Public Health 211 (2022) 72–74

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Short Communication

# Adopting a systems view of disrupting crisis-driven food insecurity

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ARTICLE INFO

*Article history:*
Received 17 May 2022
Received in revised form
7 July 2022
Accepted 10 July 2022
Available online 26 August 2022

*Keywords:*
Food insecurity
COVID-19
Macro-miso-micro
Framework

ABSTRACT

*Objectives:* During the COVID crisis, the incidence of food insecurity worsened around the globe. We were reminded that: food insecurity existed before COVID, worsened during this crisis, and will unfortunately be a persistent phenomenon in the post-COVID world. It is evident that to counter this public health threat, systematic changes will need to happen. In this short communication, we introduce the notion of a systems-oriented framework that can guide appropriate actions for us to disrupt future food insecurity crises.
*Study design:* This short communication identifies preliminary observations based on relevant past studies that documented the impact of COVID-19 on food insecurity, and the researchers' conceptualization of a framework on how we may address future crisis-driven food insecurity challenges.
*Methods:* Systems-oriented framework was conceptualized based on preliminary observations in studies that investigated food insecurity during the COVID-19 pandemic.
*Results:* This short communication explores the notion of a systems-oriented framework as a guide to future action to prevent crisis-driven food insecurity.
*Conclusions:* The systems-oriented framework emphasizes the importance of action across macro, meso, and micro levels, and synchronization to maximize synergies.


## Introduction

Worldwide, an estimated 820 million people were food insecure before the pandemic, and another 130 million were added during the crisis.[1] In the USA, the USDA Economic Research Service indicated that 89.5% (116.7 million) of US households were food insecure throughout 2020. Consequently, there has been a significant level of interest in investigating the impact of COVID-19 on food insecurity globally.[2] Evidence suggests that the COVID-19 pandemic aggravated pre-existing food insecurity.[3] It revealed the critical inequities (e.g. poverty, access to food, access to infrastructure) and health disparities that negatively impact individual and household food security.[4] It also recognized the importance of concerted efforts of a broad coalition of stakeholders to counter future food insecurity. Therefore, minimizing food insecurity during the next crisis will require coordinated efforts across the system (macro-meso-micro levels[5]) to spur social innovation that would potentially bring food to those in need. In this short communication, we explore this notion of a system-wide approach at the macro level (policies, regulations, and national programs), meso level (organizational and intersectoral), and micro level (household and individual) (see Fig. 1).

### *Countering food insecurity in post-COVID-19*

Food insecurity is a complex problem; a crisis such as the COVID-19 pandemic can further complicate matters. In the developed economies, food insecurity remains a distribution and an affordability challenge.[2] Elsewhere in the developing world, other challenges contributing to food insecurity include a fragile food system, poverty, socio-economic conditions, high food price inflation, natural hazards, climate change, and pests.[6] The pandemic played as an equalizer where irrespective of national economic development of nations, the underserved, across economies, experienced hunger. National level programs such as federal income support, expansion of tax credit schemes, local, private and

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https://doi.org/10.1016/j.puhe.2022.07.007
0033-3506/

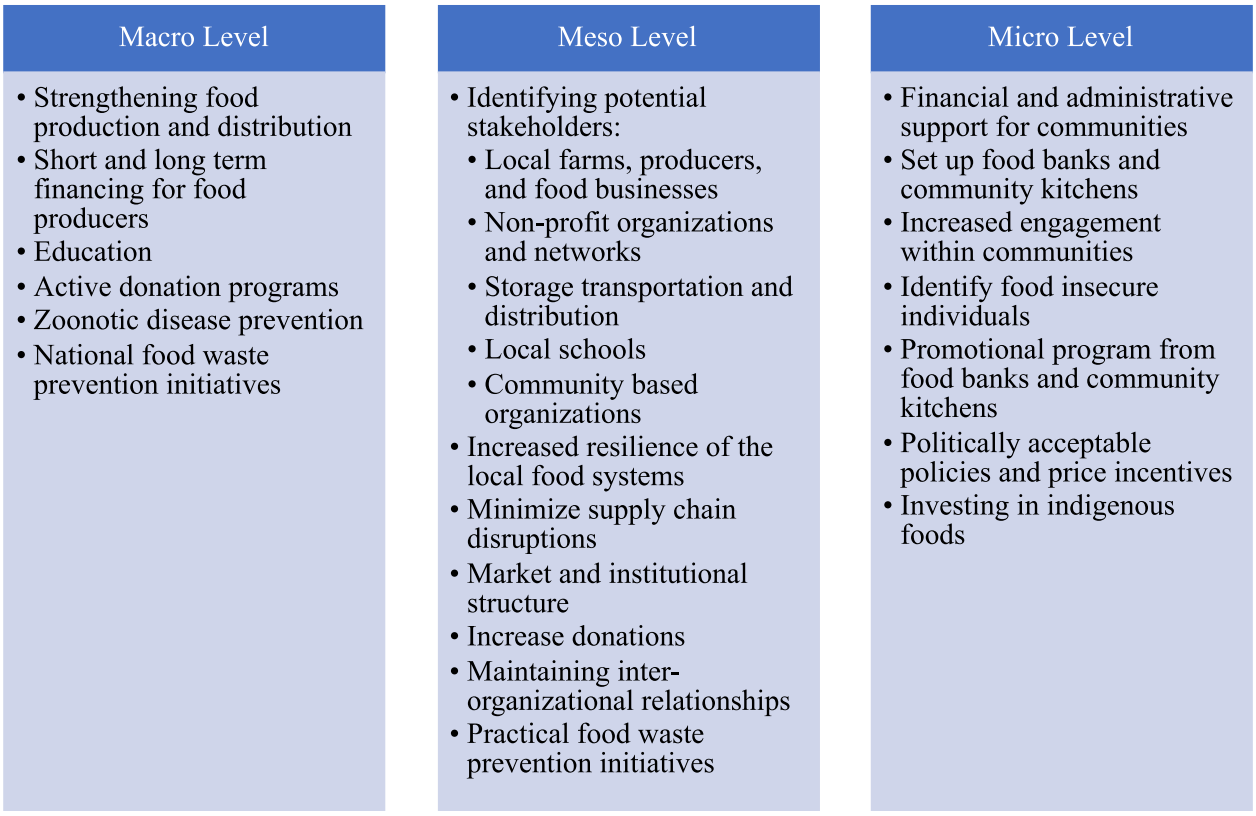


**Fig. 1.** Systems view of disrupting food insecurity: macro-meso-micro level perspectives.

government level food donations, and free school meals have targeted the immediate needs of the communities. This of course does not include those living in conflict and war zones. However, unless we address the systematic issues, as we witnessed during the COVID-19 pandemic, we can expect future crises to further deepen food insecurity for millions.

*Preparing for the next crisis — macro level*

Although different global and local food security initiatives and policies are actively applied, more ambitious and sustainable approaches should be planned. According to the Global Risk Report (2022), climate action failure and global financial crisis come as new risks after the pandemic (World Economic Forum, 2022). Strengthening food production and distribution are key to crisis preparedness. Areas such as short- and long-term financing, education, active donation programs, the next zoonotic disease prevention especially in developing countries, and effective food waste prevention initiatives must be covered. Commitment to national-level programs in these areas is needed to spur activity across the system.

