and Kerns;[44] it has been validated in Chinese youth,[45] and all items were assessed on a 5-point Likert scale (0 = never, 1 = hardly ever, 2 = sometimes, 3 = most of the time, and 4 = always). Items were summed to yield a continuous variable, and larger scores meant higher levels of parental monitoring (Cronbach's alpha = 0.845).

School connectedness

The 10-item School Connectedness Scale developed by Yu et al. was used in the present study,[46] which includes classmate support, teacher support, and school belonging. Items were assessed on a 5-point Likert scale, ranging from '0 = strongly disagree' to '4 = strongly agree.' All items were summed to yield a continuous variable, and larger scores meant higher levels of school connectedness (Cronbach's alpha = 0.859).

Covariates

Sex, age, grade, residence, paternal and maternal educational year, family economic status, left-behind adolescents, only child, academic performance (1 = very poor, 2 = poor, 3 = medium, 4 = good, 5 = very good), and school type were used as covariates. More details are listed in Appendix 1.

Statistical analysis

First, the ordinary least squares and binary Logit models were used to examine the influence of family structure on adolescent deviant behavior and depression, whereas a stepwise strategy was used to explore the mediation effects of parental monitoring and school connectedness. Subsequently, the Karlson-Holm-Breen (KHB) mediation model was used to check the significance of mediating effects through the product of coefficients (more details can be seen in Karlson et al.'s study).[47,48] In addition, the sex and urban-rural heterogeneities in the influence of family structure, parental monitoring, and school connectedness on adolescent behavioral and mental health were tested using the syntax 'diff' developed by Lian et al.,[49] and the bootstrap method (seed number = 19950111, time of repeated sampling = 1000) was used to re-estimated the standard errors. All the data analyses were performed using Stata version 14.0 (Stata Corp, College Station, TX).

Results

Influence of family structure on adolescent deviant behavior

Table 1 shows that adolescents in intact families reported fewer deviant behaviors ($\beta = -0.462$, $P < 0.01$), whereas parental monitoring and school connectedness were negatively related to adolescent deviant behavior ($\beta = -0.048$, $P < 0.001$; $\beta = -0.039$, $P < 0.001$; respectively). Parental monitoring and school connectedness appeared to partially mediate the association between family structure and adolescent deviant behavior because the negative association between family structure and adolescent deviant behavior reduced ($\beta = -0.323$, $P < 0.05$) after controlling for parental monitoring and school connectedness.

Influence of family structure on adolescent depression

Table 2 displays that with other variables controlled for, adolescents in intact families reported lower levels of depression ($\beta = -2.668$, $P < 0.01$), whereas parental monitoring and school connectedness negatively predicted adolescent depression ($\beta = -0.117$, $P < 0.01$; $\beta = -0.591$, $P < 0.001$; respectively). Parental monitoring and school connectedness appeared to be mediators in the relationship between family structure and adolescent depression because the association between family structure and adolescent depression reduced ($\beta = -1.532$, $P < 0.1$) after controlling for parental monitoring and school connectedness. Similar

Table 1
Influence of family structure, parental monitoring, and school connectedness on adolescent deviant behavior.

Variables	Model 1		Model 2	
	β	SE	β	SE
Family structure (ref: non-intact)	−0.462**	0.137	−0.323*	0.131
Sex (ref: female)	0.506***	0.067	0.334***	0.067
Age	0.020	0.047	0.017	0.045
Grade (ref: 10th)	0.082	0.080	0.008	0.077
Residence (ref: urban)	−0.173*	0.076	−0.238**	0.073
Family economic status (ref: low)				
Middle	−0.232*	0.109	−0.107	0.104
High	0.194	0.158	0.342*	0.151
Paternal educational year	−0.004	0.014	−0.009	0.013
Maternal educational year	0.013	0.012	0.017	0.011
Only child (ref: no)	−0.149	0.113	−0.140	0.108
Left-behind adolescent (ref: no)	−0.121	0.079	−0.142^	0.075
Academic performance	−0.204***	0.040	−0.136***	0.039
School type (ref: private)	−0.515***	0.082	−0.349***	0.079
Parental monitoring			−0.048***	0.006
School connectedness			−0.039***	0.005
Intercept	0.728	0.851	3.519***	0.843
R^2	0.100		0.185	
n	1576		1576	

SE, standard error.
^$P < 0.1$, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

results were yielded when adolescent depression was dichotomized (see Appendix 2).

KHB mediation test

The KHB mediation method was used to test whether the aforementioned mediation effects were statistically significant. Table 3 displays that parental monitoring and school connectedness significantly mediated the relationship between family structure and adolescent deviant behavior (β = −0.139, $P < 0.01$), which explained 30.1% of the total effect (16.5% for parental monitoring and 13.6% for school connectedness). Similarly, the mediation effects of parental monitoring and school connectedness on the relationship between family structure and adolescent depression were also statistically significant (β = −1.136, $P < 0.01$), which explained 42.6% of the total effect (6.9% for parental monitoring and 35.7% for school connectedness).

Table 2
Influence of family structure, parental monitoring, and school connectedness on adolescent depression.

Variables	Model 1		Model 2	
	β	SE	β	SE
Family structure (ref: non-intact)	−2.668**	0.897	−1.532^	0.794
Sex (ref: female)	−1.192**	0.441	−1.993***	0.404
Age	−0.174	0.309	−0.084	0.272
Grade (ref: 10th)	1.748**	0.527	1.089*	0.466
Residence (ref: urban)	0.181	0.498	−0.291	0.441
Family economic status (ref: low)				
Middle	−3.777***	0.714	−2.406***	0.633
High	−3.678***	1.033	−2.170*	0.914
Paternal educational year	0.055	0.089	0.014	0.079
Maternal educational year	−0.019	0.079	0.011	0.070
Only child (ref: no)	1.341^	0.740	1.323*	0.653
Left-behind adolescent (ref: no)	0.465	0.516	0.514	0.456
Academic performance	−1.359***	0.262	−0.605*	0.234
School type (ref: private)	−0.123	0.535	1.782***	0.481
Parental monitoring			−0.117**	0.039
School connectedness			−0.591***	0.031
Intercept	6.566	5.573	26.680***	5.113
R^2	0.061		0.271	
n	1576		1576	

SE, standard error.
$P < 0.1$, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 3
Results of KHB mediation test.

Effects	Model 1: deviant behavior		Model 2: depression	
	β	SE	β	SE
Total effect	−0.462***	0.130	−2.668**	0.791
Direct effect	−0.323*	0.131	−1.532^	0.794
Mediation effect	−0.139**	0.043	−1.136**	0.428
Parental monitoring	−0.076**	0.028	−0.185*	0.088
School connectedness	−0.063*	0.028	−0.951*	0.404

SE, standard error.
Sex, age, grade, residence, family economic status, parental educational year, maternal educational year, only child, left-behind adolescent, academic performance, and school type were controlled in Models 1 and 2.
^$P < 0.1$, *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Sex and urban-rural heterogeneities

Panel A in Appendix 3 shows that the association between family structure, parental monitoring, and school connectedness and deviant behavior between boys and girls was similar. Family structure, parental monitoring, and school connectedness were significantly related to urban adolescent deviant behavior (β = −0.351, $P < 0.1$; β = −0.058, $P < 0.001$; β = −0.044, $P < 0.001$). However, family structure did not relate to rural adolescent deviant behavior, and the association between parental monitoring and rural adolescent deviant behavior was significantly weaker (difference = −0.021, $P < 0.1$).

Panel B shows that family structure, parental monitoring, and school connectedness were significantly related to girls' depression (β = −2.153, $P < 0.1$; β = −0.102, $P < 0.1$; β = −0.686, $P < 0.001$). By contrast, family structure was not related to boys' depression, and the association between school connectedness and boys' depression was significantly weaker (difference = −0.171, $P < 0.01$). The association between family structure and depression was not significant in both urban and rural adolescents, but parental monitoring and school connectedness mattered in both urban and rural adolescents, with no significant urban-rural difference.

Effects of single-parent and reconstituted families

Panel A in Appendix 4 shows that compared with adolescents in intact families, those in single-parent and reconstituted families reported more deviant behaviors, and the effect of reconstituted family seemed to be stronger (β = 0.339, $P < 0.1$; β = 0.617, $P < 0.01$; respectively). With parental monitoring and school connectedness controlled for, the influence of single-parent and reconstituted families on adolescent deviant behavior reduced, suggesting significant mediation effects of parental monitoring and school connectedness.

Panel B shows that both single-parent and reconstituted families positively predicted adolescent depression (β = 3.014, $P < 0.05$; β = 2.232, $P < 0.1$; respectively). After controlling for parental monitoring and school connectedness, the influence of single-parent and reconstituted families on adolescent depression became non-significant, suggesting significant mediation effects of parental monitoring and school connectedness.

Discussion

The healthy growth of adolescents is of strategic significance for one country, and family structure plays a very important role. This study found that Chinese adolescents in non-intact families tended to report more deviant behaviors and depression, which was mediated by parental monitoring and school connectedness. Furthermore, urban and female adolescents in non-intact families showed more deviant behaviors and depression, respectively, whereas adolescents in reconstituted families showed more deviant behaviors than those in single-parent families.

Chinese adolescents in non-intact families were found to report more deviant behaviors and depression, and parental monitoring and school connectedness were two significant pathways, which is consistent with most previous evidence.[6,16,30] Furthermore, there are a few notable findings. First, the mediations of parental monitoring and school connectedness are slightly different. For adolescent deviant behavior, the mediations of parental monitoring and school connectedness are similar, whereas the mediation of parental monitoring on adolescent depression is much smaller than school connectedness. This finding suggests that family and school environments have similar constraint intensities for adolescent deviant behavior, but school environment exerts a stronger influence on adolescent mental health than family environment. A possible explanation is that the psychological burden of Chinese adolescents mainly comes from academic stress and social connections at school.[50]

Second, sex and urban-rural heterogeneities were observed in this study. Urban adolescents in non-intact families showed more deviant behaviors than their rural counterparts, whereas girls in non-intact families showed more depression than their male counterparts, which are basically consistent with the results in previous research.[20,25,39] Rural adolescents have stronger psychological resilience and more psychological maturity than their urban counterparts, which make the former show fewer deviant behaviors.[24,40] Faced with family breakdown and reconstitution, girls have more disadvantages in psychological development, with high psychological susceptibility and more social stress,[20,25,38,39] which makes them show more psychological problems.

Finally, the effect sizes of single-parent and reconstituted families on adolescent depression were similar, but the negative effect of reconstituted family on adolescent deviant behavior was larger than that of single-parent family. After the breakdown of family structure, it is hard for most adolescents to quickly accept a 'stranger' as their stepfather or stepmother and adapt to a new parent—child relationship.[51] Thus, family reconstitution may lead to tension in parent—child relationship,[52] and involvement in aggressive deviant behavior is a means for adolescents to express their resistance, especially for boys.[53]

Accordingly, public health policies for children and adolescents should give priority to addressing the behavioral and mental health problems of adolescents living in non-intact families that result from parental divorce or other reasons. First, more attention should be paid to adolescent mental health problems, especially those caused by academic stress and isolation. Second, we need to focus on the behavioral and mental health of adolescents in single-parent and reconstituted families. Parents should increase their supervision on their children's learning and life and try to build a good parent—child relationship. A friendly campus environment needs to be created to enhance school belonging of adolescents in non-intact families, and the coordination between school and family education should be further strengthened. Finally, it is crucial to pay attention to the mental health of girls and behavioral health of urban adolescents, as well as the rebellious behavior of adolescents in reconstituted families. Both biological parents and stepparents should be encouraged to actively communicate with their children to help them grow up more healthily.

There are some limitations to this study. First, non-intact family structure can be caused by various reasons, which may bring about distinct influences on adolescent healthy growth. However, we did not consider and distinguish them. Second, we can hardly establish a causal link between family structure and adolescent health only using cross-sectional survey data and ordinary least squares model. Third, all adolescents were recruited from high schools, and the sample size was smaller. Finally, as all the questionnaires were filled by adolescent samples, there might be some biases in the measurement of variables, such as deviant behavior and parental monitoring. Therefore, further studies are needed to elucidate the mechanisms of family structure on adolescent health using nationally representative longitudinal data.

Author statements

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Ethical approval

The study procedure was approved by the Ethics Committee of Wuhan University, and written informed consents were obtained from both adolescents and their parents.

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Competing interests

The authors declare that they have no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.013.

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Original Research

Let's Move with Leon. A randomised controlled trial of a UK digital intervention to improve physical activity in people with a musculoskeletal condition

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ABSTRACT

Objective: This article presents a real-world evaluation of a digital intervention, 'Let's Move with Leon', designed to improve physical activity and health-related quality of life (HRQoL) in people with a musculoskeletal condition.
Study design: A pragmatic randomised controlled trial.
Methods: After randomisation and withdrawals were removed, 184 participants were assigned to receive the digital intervention with 185 assigned to a control group. Self-reported physical activity was the primary outcome. Health-related quality of life, the number of days completing strength-based exercises per week, the capability, opportunity, and motivation to be active, and step count were secondary outcomes. Outcomes were assessed over 4, 8 and 13 weeks.
Results: Significant improvements were seen for self-reported physical activity at 13 weeks, reported strength days at 8 weeks, perceptions of physical capability and automatic motivation to be active at 4 and 8 weeks. No improvements were seen in step count or HRQoL over the control group.
Conclusion: Digital interventions such as 'Let's Move with Leon' have the potential to increase physical activity in people with a musculoskeletal condition; however, improvements are likely to be small. Small improvements in physical activity may not be enough to improve HRQoL.

Introduction

Physical activity has many benefits for people with a musculoskeletal condition, such as pain reduction, improved physical function and mental well-being, and protection against other long-term conditions such as heart disease and diabetes.[1–6] It is estimated that 18.8 million people in the UK have a musculoskeletal condition, many are not active to the required levels, with between 33% and 49% classified as completely inactive.[7]

Digital interventions may improve physical activity in older adults[8] but there is limited evidence in people with arthritis[9] highlighting the need for robust evaluation of such interventions. UK charity Versus Arthritis developed a digital intervention to support people with a musculoskeletal condition (Inflammatory arthritis, Osteoarthritis, chronic or long-term joint pain, Osteoporosis or weakening of the bones) to become physically active, taking an evidence-based approach. Using the COM-B model, which postulates that capability, opportunity and motivation need to align to influence behaviour, and the Behaviour Change Wheel to facilitate intervention development, a digital intervention was created.[10,11]

The digital intervention, 'Let's Move with Leon' (LMWL), is composed of 12 prerecorded YouTube exercise sessions, each lasting around 30 min in length, details of which are sent weekly over email, coupled with a 35-page Activity Tracker, which can be printed or completed digitally. The LMWL videos encourage supplementary outdoor activity. Intervention users have access to an online Activity Hub which provides introductory videos, videos on how to get started with the programme, and videos on how to get up and down from the floor safely. Users can access a frequently asked questions section, an online community, and information about the benefits of physical activity. The use of intervention functions, behaviour change techniques, and implementation approaches are reported elsewhere.[11] This article presents a real-world evaluation of LMWL assessing the intervention's

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effectiveness at improving physical activity and health-related quality of life (HRQoL).

Methods

Study design

A randomised controlled design is recognised to provide the best possible measure of effectiveness and was therefore selected for this evaluation. The evaluation was registered and an International Standard Randomised Controlled Trial Number obtained.[12] The evaluation was conducted and is reported in accordance with the Consolidated Standards of Reporting Trials.[13]

Recruitment and randomisation

Adult participants (aged 18 years and older) with a musculoskeletal condition, who could read English, provide consent, were computer and Internet literate with a working email account were eligible to take part. Digital consent was obtained following the British Psychological Society ethics guidance for Internet-mediated research.[14]

Participants were recruited using Facebook advertising between 1 August and 6 September 2021. Two thousand, eight hundred thirty-six participants expressed an interest in the study and were sent further participant information; 541 provided consent with 389 providing complete baseline data. Randomisation took place following the collection of baseline information. Interested participants were asked at the expression of interest stage to confirm that they had not taken part in 150 min or more physical activity that raised their breathing rate in a normal week, and that they had not participated in a Versus Arthritis physical activity programme within the last 12 months.

Participants were randomised by the principal investigator using simple randomisation to receive the LMWL intervention, or a survey to collect data on the outcome measures; 195 participants were assigned to the intervention group, and 194 to the control. Twenty participants withdrew from the study and had their data removed; 9 in the control (6 due to ill health and 3 due to joint replacement operations); 11 in the intervention group (7 due to ill health, 2 due to joint replacement operation, 1 due to digital literacy and 1 no longer interested in taking part) resulting in 184 in the intervention group and 185 in the control group. Participant information was collected on date of birth, gender, ethnicity, musculoskeletal condition and time since diagnosis to assess baseline characteristics between groups.

Data collection and outcome measures

The evaluation assessed the following outcomes:

1. Physical activity using the Active Lives Short Measure
2. The number of days completing strength-based exercises per week using the Active Lives Short Measure
3. HRQoL measured using the EQ5D-5L
4. Participant's *capability, opportunity* and *motivation* (components of the COM-B model) to be physically active assessed using a 6-item questionnaire based on the work of Keyworth et al.[15]
5. Step count was assessed by participants' smartphones (if they had one) using the 'Pedometer α – Step Counter' app
6. Usage data were collected for the intervention components (email, video, activity tracker, and the social networking options).

Self-reported physical activity was the primary outcome. The study was powered to see a 10% increase in minutes of physical activity over 13 weeks from baseline measures. All measures were collected over email using Qualtrics™; reminders were sent by email and text message. Participants were asked to report any adverse consequences from study involvement to the principal investigator; no adverse consequences were reported.

Data analysis

Data were analysed using intention-to-treat analysis with multiple imputation used for missing data. The exception was for step count where per-protocol analysis was performed. Data were analysed at weeks 4, 8 and 13 weeks in the intervention and control groups, and 6 months post-intervention in the intervention group only to assess maintenance of any changes. Usage data were analysed descriptively, coupled with regression analysis to identify those more likely to use the intervention videos from baseline measures of age, gender, ethnicity, physical activity and strength days, HRQoL and COM-B component scores.

The t-test was used to assess between-group and within-group differences for improvements (or not) from baseline to weeks 4, 8, and 13 for all outcome measures. A ceiling of 840 min per week (14 h or 2 h per day) was placed on the levels of self-reported physical activity. Usage of the LMWL video component was correlated against the improvements in all outcome measures over 13 weeks but excluding step-count data as this constituted a more limited data set.

Let's Move with Leon was developed using the COM-B model, assuming that the COM-B model could predict physical activity behaviour. Therefore, physical activity was correlated against capability, opportunity and motivation to be active at the end of the intervention period of 13 weeks in the intervention group, assessing the link between theory and behaviour.

Results

The flow of participants through this study is presented in Fig. 1. The baseline characteristics of the participants are presented in Table 1. The baseline characteristics were broadly similar across groups. Despite asking participants to confirm that they did not complete 150 min of moderate-intensity activity (or more) in a normal week, 35 participants were classified as active at baseline, 17 in the intervention group and 18 in the control group. These participants were not excluded from the study and are included in the analysis.

Participants were not representative of the UK population of people with a musculoskeletal condition being significantly over representative of females (96.5% compared to 55.9%), white people (97.8% compared to 91.7%), with a slightly younger profile (63.1% aged between 35 and 64 years and 35.5% aged 65 years and older compared to 49.6% and 34.1%, respectively) and a greater number classified as inactivity (68.6% compared to 49%).[7] It is postulated that the characteristics of participants (predominantly female and white) reflect the audience likely to engage with the charity through Facebook marketing.

Outcomes

The outcome measures are presented in Table 2.

Significant improvements were seen in self-reported moderate to intense physical activity between groups at 13 weeks and in the number of strength days performed each week at 8 weeks. However, the objective measure of weekly steps did not show any significant difference. The intervention group reported significant improvements over the control in the behavioural components of physical capability and automatic motivation at 4 and 8 weeks but not at 13 weeks.

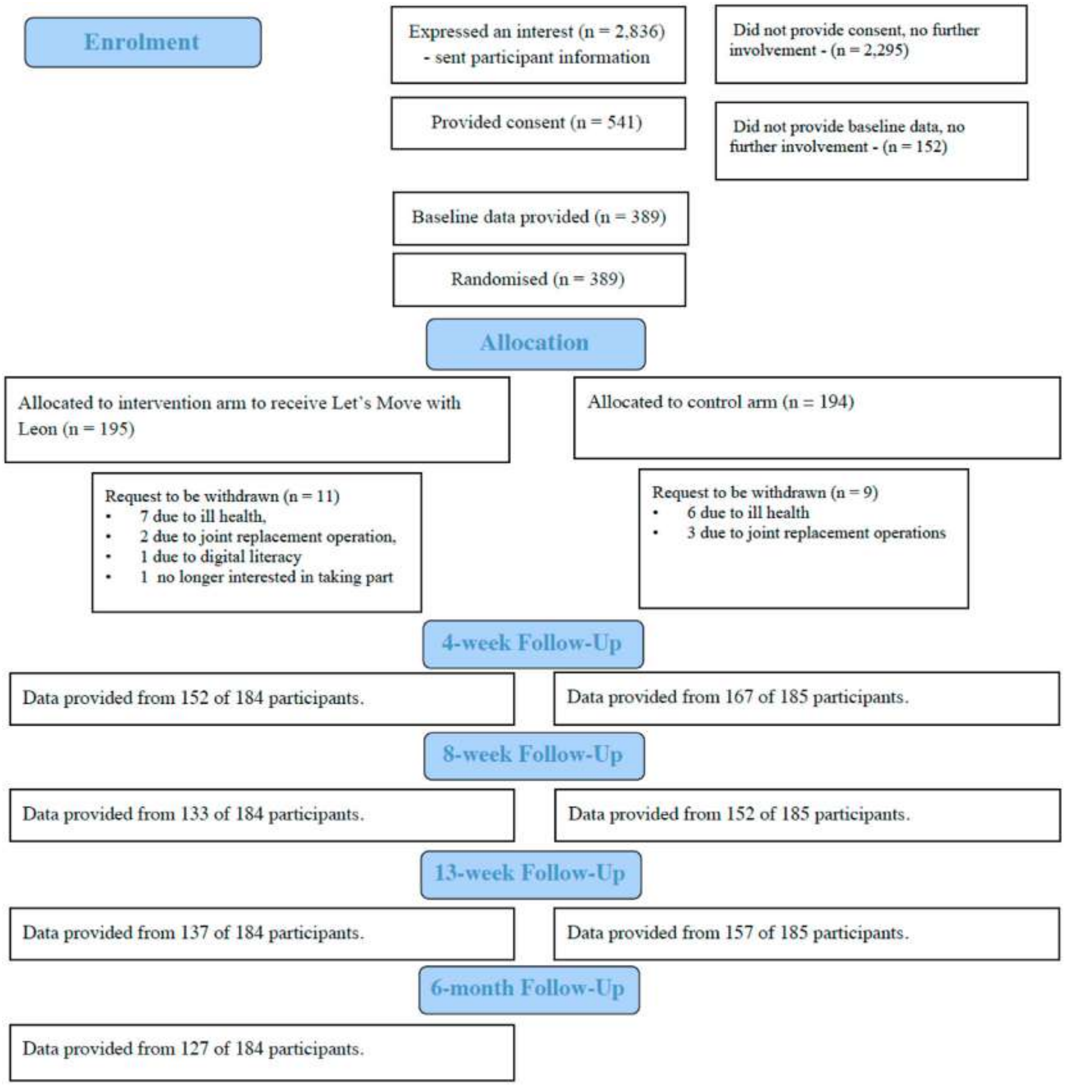

Fig. 1. Flow of participants through the evaluation.

Within-group analysis of the before and after data shows significant improvements at all time points from baseline measures and also at 6-month follow-up in the intervention group for self-reported physical activity minutes, strength days per week, HRQoL, and the behavioural components of reflective and automatic motivation, and physical capability (not at 6-months). The control group reported significant improvements in self-reported physical activity minutes, and HRQoL at weeks 4, 8 and 13, and at weeks 4 and 13 for strength days per week.

Table 3 outlines the use of the LMWL components at weeks 1, 4, 8 and 13.

Intervention use

The usage data suggest that only 70.11% of participants engaged with the intervention in week 1 of the study, with only 45.11% watching the first video. Even fewer used the activity tracker (14.13%) and the social networking opportunities (10.87%). The number of people engaging with the intervention decreased over time. Usage of the LMWL video over the 13 weeks showed a weak yet significant correlation with the 13-week improvement in strength days ($r^2 = 0.186$, $P < 0.05$). No other correlations were found.

Regression analysis suggested that those who were older (OR: 0.09, 95% CI 0.02–0.16, $P = 0.01$) and with a higher *automatic motivation* score at baseline (OR: 0.39, 95% CI 0.06–0.71, $P = 0.02$) were more likely to make use of the videos; no other relationships were found.

Relationship between COM-B component and physical activity behaviour

The correlations between COM-B component and self-reported physical activity are presented in Table 4.

Discussion

Robustly developed evidence-based interventions for changing physical activity only, rather than multiple lifestyle behaviours, with a focus on integration into everyday life have been shown to be effective.[16] This trial found that LMWL improved self-reported physical activity over 13 weeks. However, whilst a positive trend is seen in objectively measured step count, no significant difference is observed. A 2018 systematic review from Griffiths et al.[9] of the effect of interactive digital interventions on physical activity in people with inflammatory arthritis supports

Table 1
Participant characteristics.

	Intervention	%	Control	%	Total	%
Gender						
Male	7	3.80	4	2.16	11	2.98
Female	176	95.65	180	97.30	356	96.48
Non-Binary	0	0.00	1	0.54	1	0.27
Prefer not to say	1	0.54	0	0.00	1	0.27
Age	184		185			
<20	0	0.00	0	0.00	0	0
20–34	3	1.63	2	1.08	5	1.36
35–44	8	4.35	10	5.41	18	4.88
45–54	35	19.02	31	16.76	66	17.89
55–64	75	40.76	74	40.00	149	40.38
65–74	50	27.17	61	32.97	111	30.08
75–84	12	6.52	6	3.24	18	4.88
85+	1	0.54	1	0.54	2	0.54
Mean	60.57		61.26		60.91	
Ethnicity						
White	180	97.83	181	97.84	361	97.83
All other ethnicities	4	2.17	4	2.16	8	2.17
Time since diagnosis						
No diagnosis	12	6.52	8	4.32	20	5.42
Less than 4 weeks ago	3	1.63	0	0.00	3	0.81
4 weeks up to 1 year	12	6.52	17	9.19	29	7.86
1 year to 5 years	63	34.24	52	28.11	115	31.17
More than 5 years	90	48.91	107	57.84	197	53.39
Other	4	2.17	1	0.54	5	1.36
Condition						
Inflammatory arthritis or autoimmune disease	65	35.33	65	35.14	130	35.23
Osteoarthritis	125	67.93	124	67.03	249	67.48
Chronic or long-term/ongoing joint pain	116	63.04	107	57.84	223	60.43
Osteoporosis/thinning/weakening of the bones	17	9.24	11	5.95	28	7.59
Another form of joint pain	33	17.93	44	23.78	77	20.87
Data not provided	1	0.54	0	0.00	1	0.27
Multiple conditions (included within the above numbers)	122	66.30	119	64.32	241	65.31
Physical activity						
Inactive	134	72.83	119	64.32	253	68.56
Moderately active	33	17.93	48	25.95	81	21.95
Active	17	9.24	18	9.73	35	9.49
Mean mins of moderate/vigorous intensity activity (over 7 days)	44.18		55.82			
Mean strength days (over 7 days)	1.15		1.28			
Mean step count (7 days)	29756.98		27755.01			
Health-related quality of life[a]						
Mean health utility score	0.52		0.53			
Physical activity behavioural components[b]						
Capability (physical)	5.48		5.76			
Capability (psychology)	8.27		8.35			
Opportunity (physical)	7.05		7.19			
Opportunity (social)	6.48		6.30			
Motivation (reflective)	5.14		5.46			
Motivation (automatic)	4.76		5.10			

[a] Scale − 0.594 to 1.
[b] Scale 1− 10.

this, reporting no significant difference in objectively measured physical activity, but improvement in self-reported physical activity. It is noted that use of smartphone data to track steps, as in our trial, can have high variability[17] and therefore comparison to other objective measures should be interpreted with caution. All studies included in the review by Griffiths et al.[9] had a sample size of less than 160 total participants, smaller than this evaluation. Three hundred sixty-nine participants are included in this evaluation, of which 171 provided step-count data at 13 weeks (91 in the control group and 80 in the intervention group); it could be that the sample size of 171 was not large enough to pick up small changes in this outcome.

The number of days completing strength-based exercises increased significantly over 8 weeks. Interestingly, strength days continued to increase within the intervention group at 6 months, whereas self-reported physical activity declined. The 6-month follow-up fell within the winter months which may explain this. Other digital interventions are identified in the extant literature that include a strength component to their programme; however, the frequency of days performing strength-based exercises are not reported so it is not possible to draw comparison.[18–25] LMWL did not improve HRQoL, a finding supported in the wider literature.[9,26] As explained by Griffiths et al.,[9] HRQoL is multifaceted, and improving physical activity in isolation may not be enough to influence this outcome.

Berry et al.[16] identify that intervention usage is poorly reported in the extant literature. This research reviewed usage of the LMWL components; 72.3% of participants made use of at least one LMWL video, 27.2% used 8 videos or more, much lower than that reported for other digital behaviour change interventions.[16,27] The rate of intervention use declined over time, as is common.[16] It is a concern that 27.7% of participants did not make use of any videos. This suggests that the LMWL intervention does not meet the needs of many; a process evaluation is required to better understand this.

Table 2
Change in outcome measures.

Outcome and period	Intervention	Control	Difference (95% CI)
Change in physical activity minutes per week			
Baseline to week 4	68.79***	42.02**	26.77 (−8.06 to 61.60)
Baseline to week 8	64.93***	38.89**	26.04 (−5.60 to 57.68)
Baseline to week 13	69.78***	29.98**	39.80 (7.02–72.59)+
Baseline to 6 months	53.75**		
Change in strength days per week			
Baseline to week 4	0.69***	0.40**	0.29 (−0.12 to 0.71)
Baseline to week 8	0.75***	0.24	0.51 (0.10–0.91)+
Baseline to week 13	0.61***	0.33*	0.28 (−0.16 to 0.72)
Baseline to 6 months	0.91***		
Change in HRQoL (health-utility score − point-specific measure − scale −0.59 to 1)			
Baseline to week 4	0.07***	0.04**	0.03 (0.00–0.07)
Baseline to week 8	0.08***	0.05***	0.03 (−0.01 to 0.07)
Baseline to week 13	0.06***	0.05***	0.01 (−0.02 to 0.05)
Baseline to 6 months	0.05***		
Change in physical capability (scale 1–10)			
Baseline to week 4	0.46**	−0.02	0.48 (0.02–0.95)+
Baseline to week 8	0.54**	−0.02	0.56 (0.04–1.08)+
Baseline to week 13	0.47*	0.17	0.3 (−0.23 to 0.82)
Baseline to 6 months	0.22		
Change in psychological capability (scale 1–10)			
Baseline to week 4	−0.21	−0.31*	−0.1 (−0.30 to 0.52)
Baseline to week 8	−0.22	−0.26	−0.04 (−0.36 to 0.46)
Baseline to week 13	−0.35*	−0.48**	−0.13 (−0.29 to 0.54)
Baseline to 6 months	−0.40		
Change in physical opportunity (scale 1–10)			
Baseline to week 4	−0.10	−0.29	−0.19 (−0.34 to 0.72)
Baseline to week 8	−0.18	−0.18	0.00 (−0.54 to 0.54)
Baseline to week 13	−0.20	−0.17	0.03 (−0.59 to 0.53)
Baseline to 6 months	−0.17		
Change in social opportunity (scale 1–10)			
Baseline to week 4	0.21	0.22	−0.01 (−0.54 to 0.54)
Baseline to week 8	0.17	0.31	−0.14 (−0.68 to 0.41)
Baseline to week 13	0.00	0.28	−0.28 (−0.84 to 0.27)
Baseline to 6 months	0.11		
Change in reflective motivation (scale 1–10)			
Baseline to week 4	0.63***	0.44*	0.19 (−0.34 to 0.73)
Baseline to week 8	0.68***	0.43*	0.25 (−0.29 to 0.79)
Baseline to week 13	0.45*	0.34	0.11 (−0.47 to 0.69)
Baseline to 6 months	0.68**		
Change in automatic motivation (scale 1–10)			
Baseline to week 4	0.42*	−0.21	0.63 (0.08–1.18)+
Baseline to week 8	0.59**	−0.11	0.70 (0.18–1.22)++
Baseline to week 13	0.52**	0.06	0.46 (−0.09 to 1.02)
Baseline to 6 months	0.44*		
Change in weekly step count[a]			
Week 4	2931.75*	3537.98	−606.23 (−5048.45 to 3836.00)
Week 8	1251.34	3323.43*	−2072 (−6931.34 to 2787.33)
Week 13	3908.91	2782.42	1126 (−4098.88 to 6531.87)

Within group: *P = <0.05; **P = <0.01; ***P = <0.001.
Between group: +P = <0.05; ++P = <0.01.
[a] Missing data were imputed for all outcomes with the exception of weekly step count which was assessed on a per-protocol basis where matched pairs were available.

Those who did not engage with the first exercise video were more likely to disengage with the programme highlighting the need for early engagement. Data collected in this trial suggest that older people and those more motivated are more likely to have higher intervention engagement, this warrants consideration by digital behaviour change intervention designers.

The relationship between use and outcomes is inconclusive;[28,29] however, greater usage *may* result in small improvements in physical activity, particularly in regard to strength. It is possible that a sense of commitment to a physical activity programme, with the regular monitoring of outcomes, could be enough to facilitate behaviour change regardless of levels of engagement in the programme itself.[30]

The Behaviour Change Wheel has been used previously to develop a digital intervention to improve physical activity in people with diabetes;[31] however, it is believed that the use of this approach in the development of LMWL is the first in people with musculoskeletal conditions. Therefore, it is difficult to draw comparison to the wider literature on the specific behavioural components of the COM-B model which sits at the centre of the Behaviour Change Wheel.

LMWL significantly improved perceived physical capability at 8 weeks over a controlled comparison; improvements in physical function from physical activity in people with a musculoskeletal condition are widely reported.[2] The baseline measures for the psychological capability domain were the highest across all of the COM-B components, with scores of 8.27 and 8.35 in the intervention and control groups, respectively. It is argued that these high scores suggest that participants attracted to this research had good knowledge on the benefits of being active, therefore,

Table 3
Intervention usage over 13 weeks.

		Yes	No	Blank	% Of total participants[a]	
					Yes	No/blank
Week 1	Opened email	129	13	42	70.11%	29.89%
	Watched video	83	46	55	45.11%	54.89%
	Used tracker	26	102	56	14.13%	85.87%
	Accessed social network site	20	121	43	10.87%	89.13%
Week 4	Opened email	105	32	47	57.07%	42.93%
	Watched video	83	22	79	45.11%	54.89%
	Used tracker	24	76	84	13.04%	86.96%
	Accessed social network site	14	120	50	7.61%	92.39%
Week 8	Opened email	76	35	73	41.30%	58.70%
	Watched video	54	22	108	29.35%	70.65%
	Used tracker	8	65	111	4.35%	95.65%
	Accessed social network site	5	106	73	2.72%	97.28%
Week 13	Opened email	85	48	51	46.20%	53.80%
	Watched video	54	31	99	29.35%	70.65%
	Used tracker	5	77	102	2.72%	97.28%
	Accessed social network site	13	119	52	7.07%	92.93%

[a] It was assumed that if the question was not answered then the participants did not use the intervention component.

Table 4
Correlation of the COM-B components to physical activity minutes in the intervention group.

End of intervention – week 13	R value
Capability – physical	0.25***
Capability – psychological	0.16***
Opportunity – physical	0.13**
Opportunity – social	0.16***
Motivation – reflective	0.27***
Motivation – automatic	0.42***

**P = <0.01; ***P = <0.001.

improvements in this area were less likely to occur. However, a decrease in this behavioural component in both intervention and control groups was unexpected. This domain includes sufficient knowledge, memory, attention, decision-making skills and the mental stamina to be active. It is possible that the repeated data collection processes, which took between 8 and 10 min to complete, could have created some mental fatigue and impacted the mental stamina of participants over time. Furthermore, the timing of the study may have played a part. Participants started the programme at the end of the summer months, finishing during winter. As the LMWL videos encouraged supplementary outdoor activity, poor weather could have impacted on the mental stamina to take part in physical activity outside and in general.[32] This too could explain the slight negative movement of the physical opportunity scores in the intervention and control groups.

The social opportunity domain includes the support from friends and family. This behavioural domain remained relatively stable across both the intervention and control groups, with no significant changes. This finding is supported by the previous analysis of secondary data.[11] A challenge of digital interventions is to create the social interaction that participants would experience in a face-to-face setting; the lack of use of online forums and social media in such digital interventions is supported by Webb et al.[33]

The physical opportunity domain includes having the time and sufficient resources to be active. As with the social opportunity domain, no significant changes were reported. Scores for physical opportunity could be considered high at baseline, with scores of 7.05 and 7.19 out of 10 for the intervention and control groups, respectively, and therefore less amenable to change.

Baseline scores for the behavioural components of reflective (5.14 intervention and 5.46 control) and automatic motivation (4.76 intervention and 5.10 control) were the lowest when compared to the other behavioural components. The intervention group reported significant within-group improvements in reflective motivation, with the improvement maintained at 6 months. However, the control group also showed a significant within-group improvement at 4 and 8 weeks. No significant differences were reported between groups. This suggests that simply monitoring physical activity may be enough to increase the desire to be physically active, at least in the short-term.[34] Similarly, a propensity for making exercise a habit was evidenced by improved automatic motivation, being active without having to be reminded or having to think about it, in the intervention group when compared to the control group at 4 and 8 weeks.

The COM-B component of automatic motivation had a significant moderate correlation to physical activity at 13 weeks in the intervention group; all other COM-B components had a significant yet weak correlation. Research into the predictive validity of the COM-B model for physical activity suggests that the motivation component is the most important directly explaining 49% of the variance.[35] Howlett et al.[35] argue that the COM-B model performs well against other commonly used theories to explain physical activity. Our trial suggests that the usefulness of the COM-B model as a basis for intervention design in regard to physical activity remains unclear.

Implications for practice and future research

To the knowledge of the authors, this is the first pragmatic trial investigating the impact of a digital intervention on the components of physical activity behaviour using the COM-B model. Physical activity interventions based on the COM-B model should be robustly evaluated to add to the limited evidence on its use and usefulness. Standard measures should be used to collect data on the COM-B components to allow for comparison across intervention studies.[15]

Digital behaviour change interventions have the potential to increase physical activity;[8,27] however, improvements are likely to be small. Digital behaviour change interventions such as LMWL are likely to attract those that are inactive, ready to make a change, who have a knowledge of why physical activity is important. Digital interventions that are tailored to the individual are suggested to be effective;[9] whilst participants set their own goals and targets in LMWL, there is no specific tailoring to the participants; a change in this area may help increase the impact of the intervention. Engagement should be monitored closely as creating a sense of commitment to a programme with regular monitoring may be enough to instigate a change regardless of intervention engagement.

Future research and practice should consider the usage, adherence and attrition of digital interventions, even when participants are self-selecting. Comparisons between digital interventions and face-to-face delivery also warrant investigation.[27] Creating a sense of commitment and the monitoring of behaviour could be useful behaviour change techniques in supporting people to become more active.

This evaluation demonstrates that smartphone accelerometers can provide a useful mechanism to collect objective step-count data. It is acknowledged that smartphones are not a research grade objective measure; however, they offer a low-cost opportunity to evaluate physical activity programmes alongside self-reported measures which are known to over-report physical activity. Furthermore, smartphone interventions have shown promise in improving physical activity;[36] this offers an additional opportunity for future digital intervention development.

Strength and limitations

The sample size in this evaluation is larger than other identified digital intervention trials.[18–25] However, the sample is not representative of the wider population of people with musculoskeletal conditions in the UK; therefore, caution is advised when generalising the findings. A further limitation is that follow-up in this evaluation was only for 6 months. Ideally, behaviour change interventions should be followed up for at least a year.[37]

This study had one primary outcome, that of self-reported physical activity. It could be argued that with multiple analyses of secondary outcomes that a study-wide correction was necessary. We have taken the view of Perneger[38] 'describing what was done and why, and discussing the possible interpretations of each result, to enable the reader to reach a reasonable conclusion.' (p. 1237).

This trial demonstrates that it is possible to use smartphone accelerometers as a tool to support data collection in regard to physical activity, albeit step count only. It is acknowledged that not all will possess a smartphone, or know how to monitor steps; however, we contend that this offers an alternative to self-reported physical activity. As we have shown, the choice of activity measure can have important consequences for the outcome of physical activity trials.

In summary

Digital interventions such as LMWL have the potential to increase physical activity in people with a musculoskeletal condition who are aware of the benefits of being active. However, improvements in physical activity are likely to be small and intervention usage sporadic. Small improvements in physical activity on their own are likely to be insufficient to deliver sustainable improvements to broader quality of life.

Author statements

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Ethical approval

A favourable ethical opinion was received from the London Metropolitan University School of Social Sciences and Professions Ethics committee in February 2021.

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Competing interests

There are no competing interests to declare.

Author contributions

JW was the principal investigator for this trial. The trial was designed by JW and DS. The data were collected by JW. The data analysis was completed by JW and DS. The manuscript was drafted by JW with DS providing final approval.

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Themed Paper – Original Research

Lower breast cancer survival among Black women in Brazil: a population-based retrospective study

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ABSTRACT

Objectives: To analyze the rates of breast cancer survival among Black and White women according to age and stage at diagnosis.
Study design: A retrospective cohort study.
Methods: The study examined women registered in the population-based cancer registry of Campinas in 2010–2014. The primary variable was the declared race (White or Black). Other races were excluded. Data were linked with the Mortality Information System, and missing information was accessed by active search. Overall survival (OS) was calculated by the Kaplan-Meier method, comparisons were done by chi-squared tests, and hazard ratios were examined by Cox regression.
Results: The total numbers of new cases of staged breast cancer among Black and White women were 218 and 1522 cases, respectively. The rates of stages III/IV were 35.5% among White women and 43.1% among Black women ($P = 0.024$). The frequencies among White and Black women under 40 years old were 8.0% and 12.4% ($P = 0.031$), 19.6% and 26.6% ($P = 0.016$) for ages of 40–49 years, and 23.8% and 17.4% ($P = 0.037$) for ages of 60–69 years, respectively. The mean OS was 7.5 years (7.0; 8.0) among Black women and 8.4 years (8.2; 8.5) among White women. The 5-year OS was 72.3% among Black women and 80.5% among White women ($P = 0.001$). Black women had an age-adjusted risk of death that was 1.7 times higher (1.33; 2.20). The risk was 6.4 times higher for diagnoses in stage 0 (1.65; 24.90) and 1.5 times for diagnoses in stage IV (1.04; 2.17).
Conclusion: The 5-year OS for women with breast cancer was significantly lower among Black women than White women. Black women were more frequently diagnosed in stages III/IV, and their age-adjusted risk of death was 1.7 times higher. Differences in access to care may explain these differences.

Introduction

Breast cancer is a widespread problem among women worldwide and a significant cause of mortality and morbidity. It predominantly affects women between 40 and 69 years old and is the second leading cause of death by cancer among women.[1] Some predictive factors are age, stage, and size of the tumor at diagnosis, as well as socio-economic status, therapeutic management, and delays in treatment. The role of ethnicity and race is not yet evident or accepted.

Disparities related to ethnicity in breast cancer have been addressed in epidemiological research.[2,3] The incidence among Black women is slightly reduced compared to White women, yet some studies have shown that mortality rates among Black women are higher.[2,4] A recent study in Brazil demonstrated increasing mortality rates among Black women and decreasing rates among White women.[5] Black women present more regional and distant stage diseases and less localized breast cancers.[6] Lower survival rates by stage are also reported.[2,3]

In Brazil, Black women and multiracial women with Black with White represent 55% of the population.[7] This population is the most economically disadvantaged and faces structural racism. They have a lower life expectancy, and mortality rates due to breast cancer

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have increased.[8,9] It is interesting to examine how this can interfere with access to care and its quality.

Disparities in survival among Black women and White women are related to late diagnosis, tumor characteristics, comorbidities, access, delays, adherence, and treatment response. The main objective of this study was to verify and compare breast cancer survival rates between Black women and White women according to age and stage at diagnosis. This population-based cohort study was performed in Campinas in São Paulo State, Brazil, which is an urban middle-income region.

Methods

This population-based retrospective cohort study examined women diagnosed with breast cancer from 2010 to 2014 in Campinas, São Paulo, Brazil. It was conducted using data available in the population-based cancer registry (PBCR) of Campinas, and the primary variable for analysis was the declared race of the women. Campinas is a city of around 1.2 million inhabitants and is 100 km away from the city of São Paulo in the southeast region of Brazil. The human development index of the city is 0.805, which is over the national average. Health care is free of charge to all citizens through the Brazilian public health system. However, half of the Campinas population also uses private insurance financed by the user or employer.

The PBCR is managed by the Surveillance Sector of the Municipal Health Secretary (MHS), which collects information on all cancers diagnosed in the city, whether from the public or the private care system. The PBCR collects information such as cancer site, morphology, age, stage, and vital status. There is a link with the Mortality Information System (MIS) of the MHS, and this database was re-checked manually by the research team. For cases with missing information on death or stage, the research team actively searched the hospital-based cancer registries and records of the city's leading public and private clinics. Cases were censored at the last follow-up visit. Cases without vital status or with missing information on the last follow-up visit were considered alive until March 31, 2020. MIS is updated periodically from the surrounding cities and by the state's MIS. It is very unlikely that a woman's death from this sample would not be registered on MIS.

The stage at diagnosis was recorded according to the criteria of the American Joint Committee on Cancer as stages 0 to IV. Race in the PBCR is recorded according to the most accurate registry accessed with aims of consistency of the data, including the pathology result, clinical or hospital service records, and death certificates. The self-declared race is the predominant way to register race in the health sector.

The database examined was primarily composed of 2715 patients, of which 2276 (83.8%) declared a race. The analysis involved White women and Black women. In this study, 'Black women' refers to both Black women and multiracial women of both African and European descent. Women of other races (1.6%) were excluded. Of the remaining 2239 cases, stage was not indicated in 499 cases, which were also excluded, leading to a total sample of 1740 women.

Using the Kaplan-Meier method, overall survival was calculated from the diagnosis dates (histopathologic result) until death, censorship, or the end of the study. The method was also used to measure survival according to race and stage at diagnosis. Chi-squared tests were applied to compare categorical variables between Black women and White women. Cox regression models were used to calculate hazard ratios (HRs) and 95% confidence intervals (95% CIs). These models were used to characterize the relationship between race and risk of death amongst women according to age and stage at diagnosis, as well as to account for disparities in follow-up/survival time. The computer program SAS for Windows version 9.2 was used for statistical analysis (SAS Institute Inc, 2002–2008, Cary, NC, USA).

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Results

From 2010 to 2014, in the city of Campinas, the total numbers of new staged cases of breast cancer among Black women and White women were 218 and 1522 cases, respectively. Table 1 shows comparisons between races and stage groups. There were significantly more cases diagnosed in stages III and IV among Black women than among White women (35.5% among White and 43.1% among Black women, $P = 0.024$). Table 1 also compares the proportion of new cases according to age group and race. The results showed a significantly higher frequency of breast cancers among Black women than among White women under 40 years of age (12.4% vs. 8.0%, $P = 0.031$) and from 40 to 49 years of age (26.6% vs. 19.6%, $P = 0.016$). The frequency of breast cancer was lower among Black women aged 60–69 years (17.4% and 23.8%, $P = 0.037$).

The mean overall survival was 7.5 years (7.0; 8.0) among Black women and 8.4 years (8.2; 8.5) among White women. Table 2 and Fig. 1 show the Kaplan–Meier results according to stage group and race. The five-year overall survival was 72.3% among Black women and 80.5% among White women ($P = 0.001$). There was no significant difference in survival between races according to the group of stages.

Table 3 presents the age-adjusted risk of death by stage. Compared to White women, Black women had a 1.7 times higher risk of death than White women (95% CI 1.33–2.20). The risk according to stage was 6.4 times as high for diagnoses in stage 0 (1.65–24.90) and 1.5 times as high for diagnoses in stage IV (1.04–2.17).

Discussion

This study showed that in Campinas, Brazil, the 5-year overall survival was lower among Black women and that the age-adjusted risk of death was 1.7 times higher compared to White women. Race disparities in mortality and survival have already been reported in

Table 1
Distribution of breast cancers according to stage group, age group, and race in Campinas, Brazil, from 2010 to 2014.

	Black		White		*P*-value
	n	%	*N*	%	
Stage					
0 *(in situ)*	21	9.6	196	12.9	0.175
I + II	103	47.3	789	51.8	0.205
III + IV	94	43.1	537	35.3	0.024
Overall	218	100.0	1522	100.0	
Age group					
Under 40	27	12.4	122	8.0	0.031
40 to 49	58	26.6	298	19.6	0.016
50 to 59	61	28.0	410	26.9	0.746
60 to 69	38	17.4	362	23.8	0.037
70 to 79	25	11.5	235	15.4	0.124
Over 79	9	4.1	95	6.3	0.218
Overall	218	100.0	1522	100.0	

P-value: chi-squared test.

Table 2
Two- and five-year overall survival of patients with breast cancer according to stage group and race in Campinas, Brazil, from 2010 to 2014.

Stage	Overall survival % (standard error %)				*P*-value
	White		Black		
	2-year	5-year	2-year	5-year	
0 (*in situ*)	99.0 (0.7)	96.9 (1.3)	95.2 (4.6)	84.7 (8.2)	0.082
I + II	97.1 (0.6)	91.6 (1.0)	96.1 (1.9)	90.2 (2.9)	0.272
III + IV	77.0 (1.8)	58.1 (2.1)	69.1 (4.8)	50.0 (5.2)	0.057
Overall	90.3 (0.8)	80.5 (1.0)	84.4 (2.5)	72.3 (3.0)	**0.001**

P-value: log-rank test.

Table 3
Age-adjusted risk of death among Black women with breast cancer by stage compared to White women in Campinas, Brazil, from 2010 to 2014.

	P-value	HR_a	95% CI
Stage 0	0.007	6.40	**1.65–24.90**
Stage I	0.948	1.03	0.37–2.89
Stage II	0.049	1.88	**1.01–3.54**
Stage III	0.073	1.57	0.96–2.58
Stage IV	0.031	1.50	**1.04–2.17**
All stages	<0.001	1.71	**1.33–2.20**

HR_a: age-adjusted hazard ratio; CI: confidence interval. Cox regression analysis.

the literature.[2,4,10–12] The lower survival observed among Black women is probably due to multiple factors, such as social, economic, biological, and even cultural factors.[13] The differences observed in late diagnoses support that access to the health system may play a crucial role.

The lower survival observed among Black women may be explained by the biological characteristics of the tumors. We do not have access to the molecular profile of tumors in the PBCR, but a biological explanation is usually the first hypothesis considered for this issue. Regarding histology and molecular subtype, Black women are more affected by more aggressive subtypes.[2,10,14–16] White women are reported to have a higher proportion of cancers with hormone receptors, implying a better prognosis due to specific hormone therapy.[2,17,18]

It is important to note that racial disparities are possible even in less aggressive subtypes. Evidence shows up to 18% higher risk of death from breast cancer in the population of Black women, regardless of molecular subtype, age at diagnosis, marital status, tumor characteristics, forms of treatment, socio-economic status, and health insurance status.[10] Black women are more likely to die due to type A and type B luminal tumors.[19]

We observed a higher proportion of breast cancer diagnoses among Black women under 50 years old. A significant proportion of triple-negative breast cancer is diagnosed in women younger than 50 years.[19] In addition, young Black women have a higher incidence of more aggressive subtypes of breast cancer than women of other ethnicities.[20] Hung et al. reported an estimated life expectancy of localized and distant stages of 32.1 and 7.4 years among young Black women and 33.1 to 10.0 years among young White women.[21] It is possible that the lower survival rate observed in this study was due to more aggressive tumors in this group.

Regarding age, the literature points out a lower mean age at diagnosis for Black women than for White women.[2,3,10]

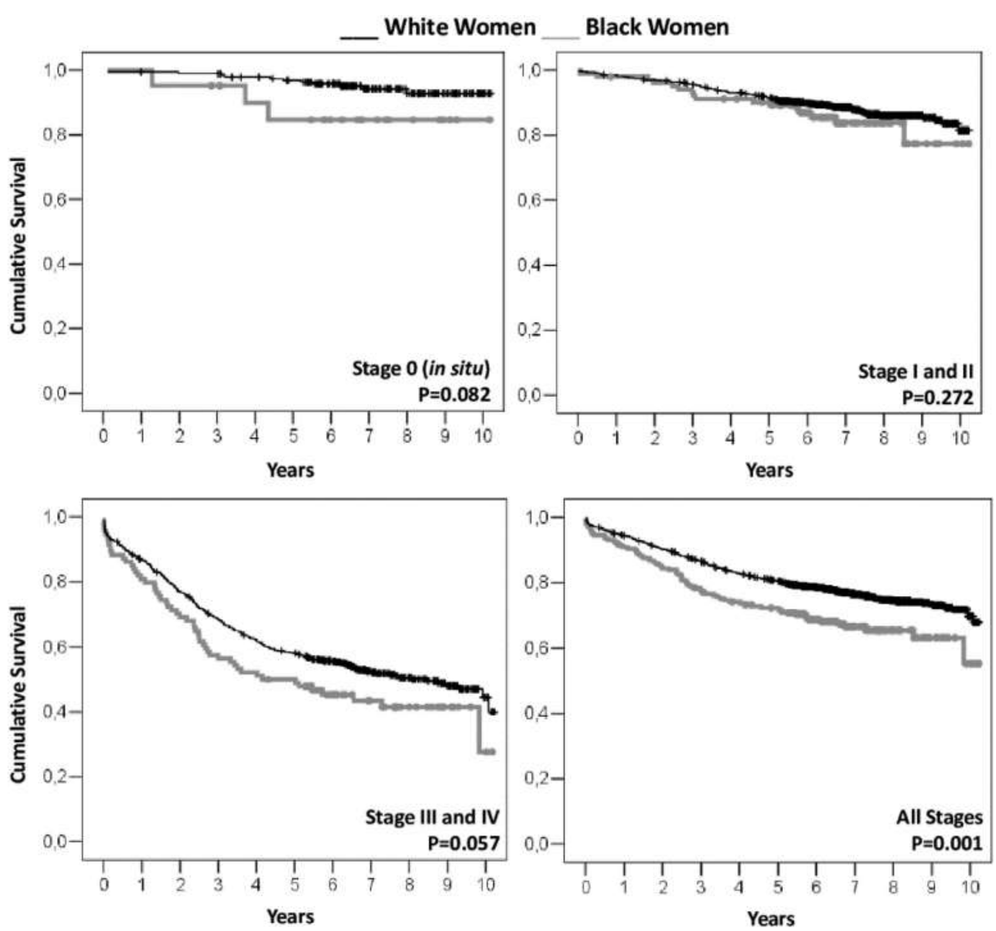

Fig. 1. Survival according to stage in breast cancer according to race in Campinas, Brazil, from 2010 to 2014. *P*-value: log-rank test.

Importantly, the increased incidence of breast cancer among young Black women could also be related to high exposure to racism, which is particularly significant among Black women under 50 years of age.[22] Compared with women who are older, White, and free of breast cancer, young Black women who are survivors of breast cancer have reported a greater fear of dying, unmet supportive-care needs, financial distress, and lower physical and functional well-being.[23]

In this study, the age-adjusted risk of death was 6.4 times higher among Black women diagnosed in stage 0 (in situ) compared to White women diagnosed at the same stage. Several factors might account for this disparity, and the most prominent ones are discrepancies in comorbidities, lifestyle, socio-economic status, and other competing risks. These could expose Black women to a more considerable risk of dying, not only from cancer but also from other causes. In the USA, for all age groups and stages, the crude risk of death due to all causes was higher among Black women than among White women.[3]

In addition, patients who suffer from racism are at increased risk for obesity, tobacco use, and binge-type alcohol abuse.[24] Rates of racism in healthcare workers are similar to those found in the general population.[25] Those who experience racism while looking for health services or even during care have a two to three times greater chance of reporting reduced trust in healthcare systems and professionals, lower satisfaction with health services, and perceived quality of care.[26] An assessment of satisfaction with healthcare and hospitalization services in Brazil showed higher dissatisfaction rates among Black women than White women, which emphasizes the possibility of structural racism delaying diagnosis.[9]

One of the findings of this study was that breast cancers among Black women were diagnosed in later stages. Such data are supported by other studies carried out in Brazil[27,28] and the USA.[10] In Brazil, breast and cervical cancer screening are opportunistic. In the absence of a call and recall system, women's participation in screening depends on their access to health services and the opportunity for screening. A study evaluating factors associated with cervical cancer screening in the same region showed a 2.2 times higher risk for Black women not being screened after adjustment for socio-economic and demographic characteristics.[29] Other studies suggest that populations with lower income, less education, and non-White race face barriers to screening.[30,31]

Some studies demonstrate Black women's difficulties in accessing screening or seeking help during early presentation. The reasons reported are low awareness of cancer symptoms and knowledge of risk factors or personal risk, lack of trust in the healthcare system, fear of conventional treatment, concerns about interactions with doctors, and lack of confidence in healthcare professionals.[32,33] Another possible explanation is that the cancers were diagnosed later because they might be more aggressive tumors.[2,10,34–36] However, it is essential to consider that survival among Black women is usually the worst regardless of stage and tumor type,[10,37] which also suggests barriers to treatment access.

In the literature, Black women have more reported delays in surgical treatment;[38] more non-protocol treatments, such as less surgical indication and less indication for sentinel biopsy and reconstructions; and more significant barriers to access or delays in adjuvant treatment and dropouts.[3,11,19,38–42] Delays in chemotherapy and hormone therapy can lead to significant differences in survival.[38,41] In Brazil, delays have been reported in populations with lower income, less education, and non-White ethnic groups.[30] In this study, Black women in advanced stages presented an even greater risk of death. The limited access to health services directly impacts the quality and adequacy of treatment received. The overall lower survival observed among Black women might be attributed to segregation according to race by association with lower income, less access to primary or secondary preventive practices that reduce comorbidities and improve screening coverage, and difficulties accessing health services. Addressing structural racism is essential for breast cancer control in this setting.

This study examined part of the largest population-based cohort published in Brazil in the last few years and has benefited from multiple data sources for its creation. It has robustness based on a large number of patients, follow-up reliability, and multiple sources used, including active search. The results reflect the reality of the most populated cities in Brazil, with different accesses and quality of care, which could guide public policies for cancer control and health management.

Given the scarcity of population-based studies in low- and middle-income countries like Brazil, the data presented are significant despite their limitations. The main limitation is that only variables available in the PBCR registry could be analyzed. Other predictive factors, such as social determinants, tumor characteristics, therapeutic management, and delays in treatment, could not be accessed due to the nature of the database. Also, most cases were considered alive at the end of the study, which is a problem inherent to population-based studies. It must be said that the death records in São Paulo State are of high quality, however, and that specific verification of vital status through individual taxpayer register records may have diminished this bias.

In this population-based retrospective cohort study, the 5-year overall survival of patients with breast cancer was 80.5% among White and 72.3% among Black women. The age-adjusted risk of death was 1.7 times higher among Black when compared to White women. The diagnosis was in stages III or IV in 43.1% of Black women and in 35.3% of White women. Differences in access to care may explain these differences.

Author statements

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Ethical approval

This study was approved by the 'Unicamp Research and Ethics Committee,' registered at 'Plataforma Brasil' under the number CAAE 89399018.2.0000.5404. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

ACM, BFM, and DBV made substantial contributions to the conception or design of the work and all other steps of the work; MCF also contributed to the acquisition and analysis; CCF to the interpretation of data. All authors drafted the work or revised it critically for important intellectual content; approved the version to be published; and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. DBV managed and supervised the study.

Data availability

The data sets generated during the present study are available from the corresponding author upon reasonable request. The Surveillance Section of the Municipal Health Department, Campinas, is the data manager and has specific restrictions to preserve confidentiality, although aggregate data may be shared upon request.

Consent to participate

Due to the study's retrospective nature, the ‘Unicamp Research and Ethics Committee’ waived the need for the consent form.

Consent to publish

Not applicable.

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Original Research

More than time: travel time to the delivery ward and maternal outcomes – onset of labour, postpartum haemorrhage and obstetric anal sphincter injury

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A R T I C L E I N F O

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Severe perineal tear

A B S T R A C T

Background: Closing delivery units increases travel time for some women. Whether increased travel time is associated with maternal outcomes is important for understanding the consequences of such closures. Previous studies are limited in measuring travel time and restricted to the outcome of caesarean section.
Methods: Our population-based cohort includes data from the Swedish Pregnancy Register for women giving birth between 2014 and 2017 ($N = 364,630$). We estimated travel time from home to the delivery ward using coordinate pairs of actual addresses. The association between travel time and onset of labour was modelled using multinomial logistic regression, and logistic regression was used for the outcomes postpartum haemorrhage (PPH) and obstetric anal sphincter injury (OASIS).
Findings: Over three-quarters of women had ≤30 min travel time (median 13.9 min). Women who travelled ≥60 min arrived to care sooner and laboured there longer. Women with further to travel had increased adjusted odds ratio (aOR) of having an elective caesarean section (31–59 min aOR 1.11; 95% confidence interval [CI] 1.07–1.16; ≥60 min aOR 1.25; 95% CI 1.16–1.36) than spontaneous onset of labour. Women (at full term with spontaneous onset) living ≥60 min away had reduced odds of having a PPH (aOR 0.84; 95% CI 0.76–0.94) or OASIS (aOR 0.79; 95% CI 0.66–0.94).
Interpretation: Longer travel time increased the odds of elective caesarean section. Women with furthest to travel arrived sooner and spent more time in care; although they had a lower risk of PPH or OASIS, they also tended to be younger, have a higher body mass index and were Nordic born.

Introduction

There has been a recent shift towards centralising delivery care to larger facilities. Between 2000 and 2019, 13 (mostly small) of 57 delivery units across Sweden were dissolved. These closures have been justified by reducing healthcare costs and a belief that patient safety increases when care is centralised to facilities with high patient volume and resources, where improved maternal and neonatal care can be provided.[1,2]

Whether the benefits of centralisation of care outweigh any harms for mothers and their children is heavily debated. Closing delivery wards increases travel time for women living in rural and remote areas,[3,4] and as such the risk of having an unplanned out-of-hospital birth,[5,6] which is associated with an increased risk of stillbirth[5] and neonatal[5] and perinatal[5–7] morbidity and mortality. From a social perspective, arriving in good time allows women peace of mind and the opportunity to receive professional support. From a medical perspective, timely arrival to the delivery ward is important for surveillance – including detecting risks and acting promptly to prevent adverse maternal and infant outcomes – while simultaneously exposing low-risk births to possibly unnecessary interventions.[4,8]

Studies investigating the association between travel time and maternal outcomes are limited in number and outcomes;[9] a systematic review summarises 15 studies with the exposure of travel distance and six studies with travel time as the exposure. Within

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this review, five studies found that greater travel times are associated with a decreased risk of emergency and increased risk of overall caesarean section; however, all are based in rural/remote areas of Canada with large travel times.[9] To our best knowledge, there are no studies investigating the association between travel time or distance and onset of labour.

The incidence of obstetric anal sphincter injuries (OASIS, defined as sustaining a grade 3 or 4 tear) in Sweden and Denmark is approximately 4%,[10] which is higher than other neighbouring Nordic countries. The strongest risk factors for OASIS are primiparity, macrosomia, having an instrumental vaginal delivery[11] and maternal age >30 years.[12] Although a number of comorbidities can result and severely hinder a woman's short- and long-term quality of life,[13] such injuries can be reduced with good care and management, such as having two midwives present during the second stage of labour.[14] To our best knowledge, there are no studies investigating the association between travel time or distance and OASIS.

As in many high-income countries, the rate of postpartum haemorrhage (PPH) has increased in Sweden, from 5.4% in 2000 to 7.3% in 2016.[15] Often preceded by chorioamnionitis, induction of labour, prolonged labour[16,17] and foetal macrosomia,[16,18] risk factors for PPH include prior history of PPH, placental disorders, uterine rupture, oxytocin use, nulliparity, multiple gestation and novel risk factors, such as hypertension, diabetes and ethnicity.[17] Other risk factors include size of the delivery unit,[2,19] advanced maternal age, multiparity and caesarean delivery.[20,21] We found one study reporting an increased risk of PPH with increased travel time.[9] Furthermore, one Canadian study, using a composite measure of maternal morbidity and mortality (including PPH), found poorer maternal outcomes with travel distances >200 km and improved outcomes in delivery units with >1000 births per year.[2]

To answer the hypothesis that longer travel times are associated with maternal and delivery outcomes, we used Swedish register data for births between 2014 and 2017. We used precise home and delivery ward addresses to estimate travel time to the delivery ward and (1) describe the association with a number of maternal and delivery characteristics and (2) investigate the association with onset of labour, postpartum haemorrhage and OASIS.

Materials and methods

Study design and participants

The Swedish Pregnancy Register (SPR) is a national quality register established in 2013, containing information for pregnancies and births in Sweden – from the first antenatal visit (approximately gestational week 9) to follow-up in postpartum care (8–12 weeks). The register has high coverage within Sweden (all births in 17 of 21 regions, comprising 92% of national births) and includes data on demographics, reproductive health and infant and maternal outcomes, including all maternal diagnoses (International Classification of Diseases - ICD-10) and procedures.[22] A large part of the data included in the SPR is also available in the Swedish Medical Birth Register, which routinely (and semi-automatically) electronically retrieves data from the National Health Registers and has been evaluated to be of very high quality.[23]

Using the Swedish Personal Identification Number[24] (issued to all Swedish residents at the time of birth or immigration) and women's registered addresses in the SPR, the data was linked to Statistics Sweden and to Lantmäteriet (the Swedish mapping, cadastral and land registration authority) to retrieve geographic coordinates.

The sample for this population-based cohort study includes all pregnancies in the SPR between 2014 and 2017 ($n = 420,850$). We excluded women with failed geocoding of addresses ($n = 49,315$), missing birth clinic information ($n = 576$) or a child born with a congenital anomaly ($n = 6329$). This resulted in 364,630 women for our analysis of onset of labour. We further restricted the sample to full-term (≥37 weeks' gestation) spontaneous births (Robson groups[25] 1,3,5) when investigating PPH ($N = 259,347$) and further excluded caesarean section births when investigating OASIS ($N = 233,091$).

Exposure – Travel time to the delivery ward of birth

Travel time from the woman's exact home address to the delivery unit was derived using the Network Analyst extension in ESRI ArcMap 10.7.1. This information was managed in a file geodatabase, including coordinate pairs of home addresses and delivery units reported in the SPR ($n = 43$). We used information on boundaries for Swedish municipalities and the official national road network NVDB (Nationell Vägdatabas), including road lengths and speed limits for 1,924,055 road segments. Coordinate pairs were matched to road segments to determine the shortest route. Travel time from home to the delivery ward of birth was calculated under the assumption that the shortest route was taken without any stops, and was categorised into ≤30 min, 31–59 min or ≥60 min intervals.

Statistics Sweden defines urban areas as cities/towns with at least 200 inhabitants. Using geodata from 2018,[26] together with the residential addresses, a select-by-function (point in polygon) was used to classify each woman's area of residence as urban or rural.

The final data merged with the SPR only contain the travel time to the delivery ward and area of residence, thus protecting women's identities.

Outcomes

Onset of labour was defined as induced, elective caesarean section or spontaneous (see Online Supplementary Material 1 for definitions using the SPR, ICD and procedure codes).

PPH was defined as bleeding >1000 mL, using estimated blood loss in millilitres (SPR) or receiving an ICD diagnosis of O72, O67.8 or O67.0, which has been validated at 88.5% sensitivity.[27]

Sustaining a severe perineal trauma involving the anal sphincter (OASIS) as a consequence of childbirth was defined as having a perineal tear of grade 3 or 4 (checkbox in the SPR, marked by a midwife/obstetrician) or receiving an ICD diagnosis of ‘O70.2’ or ‘O70.3’, or procedure code ‘MBC33’.

Maternal and delivery characteristics

Maternal and delivery characteristics were collected from the SPR. Maternal age was modelled as a continuous variable and described categorically. Other information collected at first antenatal visit include body mass index (BMI), region of birth, family situation, employment status, parity and education level.

Delivery characteristics collected from the SPR include birth outside of hospital (defined as ICD code ‘Z381’ or if the time of birth registered in the SPR was before delivery ward admittance), season of birth (April to October, November to March), and mode of delivery (elective caesarean section, emergency caesarean section, caesarean section unspecified, vaginal instrumental, vaginal non-instrumental). Severe maternal morbidity was defined using extracted maternal diagnoses (Online Supplementary Material 1).

Table 1
Characteristics of women based on travel time from home to the delivery ward ($N = 364,630$).

Maternal and delivery characteristics	Total, $N = 364,630$	Travel time to delivery ward		
		≤30 min, $N = 286,364$ (78.5%)	31–59 min, $N = 63,815$ (17.5%)	≥60 min, $N = 14,451$ (4.0%)
Travel time to delivery ward				
Mean, median (standard deviation), IQR	20.8, 13.9 (25.8), 7.1–27.0	12.2, 10.5 (7.6), 5.9–17.8	41.5, 40.1 (7.9), 35.0–46.9	99.9, 75.1 (76.1), 65.7–94.2
Maternal characteristics				
Maternal age, *n* (%)				
<20 years	3760 (1.0)	2611 (0.9)	896 (1.4)	253 (1.8)
20–24 years	41,770 (11.5)	29,766 (10.4)	9492 (14.9)	2512 (17.4)
25–29 years	114,927 (31.5)	87,198 (30.5)	22,756 (35.7)	4973 (34.5)
30–34 years	123,266 (33.8)	100,128 (35.0)	19,057 (29.9)	4081 (28.3)
≥35 years	80,822 (22.2)	66,611 (23.3)	11,596 (18.2)	2615 (18.1)
N missing	85	50	18	17
Area of residence, *n* (%)				
Rural	33,743 (9.3)	16,729 (5.8)	13,795 (21.6)	3219 (22.3)
Urban	330,887 (90.7)	269,635 (94.2)	50,020 (78.4)	11,232 (77.7)
Body mass index (BMI WHO categories), *n* (%)				
<18.5	8818 (2.6)	7228 (2.7)	1318 (2.4)	272 (2.5)
18.5–24.9	195,393 (58.1)	161,449 (59.6)	28,339 (52.3)	5605 (50.9)
25.0–29.9	86,180 (25.6)	67,846 (25.0)	15,224 (28.1)	3110 (28.2)
30.0–34.9	32,190 (9.6)	24,505 (9.0)	6309 (11.6)	1376 (12.5)
≥35.0	13,726 (4.1)	10,059 (3.7)	3013 (5.6)	654 (5.9)
N missing	28,323	15,277	9612	3434
Family situation, *n* (%)				
Cohabiting	316,856 (93.1)	255,878 (93.3)	50,794 (92.8)	10,184 (90.6)
Living alone	7273 (2.1)	5673 (2.1)	1279 (2.3)	321 (2.9)
Other	16,048 (4.7)	12,680 (4.6)	2635 (4.8)	733 (6.5)
N missing	24,453	12,133	9107	3213
Region of birth, *n* (%)				
Sweden	239,991 (73.5)	185,926 (72.1)	44,706 (79.3)	9359 (77.9)
Other Nordic (not Sweden)	3068 (0.9)	2623 (1.0)	339 (0.6)	106 (0.9)
Europe (excl. Nordics)	21,202 (6.5)	17,781 (6.9)	2925 (5.2)	496 (4.1)
Asia	14,270 (4.4)	12,066 (4.7)	1784 (3.2)	420 (3.5)
Middle-East/North Africa	27,082 (8.3)	22,720 (8.8)	3426 (6.1)	936 (7.8)
Sub-Saharan Africa	15,341 (4.7)	12,181 (4.7)	2567 (4.6)	593 (4.9)
Other	5345 (1.6)	4635 (1.8)	608 (1.1)	102 (0.8)
N missing	38,331	28,432	7460	2439
Employment status, *n* (%)				
Unemployed	13,172 (4.2)	10,258 (4.1)	2364 (4.4)	550 (5.0)
Parental, sickness, study, other	67,698 (21.7)	53,021 (21.4)	12,116 (22.6)	2561 (23.2)
Employed	231,416 (74.1)	184,336 (74.4)	39,137 (73.0)	7943 (71.9)
N missing	52,344	38,749	10,198	3397
Education level, *n* (%)				
Basic (≤9 years: ~ age 16)	25,991 (8.7)	19,896 (8.5)	4909 (9.6)	1186 (11.1)
Secondary (10–12 years: ~ age 18–19)	116,160 (39.1)	85,149 (36.2)	25,561 (49.9)	5450 (51.0)
Postsecondary (>12 years)	154,995 (52.2)	130,175 (55.3)	20,760 (40.5)	4060 (38.0)
N missing	67,484	51,144	12,585	3755
Parity, *n* (%)				
0	149,932 (42.3)	121,455 (42.7)	23,255 (39.9)	5222 (42.8)
1	131,721 (37.1)	106,442 (37.4)	21,162 (36.3)	4117 (33.8)
≥2	73,134 (20.6)	56,395 (19.8)	13,883 (23.8)	2856 (23.4)
N missing	9483	2072	5515	2256
Delivery characteristics				
Birth outside hospital, *n* (%)				
No	362,465 (99.4)	284,972 (99.5)	63,245 (99.1)	14,248 (98.6)
Yes	2165 (0.6)	1392 (0.5)	570 (0.9)	203 (1.4)
Season of birth, *n* (%)				
November to March	139,997 (38.4)	110,814 (38.7)	23,991 (37.6)	5192 (35.9)
April to October	224,633 (61.6)	175,550 (61.3)	39,824 (62.4)	9259 (64.1)
Onset of labour, *n* (%)				
Induced	64,254 (17.6)	51,084 (17.8)	10,715 (16.8)	2455 (17.0)
Elective caesarean section	28,925 (7.9)	22,876 (8.0)	4847 (7.6)	1202 (8.3)
Spontaneous	271,451 (74.4)	212,404 (74.2)	48,253 (75.6)	10,794 (74.7)
Mode of delivery, *n* (%)				
Elective caesarean section	29,025 (8.0)	22,954 (8.0)	4858 (7.6)	1213 (8.4)
Emergency caesarean section	33,257 (9.1)	26,118 (9.1)	5420 (8.5)	1719 (11.9)
Caesarean section (unspecified)	15 (0)	10 (0)	5 (0)	0 (0)
Vaginal, instrumental	20,429 (5.6)	16,374 (5.7)	3299 (5.2)	756 (5.2)
Vaginal, non-instrumental	281,903 (77.3)	220,908 (77.1)	50,233 (78.7)	10,762 (74.5)
N missing	1	0	0	1
Postpartum haemorrhage (>1000 mL), *n* (%)				
No	334,750 (91.8)	262,458 (91.7)	58,880 (92.3)	13,412 (92.8)
Yes	29,880 (8.2)	23,906 (8.3)	4935 (7.7)	1039 (7.2)

(*continued on next page*)

Table 1 (*continued*)

Maternal and delivery characteristics	Total, $N = 364{,}630$	Travel time to delivery ward		
		≤30 min, $N = 286{,}364$ (78.5%)	31–59 min, $N = 63{,}815$ (17.5%)	≥60 min, $N = 14{,}451$ (4.0%)
OASIS (obstetric anal sphincter injury), *n* (%)				
No	355,234 (97.4)	278,715 (97.3)	62,328 (97.7)	14,191 (98.2)
Yes	9396 (2.6)	7649 (2.7)	1487 (2.3)	260 (1.8)
Severe maternal morbidity,[a] *n* (%)				
No	353,703 (97.0)	277,645 (97.0)	62,012 (97.2)	14,046 (97.2)
Yes	10,927 (3.0)	8719 (3.0)	1803 (2.8)	405 (2.8)
Birth satisfaction (using VAS scale),*n (%)*				
Dissatisfied (VAS <4)	15,004 (11.0)	11,555 (11.1)	2965 (11.0)	484 (8.2)
Satisfied (≥4)	122,006 (89.0)	92,513 (88.9)	24,065 (89.0)	5428 (91.8)
Missing	227,620	182,296	36,785	8539

IQR, interquartile range; VAS, visual analogue scale; WHO, World Health Organization.

[a] Severe maternal morbidity is having any of the following (see Supplementary Table 1 for definitions based ICD diagnostic and action codes): severe haemorrhage; embolism, shock, Disseminated intravascular coagulation (DIC); sepsis; acute renal failure; cardiac complications; cerebrovascular; hysterectomy; surgical; severe uterine rupture; other (liver disorders in pregnancy, childbirth and the puerperium; acute appendicitis, unspecified appendicitis, peritonitis; adult respiratory distress syndrome; toxic liver disease or hepatic failure, not elsewhere classified; postpartum inversion of uterus; manual correction of inverted uterus).

Birth satisfaction was measured using the visual analogue scale 0–10 and dichotomised as dissatisfied (<4) or satisfied (≥4).

Among women with a spontaneous onset of labour, we calculated the time from labour starting (from the maternity delivery journal) to admission to the delivery ward, time from admission to the delivery ward to the birth, and total duration of labour. We also used SPR data indicating whether the cardiotocography admission test was 'normal' or not. We defined the following infections during delivery or early postpartum: chorioamnionitis ('O411'), urinary tract ('O862, 'N300'), puerperal ('O85', 'O86') or puerperal breast infection ('O91'). We described whether a woman had used pain management during labour (epidural, pudendal nerve block or infiltration; Online Supplementary Material 1).

Statistical analyses

Using descriptive analyses, we examined the association between a range of maternal and birth characteristics and travel time to the delivery ward, as well as having a PPH or OASIS.

The association between travel time to the delivery ward (reference ≤30 min) and onset of labour (reference spontaneous) was modelled using multinomial logistic regression. The association between travel time and both PPH and OASIS among women at full term with a spontaneous onset of labour was modelled using logistic regression. Guided by a priori knowledge, we used Directed Acyclic Graphs[28] to visualise the relationship between our exposure and outcomes (Online Supplementary Material 2). This made explicit the assumptions embedded in our statistical models. We present odds ratio (OR) estimates from both an unadjusted and fully adjusted (aOR) model with 95% confidence intervals (CIs) – for all outcomes, this included conditioning for maternal age, region of birth, education level, family situation, area of residence and season of birth.

We ran sensitivity analyses to test the robustness of our PPH results by (1) excluding women who gave birth outside of hospital and (2) modelling the association using PPH defined (in Sweden since 2020) as ≥1000 mL.

All analyses were completed in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Results

Over three-quarters of the women had ≤30 min travel time to the delivery ward (Table 1), with a median travel time of 13.9 min (interquartile range 7.1–27.0). More than half the women were aged ≥30 years at the birth, and most lived in an urban area (90.7%). Women with ≤30 min travel time tended to be older (mean age of 31.2 years, compared with 30.1 and 29.8 years for women living 31–59 and ≥60 min away, respectively). While ~60% of women had a BMI within the healthy range, women living further away had a higher BMI; over 45.0% had a BMI ≥25 kg/m^2, compared with 37.7% of women living ≤30 min away.

A higher proportion of women with ≤30 min travel time were cohabiting, born outside Sweden, and employed. More than half of these women had a postsecondary education, compared with ~40% of women living further away. Fewer women with ≤30 min travel time gave birth outside of hospital (0.5%, compared with 1.4% of women living ≥60 min away) and had two or more children before the index birth (almost one-fifth, compared with 23.4% of women with the furthest travel time).

Although most women delivered their child vaginally (82.9%), ~92% of births did not result in a PPH, and almost all women did not have an OASIS or severe maternal morbidity (~97%). Approximately 90% of women were satisfied with the birth.

Onset of labour

Compared to women with ≤30 min travel time, women with further to travel had increased odds of having an elective caesarean section (31–59 min aOR 1.11; 95% CI 1.07–1.16; and ≥60 min aOR 1.2; 95% CI 1.16–1.36) than having a spontaneous onset of labour (Table 2). There was some indication that women with a travel time of 31–59 min may have slightly reduced odds of being induced (aOR 0.95; 95% CI 0.92–0.98) than having a spontaneous onset of labour, compared to women with ≤30 min travel time.

Among women with a spontaneous onset of labour (Table 3), ~40% had used any pain management, and one-third had an epidural. These percentages were much higher among primiparas, where ~60% of women had used any pain management and half had an epidural (results not shown). Most women (94.5%) had a normal cardiotocography (CTG) on admission to the delivery ward.

The median time from admission to the delivery ward and the birth was 311 min (~5.2 h). While women living ≥60 min away spent ~30 min longer (median) in hospital than women living closer to the delivery ward, the median duration of labour (time between established labour and birth) was slightly shorter. While only 3.0% of all women had an infection (chorioamnionitis, puerperal or breast puerperal), this was lowest among the women living furthest away 1.9% (Table 3).

Table 2
The association between travel time and onset of labour [a], postpartum haemorrhage (PPH)[b], and obstetric anal sphincter injury (OASIS)[c]. Odds ratios with 95% Confidence Intervals (CI) from logistic regression models [a,b,c]

Travel time	Onset of labour[a]												Postpartum haemorrhage (PPH)[b]						Obstetric anal sphincter injury (OASIS)[c]					
	Induced (N = 49,090; 17.6%)						Elective caesarean section (N = 21,751; 7.8%)						Yes (N = 14,525; 7.1%)						Yes (N = 5805; 3.1%)					
	Unadjusted			Model 1[d]			Unadjusted			Model 1[d]			Unadjusted			Model 1[d]			Unadjusted			Model 1[d]		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
≤30 min	1.00			1.00			1.00			1.00			1.00			1.00			1.00			1.00		
31–59 min	0.94	0.91	0.96	0.95	0.92	0.98	0.97	0.93	1.01	1.11	1.07	1.16	0.92	0.88	0.96	0.94	0.90	0.99	0.93	0.86	0.99	0.99	0.92	1.06
≥60 min	0.99	0.94	1.05	1.00	0.95	1.06	1.06	0.98	1.15	1.25	1.16	1.36	0.82	0.73	0.91	0.84	0.76	0.94	0.73	0.61	0.87	0.79	0.66	0.94

Odds ratios (ORs) with 95% confidence intervals (CIs) from logistic regression models.[a,b,c]

[a] Multinomial logistic regression model estimating the odds of being induced or having an elective caesarean section, compared with having a spontaneous onset of labour (n = 207,623, 74.6%) – sample size 364,630, complete cases 278,464). Example of interpreting multinomial model: Compared with women with ≤30 min travel time to the delivery ward, women with further to travel had increased odds of having an elective caesarean section (31–59 min adjusted OR 1.11, 95% CI 1.07, 1.16; and ≥60 min OR 1.25: 1.16, 1.36) than having a spontaneous onset of labour.

[b] Logistic regression model estimating the odds of having a PPH, among women with a spontaneous onset of labour (Robson groups 1,3,5 – sample size 259,347, complete cases 205,655).

[c] Logistic regression model estimating the odds of having an OASIS, among women with a spontaneous onset of labour (Robson groups 1,3,5) who had not had a caesarean section (sample size 233,083, complete cases 185,515).

[d] Model 1 adjusted for region of birth, education level, family situation, area of residence, season of birth and maternal age.

Postpartum haemorrhage among women at full term with a spontaneous onset of labour

Compared to women without a PPH, women with a PPH were more likely to have an emergency c-section (13.7% vs 5.1%) or instrumental vaginal delivery (8.8% vs 5.4%), to be primiparous (45% vs 38%) and have a postsecondary education (55.1% vs 51.9%; Table 4). Although the time spent labouring at home was similar (median ~6.1 h), women with a PPH had a longer total duration of labour (median 15.7 h vs 12.9 h) and were more likely to have been administered oxytocin (42.0% vs 28.4%).

Compared with women with ≤30 min travel time, women with further to travel had reduced odds of having a PPH (31–59 min aOR 0.94; 95% CI 0.90–0.99, and ≥60 min aOR 0.84; 95% CI 0.76–0.94; Table 2). Our results remained the same in sensitivity analyses excluding the 1911 women who birthed their child outside of the hospital and when defining PPH as ≥1000 mL (results available on request).

OASIS among women at full term with a spontaneous onset of labour

Women with an OASIS were slightly less likely to be Nordic born (71.3% vs 74.3%) and significantly more likely to have a post-secondary education (59.7% vs 51.8%), an instrumental vaginal delivery (23.1% vs 5.7%), to be primiparous (70.3% vs 38.7%), to have severe maternal morbidity (6.0% vs 2.1%), and to be administered oxytocin (53% vs 29%; Table 5). These women spent longer labouring before being admitted at the delivery ward (median 7.4 h vs 6 h) and had a much longer time between admission and delivery (median 9 h vs 5 h; Table 5).

Women with ≥60 min travel time had reduced odds of having an OASIS (aOR 0.79; 95% CI: 0.66–0.94) compared to women with ≤30 min travel time (Table 2).

Discussion

Using Swedish register data for almost all births in Sweden between 2014 and 2017, we found that while women with a longer travel time to the delivery ward had increased odds of having an elective caesarean section, compared with a spontaneous onset of labour, there was no association with labour starting by induction. While women with ≥60 min of travel time had reduced odds of having a PPH and OASIS, it is unlikely that living further away is protective of adverse maternal outcomes, but rather an indication of other factors influencing these outcomes.

Our results show that women with the longest travel time were admitted to hospital sooner. This is likely a product of uncertainty in her making it to the delivery ward on time; both in the woman seeking care earlier, and midwives/clinicians more readily admitting the woman at an earlier stage. Given this, we are not surprised that women with ≥60 min travel time were more likely to have an elective caesarean section. A systematic review summarises five Canadian studies, four of which showed an increased risk of caesarean section among women living closer to the delivery ward and one finding no significant effect;[9] however, these studies all contained more extremes of travel time. We believe this is the first study reporting the association between travel time and onset of labour in a setting more identifiable with other European countries, including both urban and rural populations.

This same systematic review[9] also included 15 studies examining the association between travel distance to the delivery ward and maternal outcomes, such as maternal mortality and caesarean section; however, we found no studies investigating the association

Table 3
Characteristics of women by travel time from home to the delivery ward, among women with a spontaneous onset of labour (*N* = 259,347).

Labour characteristics	Total, *N* = 259,347	Travel time to delivery ward		
		≤30 min, *n* = 208,567, (80.4%)	31–59 min, *n* = 42,524 (16.4%)	≥60 min, *n* = 8256 (3.2%)
Pain management during delivery,[a] *n* (%)				
No	151,107 (58.3)	120,073 (57.6)	26,041 (61.2)	4993 (60.5)
Yes	108,240 (41.7)	88,494 (42.4)	16,483 (38.8)	3263 (39.5)
Epidural use, *n* (%)				
No	173,149 (66.8)	137,935 (66.1)	29,626 (69.7)	5588 (67.7)
Yes	86,198 (33.2)	70,632 (33.9)	12,898 (30.3)	2668 (32.3)
Admission test (CTG), *n* (%)				
Abnormal	11,503 (5.5)	9348 (5.5)	1841 (5.4)	314 (4.9)
Normal	197,979 (94.5)	159,777 (94.5)	32,097 (94.6)	6105 (95.1)
N missing	49,865	39,442	8586	1837
Time from start of labour to admission (min)				
Mean, median (standard deviation), IQR	603.2, 366.0 (993.1), 180–745	613.4, 370.0 (1001), 180–755	567.8, 353.0 (956.9), 176–705	519.1, 330.0 (954.6), 168–663
N missing	39,799	30,940	7146	1713
Time from admission to birth (min)				
Mean, median (standard deviation), IQR	459.7, 311.0 (574.0), 146–615	454.6, 311.0 (554.0), 147–612	469.6, 306.0 (648.4), 141–616	538.2, 349.0 (651.5), 160–698
Duration of labour (min)				
Mean, median (standard deviation), IQR	1049, 782.0 (1065), 447–1298	1055, 786.0 (1075), 448–1303	1023, 762.0 (1024), 442–1270	1027, 776.0 (1004), 459–1273
N missing	39,799	30,940	7146	1713
Infections				
Any infection,[b] *n* (%)				
No	251,563 (97.0)	201,987 (96.8)	41,476 (97.5)	8100 (98.1)
Yes	7784 (3.0)	6580 (3.2)	1048 (2.5)	156 (1.9)
Chorioamnionitis, *n* (%)				
No	258,820 (99.8)	208,151 (99.8)	42,430 (99.8)	8239 (99.8)
Yes	527 (0.2)	416 (0.2)	94 (0.2)	17 (0.2)
Puerperal infection, *n* (%)				
No	255,102 (98.4)	204,979 (98.3)	41,966 (98.7)	8157 (98.8)
Yes	4245 (1.6)	3588 (1.7)	558 (1.3)	99 (1.2)
Breast infection, *n* (%)				
No	256,223 (98.8)	205,903 (98.7)	42,107 (99.0)	8213 (99.5)
Yes	3124 (1.2)	2664 (1.3)	417 (1.0)	43 (0.5)
Urinary tract infection, *n* (%)				
No	258,511 (99.7)	207,847 (99.7)	42,421 (99.8)	8243 (99.8)
Yes	836 (0.3)	720 (0.3)	103 (0.2)	13 (0.2)

CTG, Cardiotocography; IQR, interquartile range.
[a] Any pain management – epidural (spinal or eda), pudendal nerve block (pdb), infiltration.
[b] Any infection after delivery or early postpartum – puerperal, chorioamnionitis, breast, urinary tract.

between travel distance or time and OASIS, so we are unable to confirm our result that longer travel time reduces the risk of OASIS.

That longer travel time was also associated with reduced odds of PPH in this population is in contrast to the study by Rygh et al showing an increased risk of PPH among women with longer to travel (>1 h).[29] Our study, as opposed to this study including only one province of Canada, uses national register data for all pregnancies and births in 17 of 21 regions of Sweden. The disparity in findings could be due to large geographical differences in the rurality of Canada and Sweden and the populations included, as well as demographic and obstetrical management differences between the two countries. In addition, so few women in our sample were living more than an hour from the delivery ward (4%).

We speculate that our findings of reduced odds of having a PPH or OASIS among women (full term with spontaneous onset of labour) living furthest away could be due to two things. First, being admitted to delivery care sooner and labouring longer there, these women had greater access to monitoring and care. This allows opportunity to detect complications sooner and provide appropriate and timely care to minimise the risk of adverse outcomes. Second, this reduced risk may be due to other characteristics of these women living furthest away, who were younger, had a higher BMI and were more often Nordic born; the latter indicating fluency in Swedish and possibly being able to communicate more effectively with caregivers.

Travel times give a more accurate measure of what distance actually means for the woman, and we were fortunate to be able to estimate this exposure using coordinate pairs of actual addresses (home and delivery unit). This increased the precision of estimated distances and subsequent travel times (exposure) and is a huge strength of this study; many studies only use estimated distances/times from central points. Another strength of our study was having data for PPH diagnoses (ICD) as well as estimated blood loss, with high sensitivity.[27]

A limitation to be considered when interpreting our study findings is that we did not have data for 4/21 regions in Sweden – Norbotten, Uppsala, Värmland and Kronoberg. While approximately 12% of the Swedish population lives rurally,[26] in our sample, 9.3% of our population gave birth in a rural location. While we estimate that any possible bias is small, given that the largest of these regions (Norrbotten) takes up 25% of Sweden's land area and yet 2% of births occur here,[5] it would be careless to dismiss that women in this region indeed have the largest travel times; their travel times are greater than the majority of women in our sample and would be most sensitive to increased distances due to closures. While data for this region are recorded in a different journal system, a

Table 4
Characteristics of women with based on postpartum haemorrhage (PPH) status, among women with a spontaneous onset of labour ($N = 259{,}347$)

Maternal and birth characteristics	Total, $N = 259{,}347$	PPH	
		No, $N = 240{,}962$ (92.8%)	Yes, $N = 18{,}385$ (7.1%)
Travel time to the delivery ward, *n* (%)			
≤30 min	208,567 (80.4)	193,520 (80.3)	15,047 (81.8)
31–59 min	42,524 (16.4)	39,680 (16.5)	2844 (15.5)
≥60 min	8256 (3.2)	7762 (3.2)	494 (2.7)
Maternal age, *n* (%)			
<20 years	2736 (1.1)	2590 (1.1)	146 (0.8)
20–24 years	30,607 (11.8)	28,695 (11.9)	1912 (10.4)
25–29 years	83,711 (32.3)	78,143 (32.4)	5568 (30.3)
30–34 years	88,372 (34.1)	81,846 (34.0)	6526 (35.5)
≥35 years	53,859 (20.8)	49,628 (20.6)	4231 (23.0)
N missing	62	60	2
Area of residence, *n* (%)			
Rural	23,526 (9.1)	21,894 (9.1)	1632 (8.9)
Urban	235,821 (90.9)	219,068 (90.9)	16,753 (91.1)
Body mass index (BMI WHO categories), *n* (%)			
<18.5	6796 (2.7)	6383 (2.8)	413 (2.3)
18.5–24.9	148,344 (59.8)	138,331 (60.1)	10,013 (56.9)
25–29.9	62,287 (25.1)	57,631 (25)	4656 (26.5)
30–34.9	21,872 (8.8)	20,115 (8.7)	1757 (10.0)
≥35.0	8599 (3.5)	7853 (3.4)	746 (4.2)
N missing	11,449	10,649	800
Family situation, *n* (%)			
Cohabiting	234,565 (93.6)	217,941 (93.5)	16,624 (93.7)
Living alone	4886 (1.9)	4550 (2.0)	336 (1.9)
Other	11,282 (4.5)	10,495 (4.5)	787 (4.4)
N missing	8614	7976	638
Region of birth, *n* (%)			
Sweden	170,621 (72.7)	158,497 (72.7)	12,124 (72.8)
Other Nordic (not Sweden)	2219 (0.9)	2071 (0.9)	148 (0.9)
Europe (excl. Nordics)	15,712 (6.7)	14,563 (6.7)	1149 (6.9)
Asia	10,656 (4.5)	9747 (4.5)	909 (5.5)
Middle-East/North Africa	20,536 (8.8)	19,362 (8.9)	1174 (7.0)
Sub-Saharan Africa	11,163 (4.8)	10,316 (4.7)	847 (5.1)
Other	3790 (1.6)	3477 (1.6)	313 (1.9)
N missing	24,650	22,929	1721
Employment status, *n* (%)			
Unemployed	9385 (4.2)	8743 (4.2)	642 (4.0)
Parental, sickness, study, other	50,479 (22.5)	47,267 (22.7)	3212 (20.1)
Employed	164,512 (73.3)	152,421 (73.1)	12,091 (75.8)
N missing	34,971	32,531	2440
Education level, *n* (%)			
Basic (≤9 years: ~ age 16)	19,168 (9)	17,955 (9.0)	1213 (8.0)
Secondary (10–12 years: ~ age 18–19)	83,258 (38.9)	77,693 (39.1)	5565 (36.8)
Postsecondary (>12 years)	111,425 (52.1)	103,101 (51.9)	8324 (55.1)
N missing	45,496	42,213	3283
Parity, *n* (%)			
0	100,455 (38.7)	92,116 (38.2)	8339 (45.4)
1	104,099 (40.1)	97,238 (40.4)	6861 (37.3)
≥2	54,793 (21.1)	51,608 (21.4)	3185 (17.3)
Birth characteristics			
Birth outside hospital, *n* (%)			
No	257,436 (99.3)	239,138 (99.2)	18,298 (99.5)
Yes	1911 (0.7)	1824 (0.8)	87 (0.5)
Season of birth, *n* (%)			
November to March	99,240 (38.3)	92,244 (38.3)	6996 (38.1)
April to October	160,107 (61.7)	148,718 (61.7)	11,389 (61.9)
Onset of labour, *n* (%)			
Induced	4646 (1.8)	4082 (1.7)	564 (3.1)
Elective caesarean section	11,398 (4.4)	10,480 (4.3)	918 (5.0)
Spontaneous	243,303 (93.8)	226,400 (94.0)	16,903 (91.9)
Mode of delivery, *n* (%)			
Elective caesarean section	11,418 (4.4)	10,497 (4.4)	921 (5.0)
Emergency caesarean section	14,838 (5.7)	12,328 (5.1)	2510 (13.7)
Caesarean section (unspecified)	8 (0)	8 (0)	0 (0)
Vaginal, instrumental	14,643 (5.6)	13,022 (5.4)	1621 (8.8)
Vaginal, non-instrumental	218,440 (84.2)	205,107 (85.1)	13,333 (72.5)
Epidural, *n* (%)			
No	173,149 (66.8)	162,488 (67.4)	10,661 (58.0)
Yes	86,198 (33.2)	78,474 (32.6)	7724 (42.0)
Oxytocin use, *n* (%)			
No	183,248 (70.7)	172,588 (71.6)	10,660 (58.0)
Yes	76,099 (29.3)	68,374 (28.4)	7725 (42.0)

(*continued on next page*)

Table 4 (*continued*)

Maternal and birth characteristics	Total, *N* = 259,347	PPH	
		No, *N* = 240,962 (92.8%)	Yes, *N* = 18,385 (7.1%)
Severe maternal morbidity,[a] *n* (%)			
No	252,935 (97.5)	238,516 (99.0)	14,419 (78.4)
Yes	6412 (2.5)	2446 (1.0)	3966 (21.6)
Time from start of labour to admission (min)			
Mean, median (standard deviation), IQR	603.2, 336.0 (993.1), 180–745	600.1, 365.0 (980.2), 180–740	645.0, 375.0 (1152), 171–785
N missing	39,799	36,586	3213
Time from admission to birth (min)			
Mean, median (standard deviation), IQR	459.7, 311.0 (574.0), 146–615	449.2, 304.0 (563.7), 143–599	597.8, 437.0 (680.4), 189–828
Duration of labour (min)			
Mean, median (standard deviation), IQR	1049, 782.0 (1065), 447–1298	1035, 771.0 (1049), 443–1281	1233, 943.0 (1239), 517–1519.5
N missing	39,799	36,586	3213
Birth satisfaction (using VAS scale),*n (%)*			
Dissatisfied (VAS <4)	10,778 (11)	10,002 (10.9)	776 (11.4)
Satisfied (≥4)	87,459 (89)	81,444 (89.1)	6015 (88.6)
N missing	161,110	149,516	11,594

IQR, interquartile range; PPH, postpartum haemorrhage; VAS, visual analogue scale; WHO, World Health Organization.

[a] Severe maternal morbidity is having any of the following (see Supplementary Table 1 for definitions based ICD diagnostic and action codes): severe haemorrhage; embolism, shock, DIC; sepsis; acute renal failure; cardiac complications; cerebrovascular; hysterectomy; surgical; severe uterine rupture; other (liver disorders in pregnancy, childbirth and the puerperium; acute appendicitis, unspecified appendicitis, peritonitis; adult respiratory distress syndrome; toxic liver disease or hepatic failure, not elsewhere classified; postpartum inversion of uterus; manual correction of inverted uterus).

Table 5
Characteristics of women based on obstetric and anal sphincter injury (OASIS) status, among women with a spontaneous onset of labour who had not had a caesarean section (N = 233,083)

Maternal and birth characteristics	Total, *N* = 233,083	OASIS	
		No, *N* = 225,782 (96.9%)	Yes, N = 7301 (3.1%)
Travel time to the delivery ward, *n* (%)			
≤30 min	187,569 (80.5)	181,551 (80.4)	6018 (82.4)
31–59 min	38,207 (16.4)	37,098 (16.4)	1109 (15.2)
≥60 min	7307 (3.1)	7133 (3.2)	174 (2.4)
Maternal age, *n* (%)			
<20 years	2607 (1.1)	2529 (1.1)	78 (1.1)
20–24 years	28,878 (12.4)	28,066 (12.4)	812 (11.1)
25–29 years	77,438 (33.2)	74,835 (33.2)	2603 (35.7)
30–34 years	79,170 (34)	76,570 (33.9)	2600 (35.6)
≥35 years	44,937 (19.3)	43,730 (19.4)	1207 (16.5)
N missing	53	52	1
Area of residence, *n* (%)			
Rural	21,410 (9.2)	20,797 (9.2)	613 (8.4)
Urban	211,673 (90.8)	204,985 (90.8)	6688 (91.6)
Body mass index (BMI WHO categories), *n* (%)			
<18.5	6377 (2.9)	6135 (2.8)	242 (3.4)
18.5–24.9	136,146 (61.1)	131,763 (61.1)	4383 (62.3)
25.0–29.9	54,798 (24.6)	53,082 (24.6)	1716 (24.4)
30.0–34.9	18,465 (8.3)	17,947 (8.3)	518 (7.4)
≥35.0	7016 (3.1)	6845 (3.2)	171 (2.4)
N missing	10,281	10,010	271
Family situation, *n* (%)			
Cohabiting	210,978 (93.6)	204,401 (93.7)	6577 (92.8)
Living alone	4327 (1.9)	4189 (1.9)	138 (1.9)
Other	9996 (4.4)	9625 (4.4)	371 (5.2)
N missing	7782	7567	215
Region of birth, *n* (%)			
Sweden	154,717 (73.2)	150,084 (73.3)	4633 (70.5)
Other Nordic (not Sweden)	2029 (1.0)	1978 (1.0)	51 (0.8)
Europe (excl. Nordics)	14,404 (6.8)	13,992 (6.8)	412 (6.3)
Asia	9369 (4.4)	8843 (4.3)	526 (8.0)
Middle-East/North Africa	17,834 (8.4)	17,324 (8.5)	510 (7.8)
Sub-Saharan Africa	9642 (4.6)	9278 (4.5)	364 (5.5)
Other	3284 (1.6)	3209 (1.6)	75 (1.1)
N missing	21,804	21,074	730
Employment status, *n* (%)			
Unemployed	8456 (4.2)	8234 (4.2)	222 (3.6)
Parental, sickness, study, other	45,238 (22.4)	44,093 (22.5)	1145 (18.4)
Employed	148,628 (73.5)	143,765 (73.3)	4863 (78.1)
N missing	30,761	29,690	1071
Education level, *n* (%)			
Basic (≤9 years: ~ age 16)	17,141 (8.9)	16,726 (8.9)	415 (6.9)
Secondary (10–12 years: ~ age 18–19)	75,395 (39.1)	73,396 (39.2)	1999 (33.4)

Table 5 (*continued*)

Maternal and birth characteristics	Total, $N = 233,083$	OASIS	
		No, $N = 225,782$ (96.9%)	Yes, N = 7301 (3.1%)
Postsecondary (>12 years)	100,468 (52.1)	96,889 (51.8)	3579 (59.7)
N missing	40,079	38,771	1308
Parity, *n* (%)			
0	92,458 (39.7)	87,324 (38.7)	5134 (70.3)
1	92,960 (39.9)	91,076 (40.3)	1884 (25.8)
≥2	47,665 (20.4)	47,382 (21)	283 (3.9)
Birth characteristics			
Birth outside hospital, *n* (%)			
No	231,173 (99.2)	223,914 (99.2)	7259 (99.4)
Yes	1910 (0.8)	1868 (0.8)	42 (0.6)
Season of birth, *n* (%)			
November to March	89,084 (38.2)	86,215 (38.2)	2869 (39.3)
April to October	143,999 (61.8)	139,567 (61.8)	4432 (60.7)
Onset of labour, *n* (%)			
Induced	3221 (1.4)	3042 (1.3)	179 (2.5)
Spontaneous	229,862 (98.6)	222,740 (98.7)	7122 (97.5)
Mode of delivery, *n* (%)			
Vaginal, instrumental	14,643 (6.3)	12,959 (5.7)	1684 (23.1)
Vaginal, non-instrumental	218,440 (93.7)	212,823 (94.3)	5617 (76.9)
Epidural, *n* (%)			
No	160,988 (69.1)	157,506 (69.8)	3482 (47.7)
Yes	72,095 (30.9)	68,276 (30.2)	3819 (52.3)
Oxytocin use, *n* (%)			
No	164,501 (70.6)	161,082 (71.3)	3419 (46.8)
Yes	68,582 (29.4)	64,700 (28.7)	3882 (53.2)
Severe maternal morbidity,[a] *n* (%)			
No	227,933 (97.8)	221,068 (97.9)	6865 (94.0)
Yes	5150 (2.2)	4714 (2.1)	436 (6.0)
Time from start of labour to admission (min)			
Mean, median (standard deviation), IQR	599.8, 365.0 (976.5), 180–738	596.3, 362.0 (970.9), 180–734	707.9, 441.0 (1131), 214–885
N missing	24,693	23,927	766
Time from admission to birth (min)			
Mean, median (standard deviation), IQR	430.0, 304.0 (469.2), 142–589	423.7, 298.0 (463.3), 140–579	624.4, 538.0 (592.6), 279–829
Duration of labour (min)			
Mean, median (standard deviation), IQR	1021, 762.0 (1041), 439–1262	1012, 753.0 (1036), 434–1250	1315, 1064 (1163), 656–1585
N missing	24,693	23,927	766
Birth satisfaction (using VAS scale),*n (%)*			
Dissatisfied (VAS <4)	9746 (10.9)	9348 (10.8)	398 (14.5)
Satisfied (≥4)	79,436 (89.1)	77,089 (89.2)	2347 (85.5)
N missing	14,3901	13,9345	4556

IQR, interquartile range; VAS, visual analogue scale; WHO, World Health Organization.
[a] Severe maternal morbidity is having any of the following (see Supplementary Table 1 for definitions based ICD diagnostic and action codes): severe haemorrhage; embolism, shock, DIC; sepsis; acute renal failure; cardiac complications; cerebrovascular; hysterectomy; surgical; severe uterine rupture; other (liver disorders in pregnancy, childbirth and the puerperium; acute appendicitis, unspecified appendicitis, peritonitis; adult respiratory distress syndrome; toxic liver disease or hepatic failure, not elsewhere classified; postpartum inversion of uterus; manual correction of inverted uterus).

thorough investigation into how travel time influences outcomes among women living in the most remote region of Sweden is warranted. While most women within the 17 regions of Sweden (we had data for) gave birth at (or within 20 min of) their closest hospital,[5] for some women there was up to 40 min difference. We also acknowledge that women with the longest distances to travel may voluntarily, or be advised to, move closer to the delivery ward when nearing their expected due date.

While the choice of categorisation of travel time is arbitrary, 96% of women in our sample had less than an hour of travel time to the delivery ward. Travel time was estimated assuming that the shortest route was taken without any stops, and while we adjusted for the season of birth to account for possibly difficult weather conditions, we cannot know whether the woman's journey was affected by other factors, such as traffic issues. We also assumed that the starting point was the woman's address, which may not have been the case, particularly for women living furthest away who had a complicated pregnancy and may have transferred closer to a hospital when nearing their due date. Despite this possible limitation, we previously found that the difference in travel time to reach the closest hospital from the woman's address vs the hospital where she gave birth was between 0 and 30 min;[5] if this were the case, our results would be biased towards the null.

Travel time to the labour ward is associated with maternal outcomes and therefore clinical management and planning access to delivery care. Uncertainty and worry about reaching the delivery ward in time may drive the association of increased odds of elective caesarean section among women with the longest travel time. These women also arrived to the delivery ward sooner and so spent more time labouring there; this may contribute to their lower risk of having a PPH or OASIS, in addition to other factors such as being younger, having a higher BMI and being Nordic born.

Author statements

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Ethical approval

Permission was obtained from the Regional Ethical Review Board in Stockholm, Sweden (dnr 2017/2385-31/5 - approved 11 January 2018). Amendments were also obtained; 2018/601-32 (approved 21 March 2018), 2020–00841 (approved 11 March 2020), and 2020–02571 (approved 23 June 2020).

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

N.H., M.A., O.S. and A.Ö. conceptualised the study, including the research question and study design. J.H. was responsible for the GIS analyses, including data collection, preparation and calculating travel times through network analysis. N.H. performed all data management and statistical analyses, with A.Ö. having direct access and verifying the underlying data reported in the article. N.H. wrote the initial draft of the article, tables and figures. All authors were involved in interpreting the results, draft revisions and contributing to and approving the final article, including revising it for critically important content. All authors had access to the data in the study and accept responsibility for the work, including the decision to submit for publication.

Data sharing

Data from the Swedish Pregnancy Register are available at (https://www.medscinet.com/gr/default.aspx). The data for this study are linked to the Swedish inpatient and outpatient registers, which is available by applying to the Swedish National Board of Health and Welfare (Socialstyrelsen). Our data are also linked to Statistics Sweden and to Lantmäteriet (the Swedish mapping, cadastral and land registration authority) to retrieve geographic coordinates.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.027.

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Original Research

Prevalence trends of metabolic syndrome in residents of postdisaster Fukushima: a longitudinal analysis of Fukushima Health Database 2012–2019

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ABSTRACT

Objectives: The study aimed to evaluate the long-term metabolic risk profiles of Fukushima residents after the Great East Japan Earthquake of March 2011.
Study design: This was a cross-sectional and a longitudinal design.
Methods: The Fukushima Health Database (FDB) contains 2,331,319 annual health checkup records of participants aged 40–74 years between 2012 and 2019. We checked the validity of the FDB by comparing the prevalence of metabolic factors with the National Database of Health Insurance Claims and Specific Health Checkups (NDB). We applied a regression analysis to determine the changes and project the trends of metabolic factors over the years.
Results: Compared to the NDB, the prevalence of metabolic factors in Fukushima was higher than the country average from 2013 to 2018, and they showed the same trends as those from the FDB. The prevalence of metabolic syndrome (MetS) increased from 18.9% in 2012 to 21.4% in 2019 (an annual increase of 2.74%) in men and from 6.8 to 7.4% (an annual increase of 1.80%) in women in Fukushima. The standardized prevalence of MetS, being overweight, and diabetes is projected to continue increasing, with disparities among subareas being higher in evacuees than in non-evacuees. An annual decrease of 0.38–1.97% in hypertension was mainly observed in women.
Conclusions: The prevalence of metabolic risk is higher in Fukushima as compared to the country average. The increasing metabolic risk in subareas, including the evacuation zone, highlights the need to control MetS in Fukushima residents.

Introduction

The Japanese government started a new health policy in 2008 by providing detailed health checkups, which were followed by specific counseling for subjects diagnosed with metabolic syndrome (MetS). Most of the trend analyses for MetS have been conducted using integrated population-based data. However, longitudinal analysis of individual information may elucidate accurate changes in health measurement,[1] which is imperative in evaluating the implementation of health policies in communities.

The Great East Japan Earthquake of March 2011 affected the health status of residents, especially in the disaster areas. The Fukushima health management surveys have reported increased cardiometabolic risks such as being overweight, obesity,[2–4] hypertension,[5–7] diabetes mellitus,[2,4] and dyslipidemia[2,4,8] in postdisaster residents. For example, the prevalence of hypertension peaked a year after the earthquake and then declined,[7] while body

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weight and waist circumference increased with deteriorating high-density lipoprotein cholesterol levels among relocated survivors for even longer than a year after the earthquake.[6] However, these studies were conducted in a cross-sectional manner or with a short follow-up time, with less information on the long-term changes in metabolic factors.[1,9]

Japan has achieved a universal health insurance coverage, and has three main types of public health insurance: Employee Health Insurance (EHI), National Health Insurance (NHI), and Late Elders' Insurance (LEI).[10] Many companies provide EHI to employed workers and their dependents. For those not covered by the EHI, for example, the self-employed, those working in agriculture, forestry, fishery, or small businesses, municipalities provide the NHI for persons ≤74 years, and LEI covers for persons ≥75 years.[10] The National Database of Health Insurance Claims and Specific Health Checkups of Japan (NDB) was open to the public for research, but the population-integrated information was limited only at the regional level.[11] The Fukushima prefectural government has built a health insurance database (FDB) with individual-specific health checkup information for registries in Fukushima prefecture.[12] Therefore, FDB can be used to carry out various studies with a longitudinal analysis approach to evaluate the health status of communities.

There are few studies on the changes in metabolic factors using insurance data in Japan,[13–19] some of which focused on the employees[13,16] or the short-term effect of special health guidance.[14,17–19] A recent study using the NDB (with individual information applied by the research purpose) reported that the MetS prevalence in people with evacuation experience increased significantly after the disaster compared to that before the disaster in Fukushima.[20] This study aimed to analyze the long-term trends of metabolic factors by the FDB between the years 2012 and 2019, and to elucidate the postdisaster health impact of people residing in Fukushima. The validity of the FDB will also be evaluated by comparing it with the NDB regarding available metabolic factors.

Methods

Study participants

The FDB includes data on annual specific health checkups and health insurance claims of the NHI, LEI, and a part of the EHI (i.e., Kyokai-Kenpo, for employees of small- to medium-sized enterprises), and covers about 70% of the residents of Fukushima Prefecture.[12] In this study, we extracted data from the NHI, Kyokai-Kenpo, and a few participants aged 65–74 years who were covered for disability by LEI (0.4%) from the FDB. The data included demographics (age, sex, and residential area), biochemistry (glucose levels, kidney function, liver function, lipid profile, and triglyceride levels), and self-administered questionnaires (22 items on medical history, alcohol consumption, physical activity, and dietary habits). The insurers' personal identities were anonymous.

Due to the radiation leakage from the damaged nuclear power plant after the Great East Japan Earthquake of March 11, 2011 (3.11 disaster), residents needed to relocate according to governmental orders. The present study evaluated the disparity of metabolic factors in the merged secondary medical areas (Aizu, Nakadori, and Hamadori areas) and evacuation areas. We defined the evacuation areas as, municipalities in 'total evacuation areas' and 'terminated/partial evacuation areas,' which included Naraha Town, Tomioka Town, Okuma Town, Futaba Town, Namie Town, Katsurao Village, Iitate Village, Date City, Tamura City, Minami-Soma City, Kawamata Town, Hirono Town, and Kawauchi Village.[21] In the evacuation areas, Date City, Kawamata Town, and Tamura City were in the Nakadori Area (Supplementary Fig. 1).

As the insurance coverage is different for participants in the NDB and FDB, we used the available data (i.e., blood pressure, body mass index [BMI], waist circumference, fasting blood glucose, hemoglobin A1c [HbA1c], high-density lipoprotein cholesterol [HDL-C], and triglycerides [TG]) for comparing the National average (means or prevalence) of metabolic factors from the NDB during 2013 and 2018.[11] We used NDB participants aged 40–74 years in 2016 as the reference population for standardization of the prevalence rates in Fukushima.

Definition of metabolic syndrome

MetS was defined according to the Japanese Diabetes Association guidelines of 2005 as follows: waist circumference ≥85 cm in men and ≥90 cm in women as well two or more of the following three parameters: 1) TG ≥150 mg/dl, HDL-C <40 mg/dl, or the use of anti-dyslipidemia medication; 2) systolic blood pressure (SBP) ≥130 mmHg, diastolic blood pressure (DBP) ≥85 mmHg, or the use of antihypertensive medication; and 3) elevated fasting blood glucose ≥110 mg/dl or the use of diabetes therapy.[22]

Statistical analysis

Age-standardized annual prevalence rates and weighted means of the selected metabolic factors of participants in the NDB were computed. Using the 2016 NDB population, age-standardized prevalence rates for participants in the FDB, including entire Fukushima and its sub-areas (i.e., the merged second medical areas and evacuation areas after the 3.11 disaster) were also calculated. Generalized linear regression models were applied to estimate the trends of metabolic prevalence (and confidence limits), with polynomial functions of three degrees for the age effect and two degrees for the period effect when fitting the models. The general estimating equation (GEE) model adjusted for repeated measurements in the same person was used to estimate the longitudinal changes in metabolic prevalence between 2012 and 2019.[1] The GEE was also applied to test for trend significance over the years, and the annual percent change (APC) and 95% confidence interval (CI) of prevalence between 2012 and 2019 was calculated.[1]

All data were analyzed using SAS statistical software ver. 9.4 for Windows (SAS Institute, Cary, NC). All P values reported were two-sided, and $P < 0.05$ was considered statistically significant.

Results

Prevalence of metabolic factors in the NDB

The standardized prevalence rates (SE) of the abnormal available metabolic factors in Fukushima Prefecture from the NDB are shown in Table 1, and the weighted means of the factors are shown in Supplementary Table 1. Both men and women had a notable increase in body weight, waist circumference, and fasting blood glucose, when the country average was compared with Fukushima between 2013 and 2018. Similar variance patterns in HDL-C and TG levels were observed. Only the prevalence of HbA1c >5.6% was lower in Fukushima than the country average; however, the prevalence of other metabolic factors was higher in the Fukushima population than the county average.

Crude prevalence of metabolic factors in the FDB

A total of 3,057,391 participants had health checkup records, and 92.12% of participants had at least two health checkups between 2012 and 2019. Of the 2,331,319 participants aged 40–74 years, 29.9% attended all annual health checkups between 2012 and 2019

Table 1
Standardized prevalence rates (SE)[a] of selected metabolic factors in participants aged 40–74 years, the NDB, 2013–2018.[b]

Sex	Factor	Area	2013	2014	2015	2016	2017	2018
Men	BMI ≥25 kg/m^2	Fukushima	35.2 (0.13)	35.1 (0.13)	35.4 (0.13)	36.3 (0.13)	37.3 (0.13)	38.2 (0.13)
		Japan	31.8 (0.02)	32.0 (0.01)	32.3 (0.01)	33.0 (0.01)	34.0 (0.01)	34.8 (0.01)
	Waist circumference ≥85 cm	Fukushima	49.2 (0.16)	49.0 (0.15)	49.1 (0.15)	49.7 (0.15)	50.6 (0.15)	51.8 (0.15)
		Japan	47.0 (0.02)	46.8 (0.02)	47.1 (0.02)	47.8 (0.02)	48.6 (0.02)	49.6 (0.02)
	SBP ≥130 mmHg	Fukushima	44.1 (0.15)	43.9 (0.14)	43.4 (0.14)	44.1 (0.14)	43.3 (0.14)	43.1 (0.13)
		Japan	40.3 (0.02)	39.9 (0.02)	39.7 (0.02)	39.8 (0.02)	40.0 (0.02)	39.9 (0.02)
	DBP ≥85 mmHg	Fukushima	27.5 (0.12)	28.0 (0.11)	27.5 (0.11)	28.7 (0.11)	29.4 (0.11)	29.6 (0.11)
		Japan	26.9 (0.01)	27.4 (0.01)	27.5 (0.01)	27.7 (0.01)	28.3 (0.01)	28.5 (0.01)
	Fasting blood glucose ≥110 mg/dl	Fukushima	20.4 (0.11)	20.4 (0.10)	20.4 (0.10)	21.0 (0.10)	21.7 (0.10)	22.1 (0.10)
		Japan	18.8 (0.01)	18.4 (0.01)	18.6 (0.01)	19.0 (0.01)	19.4 (0.01)	19.8 (0.01)
	HbA1c >5.6%	Fukushima	40.9 (0.17)	42.5 (0.17)	45.0 (0.17)	44.6 (0.17)	47.4 (0.18)	47.2 (0.17)
		Japan	44.9 (0.02)	47.1 (0.02)	48.8 (0.02)	49.4 (0.02)	50.3 (0.02)	49.7 (0.02)
	HDL cholesterol <40 mg/dl	Fukushima	9.1 (0.07)	8.7 (0.06)	8.9 (0.06)	8.7 (0.06)	8.1 (0.06)	8.0 (0.06)
		Japan	8.0 (0.01)	7.7 (0.01)	7.8 (0.01)	7.8 (0.01)	7.5 (0.01)	7.2 (0.01)
	Triglyceride ≥150 mg/dl	Fukushima	29.0 (0.12)	28.7 (0.12)	28.8 (0.11)	28.8 (0.11)	28.7 (0.11)	28.3 (0.11)
		Japan	28.4 (0.01)	28.1 (0.01)	27.8 (0.01)	27.8 (0.01)	28.0 (0.01)	27.6 (0.01)
Women	BMI ≥25 kg/m^2	Fukushima	23.9 (0.12)	23.5 (0.11)	23.7 (0.11)	24.2 (0.11)	25.0 (0.11)	25.6 (0.11)
		Japan	18.6 (0.01)	18.5 (0.01)	18.8 (0.01)	19.2 (0.01)	19.8 (0.01)	20.4 (0.01)
	Waist circumference ≥90 cm	Fukushima	16.5 (0.10)	16.5 (0.09)	16.6 (0.09)	17.1 (0.09)	17.3 (0.09)	18.0 (0.09)
		Japan	13.7 (0.01)	13.6 (0.01)	13.8 (0.01)	14.1 (0.01)	14.5 (0.01)	14.9 (0.01)
	SBP ≥130 mmHg	Fukushima	33.4 (0.13)	32.6 (0.13)	32.4 (0.13)	33.2 (0.13)	32.8 (0.12)	32.4 (0.12)
		Japan	29.6 (0.02)	29.0 (0.02)	28.8 (0.01)	28.6 (0.01)	28.8 (0.01)	28.7 (0.01)
	DBP ≥85 mmHg	Fukushima	14.6 (0.09)	14.8 (0.09)	14.7 (0.09)	15.8 (0.09)	15.8 (0.09)	15.7 (0.09)
		Japan	13.5 (0.01)	13.6 (0.01)	13.7 (0.01)	13.8 (0.01)	14.1 (0.01)	14.4 (0.01)
	Fasting blood glucose ≥110 mg/dl	Fukushima	8.7 (0.07)	8.8 (0.07)	9.0 (0.07)	9.3 (0.07)	9.4 (0.07)	9.7 (0.07)
		Japan	7.5 (0.01)	7.3 (0.01)	7.5 (0.01)	7.7 (0.01)	7.9 (0.01)	8.0 (0.01)
	HbA1c >5.6%	Fukushima	40.4 (0.18)	40.5 (0.17)	43.3 (0.18)	43.4 (0.17)	45.9 (0.18)	44.5 (0.17)
		Japan	41.5 (0.02)	43.9 (0.02)	45.3 (0.02)	46.0 (0.02)	46.9 (0.02)	46.0 (0.02)
	HDL cholesterol <40 mg/dl	Fukushima	2.0 (0.03)	1.8 (0.03)	1.7 (0.03)	1.6 (0.03)	1.5 (0.03)	1.5 (0.03)
		Japan	1.4 (0.004)	1.3 (0.003)	1.3 (0.003)	1.3 (0.003)	1.2 (0.003)	1.2 (0.003)
	Triglyceride ≥150 mg/dl	Fukushima	11.9 (0.08)	11.7 (0.08)	11.7 (0.08)	11.8 (0.08)	12.0 (0.07)	11.6 (0.07)
		Japan	11.9 (0.01)	11.5 (0.01)	11.4 (0.01)	11.5 (0.01)	11.6 (0.01)	11.4 (0.01)

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1C, hemoglobin A1C; HDL cholesterol, high-density lipoprotein cholesterol.
[a] SE, standard error.
[b] NDB, National Database of Health Insurance Claims and Specific Health Checkups of Japan; Standardized by the 2016 participants' population of the NDB.

(Table 2). The number of FDB participants increased from 254,432 (125,176 men and 129,256 women) in 2012 to 321,960 (159,267 men and 162,693 women) in 2019.

The measurement levels and crude prevalence of MetS and its component factors in men and women from the FDB are shown in Tables 3 and 4, respectively. Between 2012 and 2019, the prevalence of MetS increased from 18.9 to 21.4% in men and 6.8 to 7.4% in women. In men, BMI increased from 24.02 to 24.33 kg/m^2, fasting blood glucose increased from 103.53 to 104.83 mg/dl, and HDL-C increased from 55.81 to 57.71 mg/dl. Furthermore, the treatment need for hypertension increased from 31.0 to 34.2%, for diabetes 7.9 to 10.5%, and for dyslipidemia 12.6 to 17.7%. In women, similar patterns of increase were observed in BMI, blood glucose, and HDL-C, and the prevalence of dyslipidemia (high LDL and TG) and those in dyslipidemia therapy varied between 2012 and 2019.

The estimated prevalence rates (95% confidence limits) of metabolic factors at individual ages in men and women are shown in Fig. 1. The overall prevalence of MetS doubled at 74 years when compared to that at 40 years in both men and women. In men, it increased sharply below 60 years and then plateaued. In men, the prevalence of being overweight decreased after 45 years, which was an inverse pattern compared to women. Both the prevalence of hypertension and diabetes increased significantly with age, but the prevalence of diabetes declined after 65 years in men. The prevalence of dyslipidemia in women increased from 40 to 65 years and then declined, and in men, it increased up to 50 years and then

Table 2
Characteristics of total participants in the Fukushima Health Database, 2012–2019.