*Leveraging public-private-community partnerships — meso level*

The food crisis calls for mapping sustained local public and private partnerships and political movements, identifying potential stakeholders. The framework tested between various sectors of production, storage transportation, and distribution will provide directions for scaling up. There should be increased resilience of the local food systems to minimize supply chain disruptions. Coordinated effort can strengthen the local food systems through organizations such as local farms, producers, and food businesses that understand the local community needs, and non-profit organizations and networks that are aware of the gaps in the market and institutional structure. Identifying crisis preparedness protocols at focal points of food access and distribution such as local schools and community-based organizations (food banks, places of worship, and others) can increase access to food for those at risk of being food insecure. As always, there is a need for education and information sharing about food insecurity, food loss and waste to support these organizations in their effort to increase donations, volunteering time, and maintaining inter-organizational relationships.

*Reducing food insecurity locally — micro level*

Many state and local governments aim to alleviate food insecurity by offering financial and administrative support for communities to set up food banks and community kitchens.[7] However, such programs may not be effective if food insecure individuals cannot be reached.[7] Therefore, higher engagement within communities is needed to identify the food insecure individuals. For example, community members can partner with local businesses and institutions to screen for those who are food insecure.[8] Some alternative signals (e.g., shopping frequency and significant life events) can be observed through community members to identify food insecure individuals. Furthermore, promotional programs (e.g., direct contact and marketing materials) from food banks and community kitchens can be linked to those in need to enhance the utilization of the programs. Although local initiatives are crucial, food insecurity is closely linked to regional food security challenges and income poverty. Thus, the initiatives should be supported by politically acceptable policies and price incentives to protect local and regional poor communities. Investing in indigenous foods is

likely to prevent dependency on central food production and distribution.

Another critical target population of interventions needs to be children, particularly those reliant on school meals. School closures due to COVID-19 have disrupted the normal distribution channels through which school meal programs operate and many children are without this vital source of food. School meals are a critical source of nutrition for millions of vulnerable children around the world covering over 370 million children globally, with the largest number of beneficiaries in India, Brazil, China, South Africa, and Nigeria.[9] In 2020, it was estimated globally that 39 billion in-school meals were missed during school closures by the 370 million children who were benefiting from school feeding programmes precrisis. Adapting existing programmes to use take-home rations, top-up cash transfers or food vouchers creates an important safety net. However, these are not long-term solutions. Priority should be given to targeting effective food waste initiatives, collecting and recycling untouched and unopened food packages from places that offer catering services, and delivery of nutrition more cost-effectively to yield substantial benefits in education and health outcomes to children and individuals in need.[1] Without increased efforts to bring children to school, the precrisis level of out-of-school children is likely to worsen as outcomes of the COVID-19 crisis persist. Countries can also take the opportunity to improve programme design, and address formerly neglected issues, such as the quality of diets and food-fortification options, and free meals for all school children, around the world.

### *Conclusions*

The biggest risk is inaction. There is a critical need to re-evaluate and design the current strategies, centered around emergency preparedness, creating avenues for partnerships and community engagement. Systematic efforts need to happen across the macro, meso, and micro levels of our society. Eventually, these efforts will need to be synchronized, to avoid delicacy, and to ensure synergies, thereby maximizing the impact by leveraging available resources. We may not have the luxury of doing so sequentially as the next crisis brews to again remind us of the persistence of food insecurity on our planet.

## Author statements

### *Ethical approval*

No human subjects ethical approval was needed given that no human subjects were involved in this study.

### *Funding*

No funding was used for this study.

### *Competing interests*

The authors do not have any competing interests to declare related to this study.

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Public Health 211 (2022) 66–71

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

# Ambient air pollutant concentrations and asthma-related hospital admissions during COVID-19 transport restrictions

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ARTICLE INFO

*Article history:*
Received 26 April 2022
Received in revised form
6 July 2022
Accepted 8 July 2022
Available online 18 July 2022

*Keywords:*
Air pollution
Asthma
Particulate matter
Nitrogen dioxide
COVID-19 restrictions

ABSTRACT

*Objectives:* Exposure to air pollution is a known risk factor for asthma exacerbations and hospitalisations. This study aimed to identify if COVID-19 transport restrictions led to improvements in air quality in Dublin and if this had an impact on asthma-related hospital admissions.
*Study design:* This was a population-based retrospective cohort study.
*Methods:* Daily concentration levels of particulate matter ($PM_{2.5}$ and $PM_{10}$) and nitrogen dioxide ($NO_2$) were obtained from the Environmental Protection Agency (EPA). The Hospital In-Patient Enquiry (HIPE) system provided the daily number of asthma-related hospital admissions in Dublin. The figures for 2018 −2019 were compared with the period of transport restrictions (from March 2020).
*Results:* During the period of transport restrictions, there was a significant decrease in mean daily concentrations in both $PM_{2.5}$ (8.9 vs 7.8 μg/m$^3$, $P = 0.002$) and $NO_2$ (24.0 vs 16.7 μg/m$^3$, $P < 0.001$). There was also a significant reduction in the mean number of daily asthma admissions (4.5 vs 2.8 admissions, $P < 0.001$). Only $NO_2$ showed a statistically significant correlation with asthma admissions ($r = 0.132$, $P < 0.001$).
*Conclusion:* Transport restrictions introduced to mitigate against COVID-19 led to lower pollutant levels and improved air quality. Previously described associations between pollutants and asthma would indicate that these improvements in air quality contributed to the reduction in asthma-related admissions. The complex nature of PM is the likely explanation for the lack of correlation between its concentration and asthma admissions, unlike $NO_2$ whose primary source is vehicular emissions. Public Health needs to advocate for transport policies, which can improve air quality and hence improve human health.



## Introduction

Air pollution is a major international public health concern; the burden of disease attributable to air pollution is now similar to that caused by other significant public health issues – tobacco smoking and unhealthy diets – and is the most important environmental threat to health.[1] It is defined as chemical, physical, or biological contamination of both indoor and outdoor (ambient) air.[2] In Europe, one of the main sources of ambient air pollutants is the transport sector,[3,4] the term 'traffic-related air pollution' (TRAP) describes such emissions.[5] These pollutants include nitrogen dioxide ($NO_2$) and particulate matter (PM);[2] PM being atmospheric solid and liquid particles, categorised based on their diameter – $PM_{10}$ having a diameter <10 μm and $PM_{2.5}$ having a diameter <2.5 μm.[6]

Exposure to ambient air pollutants has been shown to be associated with respiratory conditions, including asthma. A 2015 systematic review found that increases in air pollutant levels, including $NO_2$ and PM, were significantly associated with increased risk of asthma-related emergency department (ED) attendances and hospital admissions, on the same day and subsequent days.[7] Previous studies conducted in Ireland have shown a significant association between $NO_2$ and respiratory admissions, including chronic obstructive pulmonary disease (COPD),[8] as well as an association between the air quality index overall and respiratory hospital admissions.[9]

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https://doi.org/10.1016/j.puhe.2022.07.009
0033-3506/

In March 2020, the World Health Organization (WHO) declared a global pandemic following the emergence of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[10] Part of the mitigation measures implemented in Ireland included transport restrictions; non-essential services were closed, people were asked to work from home, and travel was restricted to a 2 km radius.[11] Compliance with these restrictions was estimated between 60 and 80% from April to November 2020,[12] with vehicular traffic demonstrably reduced.[13]

Similar restrictions were introduced internationally and, as a result, air pollutant concentrations were noted to be reduced in several studies.[14–16] The trends in air pollution concentration seen as a result of COVID-19 mitigation measures have allowed for exploration of the relationship between air pollutants and certain diseases. Although acknowledging that these restrictions were not sustainable long-term, recent studies have highlighted that these improvements in air quality may have had a positive impact on morbidity and mortality.[15,17] Such studies add to existing evidence on the association between air pollution and asthma, and may provide the impetus for governments to implement transport-related policy changes in order to meet the 2021 WHO air quality guidelines, recommending more stringent levels for several air pollutants.[1]

The aim of this study was to determine if the transport restrictions introduced during the COVID-19 pandemic had any impact on the concentrations of pollutants contributing to TRAP in Dublin, and to determine if this in turn had any impact on asthma-related hospital admissions.