	Men	Women	All
Total participants (aged 35–108 years), *n* (%)	1,493,014 (48.83)	1,564,377 (51.17)	3,057,391 (100)
Attended at least twice annual health checkup, *n* (%)	1,381,515 (49.05)	1,435,030 (50.95)	2,816,545 (92.12)[a]
Attended all annual health checkups, *n* (%)	419,720 (51.31)	398,328 (48.69)	818,048 (26.76)[a]
Participants aged 40–74 years, *n* (%)	1,149,245 (49.3)	1,182,074 (50.7)	2,331,319 (76.25)[a]
Attended at least twice annual health checkup, *n* (%)	1,067,246 (49.53)	1,087,699 (50.47)	2,154,945 (85.03)[b]
Attended all annual health checkups, *n* (%)	358,128 (51.46)	337,773 (48.54)	695,901 (29.9)[b]

[a] Percentage among the total of 3,057,391 participants.
[b] Percentage among the total of 2,331,319 participants aged 40–74 years.

Table 3
Measurements and prevalence of metabolic factors in men aged 40–74 years, Fukushima Health Database, 2012–2019.

Metabolic factors	2012	2013	2014	2015	2016	2017	2018	2019
Metabolic syndrome, *n* (%)	20,409 (18.9)	21,841 (19.2)	23,120 (19.4)	24,274 (19.6)	25,511 (20.2)	27,424 (20.5)	30,369 (21.1)	31,430 (21.4)
BMI (kg/m^2), Mean (SD)	24.02 (3.3)	24.01 (3.4)	24.00 (3.4)	24.04 (3.4)	24.11 (3.5)	24.20 (3.5)	24.26 (3.6)	24.33 (3.6)
≥25 kg/m^2, *n* (%)	43,879 (35.1)	45,837 (34.9)	47,439 (34.8)	49,872 (35.2)	52,202 (36.0)	56,519 (37.0)	59,341 (37.7)	61,256 (38.5)
Waist circumference (cm), Mean (SD)	85.12 (9.1)	85.08 (9.0)	85.22 (9.1)	85.33 (9.4)	85.46 (9.2)	85.68 (9.4)	85.96 (9.4)	86.12 (9.5)
Men ≥85 cm, *n* (%)	62,898 (50.4)	65,636 (50.1)	68,735 (50.5)	71,742 (50.9)	74,200 (51.4)	79,460 (52.2)	83,697 (53.4)	85,038 (53.6)
SBP (mmHg), Mean (SD)	129.14 (16.0)	128.73 (15.9)	128.76 (15.9)	128.64 (15.8)	129.13 (16.4)	128.77 (16.4)	128.74 (16.3)	128.89 (16.3)
≥130 mmHg, *n* (%)	61,739 (49.3)	63,029 (48.0)	65,603 (48.1)	67,313 (47.6)	69,465 (47.9)	71,598 (46.8)	73,465 (46.7)	74,262 (46.7)
DBP (mmHg), Mean (SD)	79.26 (10.9)	78.90 (10.9)	78.83 (11.0)	78.57 (11.0)	78.70 (11.4)	78.58 (11.4)	78.55 (11.4)	78.70 (11.5)
≥85 mmHg, *n* (%)	36,484 (29.1)	36,759 (28.0)	37,849 (27.7)	38,572 (27.3)	41,372 (28.6)	43,160 (28.2)	44,248 (28.1)	45,340 (28.5)
Hypertension, *n* (%)	79,131 (63.3)	82,641 (63.0)	86,479 (63.4)	84,255 (63.1)	92,527 (63.9)	97,221 (63.6)	100,727 (64.0)	102,150 (64.2)
Hypertension therapy, *n* (%)	38,718 (31.0)	42,066 (32.1)	44,696 (32.8)	44,528 (33.4)	47,926 (33.1)	50,896 (33.3)	53,185 (33.8)	54,503 (34.2)
Fasting blood glucose (mg/dl), Mean (SD)	103.53 (24.7)	103.57 (24.3)	103.84 (23.5)	103.84 (23.6)	104.21 (23.6)	104.62 (23.9)	104.71 (24.1)	104.83 (24.1)
≥110 mg/dl, *n* (%)	23,806 (21.9)	25,537 (22.4)	27,524 (23.1)	28,848 (23.2)	30,051 (23.7)	32,860 (24.4)	35,743 (24.7)	36,798 (25.0)
HbA1c (%), Mean (SD)	5.64 (0.8)	5.68 (0.9)	5.69 (0.8)	5.72 (0.7)	5.72 (0.8)	5.75 (0.8)	5.72 (0.8)	5.74 (0.8)
>5.6%, *n* (%)	32,747 (45.0)	34,581 (45.3)	36,702 (46.6)	39,834 (49.7)	39,611 (49.4)	42,147 (52.3)	41,474 (50.3)	42,939 (52.0)
Diabetes, *n* (%)	25,480 (23.5)	27,424 (24.0)	29,573 (24.8)	30,087 (25.0)	32,334 (25.5)	35,279 (26.2)	38,423 (26.5)	39,527 (26.9)
Diabetes therapy, *n* (%)	9819 (7.9)	10,952 (8.3)	12,009 (8.8)	12,433 (9.3)	13,662 (9.4)	15,066 (9.9)	16,161 (10.3)	16,768 (10.5)
HDL cholesterol (mg/dl), Mean (SD)	55.81 (14.7)	56.22 (14.7)	56.63 (14.8)	56.67 (14.9)	56.86 (15.0)	57.50 (15.2)	57.52 (15.2)	57.71 (15.3)
<40 mg/dl, *n* (%)	12,712 (10.2)	12,629 (9.6)	12,551 (9.2)	13,132 (9.3)	13,070 (9.0)	12,703 (8.3)	13,067 (8.3)	12,810 (8.0)
LDL cholesterol (mg/dl), Mean (SD)	120.73 (31.4)	121.18 (31.5)	121.66 (31.6)	121.55 (31.7)	121.34 (31.5)	120.97 (31.3)	121.63 (31.5)	122.00 (31.6)
≥140 mg/dl, *n* (%)	32,164 (25.7)	34,560 (26.3)	36,563 (26.8)	37,744 (26.7)	38,516 (26.6)	39,776 (26.0)	42,334 (26.9)	43,302 (27.2)
Triglyceride (mg/dl), Mean (SD)	134.03 (106.3)	135.75 (110.8)	134.93 (111.6)	135.55 (111.0)	135.49 (110.9)	135.44 (112.1)	134.83 (114.2)	133.72 (109.5)
≥150 mg/dl, *n* (%)	34,844 (27.9)	37,494 (28.5)	38,200 (28.0)	40,197 (28.4)	41,267 (28.5)	43,380 (28.4)	44,126 (28.0)	44,159 (27.7)
Dyslipidemia, *n* (%)	67,946 (54.4)	72,638 (55.4)	75,734 (55.6)	74,532 (55.9)	81,383 (56.2)	85,388 (55.9)	89,918 (57.1)	91,853 (57.7)
Dyslipidemia therapy, *n* (%)	15,747 (12.6)	17,528 (13.4)	19,227 (14.1)	19,829 (14.9)	21,461 (14.8)	23,437 (15.3)	26,329 (16.7)	28,153 (17.7)

SD, standard deviation; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1C, hemoglobin A1 C; HDL cholesterol, high-density lipoprotein cholesterol; LDL cholesterol, low-density lipoprotein cholesterol.

declined. Other selected metabolic factors related to age showed a similar tendency (Supplementary Fig. 2).

Standardized prevalence rates of metabolic factors in the FDB

For the temporal trends, significantly positive coefficients for health checkup years were observed in the simple linear regression and quadratic regression for prevalence of MetS, being overweight, and diabetes (Supplementary Table 2). For convenience of comparison, the quadratic regression results of the age-standardized rates were plotted. The prevalence of MetS, being overweight, and diabetes in men as well as being overweight in women had significantly increasing temporal trends in Fukushima (Fig. 2a). The prevalence rates of metabolic component factors were higher in Fukushima (FDB 2012–2019) than those of the country average (NDB 2013–2018) in corresponding years (Supplementary Fig. 3). In addition, area disparities in the prevalence were observed—higher prevalence rates and increased tendency of

Table 4
Measurements and prevalence of metabolic factors in women aged 40–74 years, Fukushima Health Database 2012–2019.

Metabolic factors	2012	2013	2014	2015	2016	2017	2018	2019
Metabolic syndrome, *n* (%)	7721 (6.8)	8305 (6.9)	8772 (7.0)	8582 (6.6)	9519 (7.2)	10,108 (7.2)	10,749 (7.3)	11,103 (7.4)
BMI (kg/m^2), Mean (SD)	23.00 (3.6)	22.95 (3.7)	22.91 (3.7)	22.89 (3.8)	22.93 (3.8)	23.00 (3.9)	23.04 (3.9)	23.07 (4.0)
≥25 kg/m^2, *n* (%)	32,936 (25.5)	34,342 (25.3)	35,104 (25.0)	36,238 (25.0)	37,772 (25.3)	41,093 (26.0)	42,422 (26.4)	43,368 (26.7)
Waist circumference (cm), Mean (SD)	81.10 (9.9)	81.03 (10.0)	81.16 (10.0)	81.12 (10.2)	81.21 (10.1)	81.30 (10.4)	81.46 (10.3)	81.52 (10.5)
≥90 cm, *n* (%)	23,645 (18.4)	24,959 (18.4)	26,160 (18.7)	26,894 (18.6)	28,114 (18.9)	30,330 (19.2)	31,602 (19.7)	32,100 (19.8)
SBP (mmHg), Mean (SD)	124.95 (16.3)	124.52 (16.2)	124.48 (16.1)	124.44 (16.2)	124.88 (16.7)	124.57 (16.7)	124.41 (16.7)	124.62 (16.8)
≥130 mmHg, *n* (%)	51,306 (39.7)	52,362 (38.5)	53,938 (38.4)	55,163 (38.0)	57,583 (38.6)	59,704 (37.7)	59,544 (37.0)	60,658 (37.3)
DBP (mmHg), Mean (SD)	74.79 (10.5)	74.37 (10.4)	74.35 (10.5)	74.19 (10.6)	74.06 (11.0)	73.79 (11.0)	73.62 (11.1)	73.75 (11.2)
≥85 mmHg, *n* (%)	20,555 (15.9)	20,466 (15.0)	21,299 (15.2)	22,024 (15.2)	24,173 (16.2)	24,928 (15.8)	24,893 (15.5)	25,821 (15.9)
Hypertension, *n* (%)	66,453 (51.5)	69,307 (51.0)	71,831 (51.2)	65,741 (51.8)	76,914 (51.6)	80,168 (50.7)	80,577 (50.1)	81,905 (50.4)
Hypertension therapy, *n* (%)	34,826 (27.0)	37,112 (27.3)	38,459 (27.4)	35,593 (28.0)	39,622 (26.6)	40,962 (25.9)	41,619 (25.9)	41,977 (25.8)
Fasting blood glucose (mg/dl), Mean (SD)	95.67 (16.7)	95.78 (16.4)	96.16 (16.2)	96.31 (16.5)	96.64 (16.5)	96.73 (16.5)	96.90 (16.7)	97.01 (16.9)
≥110 mg/dl, *n* (%)	11,635 (10.2)	12,468 (10.3)	13,495 (10.7)	14,321 (11.0)	15,230 (11.4)	16,325 (11.6)	17,200 (11.7)	17,943 (12.0)
HbA1c (%), Mean (SD)	5.57 (0.6)	5.62 (0.6)	5.62 (0.6)	5.65 (0.6)	5.65 (0.6)	5.68 (0.6)	5.65 (0.6)	5.67 (0.6)
>5.6%, *n* (%)	40,938 (44.5)	44,860 (46.8)	46,732 (47.5)	49,744 (49.6)	51,182 (50.4)	55,703 (53.7)	52,942 (50.8)	55,130 (53.1)
Diabetes, *n* (%)	12,812 (11.2)	13,875 (11.5)	14,946 (11.9)	14,509 (12.6)	16,840 (12.6)	18,050 (12.8)	19,040 (12.9)	19,841 (13.3)
Diabetes therapy, *n* (%)	5069 (3.9)	5805 (4.3)	6285 (4.5)	6210 (4.9)	7021 (4.7)	7690 (4.9)	8114 (5.0)	8422 (5.2)
HDL cholesterol (mg/dl), Mean (SD)	64.82 (15.4)	65.45 (15.6)	65.98 (15.6)	66.42 (15.7)	66.81 (15.7)	67.66 (16.0)	67.92 (16.1)	68.16 (16.3)
<40 mg/dl, *n* (%)	3075 (2.4)	3036 (2.2)	2795 (2.0)	2792 (1.9)	2668 (1.8)	2548 (1.6)	2528 (1.6)	2479 (1.5)
LDL cholesterol (mg/dl), Mean (SD)	124.64 (30.7)	125.43 (30.7)	125.85 (31.0)	125.85 (31.3)	125.14 (30.8)	124.50 (30.8)	124.80 (30.9)	124.86 (30.9)
≥140 mg/dl, *n* (%)	37,538 (29.1)	40,584 (29.8)	42,967 (30.6)	44,429 (30.6)	44,256 (29.7)	45,697 (28.9)	47,100 (29.3)	47,741 (29.4)
Triglyceride (mg/dl), Mean (SD)	98.44 (58.7)	99.70 (59.2)	99.03 (58.9)	99.27 (60.2)	99.14 (60.1)	99.21 (61.7)	98.21 (59.9)	98.01 (60.4)
≥150 mg/dl, *n* (%)	16,809 (13.0)	18,136 (13.3)	18,722 (13.3)	19,411 (13.4)	20,006 (13.4)	21,293 (13.5)	20,990 (13.1)	20,975 (12.9)
Dyslipidemia, *n* (%)	66,395 (51.5)	71,566 (52.7)	75,070 (53.5)	68,454 (53.9)	78,759 (52.8)	82,323 (52.0)	84,512 (52.6)	86,296 (53.1)
Dyslipidemia therapy, *n* (%)	25,732 (19.9)	28,054 (20.7)	29,848 (21.3)	28,087 (22.1)	31,920 (21.4)	33,286 (21.0)	34,931 (21.7)	36,100 (22.2)

SD, standard deviation; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1C, hemoglobin A1 C; HDL cholesterol, high-density lipoprotein cholesterol; LDL cholesterol, low-density lipoprotein cholesterol.

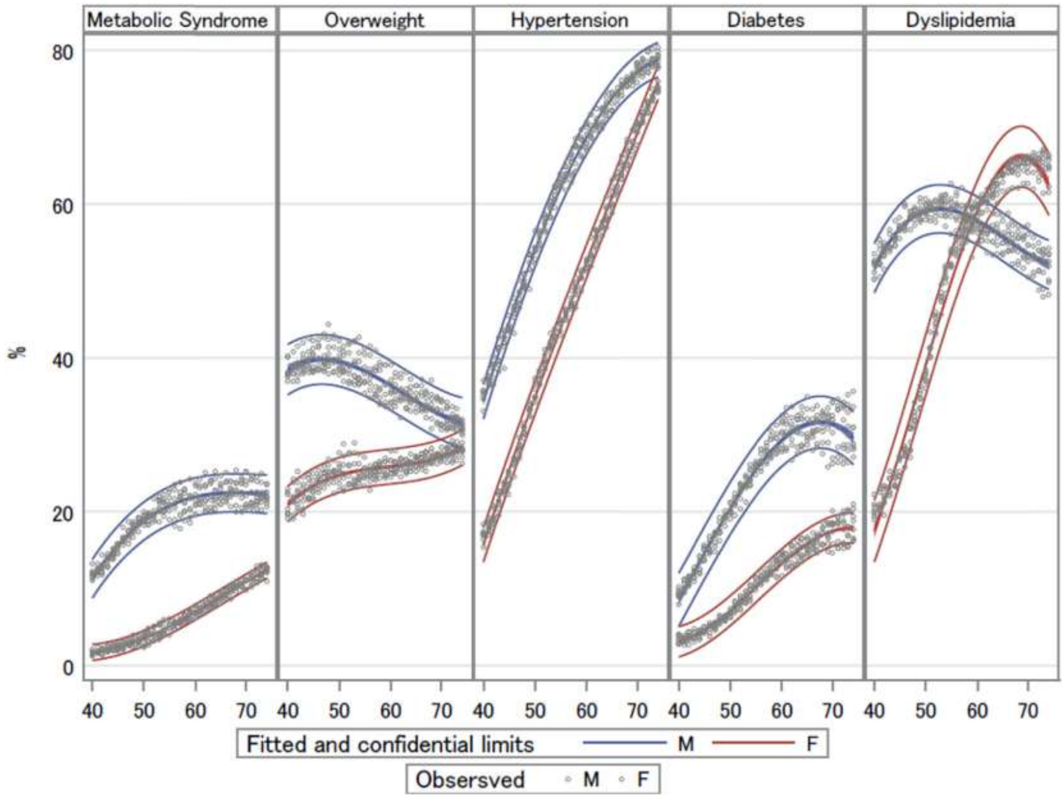

Fig. 1. Prevalence rates of metabolic syndrome and component factors by ages 40–74 years, Fukushima Health Database 2012–2019. Overweight (body mass index ≥25 kg/m^2), hypertension (systolic blood pressure ≥130 mmHg, diastolic blood pressure ≥85 mmHg, or using the antihypertension drug), diabetes mellitus (fasting blood sugar ≥110 mg/dl or using anti-diabetes drug), and dyslipidemia (high-density lipoprotein cholesterol <40 mg/dl, triglyceride ≥150 mg/dl, or using the anti-dyslipidemia drug) along with age. Curves of prevalence rates (and 95% confidence limits) were fitted by regression models with cubic function.

MetS, being overweight, diabetes, and dyslipidemia was observed in Hamadori areas, especially in men. The increasing tendency was prominent for MetS, being overweight, hypertension, and dyslipidemia in the Aizu and Nakadori areas and for diabetes in the Hamadori area (Fig. 2b).

The similar prevalence of metabolic factors and temporal trends in evacuation and non-evacuation areas were observed (Supplementary Table 2 and Fig. 3). The rates were higher in the evacuation area than in the non-evacuation area and the total area of Fukushima. A significantly increased prevalence of being overweight was observed in both quadratic and simple regression models. Both evacuated and non-evacuated residents had a significantly increased tendency for MetS, being overweight, and diabetes. Although hypertension increased in non-evacuated men but decreased in evacuated women, dyslipidemia did not increase in the evacuated and non-evacuated areas.

The highest prevalence rates of MetS, overweight, and dyslipidemia were observed in evacuation areas such as Hirono Town, Okuma Town, and Kawauchi Village. The prevalence levels of metabolic factors in partial evacuation areas such as Date City, Tamura City, and Kawauchi Village were similar to those in non-evacuation areas (Supplementary Fig. S4).

Longitudinal change of metabolic factors in the FDB

Estimated by the GEE models, the annual changes in the prevalence of MetS and the main metabolic factors are shown in Table 5. The prevalence of MetS increased by approximately 2.74% (95% CI: 2.52–2.95) in men and 1.8% (95% CI: 1.47 to 2.11) in women annually in Fukushima. Similarly, significantly increased APCs were observed with the conditions of being overweight and diabetes in both men and women. On the other hand, we only found significant decline in the prevalence of hypertension in women—0.61% in Fukushima, 0.66% in the Nakadori area, and 0.94% in the Hamadori area between 2012 and 2019.

Disparities in the APCs of metabolic factors were also observed between evacuees and non-evacuees. In men and women, evacuees and non-evacuees had approximately the same increase in APC for being overweight and diabetic, whereas non-evacuees had a higher APC for MetS than the evacuees (although APC was not significant in the evacuated women). Evacuated men (0.60%), evacuated women (1.97%), and non-evacuated women (0.38%) had decreased APCs for hypertension, but non-evacuated men had 0.91% increased prevalence for hypertension. Meanwhile, evacuated and non-evacuated men and non-evacuated women had increased APCs for dyslipidemia; however, evacuated women had a decreased APC for dyslipidemia.

Discussion

In this study, we analyzed the status and trends of metabolic factors in Fukushima between 2012 and 2019 using FDB. The analysis showed an increasing temporal propensity of MetS and its key component factors in Fukushima residents over the years, with disparities in subareas and higher levels in evacuation areas than that in non-evacuation areas. Overall, the metabolic risk status and trend analysis based on the FDB were similar to those based on the NDB. Therefore, the results indicate that the FDB is a valid database that can be used for regional health evaluations.

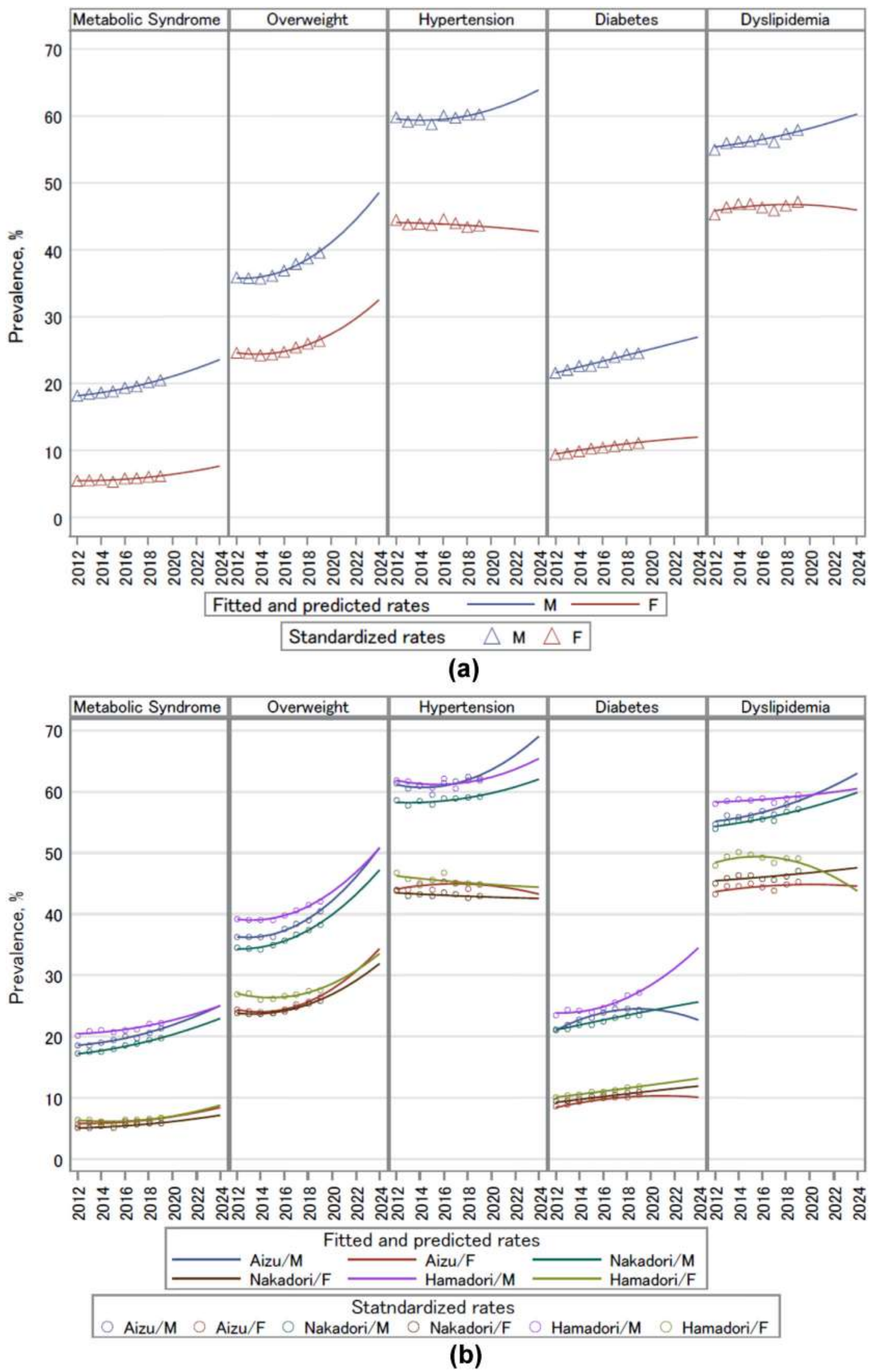

Fig. 2. Standardized prevalence rates and the projection of metabolic syndrome, being overweight, hypertension, diabetes mellitus, and dyslipidemia in the total area of Fukushima (a) and the merged secondary medical areas in Fukushima prefecture (b), Fukushima Health Database, 2012–2019 for age 40–74 years.

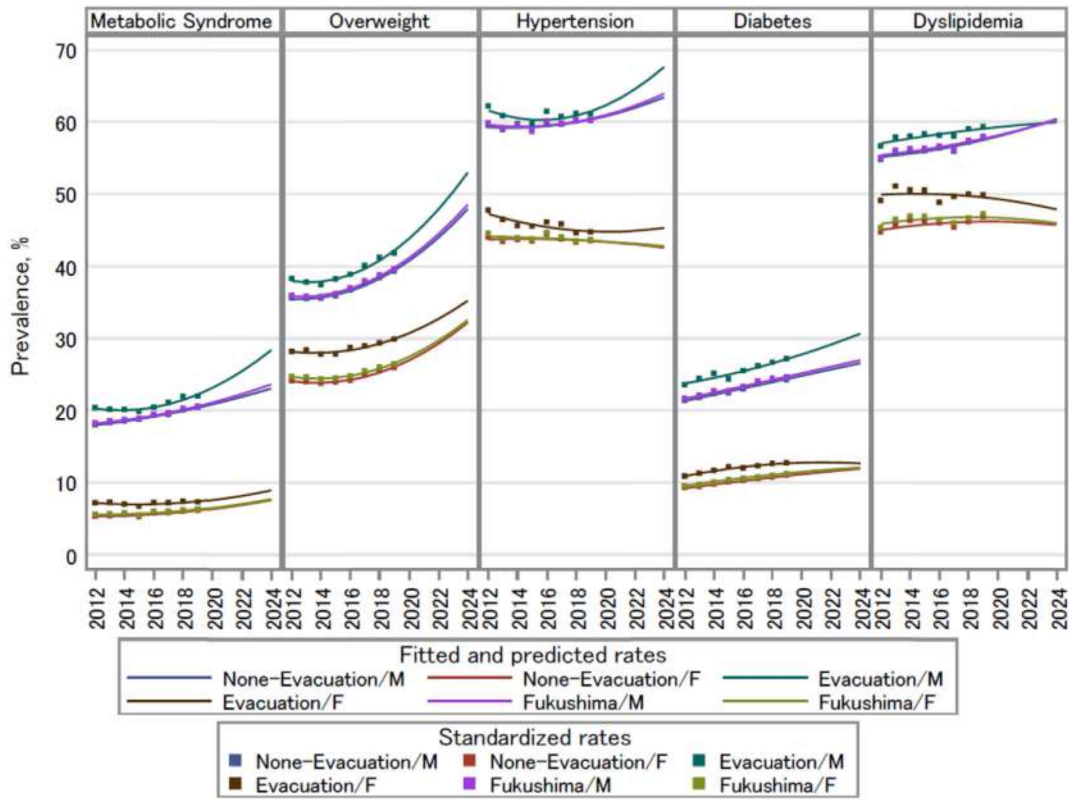

Fig. 3. Standardized prevalence rates and projections of metabolic syndrome, being overweight, hypertension, diabetes mellitus, and dyslipidemia in Fukushima's evacuation and non-evacuation areas, for age 40–74 years, Fukushima Health Database 2012–2019.

Using applied NDB with individual participants, Eguchi et al. analyzed the long-term trends of MetS prevalence between 2008 and 2017. The study demonstrated significantly increased MetS prevalence in evacuation areas than in other areas with comparisons between pre- and postdisaster periods.[20] Hashimoto et al. demonstrated that evacuation after the 3.11 disaster was associated with increased incidence of MetS in a cohort study.[2] For the Fukushima Health Management Survey, Kobari et al. recently reported that evacuation experience in men significantly affected the risk of new-onset hypertension in a 7-year follow-up after 2011.[23] Our study added evidence on MetS using a regional insurance database in Japan and highlights the consistently high metabolic risk in residents, prominently in evacuation areas, after the Great East Japan Earthquake in 2011.

The NDB was developed for surveys and analysis to facilitate, monitor, implement, and estimate health expenditure optimization plans in 2008.[11] Participants showed remarkable improvement in their metabolic risk under the special health guidance reported in the NDB study.[14] The FDB served the same purpose as the NDB, and individual health checkup information was available for conducting more detailed analyses.[24] It was observed that the specific health checkup was a voluntary participation, and the national participation rate was 55.6% in FY2019,[25] which may have been influenced by the more health-conscious individuals who participated voluntarily. Hence, the prevalence of metabolic factors reported in the NDB was lower than that reported in the National Nutrition Survey.[14,26] Furthermore, the prevalence of metabolic factors was found to be higher in Fukushima than the country's average, based on the NDB analysis. The prevalence of high HbA1C in Fukushima was lower than the country average, which might be due to the unavailability of complete data. Because of the differences in insurance coverage in the databases, the results from the FDB may not be directly compared with those from the NDB. However, the metabolic risk patterns and temporal trends were very similar in Fukushima residents in both the NDB and FDB. Owing to similarities in insurance data, we used the results of metabolic factors from the NDB as a reference, which was more realistic than the National Nutrition Survey. We believe that FDB was of good quality for elucidating and tracking the health profiles of Fukushima residents.

Aging is one of the main factors contributing to the development of MetS. MetS is associated with impairment of physical capacity and increased risk of developing physical and functional disabilities.[27] A similar aging effect was observed in a previous large Japanese cohort study in 2007.[1] However, in our study, we found that the prevalence of metabolic factors was higher in people aged 40–74 years than what was observed in the previous study,[1] with higher MetS in men aged 60 years and an earlier increase in TG levels in women from 50 years of age.[1] The aging process is complex with the spectrum of changes across multiple organs and tissues—it also begins at different times in different people and proceeds at different rates.[28] Revealing the different profiles and processes of changes in metabolic factors in men and women may help MetS control efficiently.[18]

We observed some disparity among metabolic factors in different areas of Fukushima in this study. For example, we observed an increased APC of MetS, diabetes, and dyslipidemia in men in the Aizu Area, and the increased APC of diabetes in women in the Hamadori Area. In particular, the metabolic risk was consistently higher in the evacuation area than in non-evacuation areas, although there was less increase in MetS and even a reduction in hypertension (men and women) and dyslipidemia (women) in evacuees than in non-evacuees. The disparity in metabolic risk prevalence between evacuees and non-evacuees may not be

Table 5
Annual percent change of prevalence rates of metabolic factors, Fukushima Health Database, 2012–2019.

Sex	Risk factor	Area	*n*	β (year)[a]	*P*-value	APC[b]	95% CI
Men	Metabolic syndrome	Fukushima	966,087	0.027	<0.0001	2.74	(2.52–2.95)
		Aizu Area	156,639	0.0307	<0.0001	3.12	(2.60–3.64)
		Nakadori Area	573,512	0.0285	<0.0001	2.89	(2.61–3.17)
		Hamadori Area	235,936	0.02	<0.0001	2.02	(1.61–2.44)
		Evacuation area	127,551	0.0188	<0.0001	1.90	(1.35–2.46)
		Non-evacuation area	838,536	0.0283	<0.0001	2.87	(2.64–3.10)
	Overweight	Fukushima	1,094,341	0.0256	<0.0001	2.59	(2.45–2.75)
		Aizu Area	185,162	0.0258	<0.0001	2.61	(2.27–2.95)
		Nakadori Area	648,033	0.0276	<0.0001	2.80	(2.61–2.99)
		Hamadori Area	261,046	0.201	<0.0001	2.03	(1.73–2.32)
		Evacuation area	148,274	0.0235	<0.0001	2.37	(1.98–2.77)
		Non-evacuation area	946,067	0.0260	<0.0001	2.63	(2.48–2.79)
	Hypertension	Fukushima	1,086,037	0.0073	<0.0001	0.73	(0.56–0.89)
		Aizu Area	182,732	0.0104	<0.0001	1.05	(0.63–1.45)
		Nakadori Area	643,540	0.0083	<0.0001	0.83	(0.61–1.05)
		Hamadori Area	259,765	0.0012	0.5014	0.12	(−0.23 to 0.46)
		Evacuation area	147,491	−0.0061	0.0096	−0.60	(−1.06 to −0.15)
		Non-evacuation area	938,546	0.0091	<0.0001	0.91	(0.73–1.09)
	Diabetes	Fukushima	965,396	0.0348	<0.0001	3.54	(3.37–3.73)
		Aizu Area	155,995	0.0373	<0.0001	3.80	(3.36–4.24)
		Nakadori Area	573,407	0.0337	<0.0001	3.43	(3.19–3.67)
		Hamadori Area	235,994	0.0351	<0.0001	3.57	(3.21–3.94)
		Evacuation area	127,527	0.0346	<0.0001	3.52	(3.05–3.99)
		Non-evacuation area	837,869	0.0349	<0.0001	3.55	(3.35–3.75)
	Dyslipidemia	Fukushima	1,085,700	0.0179	<0.0001	1.81	(1.65–1.96)
		Aizu Area	182,655	0.0243	<0.0001	2.46	(2.08–2.83)
		Nakadori Area	643,344	0.0188	<0.0001	1.90	(1.69–2.10)
		Hamadori Area	259,701	0.0105	<0.0001	1.06	(0.73–1.36)
		Evacuation area	147,442	0.0147	<0.0001	1.48	(1.05–1.91)
		Non-evacuation area	938,258	0.0185	<0.0001	1.87	(1.70–2.03)
Women	Metabolic syndrome	Fukushima	1,024,108	0.0178	<0.0001	1.80	(1.47–2.11)
		Aizu Area	179,534	0.0138	0.0002	1.39	(0.64–2.13)
		Nakadori Area	608,626	0.0218	<0.0001	2.20	(1.78–2.13)
		Hamadori Area	235,948	0.0107	0.0011	1.08	(0.42–1.72)
		Evacuation area	138,575	0.0057	0.1441	0.57	(−0.19 to 1.33)
		Non-evacuation area	885,533	0.0200	<0.0001	2.02	(1.67–2.37)
	Overweight	Fukushima	1,140,819	0.0153	<0.0001	1.54	(1.39–1.68)
		Aizu Area	196,025	0.0124	<0.0001	1.25	(0.89–1.60)
		Nakadori Area	676,451	0.0178	<0.0001	1.80	(1.59–1.99)
		Hamadori Area	268,343	0.0102	<0.0001	1.03	(0.72–1.32)
		Evacuation area	160,403	0.0150	<0.0001	1.51	(1.12–1.89)
		Non-evacuation area	980,416	0.0153	<0.0001	1.54	(1.38–1.71)
	Hypertension	Fukushima	1,123,096	−0.0061	<0.0001	−0.61	(−0.77 to −0.45)
		Aizu Area	193,070	−0.0009	0.6429	−0.09	(−0.46 to 0.29)
		Nakadori Area	665,274	−0.0066	<0.0001	−0.66	(−0.86 to −0.45)
		Hamadori Area	264,750	−0.0094	<0.0001	−0.94	(−1.26 to −0.62)
		Evacuation area	158,411	−0.0199	<0.0001	−1.97	(−2.38 to −1.55)
		Non-evacuation area	964,683	−0.0038	<0.0001	−0.38	(−0.55 to −0.21)
	Diabetes	Fukushima	1,013,222	0.0299	<0.0001	3.04	(2.81–3.27)
		Aizu Area	177,589	0.03	<0.0001	3.05	(2.49–3.60)
		Nakadori Area	601,973	0.0285	<0.0001	2.89	(2.59–3.20)
		Hamadori Area	233,660	0.0331	<0.0001	3.37	(2.88–3.85)
		Evacuation area	137,326	0.0311	<0.0001	3.16	(2.57–3.75)
		Non-evacuation area	875,896	0.0299	<0.0001	3.03	(2.78–3.29)
	Dyslipidemia	Fukushima	1,122,961	0.0048	<0.0001	0.48	(0.33–0.64)
		Aizu Area	193,041	0.009	<0.0001	0.90	(0.55–1.27)
		Nakadori Area	665,197	0.0054	<0.0001	0.54	(0.35–0.74)
		Hamadori Area	264,723	−0.0011	0.5174	−0.11	(−0.43 to 0.22)
		Evacuation area	158,393	−0.0054	0.0098	−0.54	(−0.95 to −0.13)
		Non-evacuation area	964,568	0.0068	<0.0001	0.68	(0.51–0.84)

[a] Regression model for the total Fukushima, adjusted for age, age square, and area. Regression models for each area, adjusted for age and age square.
[b] APC, annual percent change, presented [exp(β)−1]*100.

completely eliminated in the near future. When we conducted this analysis, more than 30,000 residents from the evacuation areas had not returned to their hometowns. The health status of those under evacuation is of continuous concern to the public. In addition, those who are not ready to improve their lifestyle-related health behavior should be motivated for enhancement, and adherence to special health guidance should be carried out in Fukushima.[19,29] One cohort study by the NDB reported that the at-risk population achieved significant reductions in waist circumference, BMI, and cardiometabolic risks within 3 years.[18] A recent study by the NDB showed that the presence/improvement of MetS was associated with a high/reduced risk of cardiovascular disease death.[30] To control MetS, further studies are needed on the mechanism of development of MetS and the cause of the variation in not only psychiatric[31] and physical[32–34] aspects but also molecular factors (e.g., visceral fat).[35,36] A healthy diet, increased physical activity, health consultations, and other means for MetS prevention in this population need to be enhanced.

FDB coverage ranged from 62.3 to 71.9% in men and 69.6 to 77.8% in women among the six secondary medical areas.[12] This might have contributed to the disparities in metabolic factors in Fukushima. It should be noted that the evacuation areas were mainly from the Hamadori area along the seashore, and non-evacuation areas were similar to the combined areas of Aizu and Nakadori. We also need to pay greater attention to the Aizu area, where the risk in men for MetS, being overweight, hypertension, and dyslipidemia was higher than that in the other two areas. Before the 3.11 disaster, the MetS prevalence was higher in mountainous (Aizu) and coastal (Hamatori) areas than in central (Nagatori) areas. After 2015, the MetS prevalence in the mountainous area was higher than that in coastal areas in women or residents aged 40–59 years.[20] Nevertheless, employment status and changes, particularly in the postdisaster stages in Fukushima, highlight the need for more studies on socio-economic profiles. Various health insurance plans to address income disparity and aging composition within the Fukushima prefecture have been advocated.[10]

The present study had some limitations. First, we did not have comprehensive data on MetS before the Great East Japan Earthquake in March 2011 as a reference; thus, we could only see the post-disaster situation[4,37] and could not evaluate as to what extent the increased metabolic risk was attributable to the disaster effect or if the status was initially high in the region before the 3.11 disaster. Second, due to different insurance coverages and less information on the employment status of the FDB limited the stratification analysis by insurance type. Therefore, some estimates may not be directly comparable to other studies, such as employee-based insurers.[13] Third, the longitudinal analysis was available for approximately 30% of the participants aged 40–74 years, who attended all the annual health checkups. Therefore, this analysis may be limited to those who are more health-conscious or have access to medical facilities, which may lead to biased estimations.[1] Fourth, the defined evacuation areas included partially evacuated areas such as Date City, Tamura City, and Kawamata Town, in which levels and trends of metabolic risk prevalence were similar to those in non-evacuation areas. Different studies may have variant definitions of evacuation areas.[2,20] Furthermore, based on the insurance registry of FDB, we could not identify residents who were never evacuated from partially evacuated areas and thus, we were unable to classify them as 'non-evacuees.' Therefore, the prevalence of metabolic factors in evacuation areas may be underestimated and may attenuate the differences between evacuation and non-evacuation areas.

In summary, we comprehensively elucidated the profiles and temporal trends of MetS and its component factors using the regional health insurance database, which is a valid database compared to the national database. Furthermore, FDB can be used to continuously and intensively monitor the health status of Fukushima residents. Furthermore, the disparity in metabolic factors, including the postearthquake evacuation zone being at a higher metabolic risk, even for the slight declining trends of hypertension prevalence, highlights the need and effort for MetS control in Fukushima in the future. The priority is to clarify the mechanisms of social, mental, psychiatric, and environmental effects on metabolic disparities in these areas.

Author statements

Ethical approval

This study was approved by the Fukushima Medical University Ethical Review Committee (Generic 2021-169).

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Competing interests

All authors have no conflict of interest to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.036.

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Racial/ethnic and income disparities in neighborhood-level broadband access in 905 US cities, 2017–2021

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ABSTRACT

Objectives: Broadband access is an essential social determinant of health, the importance of which was made apparent during the COVID-19 pandemic. We sought to understand disparities in broadband access within cities and identify potential solutions to increase urban access.
Study design: This was a descriptive secondary analysis using multi-year cross-sectional survey data.
Methods: Data were obtained from the City Health Dashboard and American Community Survey. We studied broadband access in 905 large US cities, stratifying neighborhood broadband access by neighborhood median household income and racial/ethnic composition.
Results: In 2017, 30% of urban households across 905 large US cities did not have access to high-speed broadband internet. After controlling for median household income, broadband access in majority Black and Hispanic neighborhoods was 10–15% lower than in majority White or Asian neighborhoods. Over time, lack of broadband access in urban households decreased from 30% in 2017 to 24% in 2021, but racial and income disparities persisted.
Conclusions: As an emerging social determinant, broadband access impacts health across the life course, affecting students' ability to learn and adults' ability to find and retain jobs. Resolving lack of broadband access remains an urban priority. City policymakers can harness recent infrastructure funding opportunities to reduce broadband access disparities.

Introduction

Access to fast, reliable internet ("broadband") is an important resource for obtaining essential services and information, including for health.[1] Broadband internet is widely used to access health-related resources, including remote monitoring of medical devices, delivery of healthy food from Web-based food services, and medical information.[1] Conversely, lack of broadband hinders access to essential health-related services and social services. For example, broadband access facilitates access to health care, an ability to work from home (thereby reducing exposure to COVID-19), ability to access remote learning, and other essential goods and services.[2,3] The ongoing COVID-19 pandemic has exacerbated the consequences of lack of broadband access, raising awareness of its importance, especially for racial/ethnic minority populations and in rural communities.[1,4] Despite the growing importance of broadband in daily life, a substantial number of US residents still lack access.[2,5]

Researchers have characterized city-rural differences in internet access.[2,6] Rural communities are more likely than city communities to suffer from lack of any type of internet access. In 2018, 19% of rural households still had no form of internet, compared with 14% of city households. Even fewer households had access to high-speed broadband internet services.[7] Requirements for access to high-speed broadband internet services are multifaceted, including whether or not broadband infrastructure and subscription services exist where a given household is located, whether the members of that household can afford to purchase a broadband internet subscription, whether the internet infrastructure meets the minimum speed requirement (25 Megabytes per second [download]/3 Megabytes per second [upload]) to be classified as "high-speed,"[8] whether that household can navigate how to connect to internet, and then chooses to adopt high-speed broadband internet services. This is consistent with social inclusion theories[9,10] and broadband

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access as a social determinant of health.[1,11] Many studies have attributed these disparities to the lack of investment and deployment of broadband infrastructure in rural areas.[2,6] In the 2021 infrastructure bill, $65 billion dollars were allocated to build broadband infrastructure in unserved and underserved areas, a step that should help to ameliorate infrastructure barriers to broadband connection.[12] Yet, while most US cities now have the physical infrastructure to support broadband access for all residents,[13] substantial disparities in broadband access persist within and across neighborhoods. Broadband gaps in cities are largely influenced by lack of affordability, disparities in digital literacy, and difficulties accessing broadband among populations with lower educational attainment and language barriers.[5,14] Previous research has also found evidence of profit-based discrimination in service delivery contributing to racial and geographic disparities in broadband access.[9] These factors suggest that infrastructure improvements alone may not be sufficient to eliminate disparities in broadband access for urban households.[15]

Gaps in broadband access within cities have not been as well characterized as city-rural broadband access disparities. To characterize within-city broadband access disparities across cities, and neighborhoods within them, we examined disparities in broadband access in 905 US cities (consisting of urbanized areas and urban clusters defined by Census[16]) by contrasting household median-level broadband internet access at the neighborhood level within cities (proxied by Census tract, a small, relatively permanent statistical subdivision of a county, drawn by the Census Bureau) using the data from American Community Survey (ACS), 2017–2021. To understand racial/ethnic and income disparities in broadband access, we stratified by neighborhood racial/ethnic composition and median household income. The goal of this analysis was to provide policymakers and researchers with a clear understanding of within-city disparities in broadband access to identify potential solutions to increase access and utilization.

Methods

We conducted a secondary data analysis using US Census ACS data provided by the City Health Dashboard (the Dashboard). The Dashboard includes all US cities, defined as census incorporated places and minor civil divisions with functioning governments, with a 2020 Decennial Census population of 50,000 or more ($n = 861$) and 44 additional cities with population between 2800 and 49,578. The complete list of 905 cities can be found on the Dashboard website.[17] Broadband Access, as presented on the Dashboard and calculated by ACS, is defined as the percentage of households with self-reported connections to high-speed broadband internet (including cable, fiber optic, and digital subscriber line DSL (digital subscriber line) connections).[18,19] Because ACS measured active broadband internet subscription in a household, this definition not only measured the availability of broadband infrastructure but also that the household chose and could afford to purchase broadband subscription.

The metric is reported by ACS as a percentage and presented as reported by ACS on the Dashboard. Households with only cellular data plans are excluded from this metric because cellular plans do not support the range of internet services provided by high-speed broadband.[20] We analyzed data from the years 2017–2021 for city and neighborhood broadband access.

We calculated the median percentage of households reporting broadband access at neighborhood level and further disaggregated estimates by median household income and neighborhood racial/ethnic composition. We used one-way analysis of variance to test whether the difference of broadband access across racial/ethnic groups within each income stratum is statistically significant. For median household income disaggregation, we assigned neighborhoods within cities to income quartiles (low, low to medium, medium to high, and high income) using ACS 5-year estimates (ACS variable S1901_C01_012E) relative to the other cities and neighborhoods displayed on the Dashboard. As a robustness check, we reanalyzed the data using different income cut-offs to avoid potential artifactual inferences resulting from cut-off selection (Table A2 & A3). For racial/ethnic composition disaggregation, we categorized neighborhood racial/ethnic composition by whether a racial/ethnic group comprised over half of the total population in the city/neighborhood (ACS table: DP05). Race/ethnicity categories included Asian Americans (AA), non-Hispanic Black (Black), Hispanic/Latino (Hispanic), non-Hispanic White (White), American Indian, Native Hawaiian, and other Pacific Islander (AI or NH&PI, as a single group due to low counts). Neighborhoods without an absolute majority race/ethnicity were categorized as no majority. In the “no majority” group, the average distribution of White, non-Hispanic Black, Hispanic, and AA was 35%, 20%, 28%, and 15%, respectively. As a sensitivity analysis, we also classified neighborhoods based on which racial/ethnic group had the highest population percentage, even if that percentage did not represent a majority of the city/neighborhood's population. The results of this analysis are displayed in Appendix.

Results

Across Dashboard cities, on average, three-quarters of households (76.5%) were connected to broadband internet in 2021. Income and racial/ethnicity were associated with broadband access (Table 1). The median broadband access by median household income suggested that high-income neighborhoods had the highest broadband access rate (87.2%) and low-income neighborhoods had the lowest broadband access rate (58.8%). The median broadband access by race/ethnicity group suggested that AA majority neighborhoods had the highest broadband access rate (82.3%), followed by White majority neighborhoods (81.2%) and neighborhoods with no majority race/ethnicity (76.1%). Black- and Hispanic-majority neighborhoods had the lowest broadband access rate (59% and 65.4%, respectively). At least 75% of the AA and White majority neighborhoods had higher broadband access rate than the top 25% of Black and Hispanic neighborhoods. The upper quartile of broadband access among the Black- and Hispanic-majority neighborhoods were 69.6% and 74%, respectively. In contrast, the lower quartile of broadband access among the AA and White majority neighborhoods was 73% (Fig. 1 and Table 1).

Neighborhood income quartiles and majority race distributions were highly correlated. According to Table 1, only 3% (142) of the 4479 Black predominant neighborhoods were in high-income neighborhood quartiles, and 67% (2980) were in the lowest income quantile. In contrast to Black neighborhoods, 55% (598/1093) and 36% (7123/19597) predominantly AA and White neighborhoods were considered as high-income neighborhoods, respectively. After stratifying by income, neighborhoods with majority non-White residents consistently have lower broadband access than White majority neighborhoods, including AA majority neighborhoods. Among low-income neighborhoods, the median broadband connection rate for AI and NH&PI majority neighborhoods was 51.2% (interquartile range [IQR]: 49.1, 65.9), for Black majority neighborhoods was 53.2% (IQR: 44.1, 61.9), for Hispanic-majority neighborhoods was 56.3% (IQR: 47.7, 63.9), and for AA majority neighborhoods was 56.3% (IQR: 49.4, 68.4). These numbers were considerably lower than White majority neighborhoods (65.7%; IQR: 57.6, 72.4), and neighborhoods with no majority race/ethnicity (61.8%; IQR: 53.5, 69.2). Roughly similar racial/ethnic disparities were seen in high-income neighborhoods. Overall, 73.2%

Table 1
Broadband access rates by income and majority race/ethnicity, 2017–2021.

Race/ethnicity	2017 Median (IQR)	2018 Median (IQR)	2019 Median (IQR)	2020 Median (IQR)	2021 Median (IQR)	# tracts (2020)	% change
Low income: 1st quantile (<45,250 in 2020)							
F test (P)	431.1 (<0.001)	435.6 (<0.001)	408.7 (<0.001)	337.7 (<0.001)	283.9 (<0.001)		
AI or NH&PI	36.5 (27.1, 46.7)	40.0 (30.8, 47.4)	46.3 (39.5, 51.7)	48.0 (45.7, 59.2)	51.2 (49.1, 65.9)	7	40.3
Asian	56.5 (48.8, 63.2)	54.3 (49.7, 65.2)	52.5 (46.2, 60.6)	55.0 (44.2, 65.9)	56.3 (49.4, 68.4)	86	−0.3
Black	42.4 (34.4, 50.3)	43.9 (35.5, 51.8)	45.9 (37.2, 53.8)	50.1 (40.9, 58.7)	53.2 (44.1, 61.9)	2980	25.5
Hispanic	45.7 (37.4, 54.2)	47.2 (39.1, 55.3)	49.2 (41.3, 56.8)	52.8 (44.4, 60.3)	56.3 (47.7, 63.9)	2391	23.2
No majority	52.2 (43.9, 59.1)	53.6 (45.7, 61.3)	55.2 (47.4, 62.5)	59.1 (50.6, 66.3)	61.8 (53.5, 69.2)	1887	18.4
White	57.8 (50.2, 65.0)	59.3 (51.9, 66.2)	61.0 (53.5, 67.6)	63.3 (55.7, 70.5)	65.7 (57.6, 72.4)	2323	13.7
Total	48.5 (39.0, 57.1)	49.9 (40.6, 58.8)	51.7 (42.5, 60.4)	55.9 (46.3, 64.3)	58.8 (49.5, 67.1)	9674	21.2
Low to medium income: 2nd quantile (45,250–64,395 in 2020)							
F test (P)	326.9 (<0.001)	297.9 (<0.001)	257.2 (<0.001)	226.2 (<0.001)	189.6 (<0.001)		
AI or NH&PI	59.4 (59.4, 59.4)	54.2 (54.2, 54.2)	63.2 (63.1, 65.0)	57.2 (52.4, 59.8)	57.6 (54.2, 63.2)	5	−3
Asian	68.1 (61.3, 73.1)	68.0 (62.8, 72.3)	69.6 (62.4, 74.0)	69.5 (62.8, 75.6)	70.9 (64.7, 77.2)	167	4.1
Black	60.1 (54.4, 65.9)	61.8 (55.3, 67.4)	63.4 (56.8, 69.1)	66.5 (59.2, 72.4)	68.4 (61.0, 74.7)	897	13.8
Hispanic	58.7 (51.1, 65.0)	59.9 (52.9, 66.5)	61.7 (54.8, 67.9)	64.7 (57.3, 71.1)	67.0 (60, 73.4)	2177	14.1
No majority	65.7 (59.5, 71.5)	66.6 (60.6, 72.4)	68.0 (62.0, 73.7)	71.1 (64.5, 77.2)	72.6 (66.3, 78.6)	2002	10.6
White	68.0 (62.4, 73.3)	69.2 (63.5, 74.3)	70.3 (64.7, 75.5)	72.7 (66.6, 78.3)	74.4 (68.4, 79.8)	4423	9.4
Total	64.9 (58.2, 71.0)	66.0 (59.2, 72.0)	67.3 (60.6, 73.3)	70.1 (63.2, 76.5)	71.9 (65.0, 78.1)	9671	10.8
Medium to high income 3rd quantile (64,395–90,803 in 2020)							
F test (P)	118.6 (<0.001)	121.4 (<0.001)	119.3 (<0.001)	148.9 (<0.001)	138.7 (<0.001)		
AI or NH&PI	65.9 (63.4, 70.0)	64.9 (62.4, 67.2)	64.4 (64.0, 66.9)	67.8 (65.5, 70.2)	69.0 (67.7, 75.8)	5	4.7
Asian	74.5 (69.6, 78.9)	75.2 (70.8, 79.4)	74.7 (69.0, 78.8)	75.4 (70.3, 81.2)	78.0 (71.5, 82.2)	242	4.7
Black	71.0 (64.7, 76.4)	71.6 (65.4, 76.6)	72.5 (65.7, 77.8)	73.9 (65.7, 79.8)	75.2 (67.2, 81.7)	460	5.9
Hispanic	69.7 (63.5, 75.3)	70.7 (65.1, 76.3)	72.1 (66.2, 77.1)	73.5 (67.3, 79.3)	75.1 (69.3, 80.8)	1244	7.7
No majority	75.3 (70.2, 80.1)	76.0 (71.2, 80.9)	76.7 (72.0, 81.1)	78.7 (73.4, 83.6)	79.8 (74.7, 84.8)	1993	6
White	76.5 (71.5, 81.0)	77.3 (72.4, 81.8)	78.0 (73.2, 82.5)	80.0 (74.8, 84.7)	81.1 (76.0, 85.7)	5728	6
Total	75.3 (69.8, 80.2)	76.2 (70.8, 80.9)	76.8 (71.6, 81.5)	78.7 (72.8, 83.7)	80.0 (74.3, 84.8)	9672	6.2
High income: 4th quantile (≥90,803 in 2020)							
F test (P)	60.4 (<0.001)	77.6 (<0.001)	94.5 (<0.001)	75.5 (<0.001)	72.5 (<0.001)		
AI or NH&PI	77.4 (72.6, 83.3)	74.9 (70.6, 80.4)	75.8 (72.8, 79.0)	72.6 (70.1, 75.7)	73.2 (69.4, 81.4)	8	−5.4
Asian	85.3 (80.7, 90.0)	85.7 (81.6, 89.9)	85.8 (81.1, 89.4)	86.7 (81.7, 90.7)	87.3 (82.2, 91.1)	598	2.3
Black	77.2 (70.4, 82.7)	76.8 (69.0, 83.3)	76.8 (68.7, 82.6)	79.3 (73.8, 85.3)	81.2 (74.7, 86.0)	142	5.2
Hispanic	79.7 (73.8, 84.1)	79.0 (74.5, 84.3)	79.6 (75.1, 84.9)	80.8 (74.8, 86.4)	82.3 (76.8, 87.5)	284	3.3
No majority	83.3 (78.7, 87.5)	83.4 (79.1, 87.5)	83.5 (79.4, 87.8)	85.2 (80.3, 90.0)	86.0 (81.3, 90.2)	1517	3.2
White	84.9 (80.6, 88.6)	85.4 (81.2, 89.0)	85.8 (81.9, 89.3)	86.9 (82.2, 90.6)	87.6 (83.1, 91.2)	7123	3.2
Total	84.5 (80.0, 88.4)	84.9 (80.5, 88.7)	85.3 (81.1, 89.0)	86.5 (81.5, 90.4)	87.2 (82.4, 90.9)	9672	3.2
CHDB total	70.4 (56.9, 80.5)	71.4 (58.0, 81.2)	72.4 (59.5, 81.8)	74.5 (62.4, 83.5)	76.1 (64.7, 84.5)	38,689	8.1

AI, American Indian; CHDB, City Health Dashboard; NH&PI, Native Hawaiian, and other Pacific Islander.

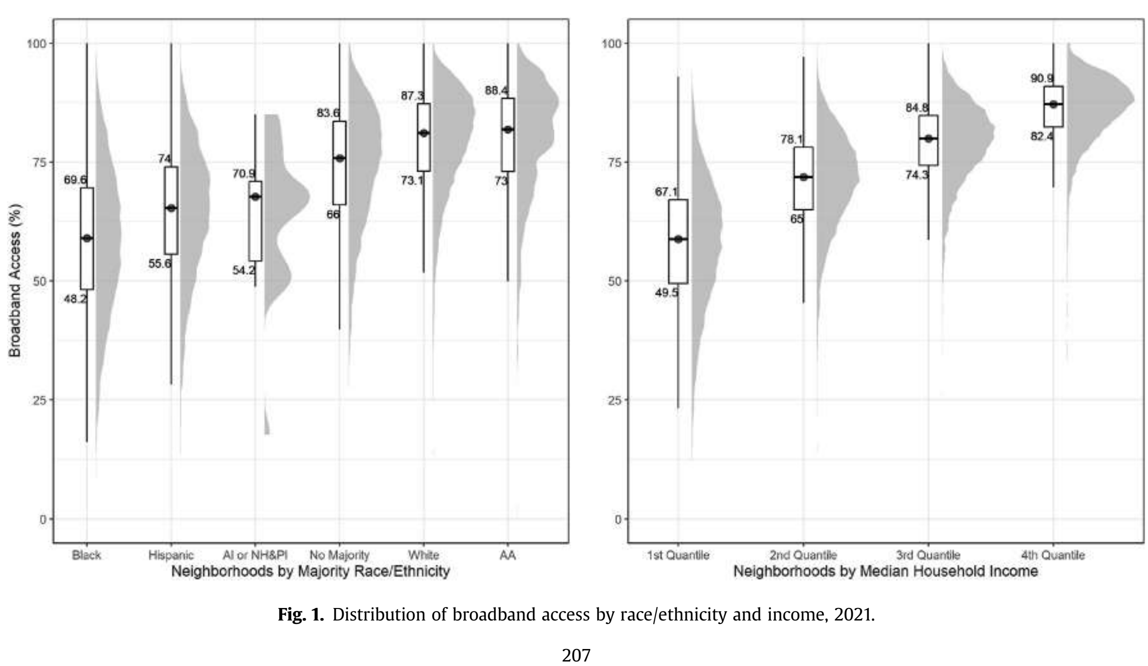

Fig. 1. Distribution of broadband access by race/ethnicity and income, 2021.

of households in AI and NH&PI majority neighborhoods, 81.2% in Black majority neighborhoods, and 82.3% in Hispanic-majority neighborhoods had broadband access, whereas 87.3% of households in AA, 87.2% of households in White majority neighborhoods, and 85.2% of the households in neighborhoods with no majority race/ethnicity group were connected to broadband internet. Differences by racial/ethnic groups are statistically significant in all income strata (Fig. 2 and Table 1). Statistical results for AI or NH&PI and AA majority should be interpreted with cautions due to small sample size (Table 1).

Between 2017 and 2021, access to broadband increased modestly, and disparities in broadband access diminished. Overall, the median broadband connection rate increased from 70.4% to 76.1% across all neighborhoods (Table 1). Broadband access increased by 15.3% in low-income neighborhoods, a faster rate than the 2.4% increase rate in high-income neighborhoods. In each income stratum, increases in broadband access were larger in Black- and Hispanic-majority neighborhoods (2–7%) than in neighborhoods with other race/ethnic compositions. Broadband access in AA majority neighborhoods fluctuated (−2.5% to 1.6%) year by year over the 5-year period (Fig. 3).

Fig. 4 shows the geographical distribution of broadband access across the 905 Dashboard cities. Generally speaking, cities in the West had higher broadband access than cities in the northeast and south. Cities in the Great Lakes region and along the southern border had the lowest broadband access among the 905 included cities.

Discussion

Four key findings emerged from our analysis of broadband access in US cities. First, in 2021, about a quarter of households in the 905 largest US cities did not have broadband access at home. Second, households in low-income neighborhoods were less likely to have broadband access compared with households in high-income neighborhoods. Third, predominantly minority neighborhoods had lower broadband access compared to White and no majority neighborhoods, regardless of income level. Our findings confirm patterns previously published by the PEW Research Center and others using smaller surveys or a more limited geographic focus.[5,9,21] Fourth, although broadband access increased only modestly between 2017 and 2021, we documented that improvements were larger in low-income and minority-predominant neighborhoods and had the effect of modestly reducing racial/ethnic and income broadband access disparities. To the best of our knowledge, this is the first article to comprehensively examine broadband access of city neighborhoods at national level.

Despite progress made over the 4-year period, our results indicate that substantial broadband access disparities persist in urban settings. Across the 905 cities analyzed, more households from low-income neighborhoods lacked access to high-speed internet than did households from high-income neighborhoods. Previous research generally ascribes lack of broadband access to an absence of broadband infrastructure, unwillingness on the part of broadband providers to invest in such infrastructure, and the cost of broadband service.[5,9] However, our data showed that at least 30% of households in low-income neighborhoods had broadband access (see the lower quartile in Fig. 1), suggesting that most of these urban neighborhoods were equipped with broadband infrastructure. Therefore, other factors, such as affordability and digital literacy, may have been the cause of low broadband adoption in these neighborhoods. Reducing the cost of broadband access, potentially through providing direct subsidies for broadband subscriptions and computer devices, could reduce disparities in broadband access.