## Methods

This study was conducted using routinely collected data from January 2018 to February 2021. This period covers the COVID-19 pandemic, declared in early 2020, as well as the two preceding years acting as control years.

Data on asthma admissions were obtained from the Health Service Executive (HSE) Hospital In-patient Enquiry (HIPE) system, a national system that collects data on discharges from, and deaths in, acute public hospitals. Each HIPE record represents an episode of care, meaning that an individual patient may have multiple HIPE entries over the study period. Without a unique patient identification number, the data is analysed in terms of episodes rather than individuals, allowing for analysis of hospital activity rather than incidence of disease. Primary diagnoses of asthma (International Classification of Disease (ICD) 10AM codes J45, J46) were included in the study. Daily counts of the asthma-related hospital admissions for all ages with an address in Dublin (city and county) were obtained, along with average age of the patients, average length of stay, and number of bed days.

The Environmental Protection Agency (EPA) provided the daily average PM and $NO_2$ concentrations for the 15 monitoring stations across Dublin city and county during the study period. Some monitors are roadside, and others are located in suburban areas. A number of the stations did not come on-line until 2020/21, and so the mean concentration for each pollutant was calculated from the available readings for each 24-h period during the study period.

Data were analysed in IBM Statistical Package for Social Sciences (SPSS) version 26. Descriptive analysis was performed, to describe the patients admitted for asthma-related diagnoses during the study period, and to describe trends in pollutant concentration over the same period. Comparative analysis was performed, using the independent t, Wilcoxon Rank-Sum and Chi-squared tests, to examine the relationship between asthma admissions and pollutant concentrations during the study period. Spearman's rank order was used to assess the correlation between pollutant concentration and asthma-related hospital admissions. Results were considered significant at $P < 0.05$ (two-tailed).

During the COVID-19 pandemic, there was an overall reduction in hospital presentations and admissions. To ensure that any change in asthma-related admissions was not due to patients avoiding hospitals due to the pandemic, chronic liver disease (CLD) was chosen to act as a control, given that it has no association with air pollution. The HIPE system was used as the source of data on CLD admissions (ICD 10AM codes K70.3, K74.4, K74.5, K74.6). The average number of daily CLD admissions over the same periods was compared using the independent *t*-test.

## Results

Taking March 2020 as the start of the global COVID-19 pandemic, 802 days of the study period were prepandemic, and the remaining 353 days were during the pandemic. Over the whole study period, there were a total of 4551 admissions to hospital with a primary diagnosis of asthma and an address in Dublin, equating to 12,673 in-patient bed days (see Table 1). Of these admissions, 2792 (61.3%) were women; the mean age was 40.9 years (standard deviation (SD) 20.3 years). The average daily concentration of each pollutant over the study period is in Table 1 and for each month of the study period is displayed in Fig. 1.

The first objective was to determine if there was any change in the concentrations of air pollutants during the pandemic period when compared to the previous few years. Table 1 shows the comparison of mean daily pollutant concentrations in the pre-pandemic and the pandemic periods. There was a significant decrease in the concentration of both $PM_{2.5}$ and $NO_2$ ($P = 0.002$ and $P < 0.001$, respectively). Although there was a decrease in mean $PM_{10}$ concentrations, this was not statistically significant.

The second objective was to determine if there was any change in asthma admissions during the pandemic period, and as shown in Table 1, there was a statistically significant reduction in the average daily admissions for asthma in Dublin (mean daily asthma admissions 4.5 (3.4) vs 2.8 (SD 2.5); $P < 0.001$). There was also a statistically significant reduction in the average in-patient bed days (median 6.0 bed days (2.0–14.0) vs 3.5 bed days (IQR 0.5–9.0); $P < 0.001$). There was no significant difference in the average age or the proportions of males and females being admitted during the pandemic when compared with the pre-pandemic period.

There was no statistically significant difference in the average daily hospital admission for CLD in Dublin during the pandemic period when compared with the pre-pandemic study period (mean daily liver admissions 2.8 (SD 1.9) vs 2.6 (SD 1.8); $P = 0.202$), as seen in Table 1. Average daily hospital admissions for asthma and CLD for each month of the study period are shown in Fig. 2, with a marked drop-off in asthma admissions seen at the introduction of transport restrictions.

Spearman's correlation coefficients (r, see Table 2) were calculated to examine the relationship between the daily concentration of pollutants and the number of asthma admissions during the study period. The concentration of $NO_2$ was significantly positively correlated with the number of daily asthma admissions. There was no statistically significant correlation between either $PM_{2.5}$ or $PM_{10}$ concentration and number of daily asthma admissions.

## Discussion

The COVID-19 pandemic led governments worldwide to take unprecedented measures in a bid to control the spread of the virus. In many countries, this included the introduction of transport restrictions. These restrictions offered researchers the opportunity to conduct large-scale quasi-natural experiments that would not have

**Table 1**
Pollutant concentrations and hospital admissions during the whole study period and comparison between the prepandemic period and during the COVID-19 pandemic.

| Variable | Valid denominator[a] | Total study period | Prepandemic | Pandemic | *P*-value |
|---|---|---|---|---|---|
| Pollutants (μg/m$^3$; mean (SD)) | | | | | |
| $PM_{2.5}$ | 1152 | 8.6 (6.6) | 8.9 (7.2) | 7.8 (5.2) | 0.002[b] |
| $PM_{10}$ | 1152 | 13.4 (7.9) | 13.5 (8.5) | 13.1 (6.5) | ns |
| $NO_2$ | 1135 | 22.2 (11.0) | 24.0 (11.5) | 16.7 (8.2) | <0.001[b] |
| Hospital admissions | | | | | |
| Asthma admissions (*n*) | | 4551 | 3573 | 978 | |
| In-patient bed days (*n*) | | 12,673 | 9222.5 | 3450.5 | |
| Asthma admissions per day (mean (SD)) | 1155 | | 4.5 (3.4) | 2.8 (2.5) | <0.001[b] |
| Average in-patient bed days (median (IQR)) | | | 6.0 (2.0–14.0) | 3.5 (0.5–9.0) | <0.001[c] |
| Asthma admissions by sex | | | | | |
| Female (*n* (%)) | | 2792 (61.3%) | 2177 (60.9) | 615 (62.9) | ns[d] |
| Male (*n* (%)) | | 1759 (38.7%) | 1396 (39.1) | 363 (37.1) | |
| Age in years (mean (SD)) | | 40.9 (20.3) | 41.6 (19.7) | 39.4 (21.8) | Ns[b] |
| Liver admissions per day (mean (SD)) | 1155 | | 2.8 (1.9) | 2.6 (1.8) | Ns[b] |

SD: standard deviation; PM: particulate matter; $NO_2$: nitrogen dioxide; IQR: inter-quartile range.
Significance taken at alpha level <0.05.
[a] Number of days for which data available.
[b] Independent *t*-test.
[c] Mann Whitney U test.
[d] Chi-squared test.