Because of population hypersegregation by race/ethnicity, the average income of Black neighborhoods only marginally overlaps with White majority neighborhoods across our sample of 905 cities.[22] However, our findings suggest that income alone cannot explain comparatively lower broadband connection rates in Black, Hispanic, and AI or NH&PI majority neighborhoods across income

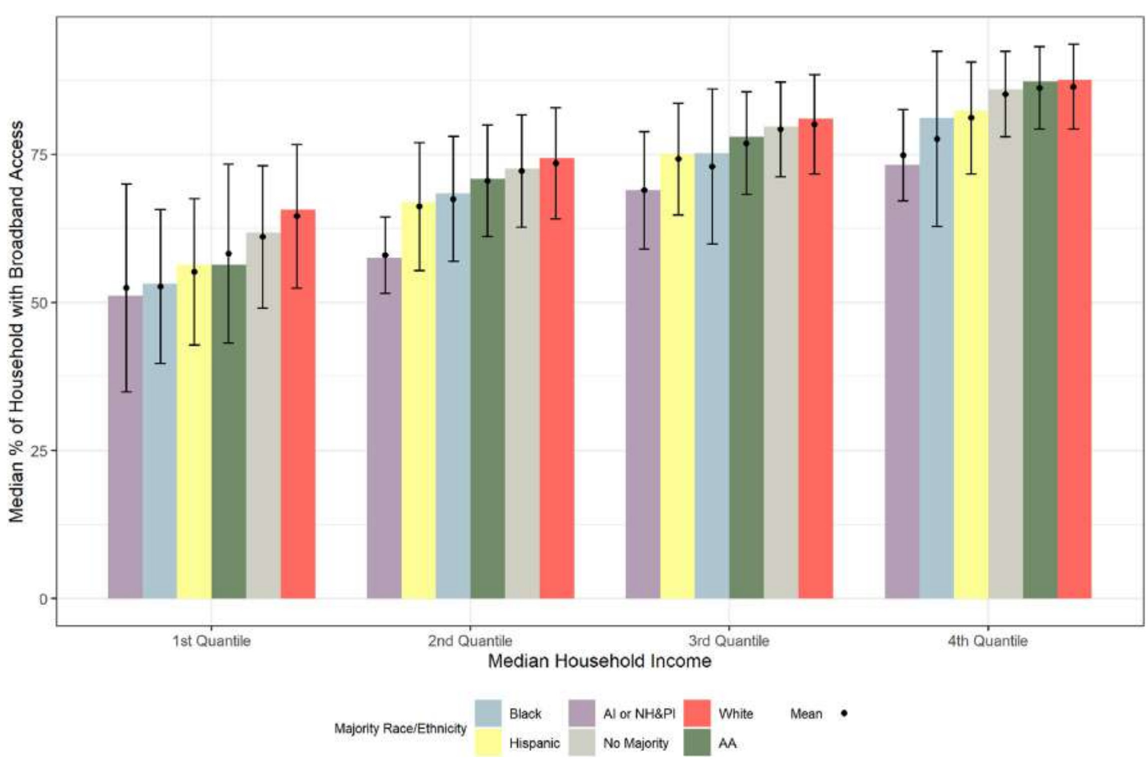

Fig. 2. Broadband access rates by Census tracts, median income, and majority race/ethnicity, 2021.

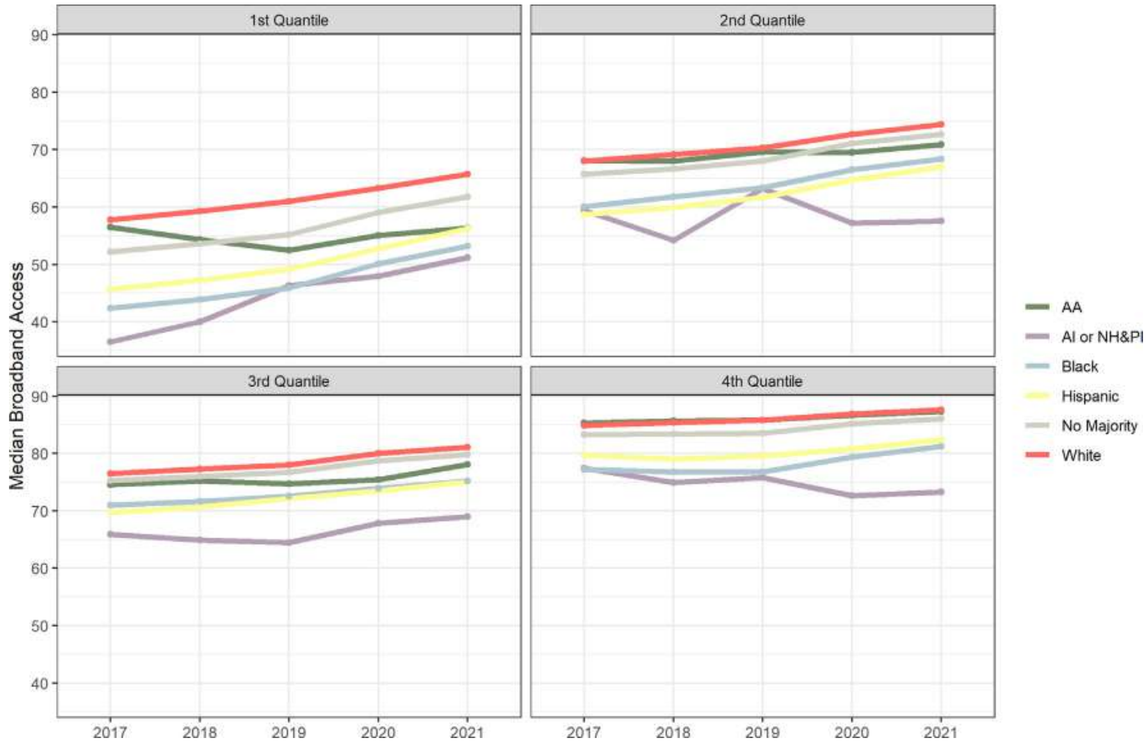

Fig. 3. Broadband access by majority race/ethnicity, stratified by income, 2017–2021.

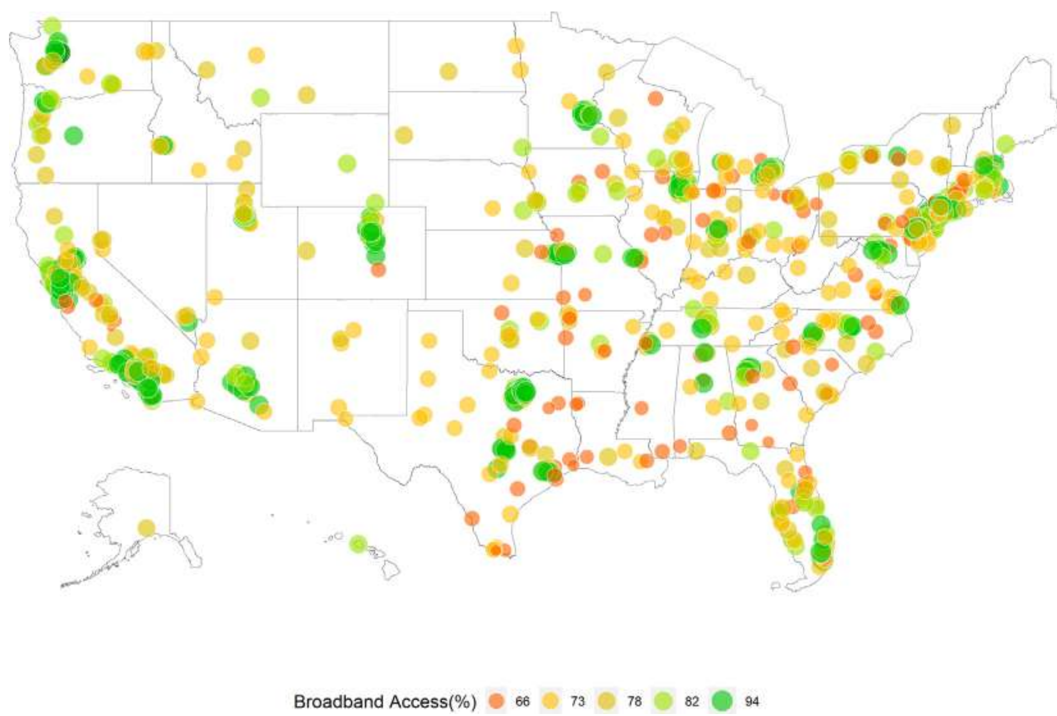

Fig. 4. Broadband access rates by city, 2021.

strata. For example, if 70% of households in a neighborhood were connected to broadband internet, that neighborhood would be more connected than three-quarters of Black- and Hispanic-majority neighborhoods in American cities, but it would be less connected than three-quarters of AA and White majority neighborhoods. This suggests significant broadband disparities by household race/ethnicity. Even among neighborhoods with high median household income, broadband access in White majority neighborhoods was 12% higher than in Black majority neighborhoods and 7.5% higher than in Hispanic-majority neighborhoods. One explanation is differences in disposable income. Even within the same income quartile, Black and Hispanic households tend to have less family wealth (e.g. savings and home ownership) than White or Asian households, which may make Black and Hispanic households more sensitive to the cost of broadband subscription.[23] In addition, in many cities, geographic broadband disparities also likely reflect a broader history of structural racism caused by disinvestment and discriminatory development and zoning practices.[24] For example, other studies have demonstrated that neighborhoods redlined more than a half-century ago have lower broadband access today.[25]

In contrast to Black neighborhoods, AA neighborhoods had the highest median broadband access rate. However, we also noticed that median broadband access in AA neighborhoods was considerably lower than White majority neighborhoods in low-income strata. The high-income AA neighborhoods drove up median broadband access rates for all AA neighborhoods and masking lower access specifically in the low-income stratum. This phenomenon further emphasizes the need for stratification in conducting social health research, especially among racial/ethnic groups that encompass a wide range of ethnic subgroups, such as AA and Hispanic populations.[24]

In response to the lessons learned from the COVID-19 pandemic, the Federal Communications Commission has launched an Advancing Broadband Connectivity as a Social Determinant of Health Initiative.[26] The task force leading the initiative acknowledges that the myriad ways in which internet adoption may influence health are not well characterized, yet correlations between broadband access and improved health outcomes are strong. The use of health-related digital tools to access health care or to seek health-related information is the best-studied route, and socioeconomic disparities in such uptake are well documented. A recent study using data from Health Information National Trends Survey found that utilization of digital health in response to COVID pandemic only increased in high-income groups.[27] A similar study also found that older people and people with low education attainment were less likely to use the internet to find healthcare provider or look for health-related information.[28] Monitoring the impacts of policy efforts to expand broadband in the post-COVID era and evaluating the subsequent impacts on health and health equity outcomes will be important steps.

There are several limitations of our study. First, ACS data are imperfect. Places with low population density may see large error margins because of sparse data (although most cities in this analysis are densely populated), and there is 2-year lag in data reporting. Methodologically, this may minimize the impact of the data lag.[9] Also, the ACS survey instrument does not collect information on the actual speed of respondents' internet connections, instead asking respondents if they have “high-speed” fixed-line internet and excluded cellular plan from the “high-speed” internet entirely. ACS also does not indicate the physical availability of broadband infrastructure. Therefore, our data cannot identify whether the lack of adoption is due to the absence of infrastructure or the cost of subscription. Second, our broadband access was measured at household level, but our racial/ethnic majority neighborhoods were measured at population level. Household broadband access rate might be higher than population broadband access rate depending on the household size in certain neighborhoods. Certain individual-level attributes, such as age, health status, and education level, cannot be analyzed because a household typically includes multiple people with various level of individual factors. Finally, due to the population distribution and residential segregation, the number of neighborhoods by different race/ethnicity group in each income stratum is unevenly distributed, especially for AI or NH&PI. Estimates from these groups should be interpreted with cautions.

Conclusion

Broadband access is an emerging social determinant of health with impacts across the life course, affecting access to information, education, health care, and other important health determinants.[29] The COVID-19 pandemic has substantially increased public understanding of the importance of broadband access. City policymakers should take advantage of recent infrastructure funding targeted at broadband access to eliminate disparities. By providing city-level maps of household broadband access for 905 large US cities, resources such as the City Health Dashboard can be used by city policymakers to target investments and interventions to close the gap in broadband access.

Author statements

Ethical approval

This work uses publicly available data and does not need any ethical approval or informed consent.

Funding

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Competing interests

The authors declare no competing interests.

Author contributions

Y.L. performed data analysis and wrote the article. T.L. and P.H. conducted the initial metric research. B.R.S., L.E.T., and M.N.G. generated the research idea and supervised the work. A.V. performed data analysis in revision. All authors reviewed and contributed to the final version of the article.

Data availability

Data are available on https://www.cityhealthdashboard.com/. All experiments were performed in accordance with relevant guidelines and regulations.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.001.

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Original Research

Risk factors for fracture by same-level falls among workers across sectors: a cross-sectional study of national open database of the occupational injuries in Japan

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ABSTRACT

Objectives: The hospitalisation rate for work-related injuries among older workers is double that of younger workers; however, the risk factors for same-level fall fractures sustained during industrial accidents remain unclear. This study aimed to estimate the influence of worker age, time of day and weather conditions on the risk of same-level fall fractures in all industrial sectors in Japan.
Study design: This was a cross-sectional study.
Methods: This study used the population-based national open database of worker death and injury reports in Japan. In total, 34,580 reports of occupational same-level falls between 2012 and 2016 were used in this study. Multiple logistic regression analysis was performed.
Results: In primary industries, workers aged ≥55 years had a 1.684 times greater risk of fracture (95% confidence interval [CI]: 1.167–2.430) compared with workers aged ≤54 years. In tertiary industries, relative to the odds ratio (OR) of injuries recorded at 0:00–2:59 a.m., the ORs recorded at 6:00–8:59 p.m., 6:00–8:59 a.m., 9:00–11:59 p.m. and 0:00–2:59 p.m. were 1.516 (95% CI: 1.202, 1.912), 1.502 (95% CI: 1.203–1.876), 1.348 (95% CI: 1.043–1.741) and 1.295 (95% CI: 1.039–1.614), respectively. The risk of fracture increased with a 1-day increase in the number of snowfall days were per month in secondary (OR = 1.056, 95% CI: 1.011–1.103) and tertiary (OR = 1.034, 95% CI: 1.009–1.061) industries. The risk of fracture decreased with every 1-degree increase in the lowest temperature in primary (OR = 0.967, 95% CI: 0.935–0.999) and tertiary (OR = 0.993, 95% CI: 0.988–0.999) industries.
Conclusions: With the increasing number of older workers and changing environmental conditions, the risk of falls in the tertiary sector industries is increasing, particularly just before and just after shift change hours. These risks may be associated with environmental obstacles during work migration. It is also important to consider the weather-associated risks of fracture.

Introduction

In Japan, the declining birth rate has resulted in a decrease in the labour force and subsequent rise in the retirement age.[1] The hospitalisation rate for work-related injuries among older workers is double that of younger workers, and many older workers are injured by falls in the Republic of Korea.[2] The Report on Occupational Injuries (≥4 days lost from work)[3] recorded 30,929 same-level fall injuries in 2020, accounting for 23.6% of all occupational injuries in Japan. A recent report by the Ministry of Health, Labour and Welfare[4] calculated that falls accounted for 22.5% of all

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0033-3506/

accidents in 2021, 60.6% of which resulted in absence from work for >1 month. The average duration of absence from work for fall-related injuries was reported to be 41.5 days, suggesting significant economic losses in Japan.[4]

In 2015, 25,949 workers experienced same-level fall injuries in Japan, accounting for 22% of all occupational injuries, an increase in both absolute counts and percentage rates compared with the 2008 values (24,792, [19.0%]).[5] Tertiary industries, specifically retail, social welfare and food service industries, have the highest rates of accidents involving same-level fall injuries, with each sub-sector accounting for 30% of all accidents.[5] Meanwhile, the manufacturing, construction and land transportation industries account for <10% of all accidents involving same-level fall injuries; however, even in these industries, the number of accidents involving falls is increasing annually.[5] A recent study has suggested that the rate of same-level fall injuries increases with age in all industrial sectors.[6] However, patterns of rate ratios and rate differences vary by age group, sex and industry.[6] Younger workers, men and manufacturing workers generally have lower rates of fall-related injuries than their counterparts.[6]

In Japan, the 12th Occupational Safety & Health Program[7] from financial year (FY) 2013 to FY 2017 was formulated by the Ministry of Health, Labour and Welfare in collaboration with occupational accident prevention organisations. The programme aimed to educate employers in the prevention of same-level fall injuries by promoting actions to reduce residual risks, such as eliminating uneven floor levels, installing handrails, ensuring appropriate lighting and encouraging physical exercise to prevent muscle deterioration in elderly workers. In addition, the increased risk of occupational accidents as a result of deteriorating physical functions and underlying diseases should be highlighted to elderly employees.[7]

The 13th Occupational Safety & Health Program[8] was formulated from FY 2018 to FY 2022. This programme promoted risk-mitigation measures that adapted to changes in the employment structure and diversified work styles. It appealed for increased awareness of the risk of fall-related injuries by senior management and implemented ‘hazard visualisation’.[8] Organisations were tasked with improving equipment through ‘hazard visualisation’ and risk assessment and improving hazard sensitivity through KY (*Kiken-Yochi*) (hazard prediction) activities.[8] This programme also called for the prevention of occupational accidents based on scientific evidence; however, the accumulation of data analysis on occupational accidents in Japan has not yet progressed.[8]

In Japan, the Occupational Safety and Health Law was revised in 2005 to make risk assessment mandatory.[9] As a safety measure in the workplace, risk assessment was introduced to Japan 20 years after its introduction in the United Kingdom. In risk assessment, hazards related to the jobs undertaken by workers are identified; risks are estimated; priorities are set to reduce the estimated risks; risk reduction measures are examined; and risk reduction measures are implemented according to the priorities.[9] Recently, world guidelines for fall prevention and management for older people[10] have been published; however, it clearly states that the population approach, including environmental design and age-friendly communities, are beyond the scope of the guidelines. Previous research indicates that the 1-year fall rate is higher among workers in the non-production section compared to those in the production section in Japan.[11]

In the workplace, the most common site for falls is the stairs, followed by tripping on a pallet.[11] Physical function measurements are not significantly associated with the occurrence of falls.[11]

An increasing number of extreme weather events has led to many studies reporting on the relationship between climate change and health hazards.[12,13] Some evidence suggests that high ambient temperatures increase the risk of occupational health problems; [14,15]however, few studies have examined the relationship between winter weather and occupational health problems. In terms of the time of the day of the same-level fall, some evidence is available in the farming sector; however, data are scarce for other sectors.[16] To the best of the authors’ knowledge, no studies investigating the relationship between environmental factors and same-level falls in the workplace have been published.

This study focused on fractures resulting from same-level fall injuries. Previous studies reported that falls with fractures occur in 6–10% of community-dwelling older adults.[17,18] To date, no studies have described fracture rates from same-level falls due to occupational injuries. A recent study has reported that older workers had higher rates of fractures than younger workers and workers overall, resulting in extended absence from work (median 32 days for workers aged 55–64 years and 42 days for workers aged ≥65 years).[19] However, there remains a lack of evidence on the factors influencing the risk of fractures from work-related same-level fall injuries. This study focused on the individual risk factor of age and also on the environmental factors of weather conditions and time of day of fall occurrence.

This study aimed to estimate the impact of age of worker, time of day and weather conditions (i.e. number of snowfall days, precipitation level, lowest temperature) on the risk of fall-related fractures in Japanese workers during the calendar year (CY) 2012 to CY 2016. To the best of the authors' knowledge, this is the first study to examine the impact of environmental factors on the incidence of fractures sustained by same-level fall injuries among workers in all industrial sectors. Furthermore, this is the first study to extract the keywords ‘fracture’, ‘broken bones’ and ‘crack of bones’ from qualitative data in the national open database and analyse it as a quantitative outcome.

Methods

Database and variables

In this study, the national open database of worker death and injury reports was used.[20] This database included data on the status of accidents, year, month and time of occurrence, size of the workplace, type of industry, causal agents and context. All database entries had qualitative information.

The type of industry was divided into 17 categories defined as follows by Occupational Safety & Health statics in Japan: (1) manufacturing, (2) mining, (3) construction, (4) transportation service, (5) cargo handling service, (6) agriculture, (7) livestock/fishery, (8) commerce, (9) financial business/advertisement, (10) movie/entertainment service, (11) telecommunication service, (12) education/research service, (13) health and hygiene service, (14) hotel/restaurant/amusement service, (15) commercial cleaning and livestock process (16) public office, and (17) others.[21] In this study, these 17 industries were classified into primary, secondary and tertiary industrial sectors as follows: primary industries (agriculture and livestock/fishery); secondary industries (manufacturing, mining and construction); and tertiary industries (transportation service, cargo handling service, commerce, financial business/advertisement, movie/entertainment service, telecommunication service, education/research service, health and hygiene service, hospitality service, commercial cleaning and livestock process, public office and others).[22]

Causal agents (i.e. agents responsible for the accident) included (1) machine; (2) crane, conveying machine; (3) other equipment; (4) temporary buildings, establishments; (5) substance, material; (6) load; (7) environment; and (8) others.[23]

Information on the context of injury was presented as text data. Qualitative analysis software (Nvivo [QSR International, Doncaster, Victoria, Australia])[24] was used to extract cases that included the word ‘fracture’, ‘broken bones’ or ‘crack of bones’ in the accident records.

Workplace size was divided into eight categories as follows: 1–9, 10–29, 30–49, 50–99, 100–299, 300–499, 500–999 and ≥1000 people.

Dummy variables were created based on age, categorising workers aged ≤54 years and those aged ≥55 years as ‘0’ and ‘1’, respectively. In Japan, the Act on Stabilisation of Employment of Elderly Persons defines older workers as those aged ≥55 years; [25] thus, in this study, older workers were also defined as those aged ≥55 years.

The time of day when the fall occurred was divided into eight categories as follows: 0:00–2:59 a.m., 3:00–5:59 a.m., 6:00–8:59 a.m., 9:00–11:59 a.m., 0:00–2:59 p.m., 3:00–5:59 p.m., 6:00–8:59 p.m. and 9:00–11:59 p.m. The reference group was 0:00–2:59 a.m.

Minimum temperature values, number of snowfall days and levels of precipitation for Tokyo were used as representative values for the whole country and were obtained from the Automated Meteorological Data Acquisition System.[26]

This study used 34,580 same-level falls from a total of 155,493 occupational injuries recorded from CY 2012 to CY 2016 in Japan. The database includes injury cases requiring ≥4 days of absence from work due to industrial accidents. One-quarter of the total number of reports were randomly selected for the original national database during data collection by the Ministry of Health, Labour and Welfare.

In the classification of occupational injury, a ‘fall’ is defined as a person slipping, tripping or falling on approximately the same level, including falls with vehicle-based machinery, among others, and excluding traffic accidents.[27] A report is submitted by the employer to the Labour Standards Inspection Office when a worker dies or loses work due to an industrial accident.[28] Even in cases when the workers' compensation insurance is not used, an injury and illness report must be completed and filed. Concealing a work-related accident is a criminal act regulated by criminal law. Article 120, Item 5 of the Safety and Health Law stipulates that failure to make a report or making a false report shall be punishable by a fine of up to 500,000 yen.[29]

Coding

Initially, one researcher independently read the data. In this study, NVivo was used to search for the words ‘fracture’, ‘broken bones’ and ‘crack of bones’ in data cells where the accident situation was described, entering a binary variable of ‘1’ if it was described and ‘0’ if not. The NVivo software was used instead of the Excel search function to increase the consistency, stability and reproducibility of the results. It was also used to save the ID numbers of the rows labelled ‘1’ (see supplementary data material S1). The retrieved data were rechecked by one researcher to ensure that there were no errors. Subsequently, two orthopaedic surgeons from the research team discussed similar codes and decided whether these were fractures or not. In this study, the validity of the results was increased by requesting the two orthopaedic surgeons to individually categorise and review cases that were not coded as fractures but may have been.

Statistical analyses

Participant characteristics are presented as means with standard deviations for continuous variables and counts with percentages for categorical variables. Descriptive variables were compared using the *t*-test and Chi-squared test. Multiple logistic regression analyses examined the association of same-level falls fractures by age of worker, time of day and weather conditions. The final model was adjusted for the year of occurrence, type of industry, causal agents and company size. All variables included in the model were dummy variables. Days of snowfall, precipitation level and lowest temperature were used as numeric variables. *P*-values <0.05 were considered statistically significant. All statistical analyses were conducted using R version 4.1.0 (R Core Team, Vienna, Austria); [30] the lme4 package was used for multiple logistic regression analysis.[31,32]

Ethical considerations

This study was based on open-source, anonymised data; therefore, the ethics board approval requirement was waived per the ethical guidelines for medical and health research involving human subjects.

Results

Descriptive statistics for 34,580 cases of same-level fall injuries divided by fracture status are presented in Table 1. Falls with fractures occur in 24.8% (8562 cases) of occupational injuries. The overall mean age of those experiencing same-level falls was 51.7 ± 13.0 years; the fracture group (53.4 ± 12.1 years old) was older than the no-fracture group (51.1 ± 13.3 years old).

Fall occurrence was most likely to occur between 9:00 a.m. and 11:59 a.m. and was least likely to occur between 0:00 a.m. and 2:59 a.m. in both the fracture and no-fracture groups (Fig. 1 and Supplementary Table S1). The mean number of snowfall days were 2.1 and 1.9 in the fracture and no-fracture groups, respectively ($P < 0.001$). The mean precipitation level was 134.0 ± 97.2 mm/month in the fracture group, which was lower than that in the non-fracture group (137.3 ± 100.4 mm/month; $P = 0.007$).

Workers employed in the tertiary industries (mean age 52.0 ± 13.0 years) were older than those employed in primary (mean age 50.4 ± 15.1 years) and secondary (mean age 50.8 ± 13.0 years) industries (see Table 2). The rates of fracture occurrence were highest from 9:00 a.m. to 11:59 a.m. and lowest from 0:00 a.m. to 2:59 a.m. in all industry groups (Fig. 1).

Impact of age of worker

The results of logistic regression analyses are presented in Table 3 (all industries) and Table 4 (industry-specific results). Models 1, 3, 4 and 5 were unadjusted, whereas Models 2, 6, 7 and 8 were adjusted for occurrence year, industry type, causal agent and company size. Workers aged ≥55 years had a higher risk of fracture as a result of same-level fall injuries than those aged ≤54 years (odds ratio [OR] = 1.310, 95% confidence interval [CI]: 1.244–1.378) overall in model 2, and primary industries (OR = 1.684, 95% CI: 1.167–2.430) in model 6, secondary (OR = 1.184, 95% CI: 1.069–1.312) industries in model 7 and tertiary industries (OR = 1.341, 95% CI: 1.263–1.424) in model 8.

Impact of time of day

Relative to the OR of injury recorded at 0:00–2:59 a.m., the ORs recorded at 6:00–8:59 a.m., 6:00–8:59 p.m., 0:00–2:59 p.m., 3:00–5:59 p.m. and 9:00–11:59 a.m. were 1.435 (95% CI: 1.183–1.741), 1.411 (95% CI: 1.151–1.729), 1.273 (95% CI: 1.051, 1.542), 1.235 (95% CI: 1.019, 1.496) and 1.234 (95% CI: 1.021, 1.490), respectively (Table 3). In the primary and secondary industries, the time of day did not impact the risk of fracture (Table 4). In tertiary

Table 1
Descriptive statics of same-level fall injuries.

Variable	All	Fracture		P-value
		No	Yes	
	n = 34,580	n = 26,018	n = 8562	
Age (years), mean (SD)	51.7 (13.0)	51.1 (13.3)	53.4 (12.1)	< .001
Occurrence year, n (%)				< .001
CY 2012	6979 (20.2%)	5142 (19.8%)	1837 (21.5%)	
CY 2013	6878 (19.9%)	5346 (20.5%)	1532 (17.9%)	
CY 2014	7005 (20.3%)	4465 (17.2%)	2540 (29.7%)	
CY 2015	6672 (19.3%)	5463 (21.0%)	1209 (14.1%)	
CY 2016	7046 (20.4%)	5602 (21.5%)	1444 (16.9%)	
Occurrence month, n (%)				<.001
January	3789 (11.0%)	2820 (10.8%)	969 (11.3%)	
February	3572 (10.3%)	2483 (9.5%)	1089 (12.7%)	
March	3030 (8.8%)	2306 (8.9%)	724 (8.5%)	
April	2568 (7.4%)	1946 (7.5%)	622 (7.3%)	
May	2541 (7.3%)	2025 (7.8%)	516 (6.0%)	
June	2480 (7.2%)	1988 (7.6%)	492 (5.7%)	
July	2612 (7.6%)	1955 (7.5%)	657 (7.7%)	
August	2546 (7.4%)	1959 (7.5%)	587 (6.9%)	
September	2442 (7.1%)	1878 (7.2%)	564 (6.6%)	
October	2698 (7.8%)	2062 (7.9%)	636 (7.4%)	
November	2968 (8.6%)	2219 (8.5%)	749 (8.7%)	
December	3334 (9.6%)	2377 (9.1%)	957 (11.2%)	
No. of days of snowfall, mean (SD)	1.9 (1.6)	1.9 (1.5)	2.1 (1.8)	<.001
Precipitation level in mm/month, mean (SD)	136.5 (99.6)	137.3 (100.4)	134.0 (97.2)	0.007
No. of employees in organisation, n (%)				<.001
1–9	5076 (14.7%)	3737 (14.4%)	1339 (15.6%)	
10–29	8100 (23.4%)	6028 (23.2%)	2072 (24.2%)	
30–49	5022 (14.5%)	3736 (14.4%)	1286 (15.0%)	
50–99	5550 (16.0%)	4286 (16.5%)	1264 (14.8%)	
100–299	6653 (19.2%)	5046 (19.4%)	1607 (18.8%)	
300–499	1890 (5.5%)	1453 (5.6%)	437 (5.1%)	
500–999	1258 (3.6%)	963 (3.7%)	295 (3.4%)	
≥1000	601 (1.7%)	447 (1.7%)	154 (1.8%)	
NA	430 (1.2%)	322 (1.2%)	108 (1.3%)	
Occurrence time of day, n (%)				<.001
0:00 a.m. to 2:59 a.m.	751 (2.2%)	599 (2.3%)	152 (1.8%)	
3:00 a.m. to 5:59 a.m.	1669 (4.8%)	1260 (4.8%)	409 (4.8%)	
6:00 a.m. to 8:59 a.m.	5047 (14.6%)	3660 (14.1%)	1387 (16.2%)	
9:00 a.m. to 11:59 a.m.	10,216 (29.5%)	7752 (29.8%)	2464 (28.8%)	
0:00 p.m. to 2:59 p.m.	6550 (18.9%)	4943 (19.0%)	1607 (18.8%)	
3:00 p.m. to 5:59 p.m.	6659 (19.3%)	5066 (19.5%)	1593 (18.6%)	
6:00 p.m. to 8:59 p.m.	2542 (7.4%)	1873 (7.2%)	669 (7.8%)	
9:00 p.m. to 11:59 p.m.	1146 (3.3%)	865 (3.3%)	281 (3.3%)	
Type of industry, n (%)				<.001
Manufacturing industry	6184 (17.9%)	4615 (17.7%)	1569 (18.3%)	
Mining industry	34 (0.1%)	24 (0.1%)	10 (0.1%)	
Construction industry	2029 (5.9%)	1560 (6.0%)	469 (5.5%)	
Transportation	3282 (9.5%)	2536 (9.7%)	749 (8.7%)	
Cargo handling business	332 (1.0%)	271 (1.0%)	61 (0.7%)	
Agriculture and forestry	511 (1.5%)	404 (1.6%)	107 (1.2%)	
Livestock and fisheries	371 (1.1%)	317 (1.2%)	54 (0.6%)	
Trade	6932 (20.0%)	4943 (19.0%)	1989 (23.2%)	
Finance and advertising	621 (1.8%)	442 (1.7%)	179 (2.1%)	
Film and theatre industry	18 (0.1%)	12 (0.1%)	6 (0.1%)	
Communications industry	770 (2.2%)	621 (2.4%)	149 (1.8%)	
Education and research industry	430 (1.2%)	302 (1.2%)	128 (1.5%)	
Health and hygiene industry	4489 (13.0%)	3545 (13.6%)	944 (11.0%)	
Hospitality and entertainment industry	3330 (9.6%)	2488 (9.6%)	842 (9.8%)	
Cleaning and slaughtering	2354 (6.8%)	1723 (6.6%)	631 (7.4%)	
Government offices	41 (0.1%)	27 (0.1%)	14 (0.2%)	
Other	2852 (8.2%)	2188 (8.4%)	646 (7.8%)	
Causal agents, n (%)				<.001
Machine	264 (0.89%)	209 (0.8%)	55 (0.6%)	
Crane, conveying machine	2160 (6.2%)	1732 (6.7%)	428 (5.0%)	
Other equipment	4095 (11.8%)	3132 (12.0%)	963 (11.2%)	
Temporary buildings, establishments	21,832 (63.1%)	16,306 (62.7%)	5526 (64.5%)	
Substance, material	825 (2.4%)	637 (2.4%)	188 (2.2%)	
Load	896 (2.6%)	700 (2.7%)	196 (2.3%)	
Environment	2925 (8.5%)	2089 (8.0%)	836 (9.8%)	
Others	1583 (4.6%)	1213 (4.7%)	370 (4.3%)	

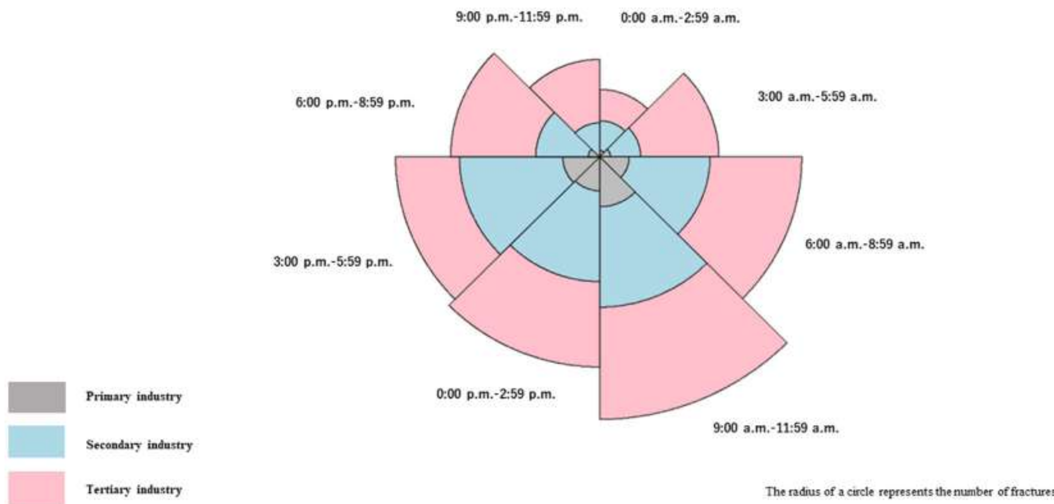

Fig. 1. Occurence time and the number of fractures.

industries, compared with 0:00–2:59 a.m., time slots 6:00–8:59 p.m., 6:00–8:59 a.m., 9:00–11:59 p.m., 0:00–2:59 p.m. and 9:00–11:59 a.m. had ORs of 1.516 (95% CI: 1.202–1.912), 1.502 (95% CI: 1.203–1.876), 1.348 (95% CI: 1.043–1.741), 1.295 (95% CI: 1.039–1.614) and 1.282 (95% CI: 1.032–1.592), respectively.

Impact of weather conditions

Overall, for every 1-day increase in the number of days of snowfall, the risk of fractures increased (OR = 1.040, 95% CI: 1.018–1.063) in Table 3. A similar association was observed in secondary (OR = 1.056, 95% CI: 1.011–1.103) and tertiary (OR = 1.034, 95% CI: 1.009–1.061) industries (Table 4); however, this association was not present in primary industries. The level of precipitation did not affect fracture risk in any of the subgroups. Overall, a 1-degree increase in the lowest temperature was associated with a decreased risk of fracture (OR = 0.994, 95% CI: 0.989–0.998); a similar association was observed in primary (OR = 0.967, 95% CI: 0.935–0.999) and tertiary industries (OR = 0.993, 95% CI: 0.988–0.999), although this association was not observed in the secondary industries.

Discussion

This study presents preliminary evidence on the risk factors for fractures by same-level fall injuries. These findings may be used to develop public and occupational health policies aimed at reducing the rates of such injuries in older adult workers in all industrial sectors. The method used to calculate the number of fractures (i.e. qualitatively analysing data on accident circumstances in the occupational accident database) is new and expands the possibilities for future research.

This study has shown that worker age, time of day, number of snowfall days and lowest temperatures were risk factors for fractures by same-level fall injuries after adjusting for the year of occurrence, type of industry, causal agents and company size. Workers aged ≥55 years and who were employed in primary sector industries had a 1.6-fold higher risk of fractures than their counterparts. In Japan, primary sector companies are often family owned, and as there is no retirement age, employees can continue working as long as they are able-bodied. As the overall number of workers in these industries is declining due to a decrease in the number of young people taking over family businesses, measures to prevent fractures are important because older workers may remain in the workforce longer. A previous study reported that no associations existed between physical capacity and the experience of occupational falls among middle-aged and older Thai farmers.[16] It should be highlighted that the mechanisms for the increased incidence of falls remain unclear.

The number of occupational accidents in Japan has been decreasing since the Occupational Safety and Health Act was enacted in 1972; however, it has been increasing since 2010,[33] partly due to the growth of the tertiary industry (commerce, catering, health and hygiene, among others).[34] The present study showed that 24.8% of same-level falls in occupational accidents resulted in fractures. This rate is higher than in studies of older people living in the community.[17,18] Falls reported as occupational injuries are likely to be serious injuries. Fall prevention is important, especially as there is a growing number of older adult workers. A recent study in Japan reported that the annual risk assessment questionnaires for falls have potentially contributed to fall prevention programmes in the workplace.[27,35] The physical, mental and cognitive changes associated with the ageing of older workers must be considered as a risk factor for occupational falls. Previous studies on the risk factors for falls were conducted in older community-dwelling adults; these studies should be expanded to include workers.[35,36]

Workers who have experienced a fall in the workplace should be asked about the details of the event, its consequences and previous falls, following the world guidelines for fall prevention and management for older adults.[10] A recent study showed that clinicians cannot rely solely on older adults reporting falls, as many do not report these events for a variety of reasons.[37] This is particularly true for men, with less than one-third mentioning the reasons of the fall to their clinician if not asked directly.[38] Currently, the risk assessment implementation support systems of the Ministry of Health, Labour and Welfare that are available on the Web site are only for 30 specific operations in the manufacturing and construction industries. The introduction of risk assessment in all industries in the future is necessary.[39]

Previously, public health has focused on fall prevention for older adults living in the community, but now older workers need to be included within the scope of this research. Workers and community-dwelling older adults should be recommended fall prevention exercise programmes. As older workers are often not at home during the day, they do not participate in community public health efforts; therefore, developing programmes that can be undertaken in the workplace is necessary. E-learning materials related to fall injury prevention should also be created.

Table 2
Descriptive statics of same-level fall injuries divided by industrial structure.

Variable	Primary industry	Secondary industry	Tertiary industry	*P*-value
	n = 882	*n* = 8247	*n* = 25,451	
Age (years), mean (SD)	50.4 (15.1)	50.8 (13.0)	52.0 (13.0)	<.001
Occurrence year, *n* (%)				<.001
CY 2012	186 (21.1%)	1752 (21.2%)	5041 (19.8%)	
CY 2013	184 (20.9%)	1632 (19.8%)	5062 (19.9%)	
CY 2014	178 (20.2%)	1661 (20.1%)	5166 (20.3%)	
CY 2015	166 (18.8%)	1549 (18.8%)	4657 (19.5%)	
CY 2016	168 (19.0%)	1653 (20.0%)	5225 (20.5%)	
Occurrence month, *n* (%)				<.001
January	74 (8.4%)	853 (10.3%)	2862 (11.2%)	
February	75 (8.5%)	879 (10.7%)	2618 (10.3%)	
March	72 (8.2%)	742 (9.0%)	2216 (8.7%)	
April	69 (7.8%)	605 (7.3%)	1894 (7.4%)	
May	71 (8.0%)	600 (7.3%)	1870 (7.3%)	
June	76 (8.6%)	603 (7.3%)	1801 (7.1%)	
July	75 (8.5%)	622 (7.5%)	1915 (7.5%)	
August	69 (7.8%)	608 (7.4%)	1869 (7.3%)	
September	65 (7.4%)	560 (6.8%)	1817 (7.1%)	
October	79 (9.0%)	613 (7.4%)	2006 (7.9%)	
November	80 (9.1%)	778 (9.4%)	2110 (8.3%)	
December	77 (8.7%)	784 (9.5%)	2473 (9.7%)	
No. of days of snowfall, mean (SD)]	0.7 (1.4)	0.9 (1.5)	0.9 (1.6)	<.001
Precipitation level in mm/month, mean (SD)	140.3 (99.4)	135.0 (97.3)	136.8 (100.3)	0.172
No. of employees in organisation, *n* (%)				<.001
1–9	400 (45.4%)	1826 (22.1%)	2850 (11.2%)	
10–29	262 (29.7%)	1915 (23.2%)	5923 (23.3%)	
30–49	99 (11.2%)	1021 (12.4%)	3092 (15.3%)	
50–99	73 (8.3%)	1108 (13.4%)	4369 (17.2%)	
100–299	28 (3.2%)	1404 (17.0%)	5221 (20.5%)	
300–499	7 (0.8%)	452 (5.5%)	1431 (5.6%)	
500–999	1 (0.1%)	287 (3.5%)	970 (3.8%)	
≥1000	4 (0.5%)	143 (1.7%)	454 (1.8%)	
NA	8 (0.9%)	91 (1.1%)	331 (1.3%)	
Occurrence time of day, *n* (%)				<.001
0:00 a.m. to 2:59 a.m.	9 (1.0%)	160 (1.9%)	582 (2.3%)	
3:00 a.m. to 5:59 a.m.	42 (4.8%)	208 (2.5%)	1419 (5.6%)	
6:00 a.m. to 8:59 a.m.	148 (16.8%)	1163 (14.1%)	3736 (14.7%)	
9:00 a.m.-11:59 a.m.	332 (37.6%)	2543 (30.8%)	7341 (28.8%)	
0:00 p.m. to 2:59 p.m.	167 (18.9%)	1597 (19.4%)	4786 (18.8%)	
3:00 p.m. to 5:59 p.m.	169 (19.2%)	1952 (23.7%)	4538 (17.8%)	
6:00 p.m. to 8:59 p.m.	11 (1.2%)	461 (5.6%)	2070 (8.1%)	
9:00 p.m. to 11:59 p.m.	4 (0.5%)	163 (2.0%)	979 (3.8%)	
Type of industry, *n* (%)				<.001
Manufacturing industry	0 (0.0%)	6184 (75.0%)	0 (0.0%)	
Mining industry	0 (0.0%)	34 (0.4%)	0 (0.0%)	
Construction industry	0 (0.0%)	2029 (24.6%)	0 (0.0%)	
Transportation	0 (0.0%)	0 (0.0%)	3282 (12.9%)	
Cargo handling business	0 (0.0%)	0 (0.0%)	332 (1.3%)	
Agriculture and forestry	511 (1.5%)	0 (0.0%)	0 (0.0%)	
Livestock and fisheries	371 (1.1%)	0 (0.0%)	0 (0.0%)	
Trade	0 (0.0%)	0 (0.0%)	6932 (27.2%)	
Finance and advertising	0 (0.0%)	0 (0.0%)	621 (2.4%)	
Film and theatre industry	0 (0.0%)	0 (0.0%)	18 (0.1%)	
Communications industry	0 (0.0%)	0 (0.0%)	770 (3.0%)	
Education and research industry	0 (0.0%)	0 (0.0%)	430 (1.7%)	
Health and hygiene industry	0 (0.0%)	0 (0.0%)	4489 (17.6%)	
Hospitality and entertainment industry	0 (0.0%)	0 (0.0%)	3330 (13.1%)	
Cleaning and slaughtering	0 (0.0%)	0 (0.0%)	2354 (9.2%)	
Government offices	0 (0.0%)	0 (0.0%)	41 (0.2%)	
Other	0 (0.0%)	0 (0.0%)	2852 (11.2%)	
Causal agents, *n* (%)				<.001
Machine	19 (2.2%)	169 (2.0%)	76 (0.3%)	
Crane, conveying machine	102 (11.6%)	298 (3.6%)	1760 (6.9%)	
Other equipment	69 (7.8%)	1157 (14.0%)	2869 (11.3%)	
Temporary buildings, establishments	319 (36.2%)	5180 (62.8%)	16,333 (64.2%)	
Substance, material	31 (3.5%)	450 (5.5%)	344 (1.4%)	
Load	17 (1.9%)	219 (2.7%)	660 (2.6%)	
Environment	301 (34.1%)	521 (6.3%)	2103 (8.3%)	
Others	24 (2.7%)	253 (3.1%)	1306 (5.1%)	

Table 3
Odds ratios obtained from multiple logistic models (all industries).

Variable	All industries (N = 34,580)	
	Model 1[a]	
	Odds ratio (95%CI)	***P*-value**
Occurrence time of day		
0:00 a.m. to 2:59 a.m.	1 (Reference)	
3:00 a.m. to 5:59 a.m.	1.279 (1.037, 1.578)	0.022
6:00 a.m. to 8:59 a.m.	1.493 (1.237, 1.803)	<0.001
9:00 a.m. to 11:59 a.m.	1.253 (1.042, 1.505)	0.016
0:00 p.m. to 2:59 p.m.	1.281 (1.063, 1.544)	0.009
3:00 p.m. to 5:59 p.m.	1.239 (1.028, 1.494)	0.024
6:00 p.m. to 8:59 p.m.	1.408 (1.154, 1.717)	<0.001
9:00 p.m. to 11:59 p.m.	1.280 (1.024, 1.600)	0.030
	Model 2[a]	
	Odds ratio (95%CI)	***P*-value**
Occurrence time of day		
0:00 a.m. to 2:59 a.m.	1 (Reference)	
3:00 a.m. to 5:59 a.m.	1.099 (0.884, 1.366)	0.394
6:00 a.m. to 8:59 a.m.	1.435 (1.183, 1.741)	<0.001
9:00 a.m. to 11:59 a.m.	1.234 (1.021, 1.490)	0.029
0:00 p.m. to 2:59 p.m.	1.273 (1.051, 1.542)	0.014
3:00 p.m. to 5:59 p.m.	1.235 (1.019, 1.496)	0.031
6:00 p.m. to 8:59 p.m.	1.411 (1.151, 1.729)	<0.001
9:00 p.m. to 11:59 p.m.	1.236 (0.983, 1.555)	0.069
No. of days of snowfall	1.040 (1.018, 1.063)	<0.001
Precipitation (mm/month)	1.000 (1.000, 1.000)	0.338
Minimum temperature (°C)	0.994 (0.989, 0.998)	0.008
Age		
≦54 years old	1 (Reference)	
≧55 years old	1.310 (1.244, 1.378)	<0.001

CI, confidence interval.
[a] Model 1 was unadjusted; Model 2 was adjusted for occurrence year, industry type, causal agent and company size.

Analysis of the time of day of falls revealed higher risks of fractures between 6:00–8:59 p.m., 6:00–8:59 a.m., 9:00–11:59 p.m., 0:00–2:59 p.m. and 9:00–11:59 a.m. compared with 0:00–2:59 a.m. in tertiary industries. The significant differences in risk of fractures due to the time of the day seen in the tertiary industry were not found in primary or secondary industries. These may be the hours during which employees in the tertiary industry change shifts. A recent study suggests that shift work is related to a higher rate of occupational injuries and accidents.[40] There is evidence that occupational injury rates are higher at night than during the daytime.[40] One study showed that injuries among healthcare workers occurred more frequently during the morning shift.[41] A recent review conducted in the rail industry in Australia found that shift durations >12 h are associated with a doubled increased risk of accidents and injuries.[42] Although there was no information in the database used in this study on whether or not a person was a shift worker, this is a characteristic found only in the tertiary industries, which has seen an increase in the number of employees in recent years. It is important to inform people of the times when the risk of falls and fractures increases to prevent them from falling and enduring fractures.

The impact of weather conditions on the risk of fractures should also be considered. Evidence from the United Kingdom suggests that extremely snowy and icy weather may double the risk of fractures compared with the risk in less snowy conditions.[43] A previous study evaluated the association between official weather warnings during the winter season and fall-related injury rates among older adults between 1998 and 2006.[32] The authors found a 20% increase in fall-related injuries when hazardous freezing rain warnings were issued, with a notable increase (31%) for men. In addition, the authors found an overall reduction in fall-related injuries on days with snowfall warnings.[44] A recent study has shown that the overall risk of fractures during snowy and icy conditions is 2.20 (95% CI: 1.7–3.0; $P < 0.01$) compared with that during control conditions.[45] It could be postulated that the group who are younger are more likely to continue with outdoor activities and therefore be subject to the risks associated with snowy and icy conditions.[43] A similar finding was reported in the Netherlands.[33] Another study reported that inclement weather, where the outdoor areas are covered with ice or snow, often increases the prevalence of slip-induced falls, unless appropriate precautions are taken.[46] In the present study, the risk of fracture by same-level falls decreased with minimum temperature increase and increased with an increased in the number of days of snowfall, which is largely consistent with previous studies. The effect of an increased minimum temperature on lowering the risk of fractures from falls is a new finding. Differences in working environments between countries and differences in worker attitudes may have additional underlying implications.

Measures to prevent falls during snowfall are considered inadequate in countries such as Japan, where snowfall is rare. This present study included data from 2014 when a ‘once in a decade’ cold wave swept through Japan,[47] causing extensive damage, which may have been partly accounted for by heavy snowfall and a lack of early weather warnings. Since then, various disaster prevention systems have been established, including the Ministry of Land, Infrastructure, Transport and Tourism Emergency Announcement on Heavy Snowfall and Weather Information on Significant Heavy Snowfall, which issues warnings and collects data.[48] The present study suggests the need for preventive measures based on previous reports from other countries that experience heavy snow cover.

The Ministry of Health, Labour and Welfare was established in 2001 through the merger of the Ministry of Health and Welfare, which oversees medical care, health and social security, and the Ministry of Labour, overseeing the welfare of workers. Measures to prevent occupational injuries in Japan have been addressed in the workplace safety policy but not in the medical and health policy. In recent years, however, the number of people working with illnesses and disabilities increased, and systems are being developed to support the balance between medical treatment and work.[49] As a result, comprehensive industrial health support centres that provide support to small- and medium-sized companies have been set up, where public health nurses promote collaboration between working and medical and health measures. The prevention of falls and fractures in the workplace must be promoted, and factors that can increase the risk of these injuries must be highlighted. In the future, as the number of elderly workers increases, the number of falls that can be prevented is expected to increase as measures are strengthened from a public health perspective.

Limitations

This study had some limitations. The meteorological information used was from the city of Tokyo; thus, the findings may not generalise to other regions of Japan. Fractures that were not explicitly mentioned when the national database was created were not extracted and included in the current analysis. A total of 45 cases were noted as follows: bone bruises (34 cases), heard popping noises (five cases), displaced bones (five cases) and twisted bones (one case). Although there was evidence that the relationship between occupational accident absence and gender was a risk factor, gender was not included in the database used in this study.[50]

Strengths

This is the first study to extract the keywords ‘fracture’, ‘broken bones’ and ‘crack of bones’ from qualitative data contained in the national open database and analyse it as a quantitative outcome.

Table 4
Odds ratios obtained from multiple logistic models (industry-specific results).

Variable	Primary industry ($N = 882$)		Secondary industry ($N = 8247$)		Tertiary industry ($N = 25,451$)	
	Model 3[a]		**Model 4**[a]		**Model 5**[a]	
	Odds ratio (95%CI)	***P*-value**	**Odds ratio (95%CI)**	***P*-value**	**Odds ratio (95%CI)**	***P*-value**
Occurrence time of day						
0:00 a.m. to 2:59 a.m.	1 (Reference)		1 (Reference)		1 (Reference)	
3:00 a.m. to 5:59 a.m.	0.368 (0.056, 2.412)	0.298	0.938 (0.564, 1.558)	0.804	1.381 (1.091,1.781)	0.007
6:00 a.m. to 8:59 a.m.	0.644 (0.126, 3.297)	0.597	1.413 (0.947, 2.108)	0.090	1.556 (1.254, 1.930)	<0.001
9:00 a.m. to 11:59 a.m.	0.852 (0.173, 4.198)	0.844	1.157 (0.784, 1.708)	0.463	1.299 (1.053, 1.603)	0.015
0:00 p.m. to 2:59 p.m.	0.736 (0.145, 3.723)	0.710	1.276 (0.859, 1.894)	0.227	1.298 (1.048, 1.608)	0.017
3:00 p.m. to 5:59 p.m.	0.914 (0.182, 4.596)	0.913	1.273 (0.860, 1.884)	0.228	1.223 (0.987, 1.516)	0.066
6:00 p.m. to 8:59 p.m.	1.315 (0.168, 10.26)	0.796	1.134 (0.733, 1.753)	0.572	1.483 (1.183, 1.857)	<0.001
9:00 p.m. to 11:59 p.m.	0.000 (0.000, 0.000)	0.976	0.836 (0.483, 1.446)	0.522	1.385 (1.080, 1.776)	0.010
	Model 6[a]		**Model 7**[a]		**Model 8**[a]	
	Odds ratio (95%CI)	***P*-value**	**Odds ratio (95%CI)**	***P*-value**	**Odds ratio (95%CI)**	***P*-value**
Age						
≦54 years old	1 (Reference)		1 (Reference)		1 (Reference)	
≧55 years old	1.684 (1.167, 2.430)	0.005	1.184 (1.069, 1.312)	<0.001	1.341 (1.263, 1.424)	<0.001
Occurrence time of day						
0:00 a.m. to 2:59 a.m.	1 (Reference)		1 (Reference)		1 (Reference)	
3:00 a.m. to 5:59 a.m.	0.284 (0.041, 1.949)	0.200	0.938 (0.560, 1.571)	0.808	1.158 (0.906,1.479)	0.242
6:00 a.m. to 8:59 a.m.	0.416 (0.078, 2.227)	0.306	1.267 (0.843, 1.905)	0.255	1.502 (1.203, 1.876)	<0.001
9:00 a.m. to 11:59 a.m.	0.501 (0.097, 2.601)	0.411	1.098 (0.737, 1.635)	0.647	1.282 (1.032, 1.592)	0.025
0:00 p.m. to 2:59 p.m.	0.411 (0.077, 2.201)	0.299	1.232 (0.823, 1.844)	0.311	1.295 (1.039, 1.614)	0.021
3:00 p.m. to 5:59 p.m.	0.485 (0.091, 2.594)	0.398	1.217 (0.815, 1.817)	0.336	1.228 (0.985, 1.533)	0.068
6:00 p.m. to 8:59 p.m.	0.593 (0.061, 5.792)	0.653	1.083 (0.695, 1.686)	0.725	1.516 (1.202, 1.912)	<0.001
9:00 p.m. to 11:59 p.m.	1.254 (0.000, 0.000)	0.979	0.810 (0.463, 1.416)	0.459	1.348 (1.043, 1.741)	0.022
No. of days of snowfall	0.997 (0.844, 1.178)	0.975	1.056 (1.011, 1.103)	0.015	1.034 (1.009, 1.061)	<0.001
Precipitation (mm/month)	1.001 (0.999, 1.003)	0.156	1.000 (0.999, 1.001)	0.941	1.000 (1.000, 1.000)	0.361
Minimum temperature (°C)	0.967 (0.935, 0.999)	0.047	0.997 (0.988, 1.007)	0.554	0.993 (0.988, 0.999)	0.017

CI, confidence interval.
[a] Models 3, 4 and 5 were unadjusted; Models 6, 7 and 8 were adjusted for the year of occurrence, type of industry, causal agents and company size.

This national database includes reports of worker deaths and injuries and is a reporting document stipulated in the Occupational Safety and Health Law (Occupational Safety and Health Regulations). This requires the document to be submitted to the labour standards office when a worker dies or loses work due to an industrial accident. This database is therefore expected to be complete. Some national open databases contain quantitative as well as qualitative data, but few studies make use of both types of data. In addition, this national database contains a large number of cases of accidents extracted from all prefectures.

Conclusion

The risk of fractures due to falls in the workforce may increase in the future, given changes in industrial sector structures, the increasing number of older workers and climate changes. Although commute-related injuries were not accounted for in the present study, the present findings suggest that the risks of work-related fractures may increase just before and just after shift changes. There remains a lack of evidence and many unexplored aspects of how to prevent fractures caused by occupational falls; thus, further study in this area is required. In Japan, where heavy snowfall is rare, measures introduced to prevent falls due to snowy and icy conditions may be limited; however, the impact of weather events, including snowfall, should be considered in public and occupational health policy development.

Author statements

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Ethical approval

This study was based on open-source, anonymised data; therefore, the ethics board approval requirement was waived per the ethical guidelines for medical and health research involving human subjects.

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Competing interests

None of the authors has a conflict of interest.

Author contributions

C.H. proposed and designed the study and analysed the data. H.T. provided technical advice for writing the article. S.O. provided technical advice for data analysis. O.T. provided expertise in fracture prevention. Orthopaedic surgeons, H.T. and O.T., classified fractures based on their expertise in the coding process. All authors interpreted the results. All authors wrote and revised manuscript drafts and provided critical comments. All authors approved the article for submission and publication. C.H. obtained study funding.

Data sharing statement

We can directly share the data used in this study from the Web site.[51] In addition, the statistical protocol and R codes used in this study are available upon request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.003.

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Original Research

Sociopolitical values, sociodemographic factors, and willingness to pay higher taxes to improve public healthcare in Turkey

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ABSTRACT

Objectives: Healthcare systems' reliance on taxes varies across countries with corresponding heterogeneity in public's willingness to pay taxes (WTP) for national healthcare provision. Turkey, a developing country that witnessed a major healthcare transformation, provides a unique context to understand what motivates WTP in a non-Western context.
Study design: This is a cross-sectional study.
Methods: We used the data from the International Social Survey Programme module on health and healthcare in Turkey. The data were collected from a nationally representative sample of adults aged >18 years (n = 1559). Using logistic regression models, we examine the association of sociopolitical values and sociodemographic factors with individuals' WTP to improve public healthcare.
Results: We find that sociopolitical values are more closely associated to the WTP in Turkey compared with sociodemographic factors. However, egalitarianism and humanitarianism were differentially linked to the WTP. Humanitarianism was positively associated, whereas egalitarianism was negatively associated with WTP.
Conclusions: This study shows the prevalence of value-based approach to healthcare provision support in a developing country in the height of healthcare reforms.

Introduction

Healthcare services entail one of the most crucial areas of public provision in any welfare regime. Countries differ in their level of public support for healthcare expenditures. One of the actors central to the provision of public healthcare services are the residents; however, the level of their contributions significantly depends on the sociopolitical context of the country.[1,2] In addition, the extent to which their residents consider these taxes fair differs, and the perception of fairness also prompts their willingness to pay higher taxes (WTP).[3] Studies have shown that several factors facilitate or impede individuals' willingness to pay higher taxes to improve public healthcare services, broadly, self-interests, and sociopolitical values.[4–9] This broad categorization of factors is formulated on the basis of Schwartz's[10] *theory of basic human values*, positioning self-transcendence on the opposite end from self-enhancement.[8] While self-enhancement relies heavily on individuals' self-interests that are shaped by their sociodemographic characteristics, self-transcendence involves sociopolitical values such as benevolence, altruism, egalitarianism, and humanitarianism. Self-interests of certain sociodemographic groups, such as senior citizens and single parents, differentially affect these groups' motivations for the support of and willingness to pay higher taxes for certain welfare provisions.[5,11,12] On the other hand, the support of welfare provisions based on sociopolitical values is argued to stem from various values such as altruism, universalism, humanitarianism, or political ideology. In this article, we focus on egalitarianism – "positive attitudes towards redistribution between the rich and the poor"[13] and humanitarianism – "a sense of obligation to help those in need."[14] Previous studies have presented mixed results on how sociopolitical values such as egalitarianism and humanitarianism inform individuals' WTP to improve public healthcare provisions.[4,9,15]

To understand the role of these factors on the WTP, most studies have predominantly focused on the Western context. Still, it is also crucial to examine the WTP in a non-Western context, especially in a developing country such as Turkey, which has a relatively less effective welfare regime but stronger adherence to public provision of healthcare services. Turkey's Health Transformation Programme

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(HTP) involves wide-ranging reorganization of the health services in the country, targeting improvements in "financial sustainability, efficiency, quality and accessibility of health services."[16] This program is unique in its amalgamation of neoliberal health reforms with a strong adherence to an egalitarian and universal healthcare coverage, leading to a categorization of Turkey's approach as "social neoliberalism."[17] Despite its egalitarian character in terms of coverage, access, and equity, HTP introduces market-oriented reforms in healthcare such as privatization, purchaser-provider split, premium payments, and performance-based evaluations for healthcare professionals.[18]

In this article, we examine public support for provision of healthcare services in Turkey by investigating the factors associated with Turkish individuals' willingness to pay higher taxes to improve public healthcare for all. We use data on Turkey from the International Social Survey Programme (ISSP) 2011 to investigate whether sociopolitical values or sociodemographic factors better explain willingness to pay higher taxes in the case of public healthcare in Turkey.

Methods

Data

To examine willingness to pay taxes, we used secondary data from the ISSP, a cross-national survey widely used in healthcare research. Specifically, we used the data from the ISSP module on health and healthcare (third release), which covers 32 countries including Turkey.[19] The data for Turkey were collected using face-to-face interviews with a nationally representative sample of adults aged >18 years (n = 1559). This rich data set is uniquely suitable to study our research question given that no other nationally representative data sets include items on health-related attitudes and behaviors as well as information about sociodemographic factors and sociopolitical values.

Study variables

In our analysis, the WTP is the outcome variable. The ISSP survey provides a question asking respondents, "how willing would [they] be to pay higher taxes to improve the level of healthcare for all people" in their country. We recoded the original response categories "very willing" and "fairly willing" as "1 = willing," and the rest as "0 = Not willing."

Based on the theoretical approaches discussed in the previous section, two groups of independent variables were included in the analysis. First, as the value-based approach highlights *egalitarianism* and *humanitarianism*, we used two proxy measures for these values. Egalitarianism was measured using a proxy question asking respondents whether "it [is] fair or unfair that people with higher incomes can afford better education for their children than people with lower incomes." The five-point response scale ranged from "1 = very fair" to "5 = very unfair," indicating that people with higher scores are more egalitarian. Respondents were also asked whether they agree or disagree with the statement that "people should have access to publicly funded healthcare even if they do not hold citizenship of the country." The response scale ranging from "1 = strongly agree" to "5 = strongly disagree" was reverse coded so that the higher values captured higher levels of humanitarianism.

The second group of independent variables consisted of sociodemographic variables, such as *age*, *sex, education,* and *main work status. Age* was included in analyses as a continuous variable. *Sex* was coded as "0 = female" and "1 = male." *Education* was coded as "1 = No formal education" to "6 = University degree completed." *Main work status* provides information about the respondents' current work situation. This variable was recoded to represent meaningful categories in the case of Turkey: "1 = Paid work," "2 = Out of labor force (non-domestic)," "3 = Domestic work," "4 = Retired." "Paid work" was used as the reference category in the subsequent analyses.

In addition to these two groups of independent variables, certain control variables were included in the analysis related to health and healthcare.[4,9] *Satisfaction with the healthcare system* was based on the question, "In general, how satisfied or dissatisfied are you with the healthcare system in [country]?" The original 7-point scale was reverse coded so that higher values indicate higher levels of satisfaction. *Confidence in the healthcare system* was measured using five-point response scale ranging from "1 = Complete confidence" to "5 = No confidence at all." Similarly, we reverse coded this variable so that a higher score means more confidence. *Health status* was assessed by a self-report question where respondents rate their health between "1 = Excellent" and "5 = Poor." The responses were reverse coded so that higher scores indicate better self-reported health status. Finally, to measure the *frequency of doctor visits,* we used an item asking respondents how often they visited a doctor during the past 12 months.[c] The response categories ranged from "1 = Never" to "5 = Very often" so that higher values indicate more frequent visits. Table 1 shows the descriptive statistics of the sample.

Statistical analysis

We estimated binary logistic regression models to analyze the association between *willingness to pay taxes*, the main independent variables, and controls. We provided odds ratios with confidence intervals to interpret the effect sizes. We used multiple imputation by chained equations to handle missing data. To address the gender imbalance in the sample, we created poststratification weights. We present results with imputation and weighting in Table 2.

Results

Table 2 presents logistic regression results on the association of the outcome and the variables of interest of this study. Model 1 begins with evaluating the relationship between the WTP and sociopolitical values, *egalitarianism* and *humanitarianism*. Model 2 examines the relationship between the WTP and sociodemographic variables, *age*, *sex*, *education*, and *main work status*. In other words, Models 1 and 2 estimate the association between outcome and main predictors based on the two main approaches that we use, respectively. Model 3 includes both sociopolitical values and sociodemographic variables. We include these focal predictors simultaneously adjusting for the effect of each other. Finally, Model 4 estimates the full model including the control variables, *satisfaction with the healthcare system, confidence in the healthcare system, health status,* and *the frequency of doctor visits*.

There was no statistically significant association between the WTP and any of the sociodemographic variables except age. Sex, education, and main work status showed no significant association with the WTP. Age was significantly and positively associated with the WTP, indicating that older people are more willing to pay higher taxes to improve public healthcare; however, its effect size was smaller compared with other statistically significant predictors in the models.

[c] (The main questionnaire item was worded as "visited or were visited by a doctor." However, the Turkish questionnaire asks only "visited a doctor." It is uncommon for doctors in Turkey to pay visits to households [authors' note].)

Table 1
Descriptive statistics.

Variables	*N*	Mean	Standard deviation	Minimum	Maximum
WTP (binary)	1447	0.238	0.426	0	1
Egalitarianism	1504	3.604	1.099	1	5
Universalism	1433	3.845	1.002	1	5
Age	1543	42.081	15.833	17	92
Sex	1559	0.405	0.491	0	1
Education	1555	2.843	1.425	1	6
Main work status					
Paid work	1554	0.270	0.444	0	1
Out of the labor force (non-domestic)	1554	0.127	0.333	0	1
Domestic work	1554	0.465	0.499	0	1
Retired	1554	0.138	0.345	0	1
Satisfaction: HC	1531	4.875	1.387	1	7
Conf: healthcare	1545	3.454	1.144	1	5
Health status	1553	2.889	0.892	1	5
P12M: doctor	1527	2.325	1.140	1	5

WTP, willingness to pay.

The results indicate that sociopolitical values, egalitarianism and humanitarianism, were significantly associated with the WTP, even after controlling for sociodemographic and control variables. However, our analyses also show that the way egalitarianism and humanitarianism were associated with the WTP is different in direction. In Model 4, a one unit increase in humanitarianism increases the odds of WTP taxes by 30%, but a one unit increase in egalitarianism decreases the odds of WTP taxes by 25%, holding other variables constant. In other words, those who hold stronger humanitarian values were found to be more willing to pay higher taxes to improve public healthcare, whereas those who hold stronger egalitarian values were shown to be less willing to pay higher taxes. The modeling assumptions of the logistic regression preclude a simple comparison of coefficients across models. Nevertheless, the coefficients of these two sociopolitical values remained statistically significant with little variation, and their directions did not change. In Table 2, we also reported AIC/BIC for models without imputations and weights. According to these criteria, Model 4 performed better in general. In other words, as relative measures, AIC and BIC indicate that Model 4 has a better fit compared with other models. When it comes to worst performing one, for example, with the highest AIC/BIC values, the results agreed on Model 2, which only includes sociodemographic variables. That is, given the estimates, Model 2 has the worse fit compared with other models. Model 2 has a worse fit even compared with Model 1, which only has egalitarianism and humanitarianism as predictors.

Among the set of control variables, health status was the only variable significantly associated with the WTP. Model 4 shows that those who report poorer health status were more willing to pay higher taxes to improve public healthcare. While health status was found to have a statistically significant association with the WTP, having doctor visits within the past 12 months was not significantly associated with the WTP. Finally, satisfaction with or confidence in the healthcare system were also not significantly associated with the WTP.

Discussion

There are several possible reasons why this study found that sociopolitical values are more strongly associated with the WTP than sociodemographic factors. First, considering that Turkey was at that time going through significant transformations in its healthcare system toward better universal coverage, many Turkish individuals might have considered that their healthcare coverage is not subject to their sociodemographic characteristics. This consideration might have led their values rather than interests to shape their WTP. Second, healthcare services are often considered as a unique circumstance, which all individuals need and deserve no matter their sociodemographic characteristics.[20] This heuristic bias might have prompted Turkish individuals' adherence to values such as humanitarianism in their support and WTP for public healthcare services. Finally, Turkish individuals who show strong support and appreciation for the healthcare reforms at the time might have been invested in the ideal of universalism in these transformations, which in return would motivate them to pay more taxes to improve public healthcare.

Furthermore, the only sociodemographic factor significantly associated with the WTP in our analysis was age, which indicates that older people were more willing to pay higher taxes to improve

Table 2
The logistic regression results for willingness to pay taxes.

Variables	Model 1	Model 2	Model 3	Model 4
Egalitarianism	0.678*** [0.604, 0.761]		0.679*** [0.605, 0.762]	0.755*** [0.666, 0.855]
Humanitarianism	1.334*** [1.151, 1.546]		1.322*** [1.140, 1.534]	1.299*** [1.118, 1.510]
Age		1.012* [1.002, 1.023]	1.011* [1.000, 1.022]	1.018** [1.007, 1.030]
Sex		1.170 [0.784, 1.745]	1.107 [0.731, 1.678]	0.958 [0.624, 1.471]
Education		1.059 [0.957, 1.172]	1.043 [0.941, 1.157]	1.056 [0.947, 1.177]
Main work status (*ref. paid work*)				
Out of the labor force (non-domestic)		0.968 [0.632, 1.481]	0.967 [0.621, 1.507]	1.021 [0.651, 1.602]
Domestic work		0.970 [0.610, 1.543]	0.921 [0.572, 1.481]	0.871 [0.538, 1.410]
Retired		0.664 [0.417, 1.058]	0.666 [0.413, 1.074]	0.655 [0.402, 1.068]
Satisfaction: HC				1.088 [0.962, 1.230]
Conf: healthcare				1.099 [0.942, 1.281]
Health status				1.467*** [1.226, 1.754]
P12M: doctor				0.968 [0.851, 1.100]
Constant	0.400** [0.207, 0.773]	0.159*** [0.074, 0.340]	0.237** [0.084, 0.673]	0.022*** [0.005, 0.093]
AIC[a]	1417.49	1576.61	1405.72	1333.07
BIC[a]	1433.08	1613.45	1452.36	1399.99
N	1447	1447	1447	1447

Exponentiated coefficients (odds ratios); 95% confidence intervals in brackets.
$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.
[a] AIC/BIC values come from the regression models without imputations and weights. Both AIC and BIC are calculated for maximum-likelihood (ML) estimates. However, the multiple imputation estimates in our analysis are not maximum-likelihood estimates. Hence, it is not possible to get AIC and BIC directly from the models using multiple imputation. A similar issue arises for using weights because ML assumptions behind AIC and BIC are violated. That's why we reported AIC/BIC values for models 1-4 without imputation and weights. Otherwise, the model specifications follow the main analysis.

public healthcare based on their self-interests. This is in line with the previous research, indicating the significance of age as one of the most influential sociodemographic characteristics in support for healthcare provisions.[11] Our results might lead to questioning whether sociodemographic factors could be considered as effective proxies for self-interests. Especially considering that health status predicted the WTP in Turkey, it could be argued that in the case of healthcare services, self-interests are better explained with the kind of factors directly related to health outcomes.

Contrary to the previous studies' findings, our results indicated that only humanitarianism is positively associated with the WTP, whereas this association is negative for egalitarianism. Svallfors[21] argues that “the relationship between egalitarianism and attitudes to taxes and spending is substantially weaker” in countries where the quality of government is comparatively lower. He supports this argument with a comparative analysis on this connection in several countries. Yet, in his analysis as well as in the analyses of other sources such as the QoG Institute,[22,23] Turkey is not one of those countries with low quality; it has instead a mid-level quality of government. Taking a closer look at respondents who are more egalitarian might reveal their lower levels of confidence in healthcare and educational systems, and therefore, their lower levels of social trust, which in turn translates into unwillingness to pay higher taxes, similar to the findings in Habibov et al.'s study.[1] Social trust is argued by these authors to be associated with higher social solidarity and cohesion as well as a greater investment in healthcare system. Therefore, in the case where individuals have lower social trust, they would also have lower levels of confidence in the healthcare system, and this might explain their lack of motivation to pay higher taxes to improve public healthcare. Alternatively, as also indicated in Maldonado et al.'s study,[9] humanitarianism could be a better variable than egalitarianism in explaining the WTP when it comes to public healthcare.

Our findings suggest several contextual and individual factors for future studies to explore. Existing studies show that healthcare provisions differ from other welfare provisions[11] and public expenditures for health services receive support at higher levels because the right to healthcare is more related to basic human rights ideals.[24] In this sense, the WTP is more likely to be shaped by values rather than self-interests. Therefore, studying public support for healthcare for all might require us to take into consideration a different set of factors. Future studies could explore the connections between the WTP in Turkey and other sociopolitical values such as universalism and left-right ideology. Considering that the welfare state understanding in Turkey is significantly different than in other countries,[25] one also needs to factor in that individuals' WTP to improve public healthcare might be shaped by how they perceive the state's role in financing and organizing those services. Moreover, country-level factors could be included in analyses to explain why self-interests are not as strongly associated with Turkish individuals' WTP as are values. Finally, further studies could examine these connections with a more contemporary and nationally representative sample to understand the outcomes of the reforms implemented through the HTP. Doing so would better capture how the neo-liberalization of the Turkish healthcare system has shaped the public perceptions and attitudes of Turkish residents toward healthcare services since 2003.

Limitations of the study

This study has some limitations. In this study, we did not include income as a measure of self-interest due to two reasons. First, in ISSP data for Turkey, there is an issue of oversampling of female respondents, who predominantly identified themselves as housewives and therefore did not declare an individual income. Therefore, we did not consider individual income a useful measure of self-interest. Second, the high prevalence of informal employment in Turkish households might have led many participants to either not declare their actual household income at all or downplay it. Therefore, we decided not to include household income as a measure of self-interest.

We also acknowledge that the data set used in this study is not contemporary. Although it provides the advantage of exploring the relationships of interest during the height of transformations, we were unable to observe the outcomes of the changes presented by the ongoing HTP. Furthermore, because no available panel data on Turkey exist including the measures of interest in this study, it was not possible to conduct a longitudinal analysis on the potential associations of the WTP with sociopolitical values and sociodemographic factors. Because this study relies on cross-sectional data, we refrain from making any causal claims on what determines the WTP. Future studies could analyze causal links between these set of factors and the WTP by using a longitudinal analysis on available data.

Conclusion

In this article, we examined both sociodemographic factors and sociopolitical values to understand what factors better explain the motivation of Turkish individuals to pay higher taxes to improve public healthcare for all. To do so, we used the ISSP 2011 data and conducted a series of logistic regression models. The results of this study show that sociopolitical values matter more than sociodemographic factors in accounting for the WTP specifically to improve public healthcare in Turkey. In addition, contrary to previous studies' findings, sociopolitical values are found to have a differential impact on the WTP, as humanitarianism was positively associated with the WTP, whereas the association between egalitarianism and the WTP was negative. Age and health status were also positively associated with Turkish individuals' WTP in the case of public healthcare.

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Ethical approval

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Competing interests

None declared.

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Original Research

Spatial patterns of prostate-specific antigen testing in asymptomatic men across Australia: a population-based cohort study, 2017–2018

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ABSTRACT

Objectives: In Australia, while prostate-specific antigen (PSA) testing rates vary by broad area-based categories of remoteness and socio-economic status, little is known about the extent of variation within them. This study aims to describe the small-area variation in PSA testing across Australia.
Study design: This was a retrospective population-based cohort study.
Methods: We received data for PSA testing from the Australian Medicare Benefits Schedule. The cohort included men (n = 925,079) aged 50–79 years who had at least one PSA test during 2017–2018. A probability-based concordance was applied across multiple iterations (n = 50) to map each postcode to small areas (Statistical Areas 2; n = 2,129). For each iteration, a Bayesian spatial Leroux model was used to generate smoothed indirectly standardized incidence ratios across each small area, with estimates combined using model averaging.
Results: About a quarter (26%) of the male population aged 50–79 years had a PSA test during 2017–2018. Testing rates among small areas varied 20-fold. Rates were higher (exceedance probability>0.8) compared with the Australian average in the majority of small areas in southern Victoria and South Australia, south-west Queensland, and some coastal regions of Western Australia but lower (exceedance probability<0.2) in Tasmania and Northern Territory.
Conclusions: The substantial geographical variation in PSA testing rates across small areas of Australia may be influenced by differences in access to and guidance provided by clinicians and attitudes and preferences of men. Greater understanding of PSA testing patterns by subregions and how these patterns relate to health outcomes could inform evidence-based approaches to identifying and managing prostate cancer risk.

Introduction

Prostate-specific antigen (PSA) testing is regularly used opportunistically to test asymptomatic men for the risk of prostate cancer;[1] however, it has a low positive predictive value that makes it difficult to distinguish between cancerous and benign prostatic conditions.[2] Consequently, this is a test that is undertaken ad hoc rather than in organized population-wide screening programs.[3]

In 2016, the Prostate Cancer Foundation of Australia and Cancer Council Australia released national guidelines that recommend if men at average risk of prostate cancer aged 50–69 years make an informed decision to have a regular PSA test, it should be offered every 2 years.[4] Summary guidelines from the Royal Australian College of General Practitioners[5] advise general practitioners (GPs) that due to screening of asymptomatic men with PSA not being recommended, GPs are not obliged to offer the test. Most international guidelines on screening and early detection of prostate

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cancer are similar to Australian Prostate Cancer Foundation of Australia guidelines, including the United States,[6] Europe,[7] Canada,[8] and the United Kingdom.[9]

Higher PSA testing rates have been reported among men living in socio-economically advantaged areas compared with those living in disadvantaged areas. In addition, testing rates have been shown to be higher for men living in urban areas compared with rural areas.[10,11] However, the lack of robust estimates for PSA testing at the small area level makes it difficult to interpret prostate cancer incidence and survival information in recent disease atlases, such as the Australian Cancer Atlas.[12]

This study, using PSA testing data from the Medicare Benefits Schedule, Australian Government's universal health funding scheme, aims to address this gap in knowledge. It will quantify how PSA testing rates vary by small geographical areas across Australia during the period following the release of the 2016 Australian clinical guidelines on PSA testing.[4]

Methods

Data

Medicare-reimbursed PSA test data for men aged 50–79 years, tested in Australia between January 2017 and December 2018, were obtained from the Commonwealth Department of Health (under the Health Insurance Act 1973). In Australia, the Medicare Benefits Schedule reimburses item number 66655, since it is specifically used for detecting asymptomatic prostate disease in men, which will refer to it as a “screening” test. The unit-record data extract contained a deidentified unique person-level ID number, postcode of residence recorded by Medicare Benefits Schedule at the time of PSA test, 10-year age group, year, and month of the conducted screening test.

Geography

A probability-based geographical correspondence file[13] was used to transform the 2011 postcode information into Statistical Areas 2 (SA2s) information from the 2011 Australian Statistical Geography Standard (ASGS). In this study, the term SA2 will be referred to as “small area”.

The correspondence file, containing the proportions of the population within each postcode that were allocated to each small area, was merged with the postcode-specific PSA data set. The postcode for each record was then randomly assigned to a small area according to these probabilities based on the uniform distribution, with the random process carried out 50 times.

The small areas were categorized by the ABS Remoteness Index and the Index of Relative Socio-Economic Advantage and Disadvantage.[14,15]

Exclusions

We selected PSA tests that were undertaken on men aged 50–79 years during the period 2017–2018 (Fig. 1). Postcodes that were exclusively used for post office boxes were excluded because it was impossible to determine its exact geographical catchment area. This study is based on the number of men rather than the number of screening tests; therefore, only the first test per individual during the study period was considered. Records where postcodes did not match with the postcode-small area concordance were removed from the cohort.

We excluded records from 67 SA2s because of male population of three men or less or were classified as remote islands ($n = 3$). The final data set included 2,129 small areas.

Population

Estimated resident population[16] by small area for men aged 50–79 years during 2017–2018 were concorded from 2016 ASGS classification to the 2011 ASGS using a population-weighted correspondence file.[17] The included 2,129 small areas had a median population of 1,479 (interquartile range: 895–2,296) men.

Statistical analyses

Spatial models

Spatial data commonly exhibit autocorrelation, or clustering, and ignoring this can lead to biased results.[18] To allow for spatial autocorrelation in the data, three Bayesian spatial models, all variants of the Intrinsic Conditional Auto-Regressive model, were initially considered to model the standardized incidence ratio (SIR): Leroux,[19] Besag, York, and Mollié (BYM),[20] and Localised.[21] Each of these models allow for autocorrelation through random effect terms on each area. Of the three, the Leroux model was preferred over the Localised model because of its more stable estimates (Figure SF 1a and b). Also, the Leroux model is more parsimonious than the BYM model because it has only one spatial random effect parameter for each area, rather than the two per area in BYM, yet still allows for both spatial autocorrelation and random variation between areas.

The Leroux model (File SFile 1) applied a Poisson distribution with an offset of the logged expected counts in each small area. Expected counts were calculated by multiplying national age-specific rates (total observed count/total population) by the age-specific population in each small area, then summing all age-specific expected counts. The expected counts and observed counts were input to the Bayesian model to calculate smoothed SIR estimates for each small area compared with the Australian average.

We undertook modeling using the CARBayes package (version 5.2.3)[22] in R (R Core Team (2020), version 4.0.0),[23] which uses Markov Chain Monte Carlo (MCMC) methods for computation. As Bayesian spatial models are too complex to compute analytically, MCMC algorithms are used to sample from probability distributions to approximate the desired distribution. There were 150,000 MCMC iterations run, with the first 50,000 iterations excluded as burn-in before selecting every 10th iteration to generate 10,000 iterations for each model. These small area–specific iterations from 50 models were combined with equal weighting, resulting in 500,000 iterations for each small area. Most small area results are based on the median value (SIR) of these 500,000 iterations. Markov chain convergence was checked by visual inspection of trace plots (Figure SF 2).

Visualization

Maps

The R package ggplot2 (version 3.3.6)[24] was used to visualize the results. The color scale on the SIR maps ranged from 0.67 to 1.5, including color breaks at 0.8, 1, and 1.25. Blue and red shades indicate low and high PSA screening rates, respectively, compared with the Australian average, as shown in yellow.

The exceedance probability is equal to the posterior probability of the modeled SIR being above 1 for each small area.[25] In the exceedance probability thematic map, green represents low (<20%) exceedance probabilities and suggests a true lower-than-average PSA screening rate, and purple represents high (>80%), suggesting a real higher-than-average PSA screening rate.

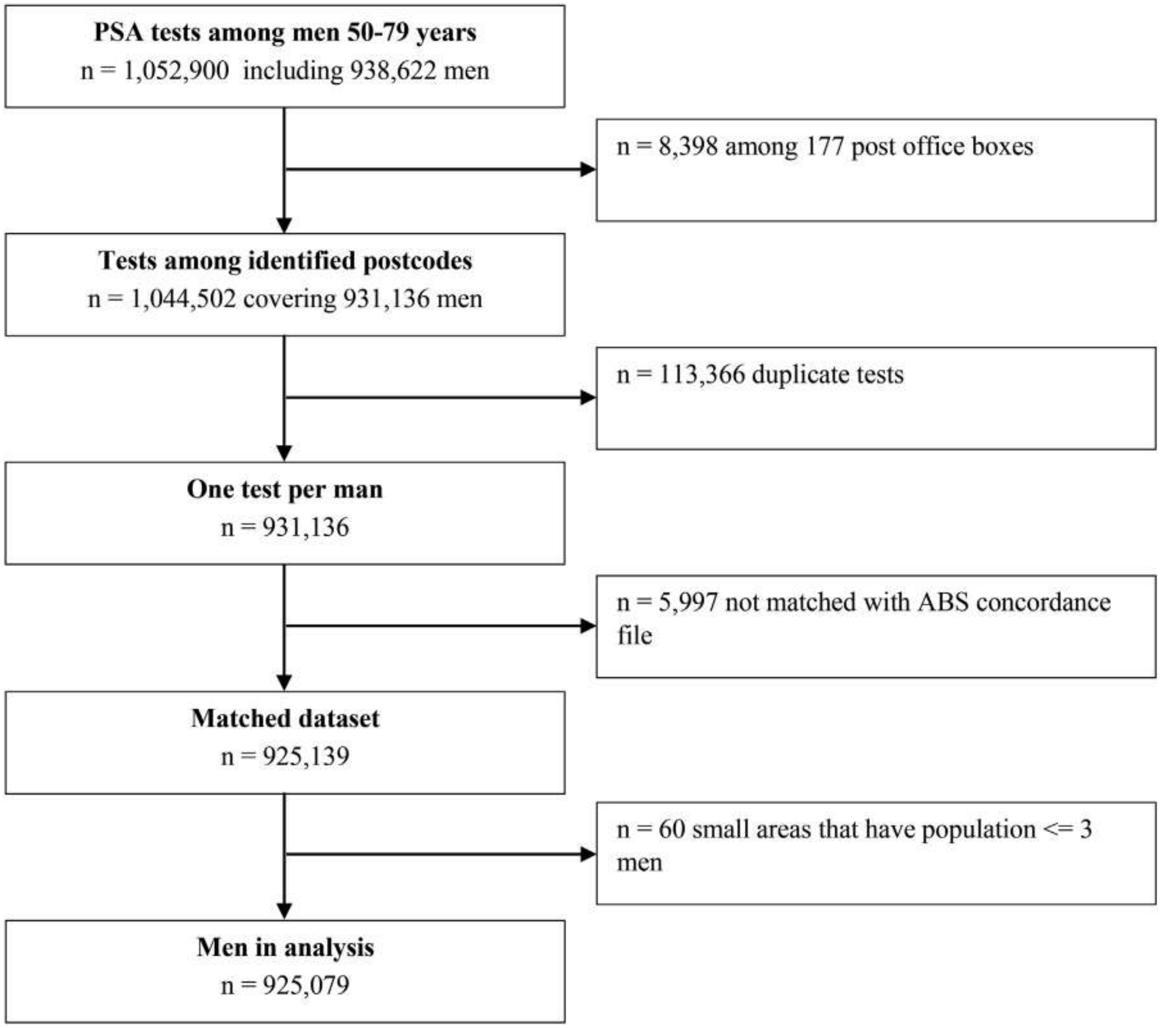

Fig. 1. Flowchart showing selection of men in analysis aged 50–79 years, Australia, 2017–2018.

Graphs

Boxplots were used to show how the small area–specific distribution of modeled estimates varied according to the categories of remoteness, socio-economic status, states/territories, and greater capital cities.

Results

During 2017–2018, 1,052,900 PSA screening tests were performed on 938,622 Australian men aged 50–79 years (Fig. 1). Of these, 8,398 (0.80%) screening tests were removed due to the postcode containing only post office boxes ($n = 177$), 113,366 (10.77%) were duplicate screening tests, 5,997 (0.57%) tests that were linked to a postcode that did not match with ABS postcode to small area correspondence files, and 60 (<0.01%) tests were in small areas that had male population aged 50–79 years less than or equal to three. The final data set included 925,079 men (one PSA test per man) aged 50–79 years, tested during 2017–2018, giving an overall crude screening rate of 260.6 per 1000 (26.1%) men.

The highest population percent of men screened was among men aged 60–69 (Table 1). Population screening percentages decreased substantially with remoteness, whereas screening rates were relatively consistent across the area-level socio-economic categories. Population PSA screening rates by states and territories were between 23.4% and 31.2%, except for lower rates in Tasmania (16.2%) and the Northern Territory (11.1%).

PSA screening patterns by smaller areas

There was a 20-fold (=2/0.1) variation in PSA screening rates (based on the modeled SIRs) across small areas of Australia (Fig. 2), with low (SIR <1) PSA screening rates in many remote areas. Approximately 5.3% of the small areas had screening rates that were more than 50% lower (SIR <0.5) than the Australian average (SIR = 1), and these were more likely to be outside capital cities, in remote and very remote areas, and most disadvantaged areas in Tasmania and Northern Territory (Table ST 1). The screening rates in about 1.8% of small areas were more than 50% higher (SIR >1.5) than average (Table ST 1). Sensitivity analyses showed similar SIR estimates by small area regardless of the choice of hyperpriors within the statistical models (Figure SF 3a and b).

Northern Territory (65/66 small areas) and Tasmania (95/95) had consistently lower screening rates than the national average. In contrast, screening rates were higher than the national average in the majority of small areas in the south of Victoria (276/427), South Australia (134/163), south-west Queensland (268/512), and coastal areas of Western Australia (150/234), along with some small areas in north-east New South Wales (144/526; Fig. 2). Considerable

Table 1
Demographic characteristics of men aged 50–79 years having at least one Medicare-funded prostate-specific antigen screening test, Australia, 2017–2018.

Characteristics	Men tested (%)	Population[a] (%)	Population percent of men tested (%)
Australia	925,079 (100)	3,549,392 (100)	26.1
Age group (years)			
50–59	354,339 (38.3)	1,494,873 (42.1)	23.7
60–69	358,708 (38.8)	1,242,648 (35.0)	28.9
70–79	212,032 (22.9)	811,871 (22.9)	26.1
Remoteness			
Major city	633,310 (68.5)	2,353,258 (66.3)	26.9
Inner regional	191,095 (20.7)	761,985 (21.5)	25.1
Outer regional	88,979 (9.6)	366,005 (10.3)	24.3
Remote	8,673 (0.9)	45,084 (1.3)	19.2
Very remote	3,022 (0.3)	23,059 (0.6)	13.1
Socio-economic status[b]			
Most advantaged	187,547 (20.3)	714,676 (20.1)	26.2
Advantaged	186,199 (20.1)	691,652 (19.5)	26.9
Middle SES[c]	195,772 (21.2)	743,578 (20.9)	26.3
Disadvantaged	189,307 (20.5)	717,915 (20.2)	26.4
Most disadvantaged	166,181 (18.0)	681,437 (19.2)	24.4
State/territory[d]			
New South Wales	269,171 (29.1)	1,143,786 (32.2)	23.5
Victoria	249,597 (27.0)	880,935 (24.8)	28.3
Queensland	189,527 (20.5)	719,050 (20.3)	26.4
South Australia	84,978 (9.2)	271,968 (7.7)	31.2
Western Australia	101,958 (11.0)	363,522 (10.2)	28.0
Tasmania	14,741 (1.6)	90,845 (2.6)	16.2
Northern Territory	3,143 (0.3)	28,240 (0.8)	11.1
Australian Capital Territory	11,952 (1.3)	50,969 (1.4)	23.4

[a] Average estimated resident population of Australia for 2017–2018.
[b] Records were excluded that do not have Index of Relative Socio-Economic Advantage and Disadvantage.
[c] Middle SES means middle socio-economic status.
[d] Records from Jervis Bay area were excluded due to classified as Other Territory.

variation in screening rates was evident both between and within capital cities. In most small areas within Sydney, PSA rates were lower than the national average, along with those within Hobart, Darwin, and Canberra, whereas higher-than-average PSA screening rates were observed in many areas within Melbourne, Brisbane, Adelaide, and Perth (Fig. 2 and SF 4b).

The majority (83%) of small areas had a screening rate likely to differ from the national average (Fig. 3). PSA screening in 957/2129 small areas was considered likely to be lower (<20% probability of being higher, Fig. 2) than the national average and higher (>80% probability, Fig. 2) in 814/2129 small areas. Screening rates in the remaining 358 small areas were considered unlikely to be different from the national average.

Distribution of small area–specific estimates within broader areas

There was no difference in the distribution of small area–specific estimates across categories of socio-economic status (Fig. 4a), and this was consistent outside and inside greater capital cities (Figure SF 4c). However, within some capital cities, including Hobart and Adelaide, there was a suggestion of contrasting patterns of socio-economic gradients (Figure SF 4e), whereas more populated capital cities of Sydney, Melbourne, and Brisbane had little variation. Likewise, there was less variability between greater capital cities and outside greater capital cities (Fig. 4d), whereas small areas within greater capital cities and outside greater capital cities of Victoria and South Australia consistently had higher screening rates than the national average (Figure SF 4a and b). The small area–specific distribution shows lower screening rates and increasing heterogeneity within categories with rising remoteness (Fig. 4b) as well as for outside greater capital cities and greater capital cities by remoteness (Figure SF 4d). While screening rates in remote areas were generally lower than the national average, there were some notable exceptions in remote areas in southern South Australia and northwest Victoria (Fig. 4c), which had very high PSA screening rates compared with the national average (Figs. 2 and 3).

Discussion

This is, to our knowledge, the first population-based study to map and describe the substantial variation in PSA screening tests in Australia by small geographical areas and the characteristics of this variation within broader socio-economic groups, remoteness categories, and states and territories.

Our results of testing patterns relating to the broad geographical classifications of urban and rural differences are consistent with international studies from Switzerland,[26] New Zealand,[27] and the United Kingdom.[28] These studies found that men living in urban areas and regions with high health service supply had higher PSA screening rates. Although we found limited variation between area-based socio-economic categories, other international studies[26,28] have reported generally increased use of PSA testing among men living in more affluent areas.

Although previous research[10,29] has demonstrated variation between large geographical regions or remoteness categories in Australia, the results of this study highlight the extent of variation within those broad regions. For example, the variation within socio-economic categories indicates that the PSA screening rate in some "disadvantaged" small areas was higher than in some "advantaged" small areas, and vice versa. In addition, not all small areas within remote and very remote categories had lower PSA screening rates than the Australian average. This emphasizes the importance of examining geographical variation between smaller geographical areas; otherwise, the heterogeneity within the larger regions is ignored.

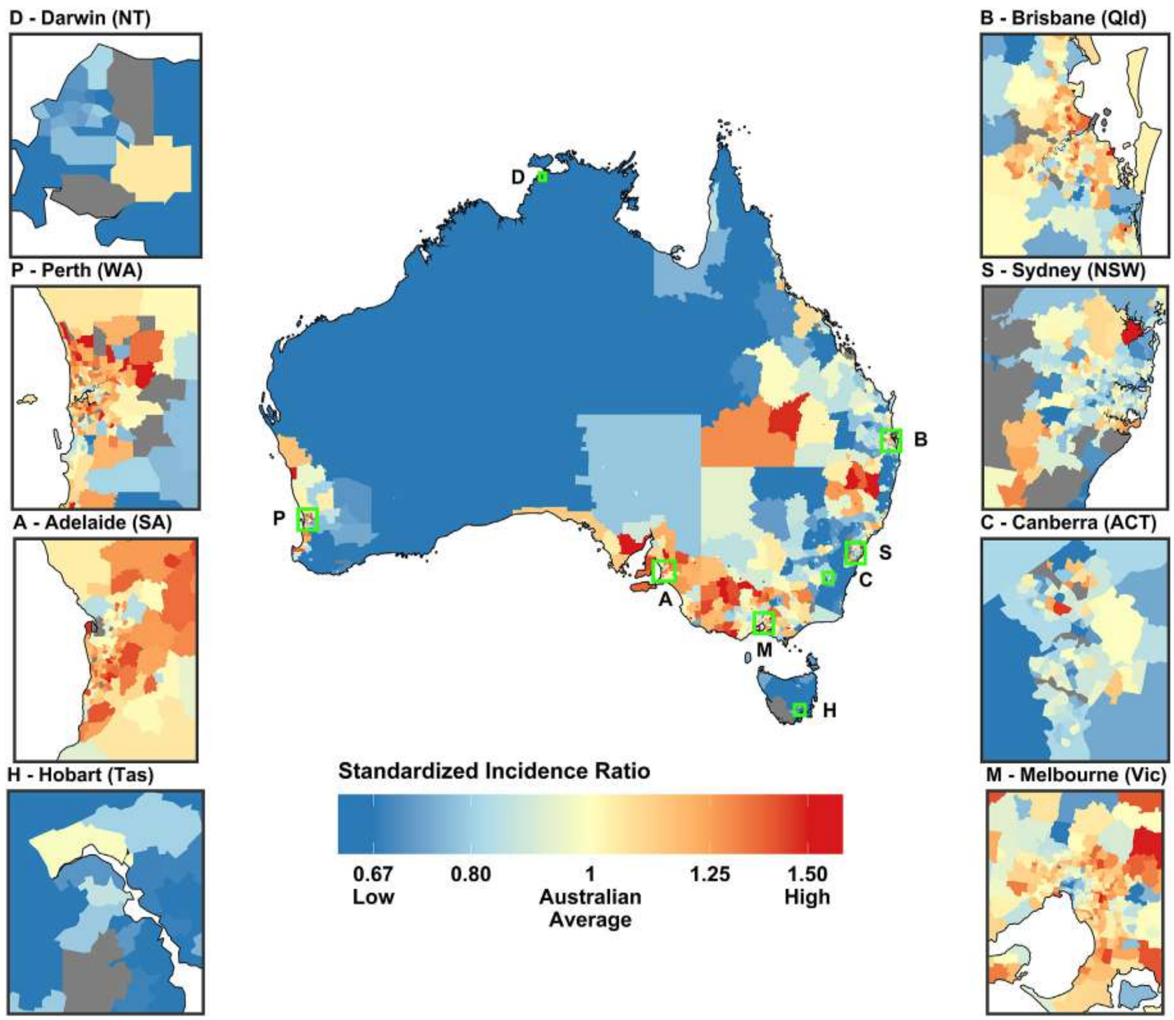

Fig. 2. Standardized incidence ratios (SIRs) of prostate-specific antigen (PSA) screening by small area[a,b], Australia, 2017–2018. [a]Insets show capital cities of each state and territory. [b]NT, Northern Territory; WA, Western Australia; SA, South Australia; Tas., Tasmania; Qld., Queensland; NSW, New South Wales; ACT, Australian Capital Territory; Vic., Victoria.

The current Australian prostate cancer screening guidelines[4,5] do not incorporate any geographical area characteristics. Therefore, if the decision-making processes for men and their GPs across Australia consistently followed the recommended guidelines and had equity in access to the resulting follow-up consultations and procedures, we might expect only a small amount of geographical variation in testing. Thus, while untangling the likely multifaceted reasons for the substantial geographical variation observed in our study requires more detailed investigations, it is likely that at least some of the reasons would relate to local area influences rather than factors operating at the national level. These could include variations in behaviors and attitudes of GPs, who are the gatekeeper to medical services, including PSA testing,[5] as well as factors relating to men living in each area, such as the activities of local PSA testing advocacy groups and accessibility to primary care and specialist services.

In general, although GPs in Australia have a good understanding of the benefits and limitations of PSA screening, many have limited knowledge of the current guidelines.[30] Previous studies have highlighted substantial variation in attitudes and practices by Australian GPs toward PSA testing,[31,32] so this may have contributed to our observed results.

Some explanations proposed for this variability between Australian GPs relate to the uncertainty about the evidence base for PSA testing and the ambiguity in PSA screening guidelines,[31] personal beliefs or experiences relating to PSA screening,[30] clinician motivation to avoid either overdiagnosis or underdiagnosis, perceived medicolegal risks during decision-making process,[31] and financial implications and incentives.[32] This variation between Australian GPs appears to be in contrast to GPs in the United Kingdom, who are advised not to proactively initiate the screening discussion with men; however, they can provide information if specifically requested.[33] UK GPs are more likely than Australian GPs to follow organizational guidelines that recommend to only provide PSA testing at the patient request.[33,34] This may suggest that in terms of PSA testing, Australian GPs operate with greater levels of individual discretion, contributing to the large geographical variation in PSA screening observed in this study.

Another possible explanation for the observed variation could be in Australian men's knowledge, attitudes, and behaviors regarding prostate health and prostate cancer testing, although little is known about how this varies by geography. Previous surveys tend to suggest low levels of knowledge about prostate cancer risks. For example, a survey conducted among Australian men in 2012[35] reported that prostate cancer was considered to be the most important health issue facing Australian men by 51% of respondents and that 55% of men felt they knew at least a reasonable amount about testing for prostate cancer. About three-fourths (72%) indicated they would "probably or definitely" have a PSA test sometime in the future.[35]

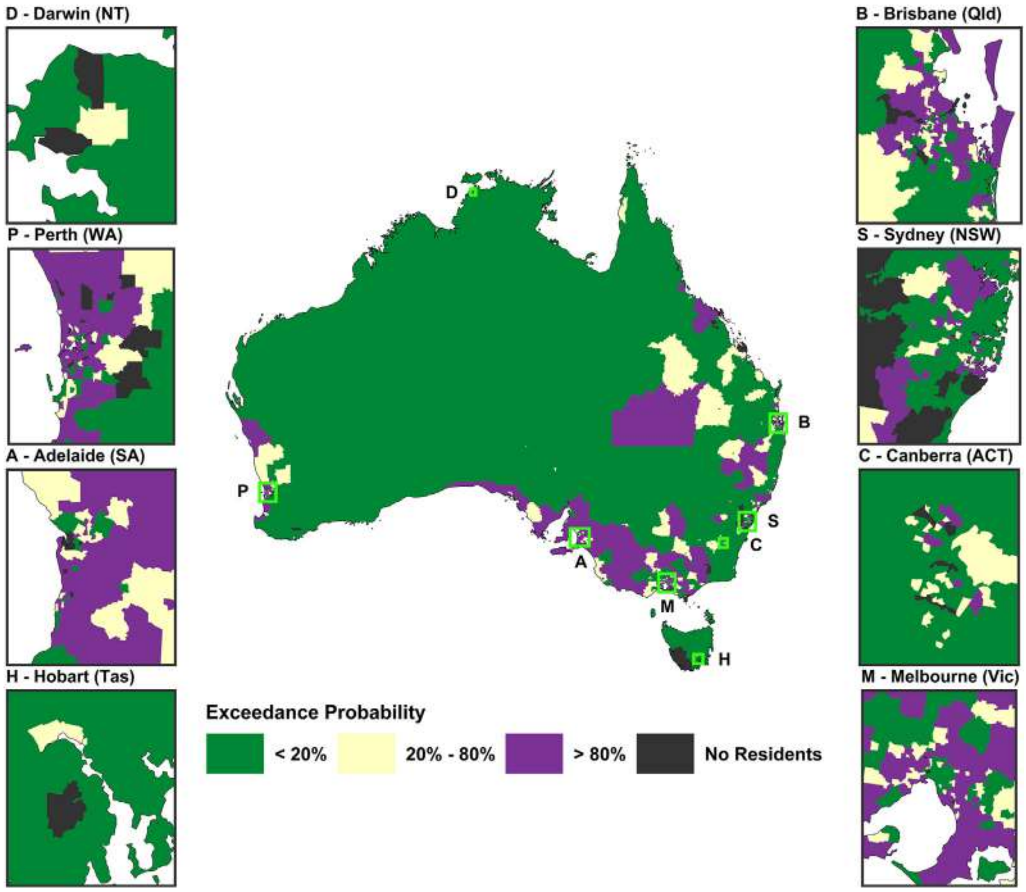

Fig. 3. Exceedance probabilities of prostate-specific antigen (PSA) screening by small area[a,b], Australia, 2017–2018. [a]Insets show capital cities of each state and territory. [b]NT, Northern Territory; WA, Western Australia; SA, South Australia; Tas., Tasmania; Qld., Queensland; NSW, New South Wales; ACT, Australian Capital Territory; Vic., Victoria.

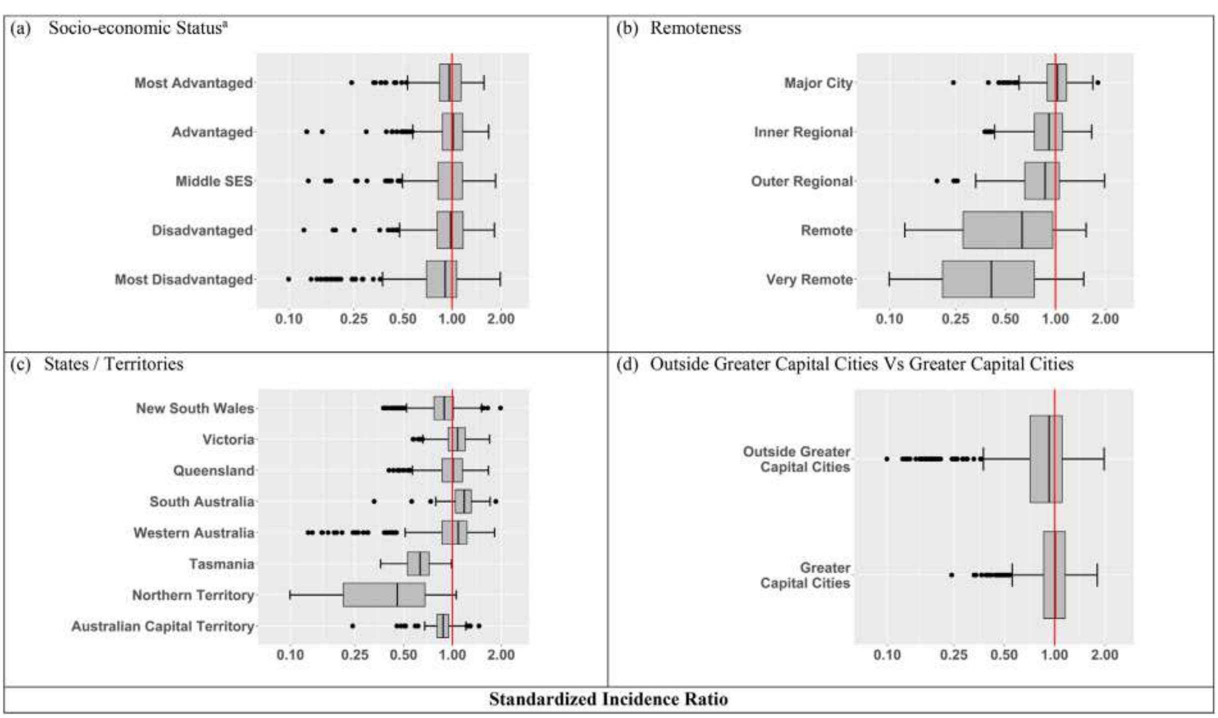

Fig. 4. Standardized incidence ratio (SIR) of prostate-specific antigen (PSA) screening for 2129 small area during 2017–2018 grouped by (a) socio-economic status, (b) remote areas, (c) states/territories, (d) outside greater capital cities vs greater capital cities. [a]Middle SES in plot means middle socio-economic status.

Advocacy and awareness campaigns, particularly if locally targeted, may contribute to the observed geographic variability in screening participation. While some have a national focus, others have a local or regional focus. Various multistate awareness programs[36] include the aim of raising awareness in men about prostate cancer and PSA testing. Other more targeted community campaigns use celebrity or sporting identities to endorse community participation in screening[37] or involve prominent members of the local community, encouraging greater involvement in testing in communities where mortality rates are high,[38] such as the “Little Prick” campaign in the Hunter region of New South Wales.[39] Although there are no data on the varying impact of these campaigns on PSA testing rates by geographical area, it is plausible to expect that the reach and impact of campaigns on men's PSA testing behavior would not be consistent across the country.

Some of the variations in PSA screening observed between small geographical areas, particularly the patterns by remoteness, may also result from differences in access to primary care practitioners, or GPs, who usually instigate the screening pathway. Outlying communities are well documented as having a lower GP supply (70.5 GPs per 100,000 people in very remote areas compared with 103.5 per 100,000 in major cities),[40] and men in rural areas typically have longer wait times to see a GP.[41] Moreover, there are fewer medical specialists (22 per 100,000 people) in very remote areas compared with major cities (143 per 100,000 people).[41] This may impact rural residents' decision whether to be tested because they would likely have to travel great distances to access follow-up diagnostic and treatment services.[41]

Strengths and limitations

One of the main strengths of this study was the use of population-based data that captured the vast majority of PSA tests among the eligible Australian male population and is not subject to known limitations of self-reported data.[42] In addition, reporting on person-based screening history, rather than test-based use as in other studies,[43] removed any impact of multiple tests over the 2-year study period. Also, the Bayesian modeling approach provides more robust estimates of the underlying small-area rates rather than being unduly impacted by the increased random fluctuations associated with small area data.[44]

Medicare claims are restricted to benefits paid to pathology during a single episode of care, known as episode coning. It is possible that coning results in differential testing patterns based on geography. For example, it may be more common in less accessible areas because men who travel greater distances to see a GP might combine multiple more expensive tests into a single visit.[45] However, it is less likely to explain small area variation compared with broader variation between urban and regional or remote areas. While up to 19% of PSA tests may be coned and hence not included in the Medicare data,[45] it is not known to what extent this would vary by small geographical area. In addition, Medicare data only captured the postcode of residence, and the probabilistic allocation of certain postcodes to multiple SA2s may have misassigned some cases to an incorrect area. For this study, the data (2017–2018) were received in the fourth quarter of 2019. We were not able to receive an updated data extract before the completion of this study. In addition, by focusing on a period before the COVID-19 pandemic, it enables us to access the underlying PSA testing patterns independently of any behavioral changes through the various COVID-19 management directives.

In summary, this population-based study identified substantial variation in the PSA screening participation rate by small geographical areas across Australia. The challenge remains to ensure that all males at risk of prostate cancer have access to the same clinical decision-making process, regardless of where they live. This will likely require the development and implementation of more effective resources, policies, and communication strategies that have broader engagement and application than those currently in place.

Author statements

Ethical approval

The ethics approval for this study was obtained from Griffith University Human Research Ethics Committee (GU Ref no: 2017/777).

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Competing interests

None declared.

Data statement

Original data are not able to be supplied by the authors due to data sharing agreement with the custodians. Those seeking original data are advised to contact the custodians. Modeled estimates may be available on reasonable request to the principal investigator (P.B.).

Author contributions

A.K., S.C., D.S., and P.B. were responsible for the conceptualization and design of the study. P.B. was responsible for data acquisition. A.K., S.C., D.S., and P.B. were responsible for data analysis and preparing the tables and figures. All authors were responsible for writing and editing the article.

Author agreement

This original article comprises unpublished work and is not under consideration elsewhere. All authors of this study have read and agreed to the submission.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.039.

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Original Research

Stressors in health care and their association to symptoms experienced by gender diverse people

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A B S T R A C T

Objectives: Many individuals whose gender does not align with the sex they were assigned at birth (gender diverse [GD] people) report stressful health care encounters. We examined the relationship of these stressors to symptoms of emotional distress and impaired physical functioning among GD people.
Study design: This study was conducted using a cross-sectional design with data from the 2015 United States Transgender Survey.
Methods: Composite metrics of health care stressors and physical impairments were developed, and the Kessler Psychological Distress Scale (K-6) provided a measure of emotional distress. Linear and logistic regression were used to analyze the aims.
Results: A total of 22,705 participants from diverse gender identity subgroups were included. Participants who experienced at least one stressor in health care during the past 12 months had more symptoms of emotional distress ($\beta = 0.14$, $P < .001$) and 85% greater odds of having a physical impairment (odds ratio = 1.85, $P < .001$). Transgender men exposed to stressors were more likely than transgender women to experience emotional distress and have a physical impairment, with other gender identity subgroups reporting less distress. Black participants exposed to stressful encounters reported more symptoms of emotional distress than White participants.
Conclusions: The results suggest that stressful encounters in health care are associated with symptoms of emotional distress and greater odds of physical impairment for GD people, with transgender men and Black individuals being at greatest risk of emotional distress. The findings indicate the need for assessment of factors that contribute to discriminatory or biased health care for GD people, education of health care workers, and support for GD people to reduce their risk of stressor-related symptoms.

Introduction

Health disparities experienced by gender diverse (GD) individuals represent a growing public health concern. GD populations include varied groups of individuals whose gender identity is not aligned with the sex that was assigned to them at birth.[1] This includes transgender people (such as transgender men and transgender women) and non-binary individuals (individuals whose gender identity is not solely masculine or feminine or may be in between or shift between masculine and feminine). Non-binary identities also include individuals who describe their gender as agender (or without gender). High rates of health disparities, both psychological and physical, have been observed in the GD community, including a greater prevalence of suicide attempts,[2] depression, and substance use[3] when compared with the general population as well as poorer overall physical health.[4] These poor health outcomes have been associated with chronic stress and

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stigma because of their socially marginalized status.[5,6] As described in the Minority Stress Model, stress related to one's minoritized identity may be experienced in the form of distal and proximal stressors. The stressors experienced by GD people when accessing health care exemplify both distal and proximal stressors.[7,8]

Distal stressors in health care (i.e. stigma such as discrimination, verbal harassment, or physical harm) have been reported by GD people in numerous studies.[9] GD people frequently describe encounters with providers who lack knowledge on GD people and their specific health needs, leaving patients with the burden of educating providers themselves.[10] Overt discrimination, such as refusal of health care services, is also frequently reported, contributing to proximal stressors, such as delaying or avoiding of health care by GD people.[9] However, little is known about these stressors among particular subgroups of GD people, such as transgender men, transgender women, non-binary people, and people who self-identify as cross-dressers. Health care experiences of transgender women have been most widely studied, describing stressors such as the refusal of health care services and inadequate provider knowledge.[9] Similar findings have been observed among transgender men and non-binary people, although they have been less widely studied.[9] Although research provides evidence that these stressors occur and are associated with poor mental health outcomes,[11,12] their relationship to physical health symptoms experienced by GD people is not well understood, One study did find that stress has been associated with poorer physical health outcomes among GD people.[4,13]

In contrast to the limited literature on gender identity, adverse health care experiences based on race/ethnicity have been described widely.[14] Experiences of racial and ethnic minority groups range from lack of provider knowledge on assessment findings unique to darker pigmented skin[15] to discrimination.[16] The limited literature examining health care experiences of GD people of color indicates mixed results ranging from no difference among racial or ethnic subgroups[17,18] to a greater likelihood of reported poor experiences in health care settings when compared to White GD people.[19,20] Intersectionality theory, a theory developed by Black feminist scholars, points to an interlocking relationship between social identities where there are differences in power.[21–23] Race, ethnicity, and gender are areas where distinct types of marginalization interface and interlock to shape differential exposure to stigma and resources, such as health care access.[24] Still, there were few studies that examined the relationship of these stressful encounters in health care to psychological or physical symptoms of GD people of color. Understanding these relationships can help in clarifying the impact of these health care stressors and in developing needed interventions within health care environments and for GD people. The primary aims of this study were to assess the relationship of stressors experienced in health care to symptoms of emotional distress and impaired physical functioning among GD people. We also assessed the moderating roles of gender identity as well as race and ethnicity in the association between these stressors and reported symptoms. We hypothesized that a greater number of stressors experienced in health care would be associated with more symptoms of both emotional distress and impaired physical functioning. We also hypothesized that both gender identity and race/ethnicity would moderate these relationships.

Methods

Data from the 2015 United States Transgender Survey (USTS) were used for these analyses. The USTS is the largest sample of GD people in the United States ($N = 27{,}715$). The survey was developed by the National Center for Transgender Equality to describe the characteristics, experiences, and health of a sample of GD people in the United States.[2] Recruitment efforts were expansive, led by a recruitment advisory group. These efforts included outreach through more than 800 health care organizations, community organizations, online recruitment, survey-focused events, and participant prizes. Participants were required to meet inclusion criteria to be included in the study: identify as GD, 18 years of age or older, and reside in the United States and its territories or foreign military bases.

Demographics

Except for variables regarding gender identity and race/ethnicity, demographic data were used primarily for descriptive purposes. This information included age, education, individual gross income, and sexual orientation. Education was measured by 14 levels (e.g. less than 8th grade, professional degree). This was recoded to four items.[25] Individual gross income was measured by asking participants to identify what their individual income was in 2014, with 18 levels ranging from "no income," $1–$5000 to "$150,000 or more" and recoded to a 6-level categorical variable for greater ease in analysis. Race/ethnicity was measured by nine discrete options (e.g. Alaska Native, Middle Eastern/North African) and a fill-in-the-blank that was recoded to an 8-item variable to facilitate comparison of race/ethnicity categories to standard census reports. Gender identity was assessed using an item for participants to self-select the description closest to their self-described gender. Participants were provided six options (i.e. cross-dresser, woman, man, "trans woman," "trans man," non-binary/genderqueer) that were then recoded and categorized into four groups (i.e. cross-dresser, non-binary, transgender man, and transgender woman).

Stressors in health care

Ten items from the USTS survey were used to measure potential stressors in health care. Participants who reported that they accessed health care within the past 12 months were asked whether they had encountered each of the 10 items during health care interactions. Participants could answer "yes" or "no" (e.g. "I had to teach my doctor or other healthcare provider about trans people so that I could get appropriate care"). The items were developed by a review of the literature performed by scholars in the field of GD health, followed by group consensus regarding which items to include in the final survey.[26] Owing to a severely right-skewed distribution, we recoded the items into a single dichotomous variable, indicating no experience of a health care stressor (0) or reports of 1 or more stressors (1).

Symptoms of emotional distress

Participants' scores on the Kessler-6 (K-6) scale were used to assess symptoms of emotional distress during the last 30 days.[27] The K-6 is a Likert-type scale, with higher scores indicating more distress (range 6–30). The measure has shown excellent validity with the sensitivity to detect serious mental illness ranging from 0.98 to 0.99 and a Cronbach alpha ranging from 0.89 to 0.80.[28] The K-6 also has demonstrated moderate to high test–retest correlation coefficients.[29,30] The sum score was used in this analysis, with a log transformation to improve normality of the distribution.

Symptoms of impaired physical functioning

Participants' symptoms of impaired physical functioning were measured using four dichotomous items in the USTS that were adapted from CDC's Behavioral Risk Factor Surveillance System[31] and the National Health Interview Survey.[32] Items assess (1) difficulty walking or climbing stairs, (2) difficulty dressing or bathing, (3) difficulty concentrating, remembering, or making decisions, and (4) difficulty independently performing activities such as errands, visiting a doctor's office, or shopping. Owing to a severely right-skewed distribution and an inability to correct the skew with various transformations, we created a single dichotomous variable from the four items indicating whether the participant had one or more symptoms of impaired physical functioning (1) or no symptoms of impairment (0).

Data analysis

All analyses were run using Stata 15.[33] Individual items were assessed for distribution and missingness. Multicollinearity of the independent variables was assessed by examining their variance inflation factors and tolerance.[34] No evidence of multicollinearity was identified. USTS survey participants who did *not* complete items about the health care stressors because they had not accessed health care in the past 12 months ($n = 3743$) or who had missing data for measures of emotional distress and physical functioning ($n = 921$) were excluded from analysis. Descriptive statistics were used to determine demographics of the remaining sample (e.g. age, highest level of education). Differences between demographic characteristics of the group that accessed health care during the past 12 months and the group that did not access health care were evaluated using a two-sample test of proportions and Wilcoxon–Mann–Whitney tests.

We used Chi-squared analyses to evaluate the association between stressors in health care and individual gender identities. Linear regression was used to examine the relationship between stressors in health care and symptoms of emotional distress. To examine the relationship between stressors in health care and symptoms of impaired physical functioning (a dichotomous variable), logistic regression was used. Health care stressors were treated as a dichotomous predictor (experienced stressors or not) in all models. All models were adjusted to account for variance due to age, education, and individual gross income.

The moderating effects of gender identity as well as race and ethnicity were evaluated by building interaction terms into the regression models. Dichotomous variables were created for each gender identity group: cross-dresser, non-binary, transgender men, and transgender women. Transgender women were chosen as the reference group in analyses due to the more

Table 1
Sample characteristics of the 2015 United States Transgender Survey ($N = 27{,}715$).

Variable	Accessed health care during past 12 months ($n = 22{,}705$), n (%)	No health care access during past 12 months ($n = 3743$)	P-value
Personal characteristics			
Age (years), mean (SD)	31.5 (13.6)	28.3 (11.61)	<0.001
18–24	9420 (41.5)	1952 (52.2)	
25–44	9137 (40.2)	1387 (37.1)	
45–64	3473 (15.3)	344 (9.2)	
65+	675 (3.0)	60 (1.6)	
Race/ethnicity			
Alaska Native/American Indian	265 (1.2)	33 (0.0)	0.373
Asian/Asian American	569 (2.5)	104 (2.8)	0.325
Black/African American	614 (2.7)	117 (3.1)	0.145
Latino/a/Hispanic	1139 (5.0)	238 (6.4)	<0.001
Multiracial	1006 (4.4)	218 (5.8)	<0.001
Native Hawaiian/Pacific Islander	49 (0.2)	9 (0.2)	0.774
Racial/ethnic identity not listed	487 (2.1)	90 (2.4)	0.341
White	18,473 (81.4)	2914 (77.9)	<0.001
Gender identity			
Cross-dresser	554 (2.4)	162 (4.3)	<0.001
Non-binary (assigned female at birth)	7670 (33.8)	1695 (45.3)	<0.001
Transgender man	6784 (29.9)	824 (22.0)	<0.001
Transgender woman	7697 (33.9)	1062 (28.4)	<0.001
Sexual orientation			
Asexual	2314 (10.2)	544 (14.5)	<0.001
Bisexual	3344 (14.7)	574 (15.3)	0.355
Gay	1076 (4.7)	172 (4.6)	0.702
Heterosexual/straight	2849 (12.6)	358 (9.6)	<0.001
Lesbian	2556 (11.3)	330 (8.8)	<0.001
Same-gender loving	211 (0.9)	39 (1.0)	0.503
Pansexual	4045 (17.8)	799 (21.4)	<0.001
Queer	4828 (21.3)	639 (17.1)	<0.001
Demisexual	223 (1.0)	55 (1.5)	<0.01
Sexual orientation not listed	1259 (5.6)	233 (6.2)	0.096
Socio-economic position			
Annual individual income			<0.001
No income	3014 (13.3)	731 (20.7)	
$1–$9999	6234 (27.5)	1184 (32.8)	
$10,000–$24,999	4904 (21.6)	912 (25.3)	
$25,000–$49,999	3834 (16.9)	435 (12.1)	
$50,000–$100,000	2847 (12.5)	240 (6.7)	
$100,000 +	1457 (6.4)	106 (2.9)	
Educational attainment			<0.001
Less than high school	679 (3.0)	192 (5.1)	
High school grad/GED	2581 (11.4)	705 (18.8)	
Some college/associate's degree	10,394 (45.8)	1849 (49.4)	
Bachelor's degree or higher	9051 (39.9)	997 (26.6)	

GED, General Educational Development; SD, standard deviation.

substantial research about this group. Dichotomous variables were also created for categories of race/ethnicity: Alaskan Native/Native American, Asian, Black, Latino/Hispanic, multiracial, Pacific Islander, White, and race-not-listed. White participants were chosen as the reference group because of the robust body of research showing minority racial and ethnic groups having poorer health outcomes than White individuals.[25]

Results

Sociodemographic characteristics of the sample are described in full in Table 1 ($N = 22{,}705$). The mean age of participants was 31.5 years (standard deviation = 3.6). Within our sample, 83.1% of participants were White, 5.1% were Latino/x or Hispanic, 4.9% were multiracial, 2.8% were Black, and 4.1% were other racial groups (see Table 1). The representation of gender identities was diverse: 33.9% transgender women, 29.9% transgender men, 33.8% non-binary, and 2.4% cross-dressers. Participants also reported diverse sexual orientations: 21.3% queer, 17.8% pansexual, 14.7% bisexual, 12.6% heterosexual/straight, and the remaining (33.6%) identified other sexual orientations. The sample was highly educated, with 85.7% reporting at least some college. It is important to note that participants who accessed health care during the past 12 months ($n = 22{,}705$) and were thus included in this analysis, had higher incomes ($P < .001$) and more education ($P < .001$) than individuals who had not accessed health care and were not included in this analysis ($n = 3743$; see Table 1).

At least one stressor in health care was reported by 66% of the participants in our sample. The most frequently endorsed stressor was answering "no" in response to the item "My doctor knew I was trans and treated [me] with respect" (Table 2). All stressors in health care showed differences across gender identities ($P < .05$).

Symptoms of emotional distress

The mean emotional distress score for the sample was 10.39, with a range of 0–24. For participants who experienced at least one stressor in health care during the past 12 months, there was a 0.10 increase in symptoms of emotional distress ($\beta = 0.14$, $P < .001$, partial $\eta^2 = 0.03$). The participants' highest level of education, and individual income were held constant (see Table 3 for full results).

We found significant effects when testing the moderating role of gender identity in the association between exposure to stressors and symptoms of emotional distress. Individuals who identified as cross-dressers ($\beta = -0.05$, $P < .01$, partial $\eta^2 = 0.001$) and non-binary people ($\beta = -0.05$, $P < .01$, partial $\eta^2 = 0.001$) who experienced stressors in health care had less symptoms of emotional distress than transgender women. However, transgender men who experienced stressors in health care had greater symptoms of emotional distress than transgender women ($\beta = 0.03$, $P < .01$, partial $\eta^2 = 0.0003$).

In testing the moderating effect of race/ethnicity, Black GD people had greater emotional distress associated with exposure to stressors in health care when compared with White GD people

Table 2
Items from 2015 United States Transgender Survey representing stressors in health care that were posed to participants who have accessed health care in the past 12 months ($n = 22{,}705$).