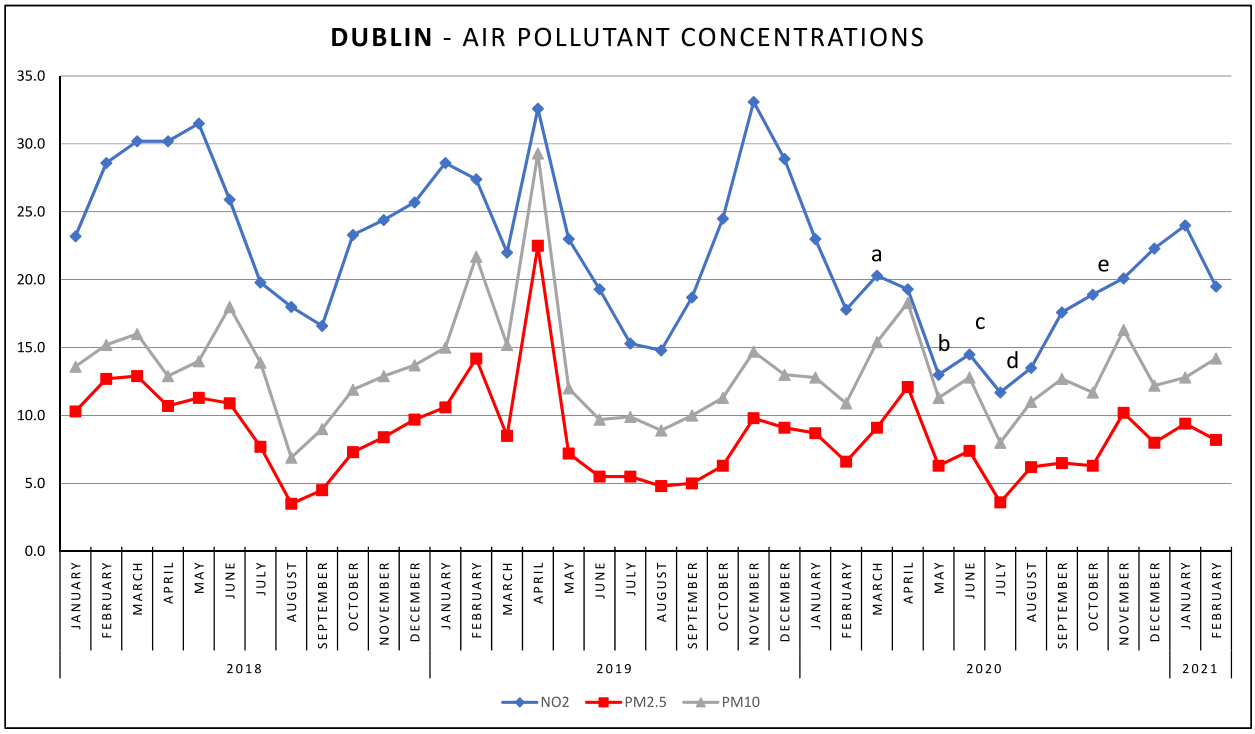


**Fig. 1.** Graph of average concentration of $NO_2$, $PM_{2.5}$ and $PM_{10}$ for each month of the study period; a: 2 km restrictions introduced, b: 5 km restrictions introduced, c: 20 km restrictions introduced, d: cross-country travel allowed, e: cross-country restrictions re-imposed.

been feasible to conduct in prepandemic times. This study set out to use the transport restrictions imposed in Ireland, to examine whether the reduction in traffic, as seen by a reduction in motorised vehicle journeys,[18] would lead to a reduction in transport-related air pollution in Dublin, and whether this could potentially have a positive impact on asthma morbidity.

The reduction in traffic during the initial pandemic period from March 2020, as measured by Transport Infrastructure Ireland (TII),[18] did lead to a significant reduction in $NO_2$ and $PM_{2.5}$ concentrations in Dublin, although not in $PM_{10}$. This finding was similar to the picture seen nationally; there was a significant decrease in $NO_2$ levels across Ireland, related to the decrease in vehicle emissions, but no significant change in $PM_{10}$ levels; the study authors attributing this to alternate non-transport sources of PM.[3] PM is a complex pollutant, produced from numerous sources, so although vehicle emissions decreased, alternate sources, such as home energy use and heating, are likely to have contributed to a greater extent in Dublin during the lockdown period, resulting in no significant change in its concentration.

Internationally, studies have demonstrated significant decreases in $NO_2$ and PM in many countries,[14,15,19,20] largely attributed to reductions in vehicle and industry emissions. A study from New York City, however, found no significant difference in PM concentration, the authors suggesting that countries with greater levels of

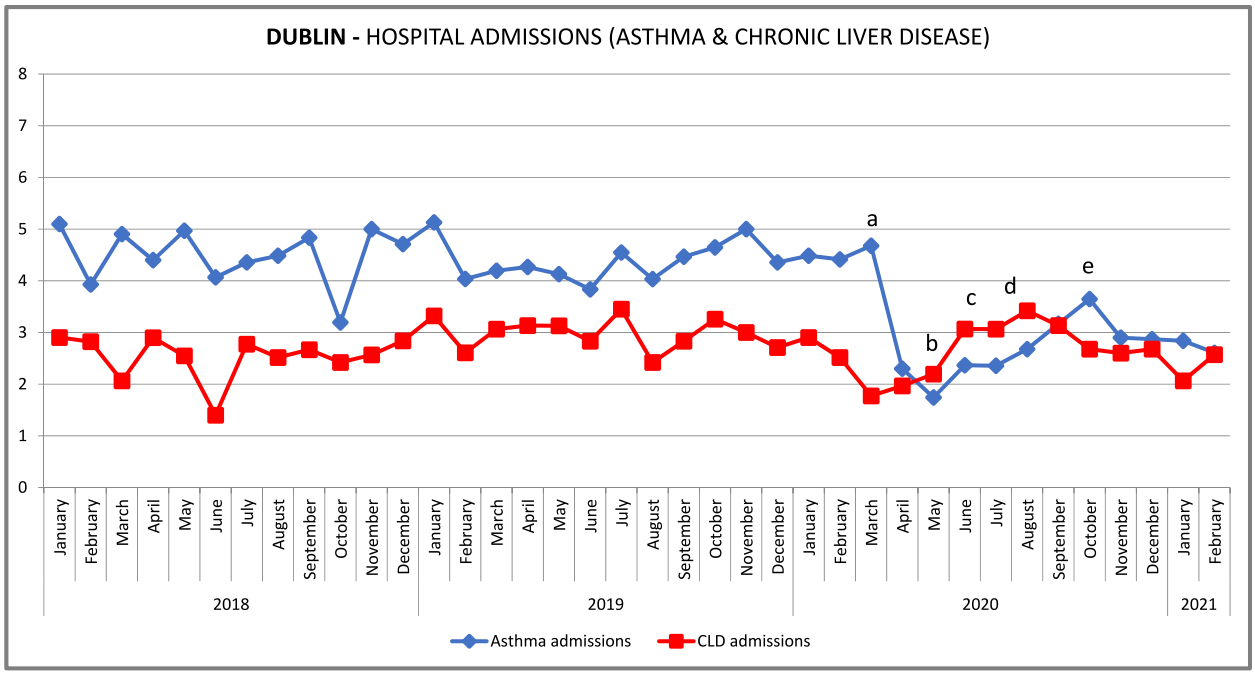


**Fig. 2.** Graph of average daily hospital admissions for asthma and chronic liver disease for each month of the study period; a: 2 km restrictions introduced, b: 5 km restrictions introduced, c: 20 km restrictions introduced, d: cross-country travel allowed, e: cross-country restrictions re-imposed.

pollutants before the pandemic would have a greater capacity to experience improvements compared with countries with lower baseline levels.[21] This may also explain the $PM_{10}$ findings in Dublin.