Question	Experienced stressor, *n* (%)	Cross-dresser, *n* (%)	Non-binary, *n* (%)	Transgender men, *n* (%)	Transgender women, *n* (%)
My doctor knew I was trans and treated with respect[a]	**13,609 (59.9)**	**443 (80.0)**	**5539 (72.2)**	**1633 (24.1)**	**1481 (19.2)**
I had to teach my doctor or other health care provider about trans people so that I could get appropriate care.	**5354 (23.6)**	**16 (2.9)**	**1221 (15.9)**	**2144 (31.6)**	**1973 (25.6)**
A doctor or other health care provider refused to give me trans-related care.	**1804 (8.0)**	**7 (1.3)**	**321 (4.2)**	**687 (10.1)**	**789 (10.3)**
A doctor or other health care provider refused to give me other health care (e.g., flu shot, physical).	**662 (2.9)**	**3 (0.5)**	**194 (2.5)**	**219 (3.2)**	**246 (3.2)**
My doctor asked me unnecessary/invasive questions about my trans status that were not related to the reason for my visit.	**3377 (14.9)**	**6 (1.1)**	**839 (10.9)**	**1422 (21.0)**	**1110 (14.4)**
A doctor or other health care provider used harsh or abusive language when treating me.	**1083 (4.8)**	**2 (0.4)**	**52 (3.7)**	**382 (5.6)**	**360 (4.7)**
A doctor or other health care provider was physically rough or abusive when treating me.	**375 (1.7)**	**2 (0.4)**	**110 (1.43)**	**123 (1.8)**	**140 (1.8)**
Was verbally harassed in a health care setting.	**1289 (5.7)**	**6 (1.1)**	**318 (4.2)**	**456 (6.7)**	**509 (6.6)**
I was physically attacked by someone during my visit in a health care setting.	**116 (0.5)**	**1 (0.2)**	**24 (0.31)**	**29 (0.4)**	**62 (0.8)**
I experienced unwanted sexual contact in a health care setting.	**279 (1.2)**	**3 (0.5)**	**60 (0.8)**	**66 (1.0)**	**150 (2.0)**

Bolded values indicate a statistically significant Chi-squared result between gender and stressor in health care ($P < .05$).
[a] The *n* (%) of participants who indicated "no" on this item is reported here.

Table 3
Results of multiple linear regression models evaluating stressors in health care on symptoms of emotional distress in the 2015 United States Transgender Survey ($n = 22{,}705$).

Variables included in the model	R^2	Adj. R^2	B	β	t	P
Model 1: Age, education, individual income, stressors in health care (dichotomous)	**0.26**	**0.25**				**<0.001**
Stressors in health care (dichotomous)			**0.10**	**0.14**	**24.45**	**<0.001**
Model 2: Age, education, individual income, stressors in health care (continuous >0)	**0.22**	**0.22**				**<0.001**
Stressors in health care (continuous >0)			**0.03**	**0.13**	**17.34**	**<0.001**
Model 3: Age, education, individual income, stressors in health care (dichotomous) × gender identity	**0.26**	**0.26**				**<0.001**
Stressors in health care (dichotomous; main effect)				**0.15**	**16.05**	**<0.001**
Cross-dresser (main effect)				0.00	0.06	0.955
Stressors in health care × cross-dresser				**−0.05**	**−3.39**	**<0.01**
Non-binary (main effect)				**0.03**	**1.98**	**0.048**
Stressors in health care × non-binary				**−0.07**	**−4.21**	**<0.001**
Transgender men (main effect)				**−0.11**	**−10.58**	**<0.01**
Stressors in health care × transgender men				**0.03**	**2.71**	**<0.01**
Transgender women (comparison group)				–	–	–
Model 4: Age, education, individual income, stressors in health care (dichotomous) × race/ethnicity	**0.25**	**0.25**				**<0.001**
Stressors in health care (dichotomous; main effect)			**0.09**	**0.13**	**20.87**	**<0.001**
Alaskan Native/American Indian (main effect)			−0.01	0.00	−0.27	0.785
Stressors in health care × Alaskan Native/American Indian			0.06	0.02	1.65	0.125
Asian/Asian American (main effect)			**−0.07**	**−0.04**	**−3.84**	**<0.001**
Stressors in health care × Asian/Asian American			0.04	0.02	1.85	0.064
Black (main effect)			**−0.05**	**−0.03**	**−3.03**	**<0.01**
Stressors in health care × Black/African American			**0.06**	**0.03**	**2.85**	**<0.01**
Latino/Hispanic			−0.02	−0.02	−1.73	0.084
Stressors in health care × Latino/Hispanic			0.03	0.02	1.78	.0.075
Multiracial (main effect)			−0.02	−0.01	−1.06	0.289
Stressors in health care × multiracial			0.02	0.01	1.18	0.237
Native Hawaiian/Pacific Islander (main effect)			−0.08	−0.01	−1.38	0.166
Stressors in health care × Native Hawaiian/Pacific Islander			0.15	0.02	1.91	0.056
Race/ethnicity not listed (main effect)			0.14	0.02	1.83	0.067
Stressors in health care × race/ethnicity not listed			−0.06	−0.01	−0.68	0.497
Stressors in health care × White (comparison)				–	–	–

All models covaried for age, education, and individual income.
Bolded valued indicate statistical significance of p<.05.

($\beta = 0.06$, $P < .01$, partial $\eta^2 = 0.001$). No differences were found among other racial or ethnic groups.

All significant relationships between stressors and emotional distress had standardized beta coefficients ranging from $\beta = 0.03$ to $\beta = 0.14$. Partial eta squared values ranged from $\eta^2 = 0.0003$ to $\eta^2 = 0.03$. These coefficients would be interpreted as small effects sizes.[35,36]

Symptoms of physical impairment

In our sample, 37.5% ($n = 8523$) of participants reported one or more symptoms of physical impairment. As shown in Table 4, participants reporting at least one stressor in health care during the past 12 months had 86% greater odds (odds ratio [OR] = 1.86, $P < .001$, 95% confidence interval [CI] 1.74–1.98) of at least one symptom of physical impairment compared with participants who reported no stressors. The model adjusted for age, highest level of education, and individual income (see Table 4).

We found significant differences for two gender identity subgroups when compared with the reference group, transgender women. Individuals who identified as cross-dressers had lower odds of health care stressors being associated with symptoms of physical impairment than did transgender women (OR = 0.36, $P < .01$; 95% CI 0.20, 0.65). In contrast, transgender men who experienced stressors in health care had greater odds of health care stressors being associated with symptoms of physical impairment than did transgender women (OR = 1.20, $P < .05$; 95% CI 1.03, 1.40). Tests for the moderating effect of race/ethnicity indicated no differences between racial/ethnic groups in the relationship between stressors in health care and symptoms of physical impairment.

Discussion

The results indicate that experiencing even one stressor in health care is associated with greater symptoms of emotional distress. These findings are consistent with previous literature describing discrimination as associated with poor mental health outcomes, such as suicidal ideation,[37] depression,[38] and anxiety.[39] Discrimination in health care has also specifically been associated with suicidal ideation,[11] depression,[18] and psychological distress among GD people. Despite the significance of our results, all beta and eta squared coefficients indicate small effect sizes, suggesting only modest relationships between exposure to stressors and emotional distress and the consequent need for further study.

Some of our most important findings center on the vulnerability of gender identity subgroups. The relationship between experiencing health care stressors and emotional distress was significantly stronger for transgender women than cross-dressers or non-binary people. Although we cannot assume a causal effect because of the cross-sectional nature of these data, the results suggest that the emotional well-being of transgender women may be more adversely affected by the disrespect or discrimination they experience in health care than individuals in many other GD groups This finding extends previous research showing that transgender women are highly stigmatized compared with the general population[2,40] by providing evidence of potential effects of such stigmatization on their mental health. However, transgender men had an even greater association between health care stressors and symptoms of emotional distress than did transgender women. Because greater avoidance of health care has been noted among transgender men when they experience stressors in health care,[17]

Table 4
Results of logistic regression models evaluating stressors in health care on symptoms of emotional distress in the 2015 United States Transgender Survey ($n = 22{,}705$).

Variables included in the model	OR	CI	*P*
Model 1: Age, education, individual income, stressors in health care (dichotomous)			
Stressors in health care (dichotomous)	**1.86**	**1.74, 1.98**	**<0.001**
Model 2: Age, education, individual income, stressors in health care (dichotomous) × gender identity			
Stressors in health care (dichotomous; main effect)	**1.57**	**1.41, 1.74**	**<0.001**
Cross-dresser (main effect)	1.44	0.86, 2.43	0.168
Stressors in health care × cross-dresser	**0.36**	**0.20, 0.65**	**<0.01**
Non-binary (main effect)	**1.94**	**1.66, 2.27**	**<0.001**
Stressors in health care × non-binary	0.96	0.81, 1.15	0.686
Transgender men (main effect)	1.00	0.88, 1.13	0.958
Stressors in health care × transgender men	**1.20**	**1.03, 1.40**	**<0.05**
Transgender women (comparison group)	–	–	–
Model 3: Age, education, individual income, stressors in health care (dichotomous) × race/ethnicity			
Stressors in health care (dichotomous; main effect)	**1.80**	**1.68, 1.94**	**<0.001**
Alaskan Native/American Indian (main effect)	1.60	0.96, 2.68	0.074
Stressors in health care × Alaskan Native/American Indian	1.00	0.55, 1.82	1.00
Asian/Asian American (main effect)	**0.58**	**0.40, 0.85**	**<0.01**
Stressors in health care × Asian/Asian American	1.32	0.86, 2.04	0.205
Black (main effect)	0.93	0.69, 1.26	0.631
Stressors in health care × Black/African American	1.17	0.81, 1.71	0.38
Latino/x/Hispanic	0.79	0.61, 1.02	0.069
Stressors in health care × Latino/Hispanic	1.23	0.91, 1.66	0.169
Multiracial (main effect)	**1.31**	**1.03, 1.68**	**0.030**
Stressors in health care × multiracial	0.99	0.74, 1.33	0.964
Native Hawaiian/Pacific Islander (main effect)	1.10	0.42, 2.88	0.847
Stressors in health care × Native Hawaiian/Pacific Islander	1.12	0.32, 3.94	0.864
Race/ethnicity not listed (main effect)	3.22	0.91, 11.44	0.070
Stressors in health care × race/ethnicity not listed	0.67	0.15, 3.07	0.611
Stressors in health care × White (comparison)	–	–	–

CI, confidence interval; OR, odds ratio.
All models covaried for age, education, and individual income.

delayed access to needed services could contribute to their increased symptoms of distress.

Our results for the moderating effect of race/ethnicity show differences between Black and White GD people but for no other racial/ethnic groups. Black participants had a greater effect size for the relationship between reported stressors and symptoms of emotional distress compared with White participants. Although previous literature has found higher rates of stigma and discrimination among Black GD people,[38] our results indicate that these types of stressors may have a more substantial impact on the emotional well-being of Black GD people.

The results also indicate that GD people who experience stressors in health care have greater odds of physical impairment than individuals who do not experience stressors. Stressors in health care have been shown previously to have deleterious effects on physical health as well as on one's willingness to seek health care services.[9,12,41] Individuals who have experienced mistreatment in health care settings may delay care, with negative effects on their physical health, or they may experience a greater impact on physical symptoms because they are more sensitized to health care stressors.[12] Because we cannot assume the direction of the relationship in these analyses, it is also possible that individuals who have more frequent health care visits because of impairments in physical functioning are more frequently exposed to stressors in health care.

Our findings for differences between gender identity subgroups in the relationship between health care stressors and physical functioning show a similar pattern as our results for emotional distress. Transgender men appeared to be at greatest risk of physical impairments in relation to health care stressors when compared with the other gender identity subgroups in our analysis. Although research on mental health outcomes among gender identity subgroups is limited, there is some evidence that mental health disorders, such as anxiety, may be more prevalent among transgender men.[42] Studies are needed to examine potential biological and psychosocial factors that may increase the potential for increased vulnerability of transgender men to health care stressors and symptom development.

There were no moderating effects of race/ethnicity on the relationship between reported stressors in health care and symptoms of physical impairment. A meta-analysis on the effects of racism in health care indicated that discrimination in health care settings had a greater association with mental health outcomes such as depression than with physical or general health.[43] This could explain why we found that Black GD people experienced greater symptoms of emotional distress in relation to health care stressors than White participants but found no racial differences for physical impairment. However, despite our large sample, it is important to note that statistical power may be a root cause of our lack of more moderating effects for race and ethnicity. The proportion of racial and ethnic minority participants was small, with groups ranging from 0.2% to 5%, in comparison to our White sample (81.4%). Furthermore, in addition to improved efforts for gender-affirming health care environments, multilevel antiracism efforts are needed to address inequities among GD people who are marginalized both in gender and racial identities.[44]

Study limitations should be considered. The cross-sectional design prevents causal inferences about the direction of the relationship between stressors in health care and symptoms. In addition, items representing stressors in health care were only given to participants in the USTS survey who indicated that they had accessed health care in the past 12 months, eliminating some participants from the analysis. As noted under the results, individuals who did not complete the survey appeared to have more socio-economic challenges (lower incomes and less education), decreasing our ability to generalize to these important populations. In addition, original items in the survey representing stressors in health care only offered participants the response options of "yes" or "no," precluding the ability to know the frequency or severity, or in what setting participants experienced each stressor. Furthermore, social desirability bias may have influenced participant responses to sensitive questions, particularly around experiences of mistreatment or violence in health care settings. The mismatch between time frames assessed for health care stressors (the past 12 months) and symptoms of emotional distress (the past 30 days) may have limited our ability to identify concurrent associations between stressors and symptoms experienced earlier in the year. Future work with more nuanced measurements of stressors in health care would help advance our understanding of this phenomenon,[45] particularly to assist in determining the clinical significance of these relationships.

Our need to dichotomize the variables measuring stressors in health care and symptoms of physical impairment (because of their skewed distributions) reduced variability and our power to detect significant effects.[46,47] Because this was a secondary analysis, our measure of physical impairment was limited in scope, representing a small portion of the varied symptoms associated with impairments in physical functioning. As a result, we may have missed participants with symptoms of other impairments, some of which may not affect their daily function but none-the-less impact their health (e.g. hypertension, diabetes). It is not clear whether the increase in symptom burden that was related to stressors for particular groups is due to their frequency of experiencing stressors in health care, the severity or intensity of particular stressors, the unique perception/interpretation of the stressor(s) by the individual, or other factors. Finally, our sample was 83% White non-Hispanic, which is greater than population estimates for GD people in the United States.[48] Similarly, Black & African American participants accounted for only 2.7% of our total sample but are estimated to account for 16% of the GD populations in the United States. Representativeness was also limited in terms of the educational status and income levels of our sample's participants. Our sample was highly educated, with almost 40% of our sample reporting that they have a Bachelor's degree or higher. This varies from what is known about the education level of the broader GD populations, of whom 13% are estimated to have completed college as described by a population-based sample.[49] However, non-probability samples, such as the USTS, allow for analysis of questions, such as stressors in health care, that are unique to the GD community and would be otherwise unaddressed in population-based surveys.[50]

Still, this study provides an important foundation for future research. Further studies can explore the nature of stressors experienced by people of different gender identities as well as the frequency and severity of stressors. The findings also indicate a need for assessment of organizational and individual factors within health care systems that contribute to discrimination, abusive, or insensitive care for GD people. In addition, future research should be extended to specific types of emotional distress and other physical impairments with a more diverse sample. Tailoring recruitment efforts to include both researchers and study personnel from the minoritized groups who are being sought, such as racial and ethnic minority groups, is a key component to effective recruitment practices.[51,52]

Conclusions

Stressors in health care were associated with symptoms of emotional distress and physical impairment among GD people in our sample. Most notably, transgender men and Black participants had a greater symptom burden in association with stressors in health care when compared with transgender women and White participants. Increased research on the characteristics of stressors in health care and how these are experienced among diverse gender and racial groups will increase the opportunity for the development of targeted interventions. The development of affirming and inclusive health care environments that incorporate antiracism principles, including diversifying the health care workforce, should be prioritized to improve the health care experiences of diverse groups of GD people. Furthermore, health care systems can use a more inclusive workforce that reflects the communities they serve.

Author statements

Ethical approval

The United States Transgender Study was originally approved by the University of California, Los Angeles' North General Institutional Review Board. Full details regarding the survey can be found in the final report of its initial findings.[2] Owing to the removal of identifiable data, this secondary analysis was determined to be exempt by the Institutional review Board at the University of California San Francisco. K.D.C was supported in part by the National Institute of Nursing Research (Grant 1F31NR019000-01). Contents are solely the responsibility of the authors and do not necessarily represent the views of the National Institute of Health.

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Competing interests

The authors have no conflicts of interest to report.

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Original Research

Suicide as globalisation's Black Swan: global evidence

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ABSTRACT

Objectives: This empirical study investigated the relationship between globalisation and suicide rates. We examined whether there is a beneficial or harmful relationship between economic, political and social globalisation and the suicide rate. We also estimated whether this relationship differs in high-, middle- and low-income countries.
Study design: Using panel data from 190 countries over the period 1990–2019, we examined the relationship between globalisation and suicide.
Method: We compared the estimated effect of globalisation on suicide rates using robust fixed-effects models. Our results were robust to dynamic models and models with country-specific time trends.
Results: The effect of the KOF Globalisation Index on suicide was initially positive, leading to an increase in the suicide rate before decreasing. Concerning the effects of economic, political, and social dimensions of globalisation, we found a similar inverted U-shaped relationship. Unlike the middle-income and high-income countries, we found a U-shaped relationship for the case of low-income countries, indicating that suicide decreased with globalisation and then increased as globalisation continues to increase. Moreover, the effect of political globalisation disappeared in low-income countries.
Conclusion: Policy-makers in high- and middle-income countries, below the turning points, and low-income countries, above the turning points, must protect vulnerable groups from globalisation's disruptive forces, which can increase social inequality. Consideration of local and global factors of suicide will potentially stimulate the development of measures that might reduce the suicide rate.

Introduction

Suicide is a major public health concern worldwide, and every year, an alarming number of people commit suicide. More than half of suicides occur in low- and middle-income countries, where mental health services are scarce.[1] Furthermore, suicide has resulted in the loss of valuable human capital to society and has substantially influenced life expectancy.[2,3] It also has a devastating and widespread impact on family members, friends, acquaintances, healthcare professionals and local communities. To reduce the global suicide rate, we must first improve our understanding of suicidal behaviour and its dynamics. For this purpose, the United Nations has included suicide prevention as one of 17 goals in its 2030 Agenda for Sustainable Development.[4] Accordingly, we aimed to investigate the relationship between globalisation and the suicide rate on a global scale.

Globalisation (the late 20th century's 'big idea') captures components of a common view of increasing global interconnections in all sectors of society.[5,6] We know that globalisation is transforming our physical reality and that its consequences on inequality, public services, employment and our environments are progressively reshaping our mental health.[7] Changes in economic, political and social interactions are all part of this process. Nevertheless, there has been little discussion of the relationship between globalisation and suicide since Milner et al.'s[8,9] studies.[10] Using the KOF Globalisation Index, we contributed to the literature by estimating the association between globalisation and the suicide rate by countries' income levels separately by subgroups of globalisation. Our research offers new insights to support global policy-makers in developing more effective responses to suicide.

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Durkheim[11] proposed that suicide rates varied with economic and social change and considered that societal changes caused a breakdown in protective ties and values, increasing the likelihood of suicide. Milner et al.[8] supported Durkheim's view with their findings that the changes associated with modernisation were reflected in the increase in suicide rates among European countries. In addition, they argued that global dynamics could impact countries' economic, political, social and cultural systems and contextual determinants of health and mortality. In terms of mental health, Pierce and Schott[12] provided evidence that post-2000 US-China trade liberalisation was associated with an increase in suicide deaths among manufacturing workers in US states. However, although more studies are being conducted on the health-related implications of globalisation, less is known about its impact on suicide or mental health.[7,13–16] In addition, Cai et al.[3] also emphasised the need for globalisation and suicide research as a necessary step forwards in their scientometric analysis of suicide research.

In this article, we investigated the non-linear association between globalisation and suicide rate in three decades. Our hypothesis was that there is a significant relationship between the globalisation of societies and increasing suicide rates. For the purpose of the study, we used a measure of globalisation referred to as the 'KOF Globalisation Index' and its subindices, which Dreher[17] developed for almost every country.[18] To our knowledge, this is the first study to use the recently revised globalisation index as a possible predictor of suicide rate in a global context, including 190 countries for the years 1990–2019. In addition, the relationship between economic, political and social globalisation, which are subdimensions of globalisation, and the suicide rate were used for the first time in this study. Furthermore, this study considered the role of globalisation in countries with varying income levels. According to the World Health Organization,[1] suicide is a worldwide phenomenon. However, few studies include low- and middle-income countries, although these countries account for most suicide deaths worldwide.[19] To gain deeper insight into the problem, we extended the longitudinal suicide studies to include more countries and categorise them according to their income levels.

Methods

Data

Our data consisted of 190 countries for the years 1990–2019. The dependent variable was the suicide rate, measured as the number of suicides per 100,000 population in a country, and it was obtained from the Institute for Health Metrics and Evaluation (IHME)[20] for the publicly available years 1990–2019. The main variables of interest were the KOF Globalisation Index and its subindices: the Economic Globalisation Index, Political Globalisation Index and Social Globalisation Index (for more details, see Dreher[17] and Gygli et al.[18]), reflecting three different dimensions of globalisation. We used the latest version of the data provided in the database of the Swiss Federal Institute of Technology (KOF).[18]

The analysis included a set of control variables based on the previous literature, all of which were assumed to be exogenous in our empirical model. We reported the descriptive statistics in Table 1. First, we included the age-standardised prevalence of the depressive orders, as depression is linked to the risk of suicide[21] because there are significant differences in how depression is diagnosed across cultures.[22] Second, considering the mental impact of changes in income, the annual growth rate of the gross domestic product per capita was added to the analysis, used in constant US dollars.[23] Third, we used the unemployment rate to control job market conditions.[8,24] The unemployment rate represented the number of people who are unemployed as a share of the labour force. The fourth and fifth control variables were female labour force participation[25] as a proxy for social integration and the rural population rate in a country.[8] These control variables were selected as potential predictors of suicide rates at the national level over time. Suicide rates were also controlled for age structure across countries and over time; however, the age structure variable causes a multicollinearity problem in our model. We reported the correlation matrix for the variables in Table 2.

Statistical analysis

The analysed model was a fixed-effects model based on the literature.[26–28] Furthermore, we controlled for the year effects in the analysis. The adopted model is shown in Equation (1).

$$Suicide\ Rate_{i,t} = a + \beta_1 Globalisation_{i,t} + \beta_2 Globalisation^2_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t} \quad (1)$$

where $Suicide\ Rate_{i,t}$ is the suicide rate for country i at year t, and $\varepsilon_{i,t}$ is the error term. $Globalization_{i,t}$ denotes the KOF Globalisation Index and its subindices Economic Globalisation Index, Political Globalisation Index and Social Globalisation Index, whereas $Globalization^2_{i,t}$ is the quadratic form of the said variables. Each index entered the estimation separately with its quadratic form. Finally, $X_{i,t}$ is the set of control variables used in the analysis. Suicide and globalisation may be affected by various factors, including a country's laws, culture and location, but the fixed-effect model controls for these potential confounding factors.

In the first step, we examined the association between the suicide rate and globalisation with its subindices in the full sample. Following the panel data analysis of 190 countries, we observed the association between the suicide rate and the main regressors for three country groups based on their income levels, namely, high-, middle- and low-income countries. These groups are formed based on the World Bank classification in 2019,[29] the last year to include in the analysis. In addition, we performed sensitivity analyses in our models, taking into account the country-specific time trend. We replicated our models with country-specific time trends, including estimations in different income level groups. Finally, we also estimated the dynamic relationship between suicide rates and globalisation and used a two-step generalised method of moments estimator approach for the global sample.[30]

Results

Table 3 presented the estimated effects of globalisation on the suicide rate. First, we estimated a model with only the globalisation index and its quadratic form as the explanatory variables (Column 1 in Table 3). Then, we extended this model in Table 3 by introducing subdimensions of globalisation (Columns 2–4). We introduced in Table 3 the control variables for each of the four models in Columns 5–8. The results of the fixed-effects analysis documented a significant and non-linear relationship between the KOF Globalisation Index and the suicide rate. In addition, we presented the turning point, when indices and their quadratic forms are significant at least at 10%, and the average of globalisation for all models.

The effect of globalisation on suicide was initially positive, leading to an increase in the suicide rate before decreasing. More specifically, in Column 1 in Table 3, the coefficients of globalisation and globalisation^2 were 0.349 and −0.004, respectively. The relationship between globalisation and the suicide rate remained relatively unchanged after the control variables have been

Table 1
Summary statistics.

Variable	Observations	Mean	Standard deviation	Minimum	Maximum	Description	Sources
Dependent variable							
Suicide rate	6120	11.34	9.39	1.43	95.57	Suicide mortality rate (per 100,000 population)	Institute for Health Metrics and Evaluation[20]
Variables of interest							
Globalisation	5658	54.49	16.15	18.87	90.91	KOF Globalisation Index	Gygli et al.[18]
Economic globalisation	5511	53.52	15.89	14.51	94.96	KOF Economic Globalisation Index	
Political globalisation	5768	56.21	24.57	1.19	98.14	KOF Political Globalisation Index	
Social globalisation	5768	53.92	20.51	6.40	92	KOF Social Globalisation Index	
Control variables							
Depression	6032	3.95	0.95	1.64	7.69	Prevalence of depressive disorders, age standardised	Institute for Health Metrics and Evaluation[41]
Income growth	5618	2	5.99	−64.99	140.37	GDP per capita growth (annual %)	World Bank[42]
Unemployment	5278	8.28	6.43	0.10	38.80	Unemployment rate, modelled ILO estimate	
Female labour participation	5457	40.32	9.64	8.26	56.04	Labour force, female (% of total labour force)	
Rural population	5992	43.94	23.96	0	94.58	Rural population (% of total population)	

Note: The variables are explained in detail in the description column. All data sources are publicly available.

accounted for (Column 5 in Table 3). These results for globalisation imply that the effect of globalisation is positive up to a certain point, after which the effect becomes negative. We found similar results for economic, political, and social globalisation, social globalisation's coefficient decreases to 0.079, and social globalisation^2 is −0.001 (Column 8 in Table 3). As a result, we found similar turning points for globalisation and its subindices, such as economic and political globalisation, 51.49, 50.09 and 53.93, respectively (Columns 5, 6 and 7 in Table 3). These results were also slightly below the average for globalisation. However, we found that the effect of social globalisation is positive up to 31.02 (Column 8 in Table 3); after that, the effect became negative. Compared with the other indices' results, it was noticeably lower than the average value. Overall, we observed a significant inverted U-shaped relationship between the KOF Globalisation Index, including all subindices, and the suicide rate.

In Table 4, we analysed whether the effects of globalisation varied in different income-level country groups. The estimations showed a significant inverted U-shaped relationship between the KOF Globalisation Index and the suicide rate for high- and middle-income countries; however, the direction of the relationship was different in low-income countries. The estimated coefficient of globalisation for high-income countries was 1.190, and globalisation^2 is −0.010 (Column 1 in Table 4). We found that the effect of globalisation in high-income countries is positive up to 62.69; after that, the effect turns negative. For economic, political and social globalisation, we documented a similar relationship between globalisation and suicide rate, and turning points were 62.52, 54.64 and 60.53, respectively (Columns 2, 3 and 4 in Table 4). This result demonstrated that the average relationship between globalisation and suicide was more substantial in high-income countries than in others (Column 1 in Table 4; *see for country-specific turning points for 1990 and 2019*, Appendix Fig. A1). Although the results for middle-income countries (Columns 5–8 in Table 4; see Appendix Fig. A2) were similar to those we found without country separation, for the case of low-income countries, we observed a U-shaped relationship between globalisation and the suicide rate (Columns 9–12 in Table 4; see Appendix Fig. A3). This suggests that globalisation decreases the suicide rate in low-income countries in the beginning periods to 40.30 (Column 9); after that, the suicide rate increases as the countries become more globalised.

Looking at economic globalisation, we found a similar inverted U-shaped relationship with globalisation in the case of high-income countries (Column 2 in Table 4), while we again saw a U-shaped relationship for low-income countries (Column 10 in Table 4). According to our findings, economic globalisation had no significant relationship with economic globalisation for middle-income countries (Column 6 in Table 4). Regarding political globalisation, we reported a similar relationship between globalisation and suicide rates in high- and middle-income countries (Columns 3

Table 2
Matrix of correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Suicide rate	1.000									
Globalisation	0.269	1.000								
Economic globalisation	0.226	0.849	1.000							
Political globalisation	0.181	0.784	0.421	1.000						
Social globalisation	0.268	0.874	0.798	0.441	1.000					
Depression	−0.011	−0.168	−0.137	−0.043	−0.247	1.000				
Income growth	0.050	0.028	0.070	0.012	0.001	−0.040	1.000			
Unemployment	0.159	0.053	0.074	−0.056	0.139	0.073	0.010	1.000		
Female labour participation	0.317	0.046	0.013	0.051	0.032	−0.076	0.022	−0.076	1.000	
Rural population	−0.122	−0.687	−0.585	−0.464	−0.686	0.061	0.045	−0.131	0.200	1.000

Note: Table reports the matrix of Pearson correlations. Suicide rate is the dependent variable, whereas the globalisation and its subindices (variables from 2 to 5) are main variables of interest, which enter the estimation separately due to the high correlation.

Table 3
Fixed-effects estimations of the effect of globalisation and subindices on suicide rates.

Variable	Model of suicide rate							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Globalisation	0.349***				0.338***			
	(0.089)				(0.070)			
Globalisation^2	−0.004***				−0.003***			
	(0.001)				(0.001)			
Economic globalisation		0.316***				0.203***		
		(0.083)				(0.058)		
Economic globalisation^2		−0.003***				−0.002***		
		(0.001)				(0.001)		
Political globalisation			0.187***				0.222***	
			(0.052)				(0.045)	
Political globalisation^2			−0.002***				−0.002***	
			(0.001)				(0.000)	
Social globalisation				0.101*				0.079*
				(0.052)				(0.047)
Social globalisation^2				−0.002***				−0.001***
				(0.001)				(0.000)
Depression					6.169***	6.389***	6.277***	6.511***
					(1.045)	(1.151)	(1.048)	(1.106)
Income growth					0.006	0.011	0.013	0.012
					(0.007)	(0.007)	(0.008)	(0.008)
Unemployment					0.085	0.096	0.091	0.101*
					(0.058)	(0.059)	(0.056)	(0.058)
Female labour participation					0.067	0.006	0.037	0.030
					(0.068)	(0.064)	(0.060)	(0.068)
Rural population					−0.0017	−0.010	−0.045	−0.009
					(0.036)	(0.039)	(0.037)	(0.038)
Constant	3.388	3.949*	7.553***	10.460***	−24.955***	−19.947***	−19.237***	−17.505***
	(2.176)	(2.006)	(1.182)	(1.478)	(5.361)	(5.241)	(4.899)	(5.496)
Observations	5658	5511	5768	5768	4838	4806	4884	4884
Number of countries	190	186	194	194	175	174	177	177
Turning points	48.54	49.12	52.07	33.84	51.49	50.09	53.93	31.02
Mean globalisation	54.49	53.52	56.21	53.93	54.49	53.52	56.21	53.93
R-squared	0.137	0.124	0.105	0.099	0.323	0.291	0.315	0.296

Note: The first four columns present the baseline estimations for the globalisation index, its subindices, and their quadratic forms. The columns from 5 to 8 include the estimations with control variables. We control for year fixed effects and employ fixed effects models. Estimations report the unstandardised beta-coefficients. Robust standard errors are in parentheses. We calculate the turning point when indices and their quadratic forms are significant at least at 10%. Mean globalisation presents the average of the globalisation and its' subindices for the global sample.
***, ** and * indicate the significance levels at 1%, 5% and 10%, respectively.

and 7 in Table 4, respectively), but this effect disappeared in low-income countries. However, social globalisation followed the same pattern as globalisation only for high-income countries: a positive linear connection and a negative quadratic relationship, and the opposite was true for low-income countries.

Discussion

This was the first study to examine the relationship between globalisation's economic, political and social subdimensions and suicide rates. Furthermore, for the first time, we used the recently revised globalisation index to estimate suicide rates in 190 countries from 1990 to 2019. Our main finding was that globalisation initially increases suicide before decreasing it. This was in line with the findings of Milner et al.[8] Concerning the effects of economic, political and social dimensions of globalisation on the suicide rate, we found a similar non-linear relationship. These subindices were first associated with an increase in the suicide rate and then a decrease.

We found interesting and different results when we subgrouped the countries based on income levels. Although we found that economic and social globalisation positively correlated with suicides in high-income countries, we observed the opposite direction for low-income countries. In addition, unlike in high-income countries, political globalisation had no effect in low-income countries. The first impression from this result is that residing in a country with a low standard of living confers a benefit of globalisation concerning the incidence of suicide. Explaining the relationship between suicide rate and country income level is more complex than demonstrating it. Nevertheless, these findings provided provocative evidence for the vulnerability paradox.[31] Similar to Dückers et al.[31] and Hofstede,[32] we hypothesised that higher degrees of individualism, a more equitable power distribution and less constraint in following fundamental human impulses may increase sensitivity to societal failure and restricted expectations. Rudmin et al.'s[33] findings for 33 countries also supported our hypothesis. Nevertheless, increased suicide rates and individualism do not necessarily mean that individualism is the root cause of the problem.[33] Political globalisation appeared to be the only subdimension of globalisation related to the high suicide rate in middle-income countries.

As Marsella[34] portrayed, with globalisation, we can travel from one culture to another as if we were riding the waves of television, the internet, movies and literature while avoiding natural and manufactured borders. By causing identity uncertainty and modifying cultural value frameworks, globalisation may indirectly affect the suicide rate.[8,13,35] In addition, suicide rates in high- and middle-income countries can be linked to the rise in health inequalities that comes with modernisation as socio-economic inequalities persist in health.[36]

In terms of the control variables, only depression had a statistically significant and positive effect on suicide for all models, implying that a higher prevalence of depressive disorders was linked to higher suicide rates. It is known that the degree of depressive symptoms and the risk of suicidal behaviour are strongly related.[37] The important finding here is changing the size

Table 4
Fixed-effects estimations of the effect of globalisation and subindices in high-, middle- and low-income country groups.

Variable	Model of suicide rate											
	High-income countries				Middle-income countries				Low-income countries			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Globalisation	1.190***				0.273**				−0.364***			
	(0.242)				(0.119)				(0.115)			
Globalisation^2	−0.010***				−0.003**				0.005***			
	(0.002)				(0.001)				(0.001)			
Economic globalisation		0.598**				0.100				−0.205***		
		(0.225)				(0.071)				(0.054)		
Economic globalisation^2		−0.005**				−0.001				0.003***		
		(0.002)				(0.001)				(0.001)		
Political globalisation			0.375***				0.155***				0.082	
			(0.126)				(0.056)				(0.051)	
Political globalisation^2			−0.003***				−0.002***				−0.001	
			(0.001)				(0.001)				(0.001)	
Social globalisation				0.835***				−0.037				−0.205***
				(0.201)				(0.061)				(0.065)
Social globalisation^2				−0.007***				−0.001				0.003***
				(0.002)				(0.001)				(0.001)
Depression	5.200***	5.398***	5.702***	5.695***	6.890***	7.142***	6.710***	7.054***	3.376***	3.503***	3.648***	3.479***
	(1.330)	(1.521)	(1.476)	(1.498)	(1.831)	(2.162)	(1.769)	(1.836)	(0.866)	(0.980)	(1.089)	(0.855)
Income growth	0.052*	0.038	0.032	0.026	0.008	0.010	0.010	0.011	−0.008	−0.007*	−0.007*	−0.006
	(0.028)	(0.031)	(0.027)	(0.027)	(0.009)	(0.009)	(0.010)	(0.010)	(0.005)	(0.004)	(0.004)	(0.004)
Unemployment	0.092*	0.077	0.102*	0.075	0.080	0.091	0.078	0.096	0.024	0.030	−0.014	−0.009
	(0.053)	(0.051)	(0.052)	(0.050)	(0.091)	(0.092)	(0.090)	(0.089)	(0.037)	(0.041)	(0.038)	(0.033)
Female labour participation	0.230*	0.226*	0.182	0.197*	0.004	−0.017	0.033	−0.028	−0.015	−0.022	−0.036	−0.061**
	(0.120)	(0.126)	(0.123)	(0.110)	(0.118)	(0.119)	(0.109)	(0.117)	(0.025)	(0.028)	(0.032)	(0.029)
Rural population	−0.122	−0.149*	−0.117	−0.112	0.043	0.042	0.021	0.034	−0.007	−0.036	−0.052*	−0.024
	(0.078)	(0.082)	(0.075)	(0.075)	(0.048)	(0.051)	(0.049)	(0.048)	(0.033)	(0.030)	(0.030)	(0.024)
Constant	−47.346***	−29.051**	−19.785**	−36.734***	−26.059***	−22.512***	−22.291***	−16.842***	−1.164	−2.393	−6.404	−2.199
	(11.782)	(11.224)	(9.186)	(10.664)	(6.729)	(6.686)	(5.862)	(5.927)	(5.345)	(5.571)	(5.902)	(4.831)
Observations	1330	1330	1376	1376	2723	2694	2723	2723	785	782	785	785
Number of countries	48	48	50	50	98	97	98	98	29	29	29	29
Turning points	62.69	62.52	54.64	60.53	46.54	–	47.65	–	40.30	38.74	–	37.27
Mean globalisation	69.40	69.06	63.44	74.77	50.63	49.61	54.01	49.08	38.43	37.32	49.00	27.96
R-squared	0.586	0.532	0.545	0.544	0.225	0.193	0.228	0.222	0.613	0.585	0.559	0.624

Notes: Control variables remain the same for the estimation of the effect of globalisation, its subindices and their quadratic forms in income-based country groups, which are formed according to the World Bank Classification in the year 2019. We control for year fixed effects and use fixed effects models. Estimations report the unstandardised beta-coefficients. Robust standard errors are in parentheses. We calculate the turning point when indices and their quadratic forms are significant at least at 10%. The mean globalisation presents the average of the globalisation and its subindices based on different income levels.
***, ** and * indicate the significance levels at 1%, 5% and 10%, respectively.

of coefficients among the income-level country groups. According to Bhugra and Mastrogianni,[22] the symptoms of depression can vary from one culture to the next depending on factors, such as social norms, cultural differences and religious beliefs. Therefore, depression may be underdiagnosed in some cultures, and its relationship with suicide rates may vary widely from one society to another.

Strengths and limitations

This was the first study to use the recently revised KOF globalisation index and estimate suicide rates. The study findings provided guidance for improving suicide prevention measures at both the regional and international levels. We acknowledge that the index developed to measure globalisation has not yet been fully validated. On the other hand, it has been used in a considerable number of studies. Gozgor's[38] robust evidence showed that the construction of the KOF index of economic globalisation has not suffered from any significant measurement errors.

Similar to most other globalisation indices, the KOF Globalisation Index focused on measuring globalisation at the country level, omitting all within-country transactions.[18] Despite a sensitive methodology, the results might have been affected by time and country context.[8] Compared with high-income countries, low- and middle-income countries are more likely to underreport suicide rates.[8,9,39] However, this possible bias is generally recognised to be stable over time, even when potential sources of bias in data recording are taken into account. Although aggregate studies are more likely to result in methodological issues such as ecological fallacy, globalisation does not directly affect suicide rates at the individual level. However, as Neumayer[40] pointed out, the current findings showed that explaining variation in aggregate large-unit suicide data cannot be dismissed outright due to an alleged ecological fallacy.

Conclusion

We showed that globalisation and its subdimensions were positively associated with suicide rates in high- and middle-income countries, up to a point. The findings on globalisation and social globalisation in low-income countries are contrary to the results in high- and middle-income countries; we also found no significant relationship between political globalisation and suicide rates for this country group. According to our findings, policy-makers in high- and middle-income countries, below the turning points, and low-income countries, above the turning points, must address globalisation and its relationship with suicide carefully. We recommend protecting vulnerable groups from the negative consequences of globalisation's disruptive shifts, which can cause more significant inequalities in society.

Consideration of local and global factors of suicide will potentially stimulate the development of measures that might potentially reduce the suicide rate. In addition, individualist and market-centric approaches to policy-making should be redefined in favour of those that emphasise the well-being of society as a whole. In addition, there is a need for scholars to widen existing understandings of suicide prevention from individual- or community-level viewpoints to a global perspective, given the far-reaching implications of globalisation on societies throughout the globe. As this study only presented a general viewpoint on globalisation and its subdimensions, further research is needed before firm conclusions can be reached regarding the relationship between globalisation and suicide. For example, conducting a similar study based on age groups and gender will provide resources to define the target group for health policies more clearly. On the basis of global-scale findings such as ours, more centralised research using country-representative data can directly investigate the mental health effects of globalisation on people in that region, which can be linked to suicide. Thus, we can uncover more specific underpinning mechanisms, such as 'how' and 'why' globalisation affects suicide.

Author statements

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Ethical approval

Not applicable.

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Competing interests

The authors have no competing interests to declare.

Appendix A. Supplementary data

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Themed Paper – Original Research

The development of a family-based wearable intervention using behaviour change and co-design approaches: move and connect

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A B S T R A C T

Background: Previous research has explored the effectiveness of wearable activity trackers (wearables) for increasing child physical activity (PA) levels, but there have been mixed results. The use of theoretical frameworks and co-design techniques are recognised ways of increasing an intervention's acceptability and effectiveness.
Aims: This study aims to use co-design workshops and an evidence-based theoretical framework (the Behaviour Change Wheel) to develop a family-based PA intervention using wearables.
Methods: Three stages of intervention development outlined by the Behaviour Change Wheel were used. Co-design workshops with seven families (11 parents and 12 children) and seven PA experts were conducted where stakeholders discussed how to overcome previously identified barriers to families being active and using wearables. This resulted in the intervention's components being developed, with each component's mechanisms of action (e.g. intervention functions and behaviour change techniques) being retrospectively identified.
Results: The 'Move & Connect' intervention was developed, which targets family PA and wearable use. The intervention takes a flexible approach and includes eight components, including wearable devices (Fitbit Alta HR), support resources, an introductory workshop, collective challenges, goal setting and reviewing, engagement prompts, social support and health-related resources (e.g. educational videos). The intervention incorporates six intervention functions targeting PA and wearable use: education, training, modelling, persuasion, incentivisation and environmental restructuring and 24 behaviour change techniques, including goal setting, social comparison, feedback on behaviour and graded task.
Conclusions: This is the first known study to use an evidence-based framework and co-design to develop a family-based wearable intervention. The identification of the intervention's mechanisms of action will prove useful when implementing and evaluating the 'Move & Connect' intervention and allow researchers to replicate its components.

Introduction

Physical inactivity during childhood is a public health concern,[1,2] with some studies estimating as few as 29% of children are meeting physical activity (PA) recommendations of 60-min of moderate-to-vigorous-intensity PA per day.[3] Approaches to increasing PA are conducted at an individual level, community level and policy level[4] but have had varying success.[5] Advances in technology have led to greater ability to monitor and change movement behaviours, such as PA.[6–8] Technology intervention tools (e.g. apps,[9] pedometers[10]) have previously been implemented in various settings (e.g. school,[11–13] family[14–16]) aimed at increasing child PA levels. Previous research has found that wearable activity trackers (wearables) can increase step counts and moderate-to-vigorous-intensity PA (MVPA) in 5- to 19-year-olds,[17] and their use in the family environment is acceptable and can increase motivation for PA.[14]

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However, there is limited research exploring wearable's ability to increase child and adult PA, when implemented in the family.[17]

The Behaviour Change Wheel

The Medical Research Council (MRC) recommends complex interventions should be developed based on appropriate evidence and theory to clearly understand the intervention's process of change.[18] The Behaviour Change Wheel (BCW) is one framework used to systematically develop behaviour change interventions.[19] The BCW is a synthesis of 19 frameworks and uses the Capability, opportunity, motivation and behaviour (COM-B) model[19] and Theoretical Domains Framework (TDF)[19] to consider how interventions can incorporate functions and behaviour change techniques (BCTs) to change behaviour.[19] The COM-B model suggests a change in capability, opportunity and/or motivation may directly change behaviour or a change in capability or opportunity may indirectly change behaviour via motivation.[19] The TDF is an extension of the COM-B model and further differentiates a set of 14 domains that correspond with capability (knowledge; behavioural regulation; memory, attention and decision process; skills), opportunity (environmental context and resources; social influences) and motivation (goals; optimism; intentions; beliefs about capabilities; beliefs about consequences; professional/social role and identity; reinforcement; emotion).[19] The BCW develops ‘theory-based’ interventions by systematically linking barriers of a behaviour (identified by the COM-B model and TDF) to intervention functions and BCTs to change the behaviour.[19,20] This compares to ‘theory-inspired’ interventions, where elements of a theory are loosely embedded within an intervention, or it is unclear whether theoretical underpinnings were used in the development of the intervention (e.g. theory could be referenced retrospectively).[19,20] The BCW outlines three stages of intervention development, which have previously been used to develop interventions aimed at increasing PA[15] and reducing sedentary behaviour[21] in adults.

Co-design

Limitations of evidence- and theory-based interventions (e.g. using the BCW) are that they do not always translate into practice, which is known as the ‘research-practice gap’.[22] A way of overcoming this gap is to engage intervention target users in the development of the intervention, treating them as equal partners to researchers, practitioners and other experts in the field.[22] Examples of such participatory research methods are co-production, co-creation and co-design.[23,24] These terms are often used interchangeably, with no clear difference in definitions between them.[25] The term co-design will be used in the present study, consistent with previous research using similar methodology (e.g. workshops).[26,27] Co-design techniques (e.g. workshops, forums, surveys[28]) may increase the efficacy of behaviour change interventions[25,28] and enable researchers to examine whether interventions are acceptable, feasible, enjoyable, motivating and informative for the target group.[29] Previous research has identified several barriers to implementing family-based wearable interventions, such as technical difficulties, inability to interpret wearable outputs and use wearable features.[14,30,31] Combining theory-based and co-design methodology, within the present study, is expected to increase the efficacy of the newly developed intervention and overcome previously identified barriers to families using wearables.

This study aims to use co-design workshops and an evidence-based theoretical framework (the three stages outlined by the BCW[19]) to develop a family-based intervention using wearable activity trackers.

Methods

This study used participatory methods to develop a family-based wearable intervention, informed by co-design workshops, previous research[14,17] and the BCW.[19]

Recruitment and stakeholders

Stakeholders were split into two groups: (1) families and (2) PA experts.

- Families: Families (parents and children) were recruited using convenience sampling (e.g. existing connections and social media posts). Families were eligible to participate if they (1) had at least one child, aged 5 to 9 years; (2) considered at least one member to not participate in regular PA; and (3) had access to Wi-Fi/internet and a smart device to participate in the online workshops. Online workshops were chosen due to COVID-19 restrictions at the time of this study (social distancing measures were in place). Families with 5- to 9-year-olds were selected as few wearable-based interventions have targeted this age group,[17] and preliminary research, which informed the co-design workshops, were informed by an acceptability study targeting families with 5- to 9-year-olds.[14]
- PA experts: Experts were purposefully recruited (via existing connections) if they had experience in one or more of the following areas:
  1. Development or design of a PA intervention.
  2. Implementation or evaluation of a PA intervention.
  3. Using wearable activity trackers as a feasibility or intervention tool.
  4. Working with children and/or families in a research or community setting, such as (but not limited to) community workers or practitioners.

Experts' eligibility against these criteria was assessed via the expert's online bibliographies, publication records and/or informal correspondence with the study's research team to discuss their previous and current experience and/or job role(s).

Ethical approval

This study was approved by Loughborough University Ethical Approvals (Human Participants) Sub-Committee (REF: 2021-29221-5132). All family members and experts provided informed consent (parents on behalf of children), and children provided their own assent.

Materials and procedure

Demographic questionnaire

All workshop participants completed a demographic questionnaire before attending the online workshops.

- Families: All family member's age, gender, ethnicity, home postcode and wearable use were collected. Self-reported PA levels, using the short version of the International PA Questionnaire (IPAQ-SF[32]), were also collected (parental report for all children). The IPAQ-SF has previously been found to have acceptable reliability and validity for adults and children.[33,34] The IPAQ-SF documents the number of days (in the last 7 days) spent participating in moderate PA and vigorous PA (frequency 0–7) and the average number of minutes spent during those days (duration; 10-min increments from 10 min to more than 120 min). The number (percentage) of family members

meeting the UK's Chief Medical Officers' PA recommendations of an average 60 min of MVPA per day (3–18 years) and an average of 150 min of moderate physical activity (MPA) or 75 min of vigorous physical activity (VPA) per week (≥18 years) were calculated. Adults also reported their highest educational qualification (none, General Certificate of Secondary Education, Advanced level, National Vocational Qualification level 4, Bachelor's degree, Master's degree, doctorate or other).
- PA experts: Expert's ethnicity, highest educational qualification, job role, work setting/sector and wearable use were collected.

Intervention development

This study followed the three stages of intervention development outlined by the BCW[19] (Fig. 1). Stage 1 (understanding the behaviour) was conducted before the co-design workshops, and Stages 2 (identify intervention options) and 3 (identify content and implementation option) were conducted after the co-design workshops.

Stage 1. understand the behaviour (steps 1–3). The guidance outlined as part of the BCW was followed to address steps 1, 2 and 3.[19] Step 1 required the present research team to operationalise (1) the target individual, group or population involved in the behaviour; and (2) the behaviour itself.[19] The research team discussed the following questions, as recommended by the BCW:[19] (1) What are the behaviours? (2) Who is involved in performing the behaviour? (3) Where does the behaviour occur?

The first author (A.V.C.) then completed step 2 by generating a list of potential behaviours that may influence the selected target behaviour(s). The behaviours were then reviewed by the wider research team, and the following discussed, as recommended.[19]

1. The likely impact if the behaviour were to be changed.
2. How easy it would be to change the behaviour.
3. The centrality of the behaviour within the system of behaviours. The positive 'spill-over' effect if that behaviour were to be changed.
4. How easy it is to measure the behaviour.

The target behaviours were then further refined, collaboratively by the research team, using the following questions (step 3):[19] (1) *Who* needs to perform the behaviour? (2) *What* does the person need to do differently to achieve the desired change? (3) *When* will they do it? (4) *Where* will they do it? (5) *How often* will they do it?

Stage 1. identify what needs to change (step 4). The final step of stage 1 was to identify what needs to change for families to use wearables to increase their PA. The findings from previous research[14,17] were used to form the basis of the co-design workshops. A.V.C. pooled together the findings from previous work, which included a systematic review exploring the acceptability, feasibility and effectiveness of wearables for increasing PA in 5- to 19-year-olds[17] and a 4-week study exploring families' acceptability of using wearables.[14] Key findings from these studies were aligned with components of the COM-B model[19] and TDF,[35] and A.V.C. generated a list of barriers preventing families from using wearables to be physically active. A.V.C. and H.A.J.B. discussed each barrier and came to a final decision for each barrier: 'very promising', 'quite promising', 'unpromising but worth considering' or 'unacceptable'.[19] Previous research also reported families' suggestions for future wearable interventions.[14,17] These intervention suggestions were evaluated by A.V.C. and H.A.J.B. using the 'APEASE' criteria (affordability, practicability, effectiveness and cost-effectiveness, acceptability, side-effects, equity). These evaluation criteria were used to decide which barriers and intervention suggestions were presented as vignettes in the co-design workshops. Based on the duration of the workshops (1.5 h each), it was anticipated that between eight to ten vignettes could be presented.

Co-design workshops. All families and PA experts took part in two 1.5-h online workshops (using the online teleconferencing platform, Zoom). Family and expert workshops were conducted separately, with both family workshops taking place before the two expert workshops. All family and expert workshops were led by A.V.C. and facilitated by S.A.C. and D.D.B., were audio recorded and transcribed by A.V.C.

Family workshops

Workshop 1

Families were presented with vignettes that displayed family-related barriers to the target behaviours (PA and wearable use) and intervention suggestions. Vignettes are stories or descriptions (e.g. textual or pictographic form) of hypothetical characters in circumstances or scenarios.[36,37] Their advantages include reducing pressure and social desirability and allowing participants to lead their own discussions and interpretations of the scenarios presented.[36] Participants were asked to discuss what the intervention could include to overcome the presented barriers and whether they would incorporate the intervention suggestions into the intervention. At the end of workshop 1, family members were encouraged to consider the intervention's name. These were discussed in workshop 2. After workshop 1, A.V.C. and H.A.J.B. synthesised the key findings from workshop 1 by grouping together families' suggestions for each vignette presented.

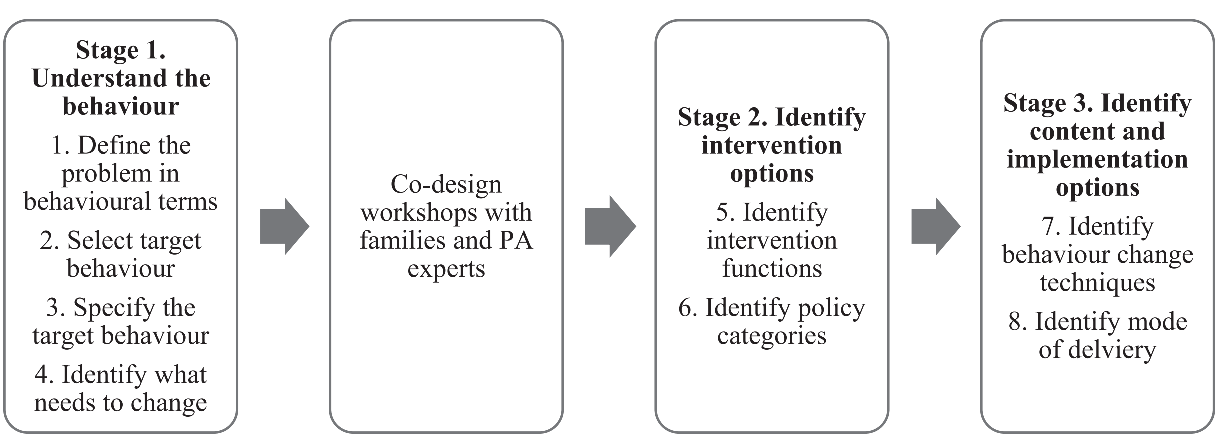

Fig. 1. Stages of intervention development outlined by the Behaviour Change Wheel,[19] with the addition of co-design workshops, used in the present study.

Workshop 2

Suggestions for implementing intervention components discussed in workshop 1 were re-presented in the second workshop, and family members were asked to refine the intervention components (e.g. any additions, adaptations or removal of intervention components). Family members were then asked about their suggestions for the intervention name. A.V.C. and H.A.J.B. pooled together key findings from both family workshops to inform the expert co-design workshops.

Expert workshops. Both expert workshops followed the same format as the family workshops but included the addition of families' intervention suggestions and responses to the vignettes. Experts were told the purpose of consulting with them was to consider how families' intervention suggestions may be adapted to increase the intervention's effectiveness, sustainability and scalability. Experts were encouraged to discuss their knowledge and experience of implementing similar intervention components, particularly considering what has, and has not, been successful in their previous research.

Stage 2. Identify intervention options. The remaining steps took place after the co-design workshops. All workshop content (families and experts) were transcribed by A.V.C. and summarised using three stages of thematic analysis[38] by A.V.C. and H.A.J.B. A.V.C. and H.A.J.B. familiarised themselves with the transcriptions and used NVivo software (QSR International, Melbourne, Australia) to independently develop inductive free codes by coding each line (family and expert responses) according to its meaning. Free codes were then developed inductively into themes, which reflected intervention components. A.V.C. and H.A.J.B. discussed each theme and collaboratively refined them, resulting in the intervention's components. A.V.C. and H.A.J.B. summarised the key intervention components and used the 'APEASE' criteria[19] (same as step 4) to determine which were to be included and excluded in the intervention. This included considering whether the intervention components were affordable, practicable, effective, cost-effective, acceptable, equitable or would result in any negative side-effects, when considering the availability of funds and resources to implement the intervention in the near future.

Stage 2. Identify intervention functions (step 5). A.V.C. and H.A.J.B. deductively coded for intervention functions present within each intervention component (including the wearable; Fitbit Alta HR), using the nine functions outlined by the BCW (education, persuasion, incentivisation, coercion, training, restriction, modelling, enablement and environmental restructuring).[19] A.V.C. and H.A.J.B. were provided with definitions of each function, and coding was conducted independently. Once completed, the results were discussed, and any disagreements resolved. To code for intervention functions in the wearable, A.V.C. and H.A.J.B. wore and interacted with the Fitbit Alta HR, and its partnering app for four consecutive weeks, and carried out the same coding procedure described previously.

Stage 2. Identify policy categories (step 6). As the intervention was intended to be implemented at an individual level, the authors did not identify policy categories.

Stage 3. Identify content and implementation options

Stage 3. Identify BCTs (step 7). A.V.C. and H.A.J.B. deductively coded for BCTs present within each intervention component, and the Fitbit Alta HR, using the 93 BCTs outlined by the BCTTv1[19,39] (part of the BCW). A.V.C. and H.A.J.B. were provided with definitions of each BCT and had completed BCTTv1 online training (https://www.bct-taxonomy.com/), which included tasks to identify BCTs present in interventions. Coding was conducted independently and, once completed, resolved any disagreements (same as step 5). To code for BCTs in the wearable, A.V.C. and H.A.J.B. wore and interacted with the Fitbit Alta HR and its partnering app for four consecutive weeks and carried out the same coding procedure described above (similar to Stage 2, Step 5).

Stage 3. Identify the mode of delivery (step 8). The mode of delivery for each intervention component was discussed with families and experts throughout the co-design workshops. If the delivery of intervention components was unclear, these were discussed amongst the current research team (A.V.C., H.A.J.B., D.D.B., S.A.C. and S.C.).

Results

Preworkshops

Define the problem in behavioural terms and select and specify the target behaviour (steps 1–3)

Table 1 outlines the results from steps 1, 2 and 3. Two target behaviours were selected: (1) PA and (2) wearable use. Physical activity was selected, as few children[3] and adults[40] are meeting PA guidelines, and wearable use was selected as previous research has reported children and adults experience a 'novelty effect' (reduction in use after using a wearable for a period due to loss of interest; ~2–4 weeks[41]) when using wearables.[14,17,42] Potential behaviours impacting PA and wearable use in children and adults were

Table 1
Defining and specifying the intervention's target behaviours: PA and wearable use.

Target behaviour 1	Increase family PA to meet the guidelines of ≥60 min of MVPA/day for children and ≥150 min of MPA or ≥75 min of VPA/week for adults. Encourage family co-participation in PA, where possible.
Who needs to perform the behaviour?	All family members. Families must live in Bradford, West Yorkshire, UK.
What does the person need to do differently to achieve the desired change?	Participate in the intervention and use the Fitbit to support this change.
When will they do it?	Habitual. Anytime that works for their family.
Where will they do it?	Anywhere.
How often will they do it?	Every day (for children) and weekly (for adults). Co-participation in PA when possible.
Target behaviour 2	Encourage wearable use.
Who needs to perform the behaviour?	All family members.
What does the person need to do differently to achieve the desired change?	Use the Fitbit and Fitbit app.
When will they do it?	Daily.
Where will they do it?	Everywhere.
How often will they do it?	Every day.

MVPA, moderate-to-vigorous-intensity physical activity; PA, physical activity.

considered based on previous research identifying key correlates and determinants of PA and wearable use.[14,17,43–45] Biological (age, sex), sociocultural (social support), socio-economic (household income) and behavioural (active travel) correlates and determinants were identified. The authors opted for the intervention's target behaviours to be broad and refer to global recommendations where possible (e.g. meeting PA guidelines; Table 1), as vignettes presented in the co-design workshops were used to ensure the intervention's components and delivery (e.g. active travel) were led by families and experts, rather than predetermining its components.

Selecting workshop content based on 'what needs to change' (step 4)

Supplementary Tables S1 and S2 demonstrate the selection process used to determine which barriers and intervention suggestions were included in the workshops, as vignettes. In total, 26 barriers were identified (n = 14 for PA, n = 12 for wearable use). Seven intervention suggestions were identified in the previous research.[14,17] Nine vignettes were presented in family workshop 1 and across both expert workshops. These vignettes reflected eight barriers (PA: n = 7, wearable use: n = 1) and six intervention suggestions. Barriers included in the co-design workshops reflected psychological capability (knowledge: n = 2; memory, attention and decision processes: n = 1), social opportunity (social influences: n = 1); automatic motivation (emotion: n = 1); and reflective motivation (intentions: n = 1, goals: n = 1, optimism: n = 1).

Co-design workshops

Stakeholder demographics

Seven families, including seven mothers, four fathers and 12 children (four boys, eight girls), and seven PA experts took part in the workshops. Stakeholder demographics are presented in Tables 2 and 3.

The developed intervention and its mechanisms of action (steps 5, 7 and 8)

Based on families' suggestions, the 'Move & Connect' intervention was developed:

> *"Fitbit Connect" because I felt like with the Fitbit (wearable brand) it allows you to connect with yourself by looking at what you're doing and what you could be doing to reach those goals but also connecting with other people" (Mother)*

The 'Move & Connect' intervention is designed to be implemented at an individual level, with a suggested pilot duration of 12 weeks. The intervention will take a 'flexible' approach, which provides families with the tools (e.g. the Fitbit) to increase PA when it works best for them:

> *"It's quite nice to have something where I don't need to commit to anybody else" (Father, Family 1); "Increasing the flexibility of interventions, so there are less rigid fixed components" (Senior Research Fellow); "It's just giving them the tools and letting them fit it in to their schedule" (Senior Research Associate).*

Table 4 displays the 'Move & Connect' intervention components and their corresponding intervention functions and BCTs. The results of the thematic analysis, which reflect each intervention component, is presented in Supplementary Table S3. The 'Move & Connect' intervention is a multicomponent intervention with eight components, which content aligns with six

Table 2
Family demographics.

Demographics	Parents (n = 11)	Children (n = 12)[a]
Age		
Mean (SD)	42 (5.68)	8 (4.01)
Range	32–50 years	5–18 years
Ethnicity, *n* (%)		
White British	7 (64%)	6 (50%)
Pakistani Heritage	4 (36%)	6 (50%)
Wearable use, *n* (%)		
Currently use	7 (64%)	4 (33%)
Previously used	2 (18%)	6 (50%)
<1 month	1	4
1–5 months	2	4
6–11 months	1	1
1–2 years	2	1
>2 years	3	0
Never used	2 (18%)	2 (17%)
Meeting physical activity guidelines, *n* (%)[b]		
Yes	2 (18%)	5 (42%)
No	9 (82%)	7 (58%)
Index of multiple deprivation, *n* (%)[c]		
Decile 1–3 (most deprived)	5 (71%)	
Decile 4–7	1 (14%)	
Decile 8–10 (least deprived)	1 (14%)	
Highest educational qualification, *n* (%)		
Advanced level (A level)	2 (18%)	
Undergraduate degree	2 (18%)	
Professional degree	2 (18%)	
Master's degree	4 (57%)	
Doctoral degree	1 (14%)	

SD, standard deviation.
[a] Includes a child who was 18 years.
[b] Child: ≥60 min of MVPA/day, adult: ≥75 min of VPA/week or ≥150 min of MPA/week.
[c] Index of Multiple Deprivation based on home postcode (per family, n = 7).

intervention functions (education, training, modelling, persuasion, incentivisation and environmental restructuring) and 24 BCTs. Most intervention components are intended to be delivered using an invitation-only group developed by the research team on the Fitbit app (the 'hub').