The second objective was to determine if there was a change in asthma admissions during the pandemic period. In Dublin, there was a statistically significant decrease in the average number of asthma admissions. This is in keeping with international findings.[17,22–25] This study chose to focus on asthma admissions, rather than other markers of morbidity, such as ED attendances or systemic steroid use. This is because data on hospital admissions are easily accessible through HIPE, whereas data on prescriptions and ED attendances are not as readily available.

There are several factors, in addition to improved air quality, which may have contributed to the reduction seen in asthma admissions, such as improved adherence to baseline medications, and lower levels of respiratory viruses and pollen. Adherence to treatment was not included in this study as it is too difficult to adequately quantify. Other studies had previously concluded there was no significant change in pollen levels during the pandemic period and so had no impact on the reduction in asthma admissions.[17,24]

In Europe, levels of non-COVID respiratory viral pathogens, such as Respiratory Syncytial Virus (RSV)[26] and influenza,[27] were substantially lower in 2020, likely due to the restrictions and non-pharmacological interventions (NPIs) introduced as pandemic mitigation measures.[27] Viruses are an important cause of asthma exacerbations; with rhinovirus being the most commonly identified pathogen.[28] Although it is likely that the NPIs introduced for SARS-CoV-2 would have reduced the incidence of rhinovirus infections, these data were not available as rhinoviruses are not notifiable in Ireland. Also, it is important to note that asthma admissions were lower even over the summer period, which is not the traditional respiratory pathogen season.

Another factor which may have had an impact on asthma admissions was the idea that fear of COVID-19 may have resulted in fewer people attending hospitals. To acknowledge this, a disease entity that is not associated with air pollution was chosen to act as control in this study. Daily admissions numbers for CLD were compared between the pandemic period and the preceding two years, and no difference was found. This means that those patients who warranted admission were still attending the hospital and receiving appropriate treatment, suggesting that the number of people requiring hospital admission for asthma was actually lower during the pandemic period.

The final objective was to identify if there was an association between air pollutant concentration and the number of asthma admissions. The pandemic period saw a significant reduction in daily asthma admissions in parallel with a significant reduction in $NO_2$ and $PM_{2.5}$ concentrations. Beyond that, however, this study has also shown that daily $NO_2$ concentration is significantly positively correlated with daily asthma admissions, similar to the findings of Sigala et al.[25] The primary source of $NO_2$ is vehicle emissions.[3] Therefore, the travel restrictions imposed as part of the Irish government's pandemic response resulted in a reduction in $NO_2$ levels, and this improvement in air quality likely had a positive effect on asthma morbidity, as measured in hospital admissions. However, whilst $NO_2$ is a 'key indicator of traffic-related changes in pollution,' particulate matter is more complex, coming numerous sources.[3] Hence, whilst the link between traffic restrictions, reduced $NO_2$ concentration and fewer asthma admissions is apparent, it is not unexpected that there was no significant correlation between PM concentration and asthma admissions.

There are several strengths to this study. All asthma-related admissions to public hospitals of individuals with an address in Dublin during the study period were included in the analysis. These

**Table 2**
Spearman's correlation co-efficients for air pollutant concentrations and asthma admissions.

| | $PM_{2.5}$ | $PM_{10}$ | $NO_2$ |
|---|---|---|---|
| r | −0.004 | 0.035 | 0.132 |
| *P*-value | 0.882 | 0.242 | **<0.001** |

PM: particulate matter; $NO_2$: nitrogen dioxide.
r: Spearman's correlation co-efficient with significance taken at alpha level <0.05 (highlighted bold).

data were collected from HIPE, a national system which undertakes audits to enhance its data quality. The environmental data was provided by the EPA, from 15 monitoring stations around Dublin. Only stations with certified equivalent instruments were included, meaning the data are comparable between stations, allowing for an average daily concentration for each pollutant to be calculated that was representative of the Dublin region.

Another strength of this study was the inclusion of another disease entity as a control factor. By finding no reduction in CLD-related admissions during the study period suggests that people requiring admission were still presenting to hospital, lending weight to the idea that there were actually fewer people requiring admission for asthma-related reasons.

There are, however, several limitations. This is an observational study using ecological data and so it is not appropriate to draw causal conclusions from the data analysis. The findings of lower concentrations of common air pollutants are presented alongside the finding of reduced number of asthma admissions; however, it would be inappropriate to say conclusively that the reduction in asthma-related admissions was due to the improvement in air quality. Given what is known about air pollution and its link with asthma exacerbations, it stands to reason that the improvements seen in $NO_2$ and $PM_{2.5}$ levels likely did contribute to a reduction in asthma exacerbations, which in turn would have led to a decrease in asthma admissions. However, as discussed, there are several additional factors that may also have had an impact on the reduction in admissions, which were not included in this analysis.

HIPE data does not include admissions to private hospitals, so they were not included in this study, and the HIPE output is dependent on the data input, meaning that errors or omissions by the clinical team in documenting the diagnosis or errors made by the HIPE team in coding may result in the numbers of asthma admissions being either under- or over-reported. Many of the air quality monitoring stations did not have readings on all of the dates in this study, with several stations only commencing data collection in 2020. This means that the average concentrations used, particularly in 2018/19, may not be as truly representative of the average air quality in Dublin as compared with 2020.

Nonetheless, the results in this study are in keeping with similar international studies published in recent months. Therefore, when taken into the wider context, this study adds to the existing body of evidence that during the period of pandemic transport restrictions, there was a significant reduction in asthma hospital admissions and this corresponded with the significant reduction in air pollutants seen in many countries around the world. Although not possible to draw causal association, it is likely that an improvement in air quality contributed to this reduction in asthma morbidity.

Air pollution is a major public health issue, causing substantial morbidity and mortality each year.[1] The findings of this study suggest that significant air quality improvements can be made through more stringent transport policies aimed at significantly reducing the number of cars on the road. This improvement in air quality would have a substantial impact on public health; contributing to fewer asthma exacerbations and hospitalisations, as well as reducing healthy life years lost and premature deaths.

## Author statements

### *Acknowledgements*

The authors are grateful to Healthcare Pricing Office (HPO) for allowing access to the HIPE data that were used in this study.

### *Ethical approval*

This research uses routinely collected data at the population level rather than the individual level; it conforms to the Helsinki Declaration and does not require approval from a research ethics committee.

### *Funding*

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

### *Competing interests*

The authors declare no conflict of interests.

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Public Health 211 (2022) 14–20

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

# An interrupted time series analysis of gambling behavior based on gambling operator revenue-based taxation during the COVID-19 pandemic in Sweden

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ARTICLE INFO

*Article history:*
Received 29 March 2022
Received in revised form
27 June 2022
Accepted 4 July 2022
Available online 19 August 2022

*Keywords:*
Gambling disorder
Problem gambling
Behavioral addiction
COVID-19
Interrupted time series analysis

ABSTRACT

*Objectives:* The impact of COVID-19 on gambling behavior and the gambling industry itself has been widely speculated. Prior studies have shown how boredom, social isolation, poor mental health, and financial hardships, all of which have been associated with COVID-19, can aggravate problem gambling behaviors in patients with gambling disorders while also luring newcomers. Few studies have used methods other than self-report to assess longitudinal behavioral changes in gambling behavior before versus during the pandemic.
*Study design:* The present study addresses this gap by using an interrupted time series approach on data obtained from the Swedish Gambling Authority measuring taxation on gambling vendors' revenue between January 2019 and November 2021.
*Methods:* March, June, and October 2020 were chosen as interruption points as they correspond to the pandemic's commencement, the return of elite sports, and the second wave of cases in Sweden, respectively. We hypothesized that the pandemic would be associated with both temporary changes for select gambling types and long-term increases in online gambling.
*Results:* Results revealed the pandemic's onset was associated with transient effects at each point of interruption, as well as long-term upward trends in total gambling and commercial online gambling, excluding horse betting and the state-owned operator for online casinos and betting.
*Conclusions:* The present study's findings, although consistent with the theory that gambling activity could increase during the pandemic, contradict previous studies that found no changes or a decrease from pre-COVID-19 levels. Findings indicate that the pandemic and Sweden's reaction to it were associated with increased use of some gambling products.


## Introduction

The spread of a novel coronavirus (SARS-CoV-2) causing the coronavirus pandemic of 2019 (COVID-19) may have been conducive to the development and exacerbation of problem gambling behaviors and gambling disorders (GD) worldwide.[1–3] Extant literature highlights numerous psychosocial risk factors that are implicated in some individuals' increased gambling, most notably during times of high stress, depression, and substance use,[4–7] all of which have been associated with pandemic-related changes.[8–10] Unique to times of COVID-19, increased psychological distress associated with financial insecurity and health risks, increased alcohol consumption and other escape coping strategies to alleviate stress and boredom, as well as increased time spent at home and social isolation, have all been postulated to have contributed to gambling becoming an attractive activity for regulars and newcomers alike during the pandemic.[11–13] Many countries recognized

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https://doi.org/10.1016/j.puhe.2022.07.003

the potential liabilities associated with hazardous gambling during this time and therefore imposed restrictions in the form of limitations on gambling advertising and deposit amounts, as well as total bans (see Brodeur et al. for a review of governmental interventions[14]). Despite these precautions, uncertainty persists regarding the pandemic's impact on gambling behavior and public health.

Countries worldwide introduced mandated lockdowns and quarantine measures early on to limit the virus's spread.[15,16] Sweden, on the other hand, was a country that did not impose any strict restrictions or lockdowns on its people at any point during the pandemic. Because of Sweden's hands-off approach and easily accessible online gambling market, the resulting pandemic-related changes are critical for understanding the benefits and ramifications of a strategy that avoids lockdown and social isolation mandates during a time of high psychological and financial stress, as well as infection risk. However, to comply with social distancing recommendations, many professional sports and events with large crowds were originally canceled, rescheduled, or restricted, potentially leading to increased gambling through increased boredom and social isolation.[2,5,17,18] Despite restrictions and the cancelation of sporting events that involved large-scale sports betting, some studies measuring gambling behaviors at the level of the individual in Sweden have shown increases in problem gambling for other types of gambling among some vulnerable populations, particularly those with premorbid GD of high severity and those continuing to bet on sports despite its limited availability.[1,19,20] In contrast, however, another study reported that although the number of online gamblers in Sweden had increased during the pandemic's first five months, the average daily wager decreased for those with serious GD but climbed for those in the lowest risk group.[21]

Studies using aggregated data sets from the general population have indicated little to no overall change in gambling measures before versus during the pandemic.[18,22–24] Although these data are incapable of revealing changes in financial burden and psychological stress, they are nonetheless a significant indicator of overall gambling activity. First, a study using daily time series data from a single gambling operator based in Sweden, Germany, Finland, and Norway found that sports betters were not more likely to transfer to online gambling casinos in the short term despite pandemic-related changes, such as sport cancelations occurring in March and April 2020.[22] These findings were consistent with other studies[23,24] showing that profit-based tax revenue and gambling activity remained stable for Swedish vendors during the first months of the pandemic. A follow-up study by Månsson and colleagues (2021)[18] did not find a relationship between financial burden and isolation with increased gambling. Because of the June 2020 limits and the decision to avoid a lockdown, these findings may reflect the Swedish government's effectiveness in mitigating disordered gambling behaviors.

In addition to aberrations in individual gambling behavior, COVID-19 may have had an impact on gambling economics and public health. The unavailability of certain gambling types during the pandemic presented an opportunity for market substitution or cannibalization effects between gambling products and industries to be amplified or attenuated. For instance, a meta-analysis by Marionneau and Nikkinen[25] found that casinos tend to cannibalize the market share of race betting industries, which has been postulated to be a contributor to the long-term decline of pari-mutuel/racing gambling in Western countries. In the case of COVID-19, the closure of land-based casinos may have reduced the impact that these institutions had on horse racing in the Swedish context. If this is the case, an increase in horse betting may be anticipated, which may be accompanied by a rise in the use of electronic gaming machines, as multiple studies have found that these two modalities are complementary.[25–29] Gambling, from the perspective of the Public Health Impacts of Gambling (PHIGam) model,[30] has both positive and negative impacts on overall public health at the community/society, interpersonal, and personal levels. Although unavailability of some gambling types could reduce the negative impact on financial, labor, and health outcomes, it may also diminish the positive effects as well. For example, the closing of land-based casinos may have positive interpersonal level effects by increasing the time spent at home with family but may simultaneously have negative community and personal level effects by removing the income source for casino employees. Determining the cost and benefits at each level is difficult, and therefore pragmatic research strategies are useful in explaining changes based on these theoretical models.

Studies covering changes in gambling behavior in the general population and risk groups during the pandemic in various countries have yielded varying results.[18,22–24,31–35] However, few studies have used time series data to account for secular trends to examine the pandemic's holistic effects on gambling behavior. Thus, studies deploying alternate data analysis methodologies that account for autocorrelation and pre-existing trends are warranted to better describe behavior change during this time. The aim of the present study is to fill this methodological gap by using interrupted time series (ITS) analysis to determine if the onset of the pandemic and other key time points were associated with altered gambling behavior, measured in the present study as taxes paid by Swedish gambling vendors based on their revenue. We hypothesize that the onset of the pandemic will be associated with rapid increases in gambling revenue generated for select gambling types, namely horse racing and commercial online gambling, and decreases for other types, such as a short-term drop in sports betting[21] and gambling at land-based casinos. Overall, a trend increase is expected for the total amount of tax revenue generated from commercial online casinos, as it was the most readily accessible to gamblers during this time.[1,20,23]

## Methods

In Sweden, gambling operators are required to pay a monthly 18% profit-based tax, which can be translated into their net monthly revenue and serve as an index of gambling activity. These data are free from recall bias in contrast to self-report assessments, providing a unique perspective on pandemic-related changes in gambling behavior. Gambling vendor taxation data do not include personally identifiable information and can be applied for and made available for research purposes by the Swedish Gambling Authority. The Swedish gambling laws, those enabling the licensing of domestic gambling vendors in Sweden, came into effect in January 2019.[36] Prior to 2019, the gambling market was unregulated, allowing international gambling vendors to conduct business in Sweden using licenses obtained outside of Sweden and creating a monopoly for the state-run online gambling corporation. Therefore, data were not available from earlier years. The current study used aggregated data sets that did not contain personally identifiable information about human participants and thus did not require ethical review. Gambling types represented in the Swedish gambling market are presented in Table 1.