Discussion

This is the first known study to use the BCW and co-design workshops to develop a wearable intervention, targeting family

Table 3
PA expert demographics.

	Experts (n = 7)
Ethnicity, *n* (%)	
White British	5 (71%)
Pakistani Heritage	1 (14%)
Black British	1 (14%)
Wearable use, *n* (%)	
Currently use	3 (43%)
Previously used	3 (43%)
1–2 years	4
>2 years	2
Never used	1 (14%)
Job role, *n* (%)	
Senior research fellow/associate	5 (71%)
Community engagement manager	1 (14%)
Community PA facilitator	1 (14%)
Job sector, *n* (%)	
University	3 (43%)
National Health Service (NHS)	4 (57%)
Highest educational qualification, *n* (%)	
Undergraduate degree	2 (29%)
Doctoral degree	5 (71%)

Table 4
The 'Move & Connect' intervention components, corresponding intervention functions, BCTs and supporting quotes.

Target behaviour(s)	Intervention component	Targeted COM domain(s)	Targeted TDF domain(s)	Intervention function(s)	Behaviour change technique(s)	Supporting quotes
PA and wearable use	1. **Introductory workshop** (1) An explanation of the intervention and why it is important to take part (e.g. importance of PA). (2) Practical support to link the Fitbit's to family member's smart devices. (3) How to navigate the intervention's hub. (4) Setting individual and family PA goals. (5) Answer a short series of questions: (1) What physical activities do you enjoy doing as a family? (these include any type of movement), (2) When and how (e.g. duration/frequency, context) could you find the time to do these activities?	C, M	Knowledge Skills Goals Decision processes	Education Training	Goal setting (behaviour), action planning, information about health consequences, credible source, social support (practical)	*"Part of a workshop where you get them together to form action plans"* (Senior Research Associate) *"You can't just give them the Fitbit and ask them to go away and use it you need to give them a bit of education on how to use it, so is it part of a workshop where you get them together to form action plans"* (Senior Research Associate)
Wearable use	2. **Wearable support resources** (1) Bullet-point lists with images to demonstrate how to use the Fitbit (syncing, charging) and basic features including what each PA symbol means and how to change goals. (2) Five short videos (~5 min each) demonstrating how to use some of the Fitbit's advanced features. (3) Tip of the week' – each week a useful tip of how to use the Fitbit will be posted on the hub. (4) Families will have the option to request guidance on using the Fitbit from the research team (via the hub, phone, or video call).	C	Knowledge Skills	Education Training	Instruction how to perform the behaviour, demonstration of the behaviour, social support (practical)	*"Making it clear that this watch is more beneficial with the app"* (Mother) *"You could click a certain button on the screen and it could show you a little video on how to do it"* (Male, 6 years) *"In the app if you had a tip of the day so like you know "don't forget that if you're going run make sure you press this button" or "Fitbit also measures this if you're doing this exercise"* (Father) *"Perhaps maybe a YouTube video because you could learn off somebody else"* (Female, 11 years)
PA	3. **Healthy behaviours resources** (1) Bullet-point lists with images to demonstrate the importance of PA, such as the benefits of PA, how the Fitbit can help families monitor their PA, and some family friendly physical activities to try. Reliable sources (e.g. Government website, information from peer reviewed papers) will be referred to. (2) Five short videos/webinars (~5 min each).	C, M	Knowledge Beliefs about consequences	Education Persuasion	Information about health consequences, information about emotional consequences, credible source	*"I think the actual physical benefits would be good as well because you actually know you're doing your body some good as well"* (Female, 11 years) *"It has to be something that is very visual"* (Mother) *"What does 10,000 steps or 5000 steps means to them … what do I need to know on my tracker that will let me know I'm doing something that is affecting my health"* (Community Engagement Manager)
PA	4. **Reviewing and amending PA goals** Family members' PA levels, such as step count and/or active minutes from the past 2 weeks, will be extracted via Fitbit's database. Recommended goals will be calculated using a 'rank-order percentile algorithm', which requires the researcher to rank behaviour from lowest to highest and calculate a new goal based on the 60th percentile.[46] Each family will receive an overview of their PA levels, with an indication as to whether they are performing above or below the average of the intervention. This will include an encouraging message and prompt the family to refer to the brief action plan created in the workshop. Family members will be provided with a recommendation to change their PA goal(s) and an image of how to do this.	C, M	Knowledge Goals Behavioural regulation Intention	Education Persuasion Modelling	Review behaviour goal(s), discrepancy between current behaviour and goal, information about others' approval, social comparison, feedback on behaviour, action planning	*"There's a before benchmark so this is what you were doing and, in a few weeks, look at it and say this is how far you've come"* (Father) *"There should be something where you can adjust the goal for yourself so how many steps"* (Female, 18 years) *"It's about tailoring the message you know "don't worry, keep going", "we all have slip ups" those kind of messages and motivational messages so if they are at the 15,000 steps … "you're doing great, "keep it up", "let's keep moving forwards" just as clear and simple as possible but motivating"* (Senior Research Associate) *"Rather than giving them specific details you could say "you're slightly above or below average this week, keep it up!" rather than the specific*

(*continued on next page*)

Table 4 (*continued*)

Target behaviour(s)	Intervention component	Targeted COM domain(s)	Targeted TDF domain(s)	Intervention function(s)	Behaviour change technique(s)	Supporting quotes
						details of all the numbers and percentiles" (Senior Research Fellow)
PA	5. **PA Challenges** Challenges will reflect real-life destinations, with a particular focus on local areas (e.g. X number of steps = the perimeter of a local park). Families will be made aware of the challenge via the intervention's hub. Challenges will be conveyed as 'levels', as challenges will get increasingly more demanding, and will start with 'steps' then move to 'active minutes'. This was chosen to encourage families to perform activities that are reflective of MVPA. Examples of how to obtain active minutes will be provided via an image demonstrating activities that may result in achieving active minutes. Family members will be instructed that they must participate in the activity for at least 10 continuous minutes for the active minutes to be recognised by the Fitbit. Virtual rewards will be received once the challenges have been completed.	M	Goals Reinforcement Intentions	Incentivisation Persuasion	Graded tasks, goal setting (outcome), non-specific reward, non-specific incentive, review outcome goals	*"Can your family walk the length of India or something like that and everybody works together"* (Mother) *"You could say walk twice around [a local park] and that's the same as doing x that might be quite motivating"* (Father) *"If you achieve all your badges you move on to the next level"* (Female, 8 years) *"New challenges every month I think is a really important one, as new and as fresh as possible, and adding some gamification to it especially for kids"* (Senior Research Associate) "*The beginning of those being step-based and then progress that to be more difficult which might then be active minutes"* (Senior Research Fellow)
PA	6. **Recommend a friend or family** Families will have the chance to recommend a friend/family member or family to join the intervention. Families will be encouraged to recommend individuals that they are already active with or who can provide support/encouragement for their family to be active.	O, M	Social influences Environmental context	Environmental restructuring	Social support (unspecified)	"*So you could link your family members to yours so then you could like send them a message or something"* (Female, 8 years) *"... Like hey do you want to play, do a game sort of thing?"* (Mother) *"Encourage participants to encourage their existing friends of wider family to take part in this with them"* (Senior Research Fellow)
Wearable use	7. **Engagement prompts** Engagement prompts will be sent if a family member takes <1000 steps per day for nine of 14 days (2 weeks). Prompts will first be sent via a direct (private) message on the hub, and if no response is received or engagement does not increase, a text message will be sent. Prompts will be delivered every 2 weeks (if necessary) and sent at the start of the week.	O, M	Emotion Social influences	Persuasion	Feedback on behaviour, prompts/cues	*"Maybe if there's been a couple of hours with no activity you could send a prompt"* (Mother) *"I don't know if you could detect when people aren't engaging and only send prompts then"* (Mother)
PA	8. **Wearable device (Fitbit Alta HR)**	C, O, M		Education Incentivisation Modelling Environmental restructuring	Goal setting (behaviour), goal setting (outcome), discrepancy between current behaviour and goal, feedback on behaviour, self-monitoring of behaviour, self-monitoring of outcomes of behaviour, feedback on outcomes of behaviour, social support (unspecified), instruction on how to perform the behaviour, information about health consequences, information about emotional consequences, demonstration of behaviour, social comparison, credible source, non-specific reward, non-specific incentive, reward (outcome), rewarding completion	

C, capability; O, opportunity; M, motivation; TDF, theoretical domains framework.

PA.[17] The resulting ‘Move & Connect’ intervention is a multicomponent flexible intervention targeting family PA and wearable use via education, training, modelling, persuasion, incentivisation and environmental restructuring and 24 BCTs. The intervention includes a wearable (Fitbit Alta HR), alongside additional components such as collective challenges, setting and reviewing goals, an introductory workshop and wearable and health-related resources (e.g. educational videos).

Intervention development process

The BCW was a useful intervention development framework, as it enabled previous research[14,17] to be systematically embedded within the process and prompted regular refinement of intervention components (e.g. using the APEASE criteria).[19] The eight steps of the BCW enabled the ‘Move & Connect’ intervention's target behaviours to be specified and mechanisms of action (e.g. intervention functions and BCTs) to be identified.[19] By using this approach, the intervention is expected to support families' capability, opportunity and motivation for PA and wearable use. The BCW is a comprehensive framework,[19] and previous research has reported difficulties selecting the most appropriate intervention functions and BCTs to be embedded within an intervention.[21,47] The present study engaged the intervention's target users (families) in the development process and retrospectively identified the ‘Move & Connect’ intervention's mechanisms of action based on family and experts' suggested intervention components. This overcame previous difficulties of selecting an intervention's mechanisms of action from the comprehensive list included as part of the BCW and only embedded those that were deemed appropriate by stakeholders. Indeed, using co-design techniques with family members and experts within the current intervention development process may reduce the ‘research-practice gap’,[22] by considering stakeholders' knowledge and experiences that may influence the interventions acceptability and sustainability.[29] Previous research has similarly integrated evidence from numerous sources, such as systematic reviews, qualitative research and expert opinion (like this study), and reported improvements in intervention acceptability and efficacy.[48] Indeed, in the current intervention development process, families and experts were able to shed light on what intervention components to include to overcome acceptability issues when using wearables, which may not have been considered otherwise (e.g. implementing collective challenges compared with competitions; recommending a family or friend to join the intervention). Although few studies have empirically evaluated the effectiveness of using co-design techniques to develop behaviour change interventions,[28] the partnership between co-design techniques and theoretical underpinnings forms part of the MRC's core elements of intervention development (engage stakeholders, develop an intervention based on research evidence and theory).[18] Thus, this approach may also provide opportunities to successfully secure funding to implement and evaluate the ‘Move & Connect’ intervention.

Intervention components, functions and BCTs

Some of the ‘Move & Connect’ intervention components are similar to previous interventions using wearables to increase child or adolescent PA levels.[17] Similar intervention components, such as step challenges and reviewing PA progress,[49,50] increased adolescent step counts[49] and MVPA.[50] The proposed ‘Move & Connect’ intervention also incorporates more BCTs than typically found in wearable-based interventions.[17] On average, wearable interventions incorporate eight BCTs, with multicomponent interventions incorporating an average of 10 BCTs (range: 2–12 BCTs).[17] This compares to 24 in the ‘Move & Connect’ intervention. Identifying the ‘Move & Connect’ intervention's mechanisms of action, in the present study, can provide an indication as to ‘how’ and ‘why’ an intervention works or does not work,[51] aids replicability and provides justification for modifying intervention components based on their effectiveness.[51,52] The ‘Move & Connect’ intervention must be piloted to explore its feasibility, from an implementation and evaluation perspective, and to examine whether the number or type of intervention functions or BCTs impacts its potential effectiveness.

Previous interventions targeting child or family PA levels have been limited in their long-term effectiveness,[5] including those incorporating wearables as intervention tools.[17] Therefore, the sustainability of the ‘Move & Connect’ intervention was important to consider throughout the development process (e.g. within the expert workshops). The flexible nature of the intervention may be beneficial for its sustainability and adherence, as parents often report household, family and occupational responsibilities as barriers to being physically active.[14,53] Family-based interventions developed solely by researchers have been criticised for not allowing flexibility for families to engage with intervention components.[54] Allowing families to flexibly engage with the ‘Move & Connect’ intervention will enable them to use the intervention tools when it is most convenient for them, which may help overcome previously identified external barriers to PA (e.g. time).[14] One potential drawback of implementing a flexible intervention is that engagement with intervention components may differ between families. This means that the intervention's mechanisms of action (identified functions and BCTs) may also differ between families, and there are no consistent mechanisms that are used by all. Therefore, the ability to measure families' engagement with the intervention components, including the wearable itself, may be crucial. Once implemented and evaluated, the intervention's effectiveness may be stratified based on the type and amount of engagement they had with the intervention's components.

Targeting wearable use, as well as PA, in the ‘Move & Connect’ intervention may be important for sustaining families' engagement with the intervention. The novelty effect has previously been identified as a barrier of wearable use.[14,17,41] Ridgers et al.[41] recently suggested an ‘adherence window’, which may reflect a window of opportunity (2–4 weeks) for researchers to encourage long-term wearable use. By regularly monitoring families' wearable use and providing prompts, alongside tailored messages, this may encourage wearable use and engagement with the intervention. To our knowledge, this has not been considered in wearable interventions targeting child PA.[17] The ‘Move & Connect’ intervention must be piloted to explore its acceptability, feasibility and fidelity. To potentially increase the intervention's effectiveness, a whole systems approach is likely required. A whole systems approach considers a behaviour's interactive, ongoing and dynamic complexities with other behaviours and settings.[55] Whole system approaches encourage stakeholders to share understanding, consider the integration of behaviours and target where to intervene that may result in potential ‘spill-over effects’.[55–57] A benefit of the ‘Move & Connect’ intervention is that it can be easily integrated within existing interventions and initiatives, if found to be effective in future trials.

Future directions

Following recommendations outlined by the MRC,[18] the ‘Move & Connect’ intervention will be implemented and evaluated to explore its acceptability, feasibility and preliminary effectiveness on families' PA levels and physical health (e.g. body mass index, body fat percentage, waist circumference) using a pilot randomised controlled trial lasting 12-weeks. A multidisciplinary team will collaborate to plan, design, and conduct the implementation and evaluation of the intervention.[18] Families from deprived backgrounds will be recruited (reflecting the demographics of families participating in the present study), and facilitators, such as community workers, will be trained to deliver the 'Move & Connect' intervention. Exploring the feasibility and fidelity of facilitators (vs researchers) implementing the current intervention will provide insights into its longevity. If the 'Move & Connect' intervention is feasible and effective, a definitive longer term trial will be conducted. There is potential for the intervention to be adapted and expanded into other settings and with other target users, such as clinical settings, following further participatory action research.

Strengths and limitations

The strengths of this study include its systematic development using theoretical underpinnings and co-design techniques with families and experts. Displaying barriers to family PA and wearable use via vignettes was a strength of this study. Vignettes can reduce social desirability and enable discussions in a non-confrontational way.[36] The accounts provided by families were typically in the first-person, which demonstrated how the vignettes were internalised and enabled families to interpret the scenarios in a way that reflected their own family circumstances.[36] However, different perspectives meant it was difficult to refine intervention components by balancing evidence-based knowledge (PA experts) and acceptability (families). This is recognised as a difficulty of conducting multistakeholder work.[58] One way to consider the alignment of views is by using a Delphi method.[59] The Delphi method is a systematic process that results in a consensus of expert opinion via several stages of data collection (e.g. questionnaires).[59] Previous studies have used multiple questionnaires to refine intervention components.[60] It may have been beneficial to use Delphi methods to follow-up with families and experts after their workshop participation. However, Delphi methods are burdensome, and dropout rates can range from 25% to 60%.[61,62] A convenience sampling strategy was used to recruit families. Therefore, the families involved in the co-design workshops may already have the capability, opportunity, and/or motivation to be active or participate in behaviour change initiatives. Gaining more families perspectives via public and patient involvement work will be crucial before implementing and evaluating the 'Move & Connect' intervention. Furthermore, most families lived in deprived areas (Index of Multiple Deprivation deciles 1–3). This not only limits the generalisability of the intervention but also allows the intervention to be implemented in such areas, where PA may be low.[63] Although the Index of Multiple Deprivation provides insight into area-level socio-economic status, the cost of wearables has previously been identified as a barrier of adults using wearables.[64] Thus, collecting additional demographic data, such as household income, when implementing and evaluating the 'Move & Connect' intervention could provide further insights into the sustainability of the intervention.

Conclusions

This is the first study to use the BCW and co-design to develop an evidence-informed family-based wearable intervention (the 'Move & Connect' intervention). This study demonstrates how the integration of previous research, theoretical underpinnings and stakeholder involvement can be used to develop behaviour change interventions and identify its mechanisms of action. Future research may wish to apply the same methodology to enable a systematic way of evaluating and replicating its intervention components. Further work is needed to examine the feasibility and acceptability of implementing and evaluating the 'Move & Connect' intervention, along with ascertaining its potential effectiveness.

Author statements

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Ethical approval

This study was approved by Loughborough University Ethical Approvals (Human Participants) Sub-Committee (REF: 2021-29221-5132).

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Competing interests

The authors declare that there are no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.018.

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Original Research

The global burden of colorectal cancer attributable to high plasma glucose in 204 countries and territories, 1990–2019: an analysis of the Global Burden of Disease Study

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ABSTRACT

Objectives: This study aimed to estimate the burden of colorectal cancer (CRC) attributable to high plasma glucose from 1990 to 2019.
Study design and methods: Data on the disease burden were retrieved from the Global Burden of Disease online database. Estimated average percentage change (EAPC) was used to quantify the age-standardized mortality rate (ASMR) and age-standardized disability-adjusted life years (DALYs) rate (ASDR) of high plasma glucose–related CRC trends by sex and location between 1990 and 2019.
Results: Globally, the death number and DALYs of CRC attributable to high plasma glucose remained a steady increase at global level from 1990 to 2019, and similar trends have been reported in age-standardized rate. The country with the largest number of death cases and DALYs of high plasma glucose–related CRC in 2019 was China, followed by the United States of America and India. Nearly three-quarters of total countries experienced an increase in the ASMR and ASDR, and the greatest increase of ASMR and ASDR was found in Uzbekistan (EAPC = 5.32) and Equatorial Guinea (EAPC = 4.65), respectively. A negative correlation was found between sociodemographic indices and the EAPC of ASMR and ASDR ($r_{ASMR} = -0.259$, $p < 0.001$; $r_{ASDR} = -0.282$, $p < 0.001$).
Conclusions: A significant increase in mortality and DALYs of CRC attributable to high plasma glucose was observed in global and most countries, especially in the developing countries. Public health policies and targeted programs are needed to reduce the burden of disease.

Introduction

Colorectal cancer (CRC) is one of the commonly diagnosed gastrointestinal carcinomas,[1,2] and it has been the second leading cause of cancer-related deaths worldwide.[3] According to the recent statistics, there were more than 2.17 million incident cases of CRC and 1.08 million deaths in 2019 globally. More importantly, the CRC incidence was reported to significantly increase in most countries over the last decades,[4–6] even among the young adults.[7,8] This unexpected increase is driven by multifaceted factors and suggests that CRC has become a major public health challenge worldwide.[9]

The risk factors for CRC have been extensively studied. The well-determined risk factors include age, obesity, diabetes, unhealthy diet, and physical inactivity.[10–12] Although enormous efforts have been made to combat these risk factors to reduce the CRC disease burden, unfortunately, some of these contributors were still on increase. For example, between 1975 and 2016, the prevalence of excess body weight in adults—defined as a body mass index ≥25 kg/m^2—increased from nearly 21% in men and 24% in women to approximately 40% in both sexes.[13] In 2017, a total of 73,222

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(8.2%) CRC-related deaths were attributed to overweight worldwide.[14] The level of fasting plasma glucose (FPG) is also deemed to be strongly associated with CRC.[15] In addition, in recent decades, the prevalence of diabetes, characterized by high plasma glucose, has large increases in virtually all regions of the world,[16] which has also greatly increased the risk of CRC.

The current understanding of international burden of and variation in plasma glucose–related CRC is limited to high-income countries and is not enough. The Global Burden of Disease (GBD) study integrated multiple levels of health data and provided us an unprecedented opportunity to comprehensively learn the disease burden at the global, regional, and national levels. In the present study, we leverage the GBD data to describe and analyze the geographical distribution and temporal trends of CRC burden attributable to high plasma glucose at the global, regional, and national levels.

Methods

Study data

We collected the data of CRC-related mortality rate, death number, and disability-adjusted life years (DALYs) attributable to high plasma glucose by sex, country or territory, region, single calendar year, and age from 1990 to 2019 using the online Global Health Data Exchange query tool.[17] The definition of high FPG is that serum FPG is greater than 4.8–5.4 mmol/L in GBD 2019. The national sociodemographic indices (SDIs), which is a composite average of the rankings of the incomes per capita, average educational attainment, and fertility rates of all areas in the GBD study,[18] were also retrieved from GBD online database.

Table 1
The mortality rate and DALYs of colorectal cancer (CRC) attributable to high plasma glucose and the temporal trends between 1990 and 2019, by age, sex, SDI region, and GBD region.

	Deaths (95% % uncertainty interval)			DALYs (95% % uncertainty interval)		
	2019		EAPC (95% CI), 1990–2019	2019	1990–2019	EAPC (95% CI), 1990–2019
	Count (× 1000)	ASMR (/10^5)		Count (× 1000)	ASDR (/10^5)	
Global	97.58 (23.83 to 212.80)	1.24 (0.30 to 2.71)	0.93 (0.79 to 1.08)	1903.48 (453.68 to 4170.38)	23.33 (5.58 to 51.17)	0.98 (0.85 to 1.10)
Age(years)						
15–49	2.67 (0.57 to 6.23)	–	2.42 (2.36 to 2.47)	124.82 (26.72 to 290.92)	–	2.41 (2.36 to 2.47)
50–69	30.40 (7.00 to 67.32)	–	0.83 (0.77 to 0.89)	883.12 (203.33 to 1969.68)	–	0.92 (0.86 to 0.99)
70+	64.50 (16.10 to 140.07)	–	1.10 (0.95 to 1.25)	895.54 (221.60 to 1940.54)	–	0.90 (0.85 to 1.10)
Sex						
Male	55.02 (10.23 to 123.88)	1.58 (0.30 to 3.56)	1.26 (1.11 to 1.42)	1128.04 (204.52 to 2572.26)	29.87 (5.44 to 67.85)	1.30 (1.16 to 1.44)
Female	42.56 (7.86 to 98.67)	0.97 (0.18 to 2.25)	0.50 (0.36 to 0.63)	775.44 (143.79 to 1794.31)	17.69 (3.28 to 40.93)	0.50 (0.39 to 0.60)
SDI region						
High	33.92 (8.53 to 73.47)	1.64 (0.40 to 3.54)	0.24 (0.14 to 0.34)	592.11 (143.40 to 1277.51)	31.28 (7.50 to 67.67)	0.23 (0.16 to 0.31)
High-middle	27.97 (6.70 to 61.68)	1.38 (0.33 to 3.06)	1.20 (0.93 to 1.48)	537.74 (125.51 to 1184.28)	26.21 (6.12 to 57.75)	1.15 (0.90 to 1.41)
Middle	22.87 (5.38 to 50.83)	1.02 (0.24 to 2.25)	2.12 (1.91 to 2.32)	491.02 (114.78 to 1109.00)	19.87 (4.66 to 44.64)	2.19 (2.00 to 2.38)
Low-middle	10.20 (2.45 to 22.39)	0.83 (0.20 to 1.83)	2.48 (2.41 to 2.55)	223.99 (53.43 to 496.57)	16.62 (3.96 to 36.64)	2.47 (2.40 to 2.53)
Low	2.56 (0.61 to 5.71)	0.60 (0.14 to 1.33)	1.79 (1.74 to 1.85)	57.35 (13.52 to 128.83)	11.62 (2.74 to 26.01)	1.76 (1.71 to 1.81)
GBD region						
Andean Latin America	0.48 (0.11 to 1.09)	0.90 (0.22 to 2.05)	2.81 (2.62 to 3.00)	8.73 (2.04 to 20.03)	15.97 (3.75 to 36.53)	2.77 (2.60 to 2.95)
Australasia	0.70 (0.17 to 1.54)	1.29 (0.30 to 2.86)	−0.20 (−0.39 to −0.01)	11.74 (2.76 to 26.02)	23.16 (5.41 to 51.59)	−0.36 (−0.59 to −0.14)
Caribbean	0.98 (0.25 to 2.12)	1.90 (0.49 to 4.10)	1.41 (1.34 to 1.48)	18.49 (4.69 to 40.52)	35.72 (9.05 to 78.28)	1.48 (1.42 to 1.55)
Central Asia	0.63 (0.15 to 1.38)	1.00 (0.25 to 2.21)	2.91 (2.70 to 3.13)	14.70 (3.57 to 32.23)	20.40 (4.91 to 44.61)	2.36 (2.18 to 2.55)
Central Europe	5.60 (1.37 to 12.12)	2.48 (0.61 to 5.37)	1.58 (1.45 to 1.70)	105.52 (25.01 to 231.36)	48.31 (11.38 to 106.06)	1.60 (1.47 to 1.72)
Central Latin America	2.83 (0.72 to 6.12)	1.24 (0.32 to 2.69)	1.26 (1.16 to 1.37)	58.49 (14.74 to 127.64)	24.92 (6.28 to 54.37)	1.65 (1.56 to 1.74)
Central Sub-Saharan Africa	0.27 (0.06 to 0.65)	0.65 (0.15 to 1.53)	0.80 (0.54 to 1.06)	6.50 (1.46 to 15.50)	12.92 (2.85 to 30.56)	0.89 (0.65 to 1.14)
East Asia	19.34 (4.30 to 44.09)	0.99 (0.22 to 2.26)	2.04 (1.59 to 2.48)	418.57 (90.88 to 964.51)	20.01 (4.39 to 45.98)	2.05 (1.62 to 2.48)
Eastern Europe	3.51 (0.82 to 7.95)	0.99 (0.23 to 2.25)	0.87 (0.65 to 1.09)	70.77 (16.41 to 160.02)	20.22 (4.68 to 45.73)	0.62 (0.37 to 0.87)
Eastern Sub-Saharan Africa	0.67 (0.16 to 1.55)	0.51 (0.12 to 1.16)	1.56 (1.51 to 1.60)	15.05 (3.43 to 34.90)	9.88 (2.25 to 22.88)	1.57 (1.52 to 1.61)
High-income Asia Pacific	5.81 (1.35 to 13.09)	1.10 (0.25 to 2.47)	−0.40 (−0.55 to −0.25)	93.82 (20.88 to 208.75)	20.85 (4.59 to 46.96)	−0.52 (−0.67 to −0.38)
High-income North America	11.92 (2.98 to 25.11)	1.80 (0.45 to 3.80)	0.96 (0.61 to 1.31)	227.97 (26.25 to 481.22)	36.46 (8.94 to 77.19)	0.89 (0.57 to 1.22)
North Africa and Middle East	4.15 (0.99 to 9.17)	1.12 (0.27 to 2.45)	3.04 (2.74 to 3.33)	90.60 (21.37 to 203.26)	21.71 (5.14 to 48.28)	2.97 (2.68 to 3.27)
Oceania	0.07 (0.02 to 0.16)	1.22 (0.32 to 2.66)	1.82 (1.78 to 1.85)	1.82 (0.45 to 4.09)	25.60 (6.41 to 56.73)	1.89 (1.86 to 1.93)
South Asia	9.06 (2.17 to 20.08)	0.72 (0.17 to 1.60)	2.30 (2.15 to 2.46)	200.45 (47.40 to 446.62)	14.46 (3.44 to 32.18)	2.30 (2.16 to 2.44)
Southeast Asia	6.69 (1.58 to 15.12)	1.28 (0.31 to 2.87)	2.67 (2.62 to 2.73)	141.47 (32.21 to 321.79)	24.20 (5.61 to 55.02)	2.57 (2.48 to 2.66)
Southern Latin America	1.77 (0.44 to 3.87)	2.06 (0.51 to 4.50)	1.68 (1.53 to 1.83)	32.06 (7.83 to 70.47)	38.08 (9.28 to 83.86)	1.70 (1.57 to 1.83)
Southern Sub-Saharan Africa	0.58 (0.15 to 1.27)	1.20 (0.30 to 2.64)	1.57 (1.26 to 1.87)	11.91 (2.94 to 26.22)	22.28 (5.56 to 49.09)	1.97 (1.65 to 2.30)
Tropical Latin America	2.48 (0.60 to 5.40)	1.07 (0.26 to 2.32)	1.10 (0.98 to 1.22)	49.82 (12.01 to 110.40)	20.65 (4.97 to 45.71)	1.21 (1.07 to 1.36)
Western Europe	19.16 (4.81 to 41.17)	1.84 (0.46 to 3.97)	0.22 (−0.06 to 0.49)	307.30 (75.90 to 662.49)	33.08 (8.07 to 71.12)	0.17 (−0.06 to 0.39)
Western Sub-Saharan Africa	0.89 (0.21 to 1.98)	0.62 (0.15 to 1.37)	2.20 (2.12 to 2.27)	17.72 (4.20 to 39.83)	10.78 (2.57 to 24.07)	2.19 (2.11 to 2.26)

ASDR, age-standardized disability-adjusted life years rate; ASMR, age-standardized mortality rate; CI, confidence interval; DALYs, disability-adjusted life years; EAPC, estimated average percentage change; GBD, Global Burden of Disease; SDI, sociodemographical index.

Statistical analysis

In this study, we used the estimated average percentage change (EAPC) to quantify age-standardized rates (ASRs), including the age-standardized mortality rate (ASMR) and the age-standardized DALYs rate (ASDR), of high plasma glucose–related CRC trends by sex and location between 1990 and 2019. The EAPC, a widely used measure of the changing trend of the rate within a specified interval, was calculated to show the secular trend of the burden attributable to high plasma glucose based on a regression model by fitting the natural logarithm of ASMR or ASDR with the calendar year.[19,20] A regression line was fitted to the natural logarithm of the rates, that is, $y = \alpha + \beta x + \varepsilon$, where $y = \ln$ (ASMR) or ln (ASDR), x = calendar year, and ε = error term. The EAPC was calculated as $100 \times (exp(\beta) - 1)$, and its 95% confidence interval (CI) was also obtained from the linear regression model.[21] The *Pearson* correlation test was used to assess the correlations between SDIs and ASRs, as well as the EAPC of ASRs, so as to explore the potential impact of SDIs on burdens-related indicators. All statistical tests were analyzed using the R program (R core team, version 4.1.1). A p value <0.05 was considered statistically significant.

Results

The trends of CRC ASMR and ASDR attributable to high plasma glucose at the global level

The death number has increased more than twofold between 1990 and 2019, and nearly 97.58 thousand people (95% uncertainty interval [UI]: 23.83–212.80) died of high plasma glucose–related CRC in 2019, contributing to 1903.48 thousand (95% UI: 453.68–4170.38) DALYs worldwide (Table 1). The ASMR of CRC attributable to high plasma glucose was 1.24 per 100,000 population (95% UI: 0.30–2.71) and ASDR of which was 23.33 per 100,000 population (95% UI: 5.58–51.17) in 2019 (Table 1). Nearly two-thirds of the total deaths occurred in people aged ≥70 years in 2019, with deaths case was 64.5 thousand (95% UI: 16.10–140.07), and DALYs of this age group accounted for nearly half of the total (ASDR = 89.54 thousand, 95% UI: 221.60–1940.54; Table 1). The population aged 15–49 years had the highest growth rates of ASMR and ASDR, with EAPC (95% CI) was 2.42 (0.57–6.23) and 2.41 (2.36–2.47), respectively. From 1990 to 2019, both males and females experienced a significant increase in mortality rate and DALYs of high plasma glucose–related CRC, and males reported a greater growth rate both of ASMR and ASDR, with EAPC being 1.26 (95% CI: 1.11–1.42) and 1.30 (95% CI: 1.16–1.44), respectively (Table 1). The proportion of death number and DALYs of CRC attributable to high plasma glucose increased from 6.58% and 5.56% in 1990 to 8.99% and 7.84% in 2019, respectively (Fig. 1). The ASMR of high plasma glucose–related CRC was also increased by 0.93% (95% CI: 0.79–1.08) per year between 1990 and 2019, and the ASDR of which was by 0.98% (95% CI: 0.85–1.10) per year (Table 1; Fig. 2).

The trends of CRC ASMR and ASDR attributable to high plasma glucose at the regional level

For SDI regions, the death number, ASMR, DALYs, and ASDR, as well as the proportion of burden in CRC, of high plasma glucose–related CRC were on increase in all SDI regions (Table 1; Fig. 1). The greatest increase of ASMR and ASDR were observed in the low-middle SDI region, in which the ASMR and ASDR increased by 2.48% (95% CI: 2.41–2.55) per year and 2.47% (95% CI: 2.40–2.53), respectively, between 1990 and 2019 (Table 1; Fig. 2). The highest death number and DALYs of high plasma glucose–related CRC was found in East Asia in 2019, whereas the highest ASMR and ASDR of high plasma glucose–related CRC were found in Central Europe, with 2.48 per 100,000 (95% UI: 0.61–5.37) and 48.31 per 100,000 (95% UI: 11.38–106.06; Table 1). The

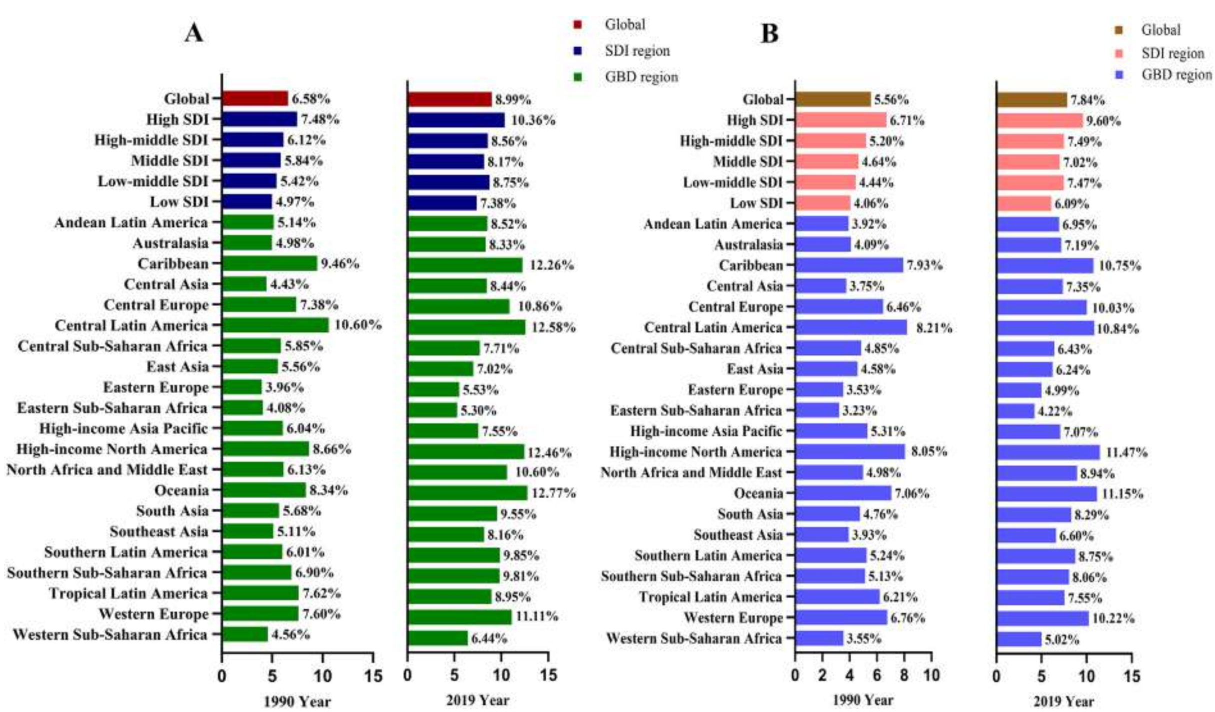

Fig. 1. The proportion of (A) number of deaths and (B) number of DALYs of colorectal cancer (CRC) attributable to high plasma glucose at the global and regional levels, 1990 and 2019.

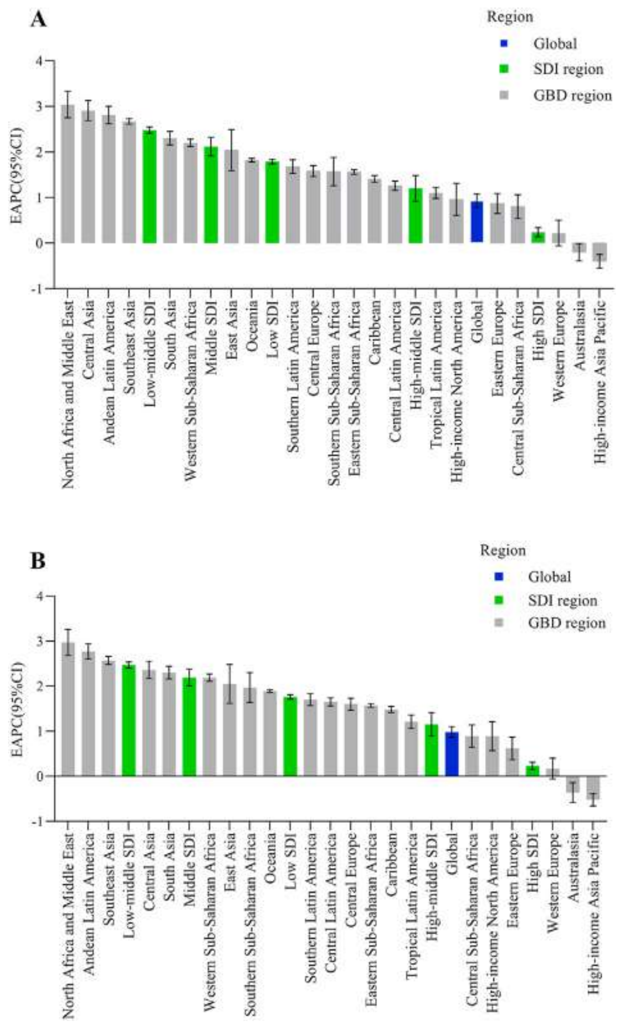

Fig. 2. Trends, represented by the estimated average percentage change (EAPC), of (A) age-standardized mortality rate (ASMR) and (B) age-standardized DALYs rate (ASDR) of the high plasma glucose–related colorectal cancer (CRC) at the global and regional levels, 1990–2019.

proportion number of deaths and DALYs of CRC attributable to high plasma glucose have increased in all regions (Fig. 1). A total of 18 GBD regions experienced a significant increase in the both ASMR and ASDR, of which the most pronounced increase was observed in North Africa and Middle East, with increasing by 3.04% (95% CI: 2.74–3.33) and 2.97% (95% CI: 2.68–3.67) per year of the ASMR and ASDR, respectively. There were two GBD regions (i.e. Australasia and high-income Asia Pacific) being seen a remarkable decrease in the both ASMR and ASDR (Table 1; Fig. 2).

The trends of CRC ASMR and ASDR attributable to high plasma glucose at the national level

The country with largest numbers of death cases of high plasma glucose–related CRC among the 204 countries and territories in 2019 were China (18.16 thousand [95% UI: 4.03–41.45]), followed by the United States of America and India (Table S1 and Fig. 3A). The DALYs showed the same pattern as mortality. The highest ASMR and ASDR were mostly observed in Brunei Darussalam (ASMR: 5.82 per 100,000, 95% UI: 1.61–11.86; ASDR: 109.32 per 100,000, 95% UI: 1.61–11.86; Table S1; Table S2; Fig. 3B; Fig. 3E). Between 1990 and 2019, a total of 184 and 6 countries or territories experienced an increase and decrease in the ASMR, respectively. In addition, there were 14 countries or territories experienced remained stable in the ASMR, such as France, Israel, and Colombia (Table S1; Fig. 3C). The greatest increase of ASMR was found in Uzbekistan (EAPC = 5.32, 95% CI: 5.05–5.58), followed by Equatorial Guinea, and Cabo Verde. The most pronounced decrease was found in Singapore (EAPC: −2.02, 95% CI: −2.26 ~ −1.78), followed by Austria and Japan (Table S1; Fig. 3C). For DALYs, most countries or territories (186/204) experienced an increase trend, and the greatest increase was found in Equatorial Guinea (EAPC: 4.65, 95% CI: 4.71–4.97), whereas the most pronounced decrease was also found in Singapore (EAPC: −2.29, 95% CI: −2.26 ~ −2.07) (Table S2; Fig. 3F).

Relationship between EAPC and economic health indicators

In this type of population-based study, we also assessed the correlations of the SDIs with high plasma glucose–related CRC ASMR and the changing trends of ASMR, as well as ASDR, at the national level. As shown in Fig. 4A and C, positive correlation was found between national SDIs and the ASMR and ASDR of high plasma glucose–related CRC ($r_{ASMR} = 0.577$, $p < 0.001$; $r_{ASDR} = 0.555$, $p < 0.001$). In contrast, a negative correlation was found between SDIs and the EAPC of ASMR and ASDR ($\rho_{ASMR} = -0.259$, $p < 0.001$; $r_{ASDR} = -0.282$, $p < 0.001$; Fig. 4B and D).

Discussion

Given the alarming increase in case number, CRC has become an emerging global public health concern over the last decade.[22,23] In this study, we analyzed the secular trends of the high plasma glucose–related CRC mortality rate and DALYs at the global, regional, and national levels. We found that the mortality rate and DALYs significantly increased at the global level between 1990 and 2019, and this rate was geographically heterogeneous and showed different trends from country to country. For example, the mortality rate was high in developed countries, whereas this rate experienced a significant decrease in part of these countries. On the contrary, the mortality rate increased with different magnitudes in most developing countries, where CRC was previously less diagnosed. All these findings highlight the importance of public health policies and programs, aimed at raising awareness of CRC, from screening to the development of early detection and management strategies to reduce CRC-related mortality and disease burden.

In terms of sex difference, the results suggested that males have shown a higher ASMR and a greater increase than females, which indicated that the male population faced a higher risk of CRC. Evidence from population-based studies also suggested that hyperglycemia or diabetes was significantly associated with the risk of CRC in men.[24,25] In fact, not just CRC, studies show that cancer-related incidence and mortality in males were higher than those in females worldwide.[26] A recent study that evaluated the gender-specific differences in clinical outcome for more than 20 types of cancer revealed that the risk of death in most types of tumors in females was lower than that in males (e.g. leukemia, lymphoma, and liver cancer) compared with males.[27] These sex differences might explain by the difference in the tumor microenvironment, level of the immune response, and hormone level, such as the expression of gene sets related to immunity in female patients is higher than in males.[27,28] In addition, the highest value both of ASMR and ASDR were in the age group of 70+ both for males and females, and the number of deaths in this age group accounts for two-thirds of the total. The age group with the largest increase is the age group of 14–49 years, which reflects partly that the incidence and death of CRC might show a younger trend. The screening strategy that younger adults, especially those with a high risk of

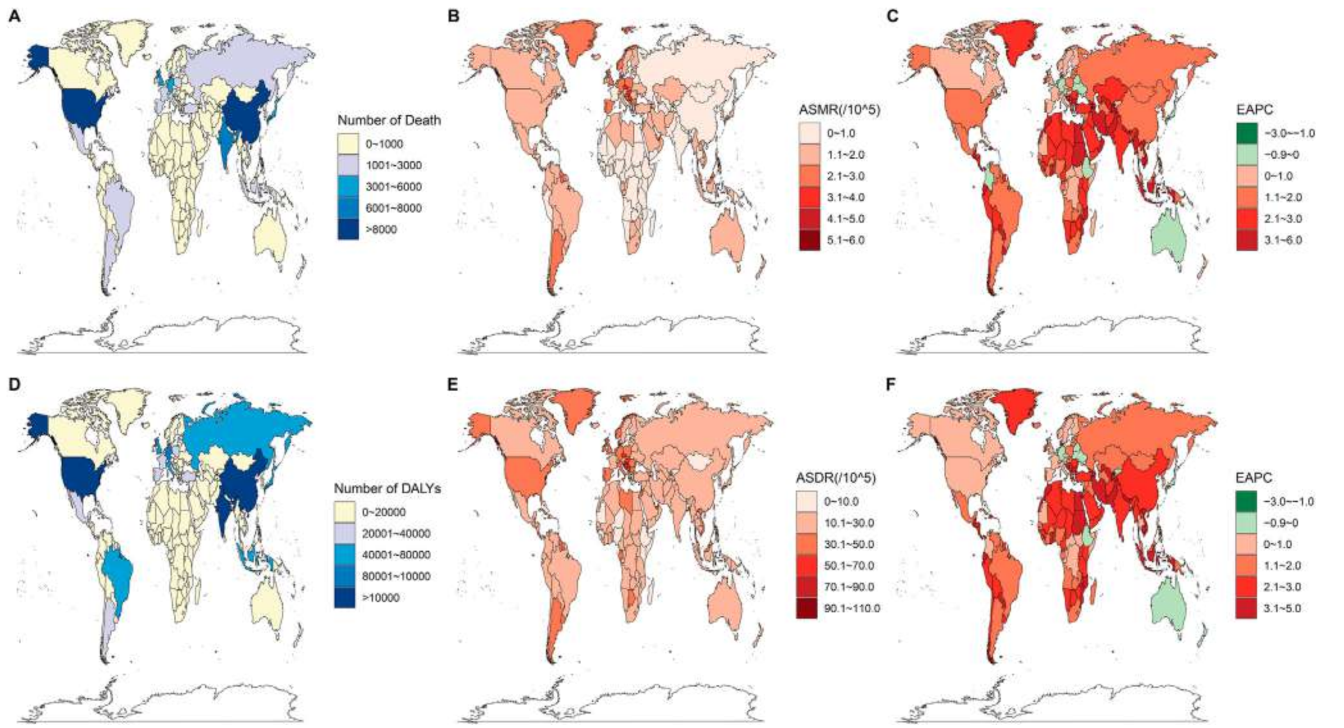

Fig. 3. The global distribution of (A) number of deaths in 2019, (B) age-standardized mortality rate (ASMR) in 2019, (C) the estimated average percentage change (EAPC) of the ASMR between 1990 and 2019, (D) number of DALYs in 2019, (E) age-standardized DALYs rate (ASDR) in 2019, and (F) the estimated average percentage change (EAPC) of the ASDR between 1990 and 2019 of the high plasma glucose–related CRC. The deeper the color, the higher the rate. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

CRC should be included in the scope of screening, is worth adjusting and being considered. Effective and available screening measures were essential to reduce the disease burden of CRC.

A large number of empirical studies have shown a close correlation between blood glucose and CRC.[29,30] Several hypotheses or pathological mechanisms underlying might explain the biological relationship between high plasma glucose and CRC, such as hyperinsulinemia through insulin-like growth factor signaling,[31,32] chronic inflammation,[33] changes in bile acid,[34] interaction with the cell cycle,[35] increased DNA damage,[36] promotion of migration and invasion of cancer cells.[37,38] Hyperglycemia could also aggravate the prognosis of CRC.[39] For example, a recent study indicated that hyperglycemia significantly increased drug resistance in CRC patients after surgery.[40] In addition, CRC was one of the most common complications of diabetes mellitus and was linked with an increased incidence of and a poor prognosis for CRC.[41,42] A meta-analysis based on a cohort study showed that CRC patients with diabetes had a shorter survival time of 5 years than those without diabetes.[43] It is worth noting that significant increase in hyperglycemia or diabetes prevalence in most countries irrespective of economic level in recent years,[44,45] and this growth continues, especially in developing countries. All these findings suggest that the burden of CRC will be further increased, even in those countries that currently have a low disease burden of CRC.

Our results show that the country with the largest death number and disease burden of high plasma glucose–related CRC is China followed by the USA and India. The possible reason might be that these regions have the largest proportion of populations worldwide; however, it should be noted that the mortality rates in where have been increasing in the past two decades. More importantly, the disease burden caused by diabetes or high plasma glucose was also increasing significantly in these areas,[46,47] and crucial strategies need to be developed to further alleviate these burdens. The ASMR and ASDR of Brunei Darussalam in 2019 were highest. There were studies showed that Brunei Darussalam has reported a steady increase in the incidence and deaths of CRC.[48,49] In Brunei Darussalam, there were currently no formal national CRC screening programs, and screening was offered in an opportunistic fashion for high-risk individuals for CRC, which might lead to the fact that currently most CRC cases are identified at late stages and thus decreased the survival rates.[48] In Brunei Darussalam, the overall 5-year survival rates for CRC patients were 49.6%.[50] These findings underscored the critical need to develop and implement CRC screening strategies and procedures, which were essential for early detection and improved prognostic survival.

In this study, the ASMR of high plasma glucose–related CRC experienced a decrease in some developed countries (e.g. Canada, Germany, Japan, and Australia). This decrease might be largely ascribed to the wide application of early screening programs, such as fecal occult blood test and colonoscopy, at the community level in these countries. Screening programs aiming at identifying CRC in its premalignant polyp phase, as well as at an early malignant stage, help to reduce the incidence and mortality of CRC by removing precancerous lesions before malignant transformation or at an early stage.[51,52] In a meta-analysis of observational studies, screening colonoscopy was associated with a reduction of 70% CRC risk and of 68% mortality.[53] In addition, the region with the highest EAPC increase in ASMR was North Africa and Middle East, followed by Central Asia, and among them, the most increased country was Uzbekistan. The vast majority of these areas are developing countries with low SDIs, and the increased ASMR may be the result of limited access to health care and late stage at diagnosis, as well as the lack of screening programs.[54] Our study results showed that a negative correlation was found between SDIs and the EAPCs of ASMR and ASDR might partly explain these changes. In developing countries, owing to the limited economic resources, healthcare structure, and

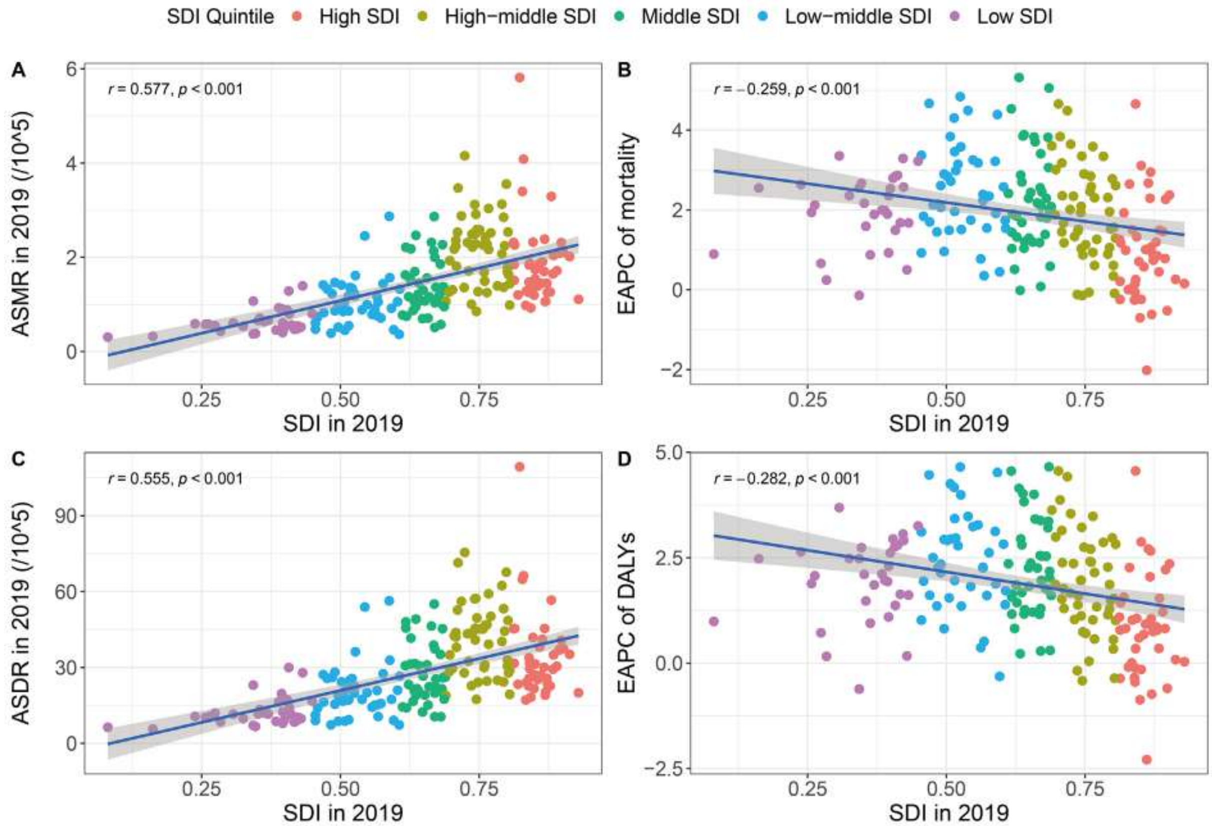

Fig. 4. The correlations of sociodemographic indices (SDIs) in 2019 with (A) age-standardized mortality rate (ASMR) in 2019, (B) the estimated average percentage change (EAPC) of the ASMR between 1990 and 2019, (C) age-standardized DALYs rate (ASDR) in 2019, and (D) the estimated average percentage change (EAPC) of the ASDR between 1990 and 2019 of the high plasma glucose–related colorectal cancer (CRC) at the national level. *r* means Pearson correlation coefficient.

infrastructure to support screening in developing countries, the CRC screening programs are far from complete. For example, in China, individuals aged 40–74 years received fecal occult blood test screening followed by rectal screening and colonoscopy. However, this program was not available to the entire population, and the national registry used to track clinical outcomes was estimated to be only 13% of the national population, which made healthcare planning difficult.[55] These results highlight that more attention should be paid to the people in developing countries and low-income regions, and the availability of screening and health resources should be supported in these countries. A set of measures are therefore urgently needed to face these challenges, including modifying the diet pattern (e.g. increasing the intake of fiber, milk, and whole grains and reducing the consumption of red and processed meat), improving weight management, initiating or expanding CRC early screening program among populations, incorporating the glucose management into the CRC screening program, high-quality health care, and better treatment modalities.[14,22]

There are some limitations that should be noted in this study. First, although the GBD uses all available data from sources such as cancer registries, regionally induced differences in data collection and coding, as well as the quality of data sources, remain unavoidable. Second, the increasing trend of CRC mortality rate might be partly driven by the increase in diagnosis in recent years because more patients were access to health care. Third, although a significant increase was found in the burden of high plasma glucose–related CRC, this trend should be interpreted with caution, as we have not excluded the patients diagnosed with diabetes.

Conclusions

In summary, in this study, we described and analyzed the mortality rate and DALYs of CRC attributable to high plasma glucose, and a significant increase of which was observed in global and most countries, especially in the developing countries. More targeted and tailored prevention strategies are urgently needed to reduce the burden of disease.

Author statements

Author contributions

W.W. and Q.W. designed this study. B.Y. and Y.Lv. performed the analysis of data and wrote the first draft of article. O.S. and M.Y. contributed to the data analysis and interpretation. X.L., W.K., and Y.Y. reviewed and revised the article. All authors approved the final version of article.

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Ethics approval

Not applicable.

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Competing interests

None declared.

Data availability statement

All data generated or analyzed during this study are available in Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019 (GBD 2019) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2020. Available from http://ghdx.healthdata.org/gbd-results-tool.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.024.

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Original Research

The political component of COVID-19 vaccine choice: Results from a conjoint experiment

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ABSTRACT

Objectives: Prior research highlights the role of efficacy, vaccine safety, and availability in vaccine hesitancy. Research is needed to better understand the political driving forces behind COVID-19 vaccine uptake. We examine the effects of the origin of a vaccine, and approval status within the EU on vaccine choice. We also test if these effects differ by party affiliation among Hungarians.

Study design: We use a conjoint experimental design to assess multiple causal relationships. Respondents choose between two hypothetical vaccine profiles randomly generated from 10 attributes. The data were gathered from an online panel in September 2022. We applied a quota for vaccination status and party preference. Three hundred twenty-four respondents evaluated 3888 randomly generated vaccine profiles.

Methods: We analyse the data using an OLS estimator with standard errors clustered by respondents. To further nuance our results, we test for task, profile, and treatment heterogeneity effects.

Results: By origin, respondents prefer German (MM 0.55; 95% CI 0.52–0.58) and Hungarian (0.55; 0.52–0.59) vaccines over US (0.49; 0.45–0.52) and Chinese vaccines (0.44; 0.41–0.47). By approval status, vaccines approved by the EU (0.55, 0.52–0.57) or pending authorization (0.5, 0.48–0.53) are preferred over unauthorised ones (0.45, 0.43–0.47). Both effects are conditional on party affiliation. Government voters especially prefer Hungarian vaccines (0.6; 0.55–0.65) over others.

Conclusions: The complexity of vaccination decisions calls for the usage of information shortcuts. Our findings demonstrate a strong political component that motivates vaccine choice. We demonstrate that politics and ideology have broken into fields of individual-level decisions such as health.

Introduction

To make communication on COVID-19 vaccines more efficient and increase vaccination rates, we need more knowledge on what information people take into account in making this complex health decision. This is especially crucial in *countries with multiple vaccine choices*, where information on vaccines is denser, and people are consequently selective of information and often rely on information shortcuts. To answer this call, this study looks at the effect of various vaccine characteristics on COVID-19 vaccine choice in general, and of its political aspects in particular. While vaccination campaigns often are politicised, the political component of COVID-19 vaccine uptake is frequently overlooked.

Concerns regarding efficacy,[1–5] side-effects,[1–4,6–12] vaccine safety,[1,5,7,9–11,13,14] the vaccine's ability to prevent transmission,[5,15] and its accessibility[6,16,17] (convenience) are amongst the leading causes of COVID-19 vaccine hesitancy and delay. Multiple vaccine choices and the individual's free choice of vaccine can reduce hesitancy.[11,18] At the same time, the abundance of options may be confusing for individuals who are not competent in making such health decisions in a high-uncertainty environment.[19] Indeed, the spread of misinformation[6,10] and conspiracy theories,[12,14,19,20] inconsistent, complicated, and contradictory information on vaccination,[3,6] and the absence of sufficient information[11,12] trump vaccine uptake levels. An important determinant of vaccine uptake is political affiliation, which, people use as an information shortcut in the storm of incomplete and confusing information.

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Although people mistrust political persuasion,[21] and political polarization of the vaccine debate creates doubts about vaccines in general,[22,23] people increasingly rely on political ideology and party affiliation. Research on COVID-19 vaccine uptake confirms the findings of earlier research on general vaccine acceptance:[24–26] conservative and right-leaning people are more likely to show hesitancy than liberal and left-leaning folks.[2,9,21,27–29] People also listen to political leaders and parties,[21,30] and accept vaccines developed in 'friendly countries'.[2,11,30]

By using an experimental design, we directly compare the effects of vaccines' political characteristics such as (1) the origin of the vaccine and (2) the vaccine's approval by the European Medicines Agency (EMA), to that of the usual suspects of the scholarship. Furthermore, we seek to know if the effects of the vaccine's political features are conditional upon the party affiliation of the respondents. Our study allows us to zoom in on the interplay between politics on the supranational level (in this case, the European Union) and nationalistic tendencies in explaining vaccine choice, which, to our knowledge, makes our empirical approach unique.

For our empirical exercise, we select Hungary as a case. As of July 2022, Hungary was the fourth country in the world regarding confirmed COVID-19 deaths per one million inhabitants.[31] In September 2022, the share of fully vaccinated population (62%) was around the world average of 61%, but below the EU average (73%)[32] and within the lowest quarter of the EU. Six COVID-19 vaccines had been in use: Comirnaty (Pfizer/BioNTech), Spikevax (Moderna), Covidshield (Oxford/AstraZeneca), Janssen (Johnson & Johnson), Sputnik V (Gamalexa), and Covilo (Sinopharm).[33] Vaccines are available free of charge, and people can freely choose between them. From the beginning of the vaccination campaign (December 2020), the right-wing-populist government of Viktor Orbán promoted the emergency use (ahead of EMA approval) and the uptake of the so-called Eastern vaccines (Sputnik V and Covilo) Hungary had a big reserve of. Most of the parliamentary opposition parties expressed scepticism towards the safety and efficacy of the Eastern vaccines or campaigned against all COVID-19 vaccines (Mi Hazánk – Our Homeland).[34] As a response to the opposition's vocal distrust in the Chinese and Russian vaccines, the government tried to frame the biggest opposition parties as anti-vaxxers.[35] The vaccine issue became politically polarised.[36] Accordingly, we expect that compared to voters of opposition parties, government voters are more likely to pick up an Eastern vaccine or a vaccine that is not approved by the EMA.

Methods

Vaccine choice is a complex decision affected by factors such as efficacy, safety, accessibility or government communication. To assess and compare the role of the usual suspects on vaccine choice, this study makes use of a *conjoint experiment* which allows for the estimation of multiple causal effects simultaneously and nonparametrically.[37] Conjoint experiments are based on the idea that choices can be broken down into a set of product (here COVID-19 vaccines) attributes. This method is fruitfully applied in public health studies in estimating the effect of vaccine characteristics on vaccine uptake.[2,38–41] Our questionnaire presents respondents with two hypothetical vaccine profiles (*Vaccine A* and *Vaccine B*). We randomly generate vaccine profiles from 10 attributes (Table 1) and do not exclude any combinations of attribute levels from the experiment.

Our main attributes of interest are (1) the country in which the vaccine was developed, and (2) EMA approval. While vaccine profiles in the experiment are hypothetical, we aimed at using attribute levels that are familiar to the respondents. From the pool of countries developing COVID-19 vaccines, we include the USA, a Western European country (Germany), and two Eastern countries (Russia and China). We include a fifth country which – to date – does not have a working vaccine against COVID-19: Hungary. We suspect that voters of the right-wing-populist government are prone to vaccine nationalism[40] and hence would be more willing to accept a vaccine that was developed in Hungary vs other countries.

When designing the levels for the remaining attributes, we aimed at staying as close to reality as possible. For instance, we relied on openly available sources to scale the vaccine efficacy (i.e. the percentage of cases in which the full dosage prevents serious illness)[42] and cost per dosage attributes. We did not include the value 'Common' in the severe adverse events attribute, because no vaccine could be given the green light that commonly causes severe side-effects. The remaining values were adopted from the EMA's documentation of the Comirnaty COVID-19 mRNA vaccine with a slight modification (we excluded the category of 'very common' adverse events) to decrease the number of attribute levels.[43]

Dependent variable – vaccine choice

After reading the vaccine profiles, respondents answered the following question: *Which of the two vaccines would you accept?* (A or B). We refer to this decision as the '*task*'. Three hundred twenty-four respondents performed the task *six times* in September 2022. During the six tasks, we showed each respondent 12 vaccine profiles (two in each task). The number of evaluated vaccines in the study is 324 × 12 = 3888, of which 3846 were unique. For the analysis, we transformed the respondent-level data so that each row in the data set represents one vaccine profile in the experiment. The dependent variable of our analysis is a 0/1 variable taking 1 if the respondent picked the respective profile in the choice task, and 0 if they did not.

Randomization

We apply two types of randomization in creating the vaccine pairs. First, we randomly assign attribute levels to vaccine profiles. We do not allow the same vaccine profile to appear within the same task (i.e. respondents always have to choose from two profiles that are different), but, though very unlikely, the same vaccine profile may appear during consecutive tasks. Second, each respondent sees the attributes in a different order. However, the order of the attributes per respondent remains fixed. This restriction on randomization is recommended by Hainmueller et al.[37] to ease the 'cognitive burden' on respondents.

Sample representativeness

We did not aim at a representative sample of the Hungarian population. It was essential that there are enough observations in the matrix of two variables: COVID-19 vaccine uptake and party preference. Owing to the features of the online panel that we used, the chance that a fully representative sample would have granted us to test the interaction between profile attributes, party preference, and vaccine uptake was very unlikely. We aimed at a sample distribution of 25% vaccinated government voters, 25% unvaccinated government voters, 25% vaccinated opposition voters and 25% unvaccinated opposition voters. Although our results are not generalizable to the entire population of Hungary, such data are eligible to investigate causal relationships between variables in experimental settings.[44] We do not weight the data during the analysis,[45] but we do test for heterogeneous treatment effects to check if any of the sociodemographic variables interact with the attribute effects. Furthermore, we only include voting-age respondents in our sample. Panel members with no party

Table 1
Attributes, attribute levels in the conjoint experiment, and their frequency in the data.

Attributes	Attribute levels	Frequency (n)
The vaccine was developed in…	1 = USA	788
	2 = Germany	776
	3 = China	786
	4 = Russia	767
	5 = Hungary	771
The vaccine is fully authorised in the EU	1 = Yes	1246
	2 = No	1264
	3 = Authorization pending	1378
The vaccine's trial phase	1 = The vaccine has been given to a small number of persons	1267
	2 = The vaccine has been given to several hundred persons	1359
	3 = The vaccine has been given to several thousand persons	1262
The vaccine's documented severe adverse events (allergic reaction, hospitalization)	1 = Not common: out of 10,000 treated patients 10–100 experience severe adverse events (0.1–1% of all patients)	1323
	2 = Rare: out of 10,000 treated patients 1–10 experience side-effects (0.01–0.1% of all patients)	1254
	3 = Extremely rare: out of 10,000 treated patients less than 1 experience severe adverse events (less than 0.01% of all patients)	1311
The vaccine's documented mild adverse events (flu-like symptoms)	1 = Common: out of 10,000 treated persons 100–1000 experience mild adverse events (1–10% of all patients)	969
	2 = Not common: out of 10,000 treated persons 10–100 experience mild adverse events (0.1–1% of all patients)	1002
	3 = Rare: out of 10,000 treated persons 1–10 experience mild adverse events (0.01–0.1% of all patients)	999
	4 = Extremely rare: out of 10,000 treated persons less than 1 experience mild adverse events (less than 0.01% of all patients)	918
The vaccine's efficacy (full dosage, preventing serious illness)	1 = 95%	986
	2 = 90%	1005
	3 = 85%	953
	4 = 75%	944
How many doses are needed to reach the reported efficacy?	1 = 1	1229
	2 = 2	1353
	3 = 3	1306
Cost per dosage	1 = Free	955
	2 = 1000 HU	980
	3 = 5000 HUF	990
	4 = 10,000 HUF	963
Availability	1 = The vaccine is readily available	967
	2 = Patients have to wait for the vaccine for up to a week	985
	3 = Patients have to wait for the vaccine for up to a month	1006
	4 = Patients have to wait for the vaccine for up to 3 months	930
Transmission	1 = The vaccine prevents the transmission of the virus to other people	1970
	2 = The vaccine does not prevent the transmission of the virus to other people	1918
Number of evaluated profiles	3888	
Number of unique profiles	3846	
Number of respondents	324	

preference we exclude from the data. Compared to a nationally representative sample such as the 2021 wave of the European Social Survey (weighted by PSWEIGHT),[46] our sample is about the same age and religiousness. At the same time, our sample includes slightly more women, is generally more educated, more well off and more interested in politics (Table 2). Furthermore, the majority of our sample did not have a confirmed COVID-19 infection before the data collection (65.7%), and find it rather unlikely to contract COVID-19 during the following 6 months (avg = 4.66, 1–11 scale).

Data analysis

With no logical combinations of attribute levels excluded from the experiment, a simple linear regression estimator is unbiased and is considered the Average Marginal Component Effect (AMCE).[37] We interpret coefficients as the average change in the probability that the respective vaccine is chosen, given that the attribute level in question appears in the profile. As vaccine profiles are embedded into individual respondents, and each respondent evaluates 12 profiles, we cluster standard errors by respondents. We also report Marginal Means (MM) and interpret them as the mean outcome across all appearances of an attribute level. We discuss task, profile, and heterogeneous treatment effects in the Online Appendix.

Results

Fig. 1 shows the results of our main model. We find that all attributes in the experiment have significant (CI: 95%) effects on vaccine choice. Respondents prefer vaccines that are on a later stage of trial, have rare side-effects, that are more efficacious, are inexpensive, require a low number of doses to reach the reported efficacy, are available within a month, and prevent the transmission of the virus. We report the linear regression coefficients and predicted probabilities in the Online Appendix.

Table 2
Description of the sample.

			Sample distribution (%)	Mean	Standard deviation
Age	How old are you?			48.61	14.47
Gender	What is your gender?	Male Female	42.9 57.10		
Highest education	What is your highest level of education?	No education Primary Vocational school High-school graduation Technical and further education (Hungarian: OKJ) BSc/BA MSc/MA PhD/DLA	0.93 7.10 21.30 26.23 17.90 17.59 8.02 0.93		
Residence	Which of the following would best describe the settlement where you live?	Budapest Larger city, county capital Town Village	17.28 24.69 31.17 26.85		
Income	Here you can see an income scale on which 1 indicates the lowest income group and 11 the highest income group in Hungary. We would like to know in what group your household is. Please, specify the appropriate number, counting all wages, salaries, pensions and other incomes that come in.	Scale: 1-11		5.18	2.09
Family status	Which of the following would best describe your family status?	Married In a relationship Divorced Widowed Single	43.21 20.99 12.35 6.17 17.28		
Religiousness	Regardless of whether you belong to a particular religion, how religious would you say you are?	Scale: 1-11		5.07	3.42
Political interest	How interested would you say you are in politics?	Scale: 1-11		6.55	3.21
Previously infected with COVID-19	Have you had a confirmed COVID-19 infection before?	Yes No	34.26 65.74		
Risk of COVID-19 infection	On a scale of 1–11, how likely do you think you can be infected with COVID during the next 6 months?	Scale: 1-11		4.66	2.92
Vaccination status	Have you received at least one shot of any of the available COVID vaccines?	No At least one jab	49.38 50.62		
Government voter	Supposing that there are elections held this Sunday, which party would you vote for? (Government: Fidesz – KDNP, Opposition: MSZP, Jobbik, LMP, DK, Párbeszéd, Liberálisok, Magyar Kétfarkú Kutya Párt, Momentum, Mi Hazánk, Other)	Yes No	49.69 50.31		

In the whole sample, respondents show a preference towards German (MM 0.55; 95% CI 0.52–0.58) and Hungarian (0.55; 0.52–0.59) vaccines in contrast to vaccines from the USA (0.49; 0.45–0.52) and China (0.44; 0.41–0.47). They also prefer vaccines that are at advanced stages of EU approval (approved: 0.55, 0.52–0.57; approval pending: 0.5, 0.48–0.53; vaccine not approved: 0.45, 0.43–0.47).

Fig. 2(a) visualises the MMs of the vaccine's origin across supporters of the government and opposition parties. We report significant differences between vaccines across voter groups. On the one hand, opposition supporters reject Russian vaccines (0.42; 0.37–0.47) over vaccines from the USA (0.52; 0.47–0.57), Germany (0.59; 0.54–0.63), and Hungary (0.52; 0.47–0.57). Regarding the Chinese vaccines, they are not that negative: only German vaccines are preferred over Chinese (0.45; 0.4–0.5) jabs. On the other hand, counter to our expectation, government voters pick Western vaccines (USA: 0.46; 0.41–0.51; Germany: 0.52; 0.48–0.56) with the same likelihood as Russian shots (0.5; 0.46–0.55). For government supporters, the divide lies not between Western and Eastern vaccines but between vaccines developed in Hungary (0.6; 0.55–0.65) vs others.

Tapping into vaccine nationalism, our data indicate that there are several differences between government and opposition voters in how the various attributes affect the choice of the Hungarian vaccine. We report that for opposition voters, the trial phase, the severe side-effects, efficacy, and transmission plays a role in choosing the Hungarian jab. Contrarily, in the group of government voters, we do not see such effects. No performance measure seems to affect the choice of the Hungarian vaccine in this group. However, government voters appear to be more price sensitive, and are less likely to pick the Hungarian vaccine if it costs 10,000 HUF (0.45; 0.39–0.59) as opposed to being administered for free (0.65; 0.56–0.73). At the same time, government voters take vaccine performance (i.e. trial phase, severe side-effects, efficacy and transmission) into account when evaluating the non-Hungarian vaccines.

Concerning the vaccine's EMA approval, we find that both government and opposition supporters prefer vaccines that are approved in the EU, and this preference is stronger for opposition voters (Fig. 2(b)). Supporters of opposition parties tend to pick vaccines that are already approved (0.57; 0.54–0.61) over non-approved vaccines (0.44; 0.41–0.47) and those with pending approval (0.49; 0.46–0.52). For government voters, on the other

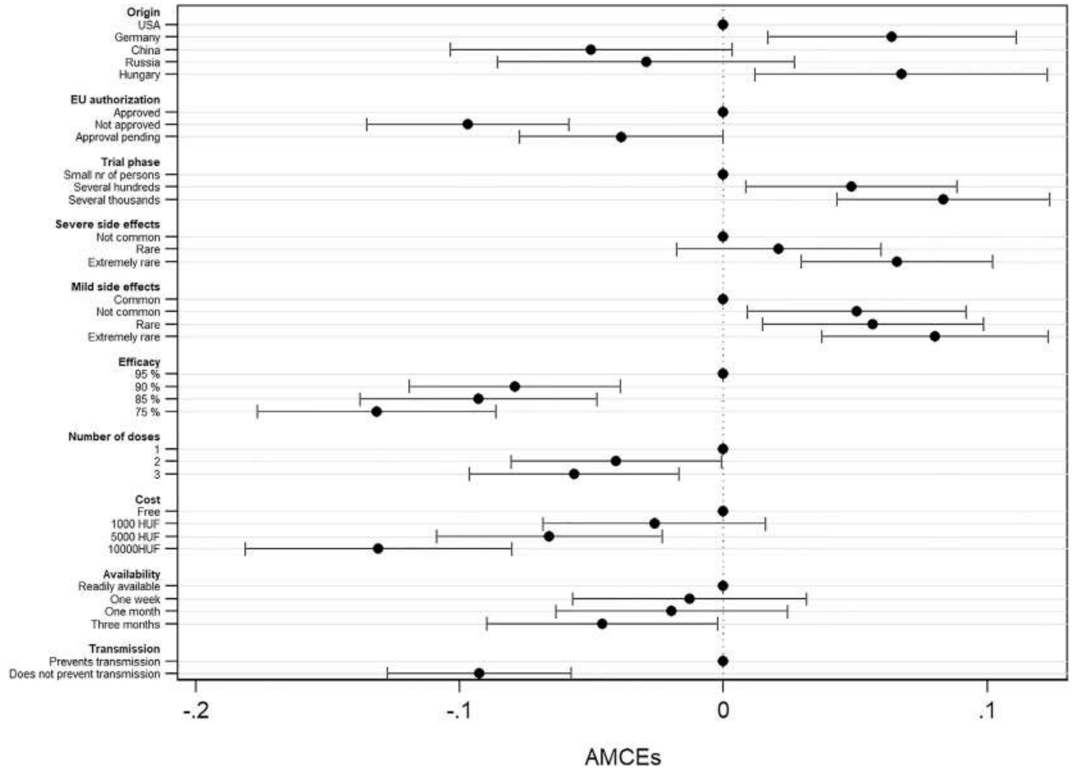

Fig. 1. AMCEs in the choice-based conjoint analysis.

hand, it is already reassuring when a vaccine's approval is in progress (0.52; 0.49–0.55) and are willing to pick such vaccines with the same probability as fully approved vaccines (0.52; 0.49–0.55) over non-authorised ones (0.46; 0.42–0.49).

To pinpoint the interplay between vaccine nationalism and supranational politics, we present the MMs of EU approval across the various levels of vaccine origin and party preference (Fig. 3). We find that in the cases of both government and opposition voters,

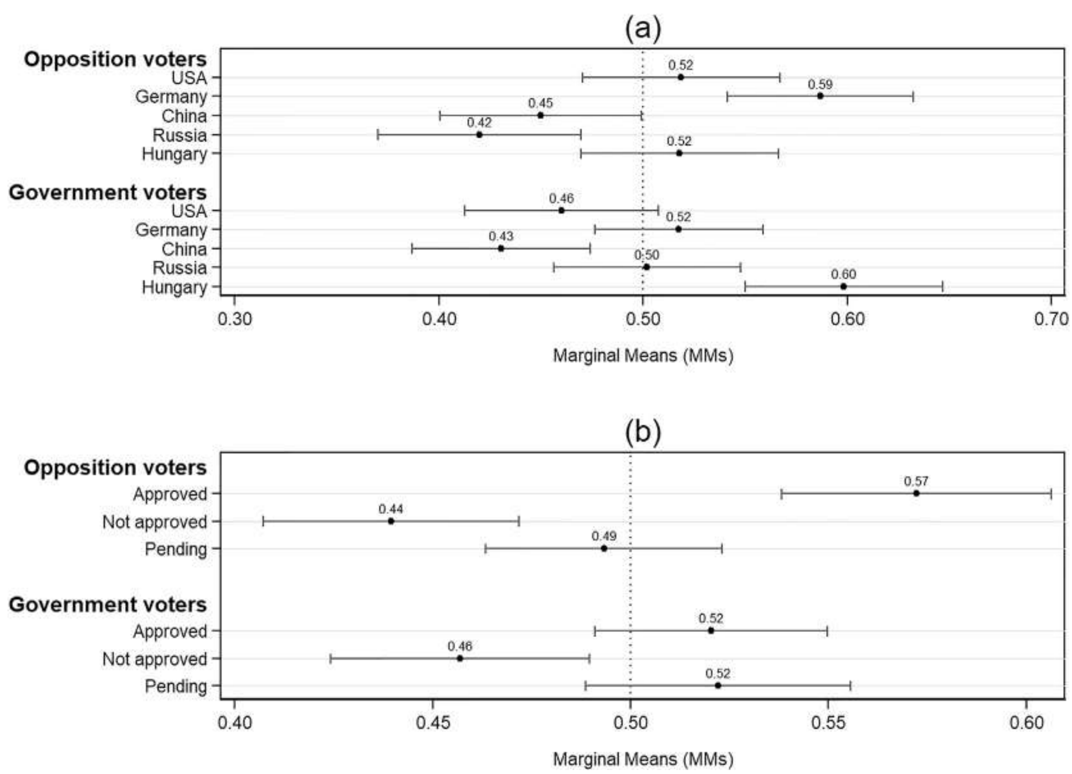

Fig. 2. Marginal Means of the (a) vaccine's origin and (b) EMA approval status across party preference.

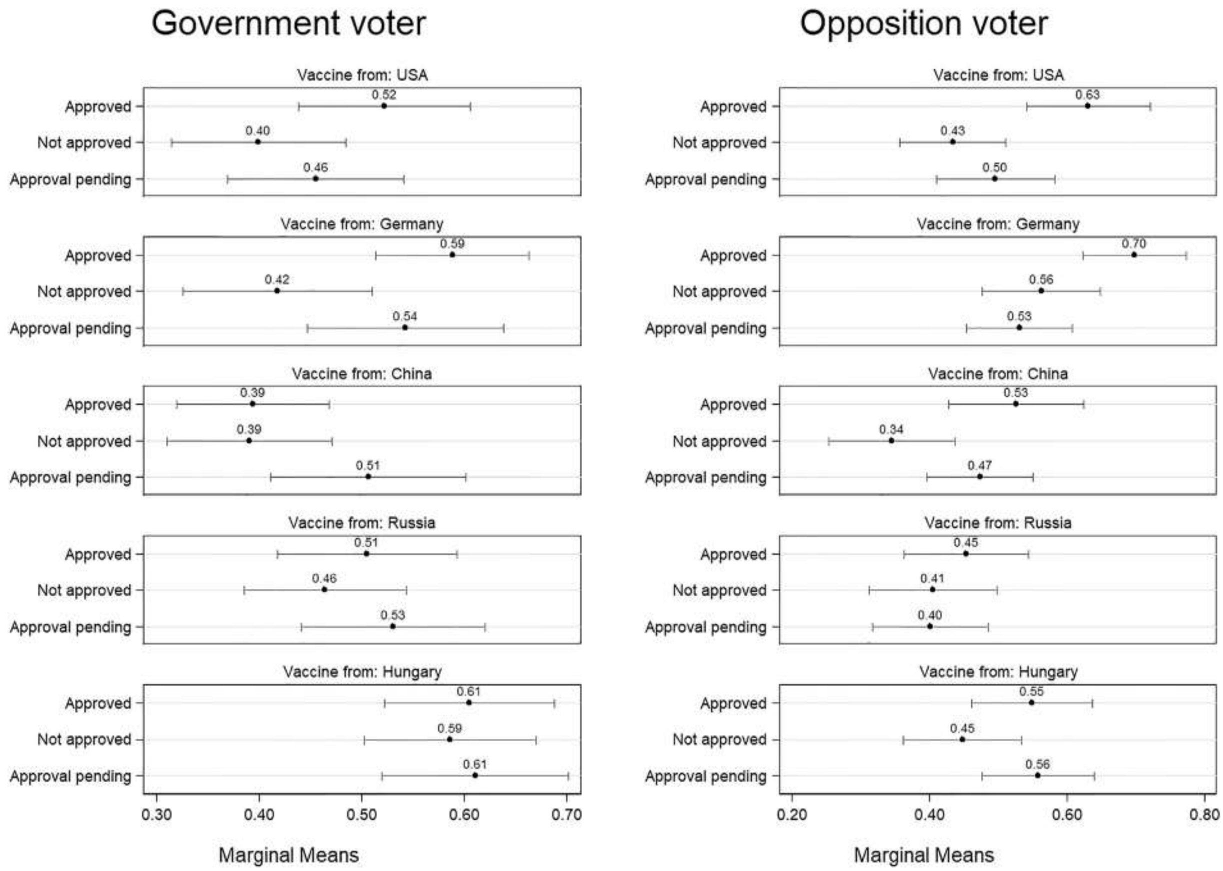

Fig. 3. Marginal Means of EMA approval across the vaccine's origin and party preference.

choosing a Western vaccine comes with a preference for EU approval. Opposition voters are also more likely to accept a Chinese vaccine when it is approved by the EU (approved: 0.52; 0.43–0.62; not approved: 0.34; 0.25–0.44). At the same time, the role of EU approval is insignificant ($P > 0.05$) in choosing a Russian or Hungarian vaccine for both, government, and opposition voters.

Robustness

To test the robustness of our results, we checked for task (i.e. the order in which the tasks are presented within the survey to the respondent affects the vaccine choice) and profile (i.e. the order in which the profiles are presented within a task affects the vaccine choice) effects. We report no significant effects related to the order of tasks (AMCE 0.001; 95% CI −0.001 to 0.004) and profiles (0.015; −0.039 to 0.069). To identify heterogeneous treatment effects, we include an interaction of the country where the vaccine was developed and EU approval with background information such as age, gender, education, place of residence, income, family status, religiousness, political interest, previous COVID-19 infection, the perceived risk of getting infected, and COVID-19 vaccination status. We find heterogeneous treatment effects in the cases of the highest level of education, place of residence, religiousness, and family status. We discuss all heterogeneous treatment effects in the Online Appendix.

Discussion

Our analyses reveal five main findings on the determinants of vaccine choice. First, the country of origin of a vaccine is a strong determinant of its likelihood of acceptance. Respondents preferred German and Hungarian vaccines to American and Chinese vaccines. Second, a vaccine is more likely to be accepted if it is either already approved by the EU, or at an advanced stage of the approval process. Third, significant differences exist between the vaccine choices of opposition and government voters, based on vaccine origin. Supporters of the ring-wing populist government show a strong preference for Hungarian vaccines over non-Hungarian vaccines. This is evidence of vaccine nationalism, and fits well together with the overall nationalist rhetoric of the Hungarian government.[47] The more left-wing opposition voters, on the other hand, show stronger proclivities towards Western vaccines. Attitudes towards Russian vaccines also differ considerably between the two groups. While opposition voters reject Russian vaccines for Western vaccines, government voters show similar propensities to accept them, compared to vaccines of Western origin. Fourth, while far from rejecting Hungarian vaccines, and contrary to government voters, supporters of opposition parties approach the Hungarian jab with more scepticism. Performance measures play an important role in the decision to accept the vaccine from Hungary. Fifth, we find that a pro-EU sentiment goes together with picking a Western vaccine for both government and opposition voters. For the Russian and Hungarian vaccines, we do not find a significant effect of the EMA approval. This suggests an alignment between the West-East narrative and attitudes towards the EU. At the same time, in the case of the Chinese vaccine, we probably witness another mechanism in place. Opposition voters are willing to pick the Chinese vaccine if the EU authority supports it. Here, the EU escapes the West-East narrative and appears as an actor that creates trust in the Chinese vaccine.

Our study is relevant for governments and public health authorities in their efforts to increase vaccine acceptance. It is in each country's best interest that their population is vaccinated with the medically best available vaccine. However, as we show, under heavy political polarization, when political vaccine attributes inform vaccine choice, they overshadow medical considerations. People have a tendency to rely on the political information shortcut even if all medical and performance data are at their disposal. Therefore, vaccination campaigns should strictly rely on scientific information on vaccines, and be organized by medical authorities using politically neutral language. A larger emphasis should be placed on vaccine features such as efficacy, side-effects, or information on transmission instead of its country of origin. In other words, vaccination campaigns should always be grounded in science and not in politics. Politicians, if they participate in vaccination campaigns, should only communicate certified medical information, and avoid transferring existing political polarization into the realm of health decisions. Our results are particularly useful to countries with (1) strong political polarization, or (2) free vaccine choice from a wide array of vaccines in their efforts to calibrate vaccination campaigns. Furthermore, research on vaccine nationalism could inform countries on whether they should invest in developing their own vaccine to boost vaccine uptake, or is it more efficient to rely on already available shots.

Limitations and next steps

This study is a single-country exercise. Generalizability may be limited to countries with multiple vaccine choices and a highly polarised political scene. At the time of study, about 6.45 million Hungarian people[33] were vaccinated, 8036 new cases registered weekly, and 35 weekly deaths, according to government services report. While new COVID-19 cases are on the rise, we are still in-between waves. We suspect that in the midst of a serious wave, vaccination decisions might depend more on factors such as efficacy and availability. It is possible that when the threat of infection is not imminent, political aspects could play a larger role. In addition, we suspect that results for Russian vaccines in the study may have been influenced by the ongoing Russia–Ukraine war, and might not be a true reflection of the actual evaluation of the respondents of the vaccine.

Our approach could benefit from replicating the study on a large, representative sample to identify demographic cohorts which are more prone to rely on political heuristics in making health decisions. Public health campaigns could target these cohorts to help them make decisions grounded in medical information.

Author statements

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Ethical approval

The study received formal approval from the Institutional Ethics Review Board at the Centre for Social Sciences, Budapest.

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Competing interests

The authors declare no conflict of interest.

Data availability

The data underlying this article are available in Figshare, at https://figshare.com/s/0e3dbaf82f4a62c6db7b.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.014.

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Themed Paper – Original Research

The practice of exclusive breastfeeding by region in Indonesia

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ABSTRACT

Objective: Exclusive breastfeeding has important benefits for both children and mothers. However, the proportion of exclusive breastfeeding is still not evenly distributed among regions, including in Indonesia. The purpose of this study was to analyze the practice of exclusive breastfeeding by region in Indonesia and its influencing factors.
Study design: This study was cross-sectional study.
Methods: This study used secondary data from the Indonesia Demographic and Health Survey 2017. The total sample was 1621 respondents, which consisted of mothers whose last child was under six months old and was still alive; the mothers did not have twins and lived with their child. Data were analyzed by using Quantum GIS and binary logistic regression statistical tests.
Results: This study shows that 51.6% of respondents gave exclusive breastfeeding in Indonesia. The highest proportion was in the Nusa Tenggara region (72.3%), whereas the lowest was in Kalimantan province (37.5%). Mothers who lived in the regions of Nusa Tenggara, Sulawesi, Java-Bali, and Sumatra had a higher chance of exclusive breastfeeding compared to those in the Kalimantan region. The factors associated with the exclusive breastfeeding vary widely across all regions, and the child's age is the only common factor associated with the exclusive breastfeeding in all regions, except Kalimantan.
Conclusion: This study shows wide variation in regional proportions and determinants of exclusive breastfeeding in Indonesia. Therefore, appropriate policies and strategies are needed to increase equitable exclusive breastfeeding practices across all regions in Indonesia.

Introduction

Breast milk (ASI) contains nutrients that are essential for the health, growth, and development of a baby.[1] Breastfeeding is one of the public health interventions to reduce the baby mortality,[2] the baby's risk of contracting digestive diseases, respiratory infections, and obesity. On the other hand, the exclusive breastfeeding can improve children's cognitive abilities[3–5] and contribute to prevent mothers from the risk of developing breast and ovarian cancer and to reduce the risk of obesity and chronic diseases such as type II diabetes mellitus.[6] In Indonesia, the infant mortality rate was 21 per 1000 live births in 2018, higher than other developing South-East Asian countries, such as Vietnam (16 per 1000 live births), Thailand (8 per 1000 live births), and Malaysia (7 per 1000 live births).[7] Exclusive breastfeeding is the process of feeding infants during the first 1 h after giving birth. According to the Indonesia Demographic and Health Survey 2017, the coverage of exclusive breastfeeding for children under six months old increased by 10% in the last 5 years, from 42% in 2012 to 52% in 2017. It shows that 48% of children under six months old across Indonesia were not exclusively breastfed. The percentage of children who did not get breast milk at all increased from 8% in the Indonesia Demographic and Health Survey 2012 to 12% in the Indonesia Demographic and Health Survey 2017.[8]

The achievement of exclusive breastfeeding in Indonesia has met the minimum target of 50% set in the national development plan for the last five years. Some regulations implemented support exclusive breastfeeding in Indonesia. However, the proportion of exclusive breastfeeding decreases as the children get older. The proportion of children receiving exclusive breastfeeding varies. Around 67% were children aged under one month, 55% were aged 2–3 months, and 38% were aged 4–5 months.[8] The proportion of exclusive breastfeeding in Indonesia is still not evenly distributed among provinces and even gaps exist among them. The five provinces with the highest rates of exclusive breastfeeding were West Nusa Tenggara, East Kalimantan, East Java, the Special Region of Yogyakarta, and East Nusa Tenggara, whilst other five lowest-achievement provinces were North Sumatra, Gorontalo, Maluku, Papua, and West Papua.[9]

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Several previous studies in Indonesia have revealed the scope and determinants of exclusive breastfeeding. A national study based on an analysis of the Indonesia Demographic and Health Survey from 2002 to 2017 showed that the proportion of mothers who exclusively breastfed their babies increased significantly between 2002 and 2017, with a greater increase among mothers from the higher wealth quintiles, working in professional sectors, and living in Java and Bali.[10] In general, the factors linked to the exclusive breastfeeding include the child's age, mother's education, occupation, type of delivery, parity, economic status, residence, and early initiation of breastfeeding.[11–14] In addition to the wide geographical, sociodemographic, and cultural diversity in Indonesia, it is important to study exclusive breastfeeding by region. To illustrate, eastern Indonesian socio-economic developments such as industry, housing, public transportation, road facilities, and health facilities are slower than those in western Indonesia, especially in the Java region.[15–18] Therefore, this study aims to analyze the practice of exclusive breastfeeding by region in Indonesia using nationally representative data from the Indonesia Demographic and Health Survey 2017. This study can complete the big picture of the exclusive breastfeeding phenomena in Indonesia, which can resolve the Indonesian exclusive breastfeeding. The purpose of this study is to analyze the practice of exclusive breastfeeding by region in Indonesia and factors that influence it.

Methods

Data source

This study performed secondary data analysis. Data were taken from the Indonesia Demographic and Health Survey (IDHS) 2017. IDHS is part of the International Demographic and Health Survey (DHS) program organized by the Inner-City Fund (ICF) to provide a comprehensive picture of the population as well as maternal and child health in Indonesia. The sample from IDHS 2017 was designed to present national and provincial estimates. It covered 1970 census blocks covering both urban and rural areas.

This survey used a two-stage stratified cluster sampling method. The first stage was the selection of several census blocks using a systematic probability proportional to measure (PPS) the number of households obtained from the SP2010 listing. The second stage selected 25 ordinary households using systematic sampling from the list. The population of this study was 49,692 Indonesian women of childbearing age (15–49 years) – data was from the 2017 IDHS. The sample used in this study was part of the population with some inclusion criteria, namely mothers whose last child was under six months old and still alive, they did not have twins and lived with their child. Ten percent was excluded due to incomplete data, 1% was due to twins, and 1% was the missing data. Finally, the samples of this study were 1621 altogether. The mothers with incomplete data were not included in the analysis.[8]

Result variables

The proportion of exclusive breastfeeding refers to infants under six months old who receive not only breast milk as their source of food, but also oral rehydration solutions, vitamin drops or syrup, and medications. The data were collected from the mother's memory of the food given to her baby in the last 24 h before the survey and it is in line with the WHO/UNICEF guidelines to assess the feeding practices of infants and children.[19] Result variables were defined in binary categories, exclusive breastfeeding and unexclusive breastfeeding.

Research factor

Research factors were adapted from previous studies.[11,13,14] These included predisposing factors and enabling factors. Predisposing factors include maternal age, child age, education, employment status, economic status, residence, parity, and early initiation of breastfeeding. Enabling factors include the number of antenatal care visits, place of delivery, type of delivery, and a number of postnatal care visits.

Maternal age was divided into three age groups, namely 15–19 years, 20–34 years, and 35–49 years. Children's age was divided into three age groups, all of which are 0–1 month, 2–3 months, and 4–5 months, and mother's education was divided into three groups; low (no school or elementary school graduates), middle (secondary school graduates), and higher (college graduates). Mother's occupation was divided into employed (e.g. professional, technician, manager and administration, clerk, sales, service, agricultural or industrial worker) and non-employed. Residence was divided into rural and urban. Using the wealth index, economic status in this study was classified into three groups, namely poor (poor and poorest), middle, and rich (rich and richest). Parity referred to the number of children born to the mothers and was categorized into 1 and >1. The number of antenatal care visits made by the mothers during pregnancy was categorized into $\geq$4 and <4. Place of delivery was categorized into health facilities and non-health facilities. The type of delivery was categorized into vaginal delivery and cesarean section. Early initiation of breastfeeding was divided into two categories, namely $\leq$1 h and >1 h. Postnatal care visits referred to children who were examined at a health facility in the first two months after birth.

Data analysis

Data analysis was done by regions grouped based on the largest islands, namely Sumatra, Java-Bali, Nusa Tenggara, Kalimantan, Sulawesi, Maluku Islands, and Papua.[18,20] Sample weights were used to analyze the data from the IDHS. All data were analyzed with a complex sample design. Statistical analyses, i.e. univariate analysis and bivariate analysis, were performed through binary logistic regression. The relationship between the independent and dependent variables was classified based on the *P*-value of the binary logistic regression test results, with $P < 0.05$ for statistically significant relationships. The direction of the relationship between the independent and dependent variables was seen based on the odd ratio value of the binary logistic regression test results, with a reference value of 1. Meanwhile, a spatial analysis was to find out the distribution map of exclusive breastfeeding by province in Indonesia. The analysis used the Statistical Product and Service Solutions (SPSS) software and Quantum GIS.

Results

Fig. 1 shows the distribution of exclusive breastfeeding in 34 provinces of Indonesia. Kalimantan region (West Kalimantan and Central Kalimantan), Maluku Island region (Maluku), and Papua region (West Papua) had the lowest distribution of exclusive breastfeeding. Meanwhile, the highest distribution of exclusive breastfeeding was in the Nusa Tenggara region.

Respondents characteristics

Table 1 shows that the proportion of mothers who give exclusive breastfeeding in Indonesia is 51.6%. The highest proportion of exclusive breastfeeding was in the Nusa Tenggara region (72.3%) and the lowest was in the Kalimantan region (37.5%). The majority

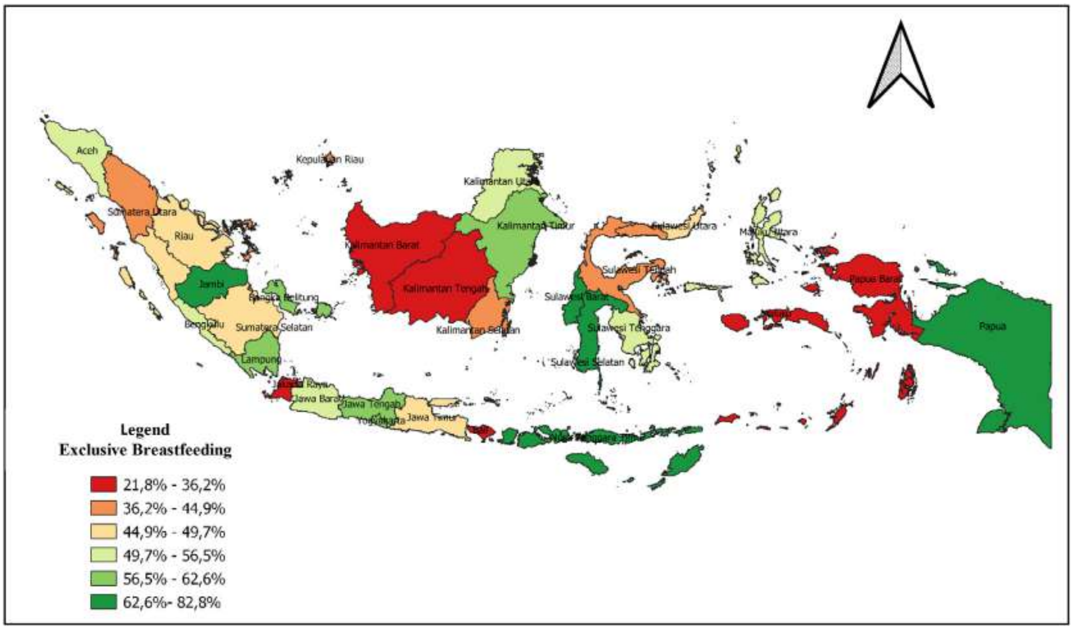

Fig. 1. Distribution of exclusive breastfeeding by province in Indonesia.

of mothers were in the age group of 20–34 years. The majority of children were in the age group of 2–3 months and 4–5 months. The Java-Bali region was dominated by women who lived in urban areas and other areas were dominated by women who lived in rural areas. The majority of mothers were secondary school graduates and they did not work, except the Papua region whose majority of mothers actively worked. All regions were dominated by women with poor economic status, except the Java-Bali region which was dominated by women with rich economic status. All regions were dominated by mothers who had ≥1 parity, making ≥ 4 times antenatal care visits during their pregnancy, and gave birth in health facilities, except Maluku regions where the majority of deliveries were still carried out in non-health facilities. The type of delivery was mostly done by vaginal delivery. Early initiation of breastfeeding was mostly done within ≤1 h, but it took ≥1 h of breastfeeding in Sumatera and Sulawesi. The majority of mothers made postnatal care visits.

Table 2 shows the results of the binary logistic regression test for regional disparities of exclusive breastfeeding in Indonesia. This analysis used the Kalimantan region as a reference because it had the lowest percentage of exclusive breastfeeding. Mothers in the Nusa Tenggara region had a 4348 times higher chance of exclusive breastfeeding than those in the Kalimantan region (OR 4348; 95% CI 2423–7800). Mothers in the Sulawesi region had a 2286 times higher chance of exclusive breastfeeding than those in the Kalimantan region (OR 2286; 95% CI 1380–3788). Mothers in the Sumatra region had a 1610 times higher chance of exclusive breastfeeding than those in the Kalimantan region (OR 1.610; 95% CI 1.011–2565). Similarly, mothers in the Java-Bali region had a 1.773 times higher chance of exclusive breastfeeding than those in the Kalimantan region (OR 1.773; 95% CI 1.114–2.822).

Table 3 presents that the variables of child's age, mother's education, occupation, economic status, number of antenatal care visits, early initiation of breastfeeding, and postnatal care visits had a relationship with exclusive breastfeeding. Children aged 0–1 month and 2–3 months in all regions, except Kalimantan ($P > 0.05$), had a higher chance of exclusive breastfeeding than those aged 4–5 months. Mothers in the Sumatra region who were secondary school graduates had a 1772 times higher chance of exclusive breastfeeding than those with lower education (OR 1772; 95% CI 1077–2916). Mothers in the Java-Bali region who did not work had a 2500 times higher chance of exclusive breastfeeding than those who worked (OR 2500; 95% CI 1.591–3928). Mothers with middle to upper economic status had a lower chance of exclusive breastfeeding compared to mothers with poorer economic status in Sumatra (OR 0.472; 95% CI 0.257–0.869) and the Java-Bali region (OR 0.415; 95% CI 0.230–0.746).

Discussion

This study shows that there are substantial variations in exclusive breastfeeding in all regions of Indonesia. This study reported that certain regions have diverse socio-economic, religious, cultural, and geographical conditions. Mothers living in the Nusa Tenggara region had the highest prevalence of exclusive breastfeeding, whereas those in the Kalimantan region was the lowest. The results of the binary logistic regression analysis revealed that all regions, except Maluku Islands and Papua, had significant differences in exclusive breastfeeding compared to Kalimantan region servings as a reference. However, the differences were not significant in Maluku Islands, Papua, and Kalimantan regions. In other words, mothers who lived in Nusa Tenggara, Java-Bali, Sulawesi, and Sumatra regions had a higher chance of exclusive breastfeeding compared to those in Kalimantan regions.

West Nusa Tenggara was the province with the highest coverage of exclusive breastfeeding in Indonesia, even in the last 5 years.[9] West Nusa Tenggara province has implemented Early Breastfeeding Initiation (IMD) and exclusive breastfeeding programs since 2010. It also has initiated Regional Regulation No. 7 of 2011 concerning the Protection and Improvement of Maternal and Child Health which requires IMD and exclusive breastfeeding. This exclusive breastfeeding was even conducted before the enactment of Government Regulation of the Republic of Indonesia No. 33 of 2012 concerning Exclusive Breastfeeding. After the regional regulations were enacted, the regional government had to disseminate the information to the community and related parties, such as hospitals and health centers. It is recommended that health services should develop written policies to support exclusive

Table 1
Respondent characteristics ($n = 1621$).

Variable	n	%	Regions: Sumatera ($n = 403$)		Java-Bali ($n = 856$)		Nusa Tenggara ($n = 78$)		Kalimantan ($n = 91$)		Sulawesi ($n = 133$)		Maluku ($n = 23$)		Papua ($n = 37$)	
			n	%	N	%	n	%	n	%	N	%	n	%	n	%
The practice of exclusive breastfeeding																
Exclusive breastfeeding	837	51.6	198	49.1	441	51.5	56	72.3	34	37.5	77	57.8	10	41.1	21	56.1
Non-exclusive breastfeeding	784	48.4	205	50.9	415	48.5	22	27.7	57	62.5	56	42.2	13	58.9	16	43.9
Maternal age (years)																
35–49	315	19.4	80	19.8	159	18.6	17	21.2	19	21.3	32	24.1	2	10.6	6	15.4
20–34	1191	73.5	293	72.7	637	74.4	57	72.9	63	68.9	94	70.5	17	73.9	30	83.7
15–19	115	7.1	30	7.4	60	7.0	4	5.9	9	9.8	7	5.4	4	15.4	1	0.9
Child's age (months)																
0–1	404	24.9	114	28.2	200	23.4	21	26.5	22	24.1	34	25.7	5	20.0	9	23.2
2–3	618	38.1	154	38.2	331	38.7	28	36.8	35	38.1	47	35.3	8	37.7	15	40.3
4–5	599	37.0	135	33.6	325	38.0	29	37.7	34	37.8	52	38.9	10	42.2	13	36.5
Residence																
Rural	870	53.6	279	69.2	333	38.8	60	76.3	59	64.4	96	72.4	15	64.2	29	78.9
Urban	751	46.4	124	30.8	523	61.2	18	23.7	32	35.6	37	27.6	8	35.8	8	21.1
Education																
Higher	254	15.7	72	17.8	117	13.7	11	13.9	11	11.5	32	23.8	5	21.3	7	19.0
Secondary	968	59.7	228	56.5	552	64.5	39	49.5	47	51.9	67	50.2	15	64.9	21	55.8
Primary	399	24.6	103	25.6	187	21.8	28	36.6	33	36.6	34	25.9	3	13.8	9	25.2
Occupation																
Not working	961	59.3	229	56.9	527	61.5	50	63.7	57	62.3	68	51.4	15	63.9	17	44.5
Working	659	40.7	174	43.1	329	38.5	28	36.3	34	37.7	65	48.6	8	36.1	20	55.5
Economic status																
Upper	599	36.9	122	30.3	408	47.7	8	10.2	21	23.3	29	22.0	3	12.8	7	19.0
Middle	341	21.0	89	22.1	198	23.1	5	6.9	20	22.2	23	16.8	3	14.3	3	7.4
Lower	681	42.0	192	47.6	250	29.2	65	82.9	50	54.6	81	61.2	17	72.9	27	73.6
Parity																
>1	1120	69.1	289	71.8	567	66.3	59	75.9	64	70.5	96	72.0	14	61.6	30	81.9
1	501	30.9	114	28.2	289	33.7	19	24.1	27	29.5	37	28.0	9	38.4	7	18.1
Number of antenatal care visits																
≥4	1426	87.9	323	80.2	790	92.3	71	90.3	83	91.0	115	86.7	17	73.6	27	72.5
<4	195	12.1	80	19.8	66	7.7	7	9.7	8	9.0	18	13.3	6	26.4	10	27.5
Place of delivery																
Health facilities	1373	84.7	323	80.0	792	92.5	63	80.7	64	70.7	102	76.4	9	40.1	20	55.4
Non-health facilities	248	15.3	80	20.0	64	7.5	15	19.3	27	29.3	31	23.6	14	59.9	17	44.6
Type of delivery																
Vaginal	1326	81.8	325	80.6	689	80.5	69	88.6	78	85.5	110	82.6	21	93.0	34	91.8
Caesar	295	18.2	78	19.4	167	19.5	9	11.4	13	14.5	23	17.4	2	7.0	3	8.2
Early initiation of breast feeding																
<1 Hour	858	52.9	175	43.3	486	56.7	56	71.9	47	51.6	62	46.5	12	53.6	20	54.9
>1 Hour	763	47.1	228	56.7	370	43.3	22	28.1	44	48.4	71	53.5	11	46.4	17	45.1
Postnatal care visit within 2 months																
Yes	1028	63.4	236	58.6	580	67.8	46	59.4	52	56.7	81	60.8	12	52.1	21	55.9
No	593	36.6	167	41.4	276	32.2	32	40.6	39	43.3	52	39.2	11	47.9	16	44.1

Table 2
Binary logistics regression analysis by region.

Variables	Exclusive breastfeeding: OR	95% CI	*P*-value
Region			
Sumatera	1.610	1.011–2.565	0.045
Java-Bali	1.773	1.114–2.822	0.016
Nusa Tenggara	4.348	2.423–7.800	0.000
Sulawesi	2.286	1.380–3.788	0.001
Maluku Islands	1.165	0.660–2.057	0.598
Papua	2.133	0.904–5.033	0.084
Kalimantan	*Ref.*		

breastfeeding, provide early initiation of breastfeeding services, and provide training for health workers to encourage and assist mothers to give exclusive breastfeeding either directly or indirectly, in maternity clinics or general hospitals.[21]

This study also shows that mothers living in Kalimantan were less likely to exclusively breastfeed their babies than those living in Java-Bali known as urban islands. In general, people who lived in urban areas had a better education than those living in rural areas. For this reason, mothers living in urban areas tend to have a better access to health facilities and information, such as lactation consultation and support.[22,23]

Kalimantan regions had a lower rate of exclusive breastfeeding compared to other regions. Several studies conducted in Kalimantan showed that a strong predictor of non-exclusive breastfeeding was low education. Mothers were less aware of the benefits of exclusive breastfeeding, most of whom believed that additional food could make their babies grow faster. The regional government contributed to this unfortunate situation because guidelines, information, and socialization on the exclusive breastfeeding were not promoted to local mothers. Even, sanctions for public operators who failed to support the exclusive breastfeeding facilities were not upheld. As a result, the implementation of exclusive breastfeeding in the Kalimantan regions was less optimum.[24,25]

Various government policies related to exclusive breastfeeding have been established, including Law Number 36 of 2009, Article

Table 3
The relationship between independent variables and the practice of exclusive breastfeeding by region in Indonesia.

Variables	Exclusive breastfeeding																			
	Indonesia				Sumatera				Java-Bali				Nusa Tenggara				Kalimantan			
	OR	95% CI		*P*-value	OR	95% CI		*P*-value	OR	95% CI		*P*-value	OR	95% CI		*P*-value	OR	95% CI		*P*-value
		Lower	Upper			Lower	Upper			Lower	Upper			Lower	Upper			Lower	Upper	
Maternal age (years)																				
35–49	0.965	0.530	1.756	0.906	1.194	0.439	3.246	0.727	0.943	0.340	2.613	0.910	0.688	0.055	8.676	0.770	0.552	0.106	2.874	0.476
20–34	1.115	0.680	1.828	0.665	1.011	0.445	2.299	0.979	0.923	0.416	2.052	0.845	2.710	0.272	27.051	0.391	3.140	0.597	16.521	0.174
15–19	*Ref.*				*Ref.*				*Ref.*				*Ref.*				*Ref.*			
Child's age (months)																				
0–1	**3.359**	**2.396**	**4.710**	**0.000**	**3.128**	**1.686**	**5.806**	**0.000**	**3.592**	**2.016**	**6.401**	**0.000**	**27.181**	**4.884**	**151.282**	**0.000**	1.722	0.539	5.501	0.354
2–3	**2.019**	**1.507**	**2.704**	**0.000**	**1.958**	**1.110**	**3.455**	**0.021**	**1.885**	**1.182**	**3.005**	**0.008**	**3.916**	**1.611**	**9.520**	**0.003**	1.255	0.367	4.292	0.714
4–5	***Ref.***				***Ref.***				***Ref.***				***Ref.***				*Ref.*			
Residence																				
Rural	1.238	0.929	1.651	0.145	1.315	0.811	2.134	0.266	1.218	0.760	1.952	0.411	1.703	0.364	7.963	0.494	1.639	0.638	4.209	0.300
Urban	*Ref.*				*Ref.*				*Ref.*				*Ref.*				*Ref.*			
Education																				
Higher	1.460	0.919	2.319	0.109	1.371	0.590	3.187	0.462	1.575	0.695	3.571	0.276	2.150	0.491	9.410	0.305	3.543	0.531	23.621	0.188
Secondary	1.210	0.864	1.694	0.266	**1.772**	**1.077**	**2.916**	**0.025**	1.116	0.609	2.045	0.722	0.622	0.211	1.833	0.385	0.858	0.240	3.062	0.811
Primary	*Ref.*				***Ref.***				*Ref.*				*Ref.*				*Ref.*			
Occupation																				
Not working	**1.578**	**1.198**	**2.078**	**0.001**	0.864	0.514	1.453	0.580	**2.500**	**1.591**	**3.928**	**0.000**	1.536	0.571	4.130	0.390	2.308	0.670	7.955	0.182
Working	***Ref.***				*Ref.*				***Ref.***				*Ref.*				*Ref.*			
Economic status																				
Upper	**0.662**	**0.457**	**0.958**	**0.029**	0.802	0.443	1.453	0.466	0.571	0.301	1.083	0.086	0.763	0.153	3.808	0.739	1.783	0.347	9.171	0.484
Middle	**0.481**	**0.341**	**0.678**	**0.000**	**0.472**	**0.257**	**0.869**	**0.016**	**0.415**	**0.230**	**0.746**	**0.003**	1.190	0.125	11.355	0.878	0.659	0.190	2.287	0.507
Lower	***Ref.***				***Ref.***				***Ref.***				*Ref.*				*Ref.*			
Parity																				
>1	1.286	0.937	1.766	0.120	1.260	0.677	2.343	0.464	1.136	0.692	1.866	0.613	1.443	0.397	5.254	0.574	1.021	0.347	3.005	0.970
1	*Ref.*				*Ref.*				*Ref.*				*Ref.*				*Ref.*			
Number of antenatal care visits																				
≥4	1.409	0.962	2.064	0.078	1.491	0.807	2.754	0.202	1.501	0.699	3.223	0.297	**19.400**	**4.549**	**82.743**	**0.000**	0.704	0.173	2.859	0.620
<4	*Ref.*				*Ref.*				*Ref.*				***Ref.***				*Ref.*			
Place of delivery																				
Health facilities	0.898	0.629	1.283	0.556	0.641	0.342	1.201	0.164	0.972	0.420	2.246	0.947	0.622	0.239	1.623	0.328	0.519	0.156	1.732	0.282
Non-health facilities	*Ref.*				*Ref.*				*Ref.*				*Ref.*				*Ref.*			
Type of delivery																				
Vaginal	1.217	0.837	1.769	0.303	1.193	0.638	2.230	0.579	1.397	0.772	2.526	0.268	0.786	0.158	3.909	0.766	0.342	0.084	1.395	0.133
Caesar	*Ref.*				*Ref.*				*Ref.*				*Ref.*				*Ref.*			
Early initiation of breastfeeding																				
<1 Hour	**1.693**	**1.308**	**2.191**	**0.000**	1.602	0.997	2.572	0.051	**1.608**	**1.044**	**2.478**	**0.031**	1.390	0.516	3.744	0.511	**4.792**	**1.738**	**13.213**	**0.003**
>1 Hour	***Ref.***				*Ref.*				***Ref.***				*Ref.*				***Ref.***			
Postnatal care visits within 2 months																				
No	0.974	0.746	1.273	0.849	1.493	0.945	2.360	0.086	0.797	0.499	1.274	0.342	0.753	0.270	2.103	0.584	1.366	0.515	3.623	0.526
Yes	*Ref.*				*Ref.*				*Ref.*				*Ref.*				*Ref.*			

Variables	Exclusive breastfeeding											
	Sulawesi				Maluku				Papua			
	OR	95% CI		*P*-value	OR	95% CI		*P*-value	OR	95% CI		*P*-value
		Lower	Upper			Lower	Upper			Lower	Upper	
Maternal age (years)												
35–49	0.344	0.054	2.199	0.258	0.398	0.029	5.506	0.486	1.417	0.123	1.631	0.895
20–34	0.768	0.132	4.463	0.768	1.287	0.276	6.012	0.745	0.848	0.110	6.541	0.914
15–19	*Ref.*				*Ref.*				*Ref.*			

(*continued on next page*)

Table 3 (*continued*)

Variables	Exclusive breastfeeding											
	Sulawesi				Maluku				Papua			
	OR	95% CI		*P*-value	OR	95% CI		*P*-value	OR	95% CI		*P*-value
		Lower	Upper			Lower	Upper			Lower	Upper	
Child's age (months)												
0–1	2.035	0.876	4.726	0.098	**3.489**	**1.003**	**12.136**	**0.049**	4.948	0.564	43.391	0.142
2–3	**2.850**	**1.417**	**5.730**	**0.004**	**3.912**	**1.328**	**11.520**	**0.014**	**7.715**	**1.401**	**42.470**	**0.021**
4–5	***Ref.***				***Ref.***				***Ref.***			
Residence												
Rural	1.664	0.847	3.269	0.138	1.054	0.329	3.378	0.928	0.083	0.001	6.516	0.252
Urban	*Ref.*				*Ref.*				*Ref.*			
Education												
Higher	0.937	0.336	2.614	0.901	1.641	0.402	6.696	0.485	0.350	0.013	9.231	0.516
Secondary	1.522	0.691	3.352	0.295	1.506	0.429	5.279	0.517	1.012	0.175	5.850	0.989
Primary	*Ref.*				*Ref.*				*Ref.*			
Occupation												
Not working	0.751	0.377	1.496	0.413	1.444	0.606	3.443	0.402	0.428	0.109	1.688	0.215
Working	*Ref.*				*Ref.*				*Ref.*			
Economic status												
Upper	0.808	0.327	1.996	0.642	0.711	0.181	2.790	0.620	0.091	0.000	24.012	0.385
Middle	0.572	0.234	1.400	0.220	0.584	0.150	2.279	0.433	0.108	0.002	6.133	0.268
Lower	*Ref.*				*Ref.*				*Ref.*			
Parity												
>1	1.622	0.703	3.745	0.255	1.845	0.681	4.999	0.225	1.308	0.078	21.815	0.846
1	*Ref.*				*Ref.*				*Ref.*			
Number of antenatal care visits												
≥4	0.991	0.417	2.355	0.984	1.807	0.589	5.547	0.296	0.966	0.121	7.710	0.973
<4	*Ref.*				*Ref.*				*Ref.*			
Place of delivery												
Health facilities	0.759	0.370	1.558	0.450	0.708	0.240	2.092	0.527	2.366	0.162	34.460	0.515
Non-health facilities	*Ref.*				*Ref.*				*Ref.*			
Type of delivery												
Vaginal	0.660	0.254	1.711	0.390	3.607	0.236	55.059	0.351	2.614	0.273	25.030	0.525
Caesar	*Ref.*				*Ref.*				*Ref.*			
Early initiation of breastfeeding												
<1 Hour	1.727	0.893	3.340	0.104	1.024	0.401	2.615	0.959	0.900	0.160	5.083	0.902
>1 Hour	*Ref.*				*Ref.*				*Ref.*			
Postnatal care visits within 2 months												
Yes	**0.432**	**0.224**	**0.830**	**0.012**	**0.407**	**0.179**	**0.924**	**0.032**	0.595	0.112	3.150	0.528
No	***Ref.***				***Ref.***				*Ref.*			

Bold value signifies if variable have *P*-value <0.05.

128 paragraphs 2 and 3. The policies state that during breastfeeding, families, regional governments, and the community must fully support mothers by providing time and required facilities. Although some regions have followed up with these regional regulations, a few have ignored them.[26]

To date, the traditional practice of infant feeding among indigenous tribes is still quite high. In eastern Indonesia, babies who are only a few days old are often fed with a liquid called sago solution as a nutritional intake. They are given mashed food when they are 2–3 months old.[27–29] Another study stated that the Javanese tradition gives sugar solution to babies since they are a few days old,[30] and Gayo people have a tradition of applying honey to the lips of newborn babies.[31] This traditional practice, on the other hand, is a challenge for health workers who have to promote exclusive breastfeeding.[32] Women living in different areas with different cultural backgrounds and beliefs may have different nutritional behaviors, including the practice of exclusive breastfeeding.[33] Therefore, efforts to promote exclusive breastfeeding must consider the sociocultural and environmental conditions of the target population.

This study shows that there was a significant relationship ($P < 0.05$) between maternal education and exclusive breastfeeding in the Sumatra region. Mothers who graduated from secondary school had a higher chance of exclusive breastfeeding than those with lower education. In line with previous studies, holding higher education degree tends to make mothers more likely to exclusively breastfeed their babies.[34] Higher education opens more access to information and thus allows mothers to think more rationally about the benefits of exclusive breastfeeding. Although it has a positive effect, higher education also opens wider access for mothers to work. In this study, the absence of a significant relationship between education and exclusive breastfeeding in other regions could cause constraints such as short maternity leave that requires mothers to return to work before the exclusive breastfeeding period ends.[35]

In Java-Bali, mothers who did not work had a higher chance of exclusive breastfeeding than those who worked. This is in line with several previous studies which found a positive relationship between non-working mothers and exclusive breastfeeding.[13,35–37] Mothers who do not work tend to have more time with their babies. On the other hand, working mothers tend to have less time with their babies due to work, resulting in shorter breastfeeding durations, which in turn inhibits exclusive breastfeeding.[35] In this case, working mothers face several challenges such as conflicting commitments at work, limited support from the workplace, and a lack of breastfeeding facilities.[38] It may be caused the women's ability to balance their family and work-women breastfeed for as long as possible while also working to provide an income for themselves and their children.

This study shows that it is important to provide breastfeeding support to working mothers. The workplace should provide a private and safe place (such as a lactation room) for pumping, equipment needed for milk preservation, and breastfeeding breaks. In addition, previous studies have shown that longer maternity leave contributes to a longer duration of exclusive breastfeeding among working mothers.[38,39]

Mothers from low socio-economic groups in Sumatra and Java-Bali were more likely to give exclusive breastfeeding than those from upper middle economic groups. This finding is in line with several previous studies.[40–42] This finding, however, surprisingly showed that low-income families have more limited resources to buy alternative foods for their babies and it causes breastfeeding the only option. In addition, high-income households have a better access to education and hence a greater opportunity for professional work. Meanwhile, working mothers tend to be less likely to give exclusive breastfeeding, especially if they do not receive support from the workplace.[41,42] However, this study is not in line with several previous studies conducted in Somalia and Ethiopia, which stated that high-income households tend to have a positive relationship with exclusive breastfeeding because they have a greater chance of being exposed to various media and better knowledge of exclusive breastfeeding.[43,44]

In this study, mothers in Nusa Tenggara who had $\geq$ 4 times antenatal care visits during their pregnancy had a higher chance of exclusive breastfeeding than those who had $\leq$4 times antenatal care visits.[45] A study conducted in Sweden found that, during antenatal care visits, most mothers asked for knowledge about the physiology of breastfeeding, signs of adequate milk supply, and ways to increase milk supply.[46] A qualitative study in Bhutan showed that one of the reasons why mothers use formula milk is the belief that they are not producing sufficient breast milk.[47] Therefore, counseling sessions during antenatal care visits are important to increase self-confidence and positive views about breastfeeding. Previous studies have shown that mothers who live in Nusa Tenggara have a 4365 times higher chance ($\geq$4) to make antenatal care visits than those in other regions.[18]

In Java-Bali and Kalimantan, mothers who initiated early breastfeeding within $\leq$1 h after delivery had a higher chance of exclusive breastfeeding than those who initiate within $\geq$1 h after delivery. This finding is in line with several previous studies.[11,48] The World Health Organization (WHO) explains that early initiation of breastfeeding can increase the chances of exclusive breastfeeding in 1–4 months after delivery.[49] Furthermore, this study shows that, in Sulawesi and Maluku, respondents who visited postnatal care within two months after delivery had a lower chance of exclusive breastfeeding. This may be due to the absence of breastfeeding counseling during postnatal care visits. In this study, the majority of mothers living in Maluku (64%) did not receive counseling about exclusive breastfeeding within the first two days after delivery. In line with the Indonesia Demographic and Health Survey 2017, this study also shows that, from several types of newborn care, only 48–59% of mothers received information about warning signs and breastfeeding counseling.[8] It may be the factors that increase the risk of low supply.

The strength of this study lies in the use of secondary data from the Indonesia Demographic and Health Survey 2017 which covers all data across regions in Indonesia. The use of a large sample and a nationally representative sampling procedure method made it possible to generalize the results of this study to all mothers throughout Indonesia. In addition, data weighting was also carried out during the analysis process to adjust disproportionate sampling techniques. This survey had a high response rate of 97.8%.[8] Data were collected by skilled personnel using standardized questionnaires to ensure the success of the survey and to obtain qualified data. Apart from the strengths, this study also had some limitations, some of which was the use of a small number of variables related to exclusive breastfeeding. Other variables include sex of the infant, birth weight, birth spacing, cultural perceptions, beliefs, and family support. Another limitation was the use of a cross-sectional analytical design that merely studied the relationships between variables without considering the cause-and-effect relationships between variables. Finally, exclusive breastfeeding was measured based on a history of information about food and drink given to infants aged 0–5 months in the last 24 h before the survey was conducted without considering the previous period. As a result, this may lead to a misclassification bias of exclusive breastfeeding.

Conclusion

This study shows substantial variations in proportions and determinants of exclusive breastfeeding across all regions in

Indonesia. The Nusa Tenggara region had the highest proportion of exclusive breastfeeding, whereas the Kalimantan region had the lowest one. The factors associated with exclusive breastfeeding varied widely in all regions, where the child's age was the only common factor associated with exclusive breastfeeding, except the Kalimantan region. Other variables related to exclusive breastfeeding were secondary education in Sumatra region, occupation in Java-Bali region, economic status in Sumatra and Java-Bali regions, early initiation of breastfeeding in Java-Bali and Kalimantan regions, postnatal care visits in Sulawesi and Maluku Island regions, and antenatal care visits in Nusa Tenggara region. Appropriate policies and strategies are needed to increase exclusive breastfeeding in all regions to reduce disparity in exclusive breastfeeding. Optimizing existing policies, the central government can impose strict sanctions on local governments and public facility operators who do not implement exclusive breastfeeding regulations. Future researchers are expected to examine variables that have not been covered in this study. These variables include sex of the infant, birth weight, birth spacing, cultural perceptions, beliefs, and family support for exclusive breastfeeding.

Author statements

Ethical approval

We used secondary data. Ethical clearance was obtained in the 2017 IDHS from the National ethics committee. Respondents provided written approval for their involvement in the study. We have obtained permission to use the data through the following website: https://dhsprogram.com/data/new-user-registration.cfm.

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Competing interests

The author declares that no conflicts of interest.

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