Based on the timing of the World Health Organization's (WHO) declaration of COVID-19 as a pandemic,[38] as well as the initial surge in cases in Sweden, March 2020 is regarded as the point at which the pandemic first had a significant impact. The initial reaction by the Swedish government was milder in comparison to other nations, but governmental recommendations prompted responses from sporting associations and other agencies that curtailed

**Table 1**
Represented gambling types in Swedish marketplace.

| Provider type | Number of operators (*n*) | Market share (Q1 2022) |
|---|---|---|
| Operators with a combined license for commercial betting/casinos (including sports and online casinos) | 86 | 64.2% |
| The state-owned operator AB Svenska Spel's sub-division for lotteries and other chance-based games | 1 | 19.8% |
| The AB Svenska Spel sub-division responsible for the state monopoly of land-based casinos (Casino Cosmopol) | 1 | 1.6% |
| Commercial operators with only a sports betting license, i.e., no involvement in online casino | 6 | Unavailable |
| Restaurant-based casinos, which typically appear in bars and restaurants and offer limited-stake table games | 29 | 0.6% |
| A minor section of gambling, typically for goods rather than money, which is associated with fun fairs and similar events | 4 | 0.6% |

*Note*. Provider type represented in present data set. Market share calculated from data derived from the Gambling Tax Authority.[37]

gambling accessibility to a comparable level. The third week of March 2020 (March 15–21) saw the canceling of Swedish elite ice-hockey league playoffs and European soccer league fixtures, the implementation of work-from-home directives, the closure of high school and university campuses, and a travel ban to the rest of the European Union from Sweden. The final week of March and first week of April 2020 saw the closing of state-owned owned land-based casino, Casino Cosmopol, the rescheduling of Swedish elite soccer leagues season starts to June, and the prohibition of gatherings of more than fifty persons at a single venue, including restaurants. In the beginning of July 2020, restrictions on online casinos and slot machines took effect and remained in effect until November 14th, 2021, after which extensions of similar restrictions were proposed in the midst of the third wave of cases in Sweden.[39] The original restrictions implemented to limit gambling during COVID-19 consisted of a deposit limit of 5000SEK (approx. $535 USD at the time), a requirement for players to set a limit on gambling time, and the limiting of bonuses for players to 100SEK.[40] These restrictions were proposed to be extended into 2022, but were ultimately left to expire when the Swedish government decided to eliminate all COVID-related restrictions in the beginning of February 2022.[41] A more comprehensive list of significant COVID-19-related events during the first five months of the pandemic is presented elsewhere.[23,24]

Each of these imposed restrictions likely had a significant impact on gambling's availability and accessibility during this time period. As a result, three points of interruption were chosen for the purpose of observing these changes. March 2020 was chosen as the date when the pandemic first had a noticeable effect on the public, June 2020 was chosen as professional sports had re-emerged both in Sweden and internationally, and October 2020 was chosen to examine changes resulting from the second wave of COVID-19 cases in Sweden.

### *Statistical methods*

Vendors were stratified by vendor category (commercial betting/casinos, fun fairs, commercial sports betting only, restaurant casinos, state-owned land-based casino, state-owned-chance-based games, card games) and summed for each month. For the current study, eight outcome variables were generated: (1) total (all vendors combined), (2) commercial betting/casinos (including sports and horse betting, online casinos), (3) horse betting (a sub-category of commercial casinos), (4) Svenska Spel (state-owned commercial operator for online casino, a sub-category of commercial casinos), (5) commercial betting/casinos excluding horse betting and Svenska Spel, (6) commercial betting/casinos excluding horse betting, Svenska Spel, and commercial sports betting only, (7) restaurant-based casinos, and (8) state lottery (chance-based games). To assess monthly changes in taxation data for each gambling subtype, we conducted ITS analyses using autoregressive integrated moving average (ARIMA) models in accordance with Schaffer et al. (2021).[42] To assess changes resulting from the pandemic's onset, the return of sports, and the second wave of COVID-19 cases, we selected March 2020, June 2020, and October 2020 as points of interruption, respectively. The March 2020 point was used to compare trend changes before and following the pandemic's onset. Each outcome variable was initially log transformed and then coefficients were interpreted as percentages.

We used the studentized Breusch-Pagan[43] and Augmented Dicky-Fuller[44] tests to assess heteroscedasticity and stationarity, respectively. If considered non-stationary, we used non-seasonal differencing to induce stationarity. After differencing, autocorrelation functions (ACF) and partial ACF plots were evaluated and used to fit AR/MA order terms for the ARIMA models. Finally, we tested for the presence of autocorrelation in model residuals using the Ljung–Box test. If the test was significant, a simpler ARIMA model with the next lowest Akaike Information Criteria (AIC) was fitted to the data or AR/MA order terms were reselected. Seasonal models were not considered because data from years before 2019 were not available and differencing would remove the first 12 observations, leaving only three data points to generate a model for forecasting. The model selection and comparison process can be seen in Table 1 of the supplementary materials. *Z*-tests were conducted to determine the presence of significant step changes after interruption and ramp changes before versus after March 2020. The *astsa()*, *forecast()*, and *lmtest()* packages in R-V3.6.3 were used to conduct all analyses. Time series data with points of interruption are illustrated in Fig. 1.

## Results

Despite log transformations, Svenska Spel and State Lottery outcome variables presented heteroscedasticity and therefore need to be interpreted with caution. Likewise, because of a near full-drop in profit-based taxes generated for restaurant casinos during the second wave of the pandemic (October 2020), stationarity could not be achieved through first and second non-seasonal differencing and therefore must likewise be interpreted with caution.

There were significant elevated trend changes prepandemic versus during concerning tax revenue generated in total, +0.8% [0.3, 1.3], $z = 2.96$, $P = .003$, commercial betting/casino excluding horse betting and Svenska Spel, +0.7% [0.1, 1.3], $z = 2.45$, $P = .014$, as well as commercial betting/casino excluding horse betting, Svenska Spel, *and* commercial sports betting, +0.5% [0.0, 1.1], $z = 2.03$, $P = .042$. In March 2020, there were significant step changes in the negative direction for total, −7.6% [−15.5, 0.3], $z = -2.01$, $P = .044$, Svenska Spel, −56.4% [−100.5, −12.3], $z = -4.09$, $P < .001$, and restaurant casinos, −24.8% [−40.1, −9.5], $z = -3.79$ $P < .001$, while there was a step change in the positive direction for horse betting, +20.1% [10.0, 30.3], $z = 3.62$, $P < .001$. In June 2020, there was a significant step change in the positive direction for commercial betting/casino gambling, +7.8% [0.7, 14.8], $z = 2.11$, $P = .034$. In October, there were significant step changes in the positive

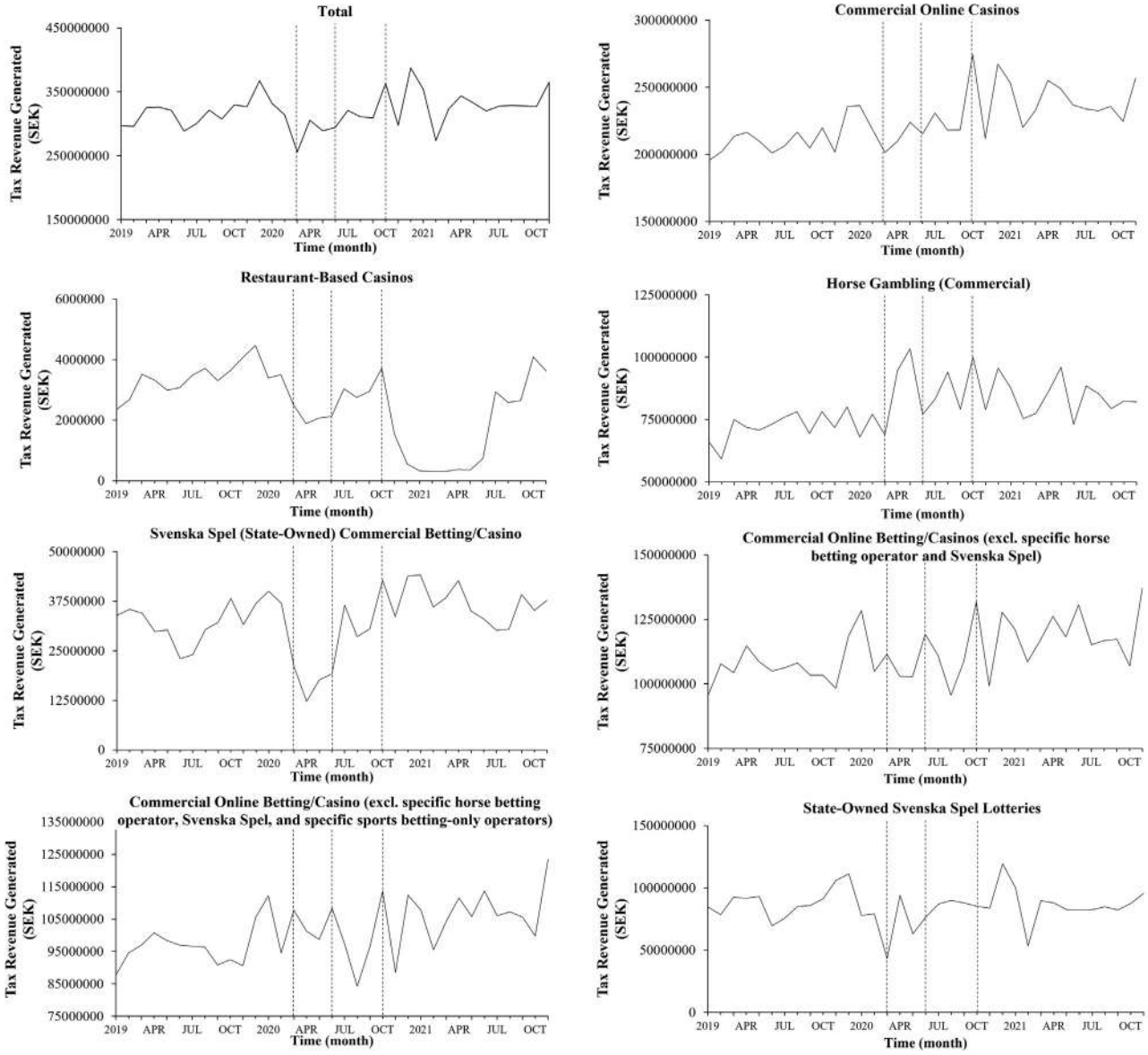


**Fig. 1.** Tax revenue generated from gambling vendors (January 2019–November 2021). *Note.* Revenue-based taxation on gambling vendors. Dotted lines indicate points of interruption (March 2020, June 2020, October 2020).

direction for commercial betting/casino gambling, +15.8% [8.4, 23.1], $z = 3.99$, $P < .001$, commercial gambling excluding horse betting and Svenska Spel, +8.7% [3.7, 13.8], $z = 3.29$, $P = .001$, and commercial gambling excluding horse betting, Svenska Spel, and sports betting-only operators, +12.0% [0.4, 23.5], $z = 1.98$, $P = .048$. A comprehensive summary of step and level changes are presented in Table 2.

## Discussion

As a result of the pandemic, there were significant trend increases for total gambling and commercial gambling when excluding the primarily horse betting-oriented operator, the state-owned operator Svenska Spel, and the operators exclusively providing sports betting, which partially supports our hypotheses. Thus, the data demonstrated a small, but increasing trend for operators with combined licenses in online sports betting and online casino gambling. Likewise, temporary fluctuations at each interruption point were as expected. These results indicate that the onset of the pandemic impacted gambling patterns both long-term and at specific time points. In March 2020, the onset of the pandemic, which in turn brought about the cancelation of many sports leagues, there was an increase in horse betting and decreases in total gambling, online gambling, and gambling in restaurant casinos. It should also be noted that the large number of operators with combined betting and online casino licenses altogether remained a strong provider of gambling throughout the first phase of the pandemic, suggesting that online casino gambling provided them with important incomes even when sports betting opportunities worldwide saw an immense decrease. When sports largely returned in June 2020, a temporary increase in commercial online gambling occurred. Then, at the start of the second wave in October 2020, there were increases seen in commercial online gambling not associated with horse betting or Svenska Spel.

The findings are consistent with other studies conducted in Sweden reporting changes in gambling behavior during the

**Table 2**
Estimated relative changes in tax revenue generated at each point of interruption.

| Variable (vendors) | Monthly *M* before March 2020 | Temporary change: March 2020 (%) | Temporary change: June 2020 (%) | Temporary change: October 2020 (%) | Trend change: Pre- vs Post-March 2020 (%) |
|---|---|---|---|---|---|
| Total ($n = 123$) | 317,949,946 | −7.6 [−15.5, 0.3]* | 0.9 [−7.7, 9.5] | 7.1 [−2.2, 16.5] | 0.8 [0.3, 1.3]** |
| Commercial ($n = 86$) | 212,794,269 | −8.3 [−20.0, 3.5] | 7.8 [0.7, 14.8]* | 15.8 [8.4, 23.1]** | 0.7 [−0.4, 1.7] |
| Primarily horse racing ($n = 1$) | 72,479,963 | 20.1 [10.0, 30.3]** | 1.3 [−24.0, 26.6] | 8.4 [-8.3,25.2] | −0.2 [−0.9, 0.5] |
| Svenska Spel commercial betting/casino ($n = 1$) | 32,677,319 | −56.4 [−100.5, −12.3]** | 4.4 [−49.5, 58.3] | 41.4 [−11.7, 94.5] | 3.8 [−2.7, 10.2] |
| Other ($n = 84$) | 107,636,987 | −0.9 [−9.4, 7.5] | 2.9 [−5.8, 11.7] | 8.7 [3.7, 13.8]** | 0.7 [0.1, 1.3]* |
| Other excl. sports betting-only operators ($n = 78$) | 96,765,853 | 1.4 [−6.4, 9.1] | −6.7 [−18.7, 5.3] | 12.0 [0.4, 23.5]* | 0.5 [0.0, 1.1]* |
| Restaurant ($n = 29$) | 3,396,508 | −24.8 [−40.1, −9.5]** | −20.8 [−89.3, 47.6] | 68.3 [−13.1, 150.0] | −1.7 [−9.1, 5.8] |
| State lottery ($n = 1$) | 87,235,719 | −16.1 [−35.1, 2.9] | 4.4 [−16.4, 25.2] | 5.2 [−18.0, 28.4] | 1.1 [−0.1, 2.4] |

*Note.* Interrupted time series analysis using ARIMA modeling. Total gambling includes card games, funfairs, and state-owned land-based casino, Casino Cosmopol, all of which are not included in any subtypes. Other includes all commercial online betting/casino operators excluding the primary horse racing operator and Svenska Spel. Percent change in tax revenue generated = (e^coeff − 1) × 100.
*$P < .05$. **$P < .01$.

pandemic,[1,19–21] but the increase in total gambling is contrary to findings from other studies.[23] This may reflect the success of temporary restrictions imposed by the Swedish government on some forms of gambling, but not others, as evidenced by the market's growth during this period. It is important to note, however, that a significant positive trend change in total gambling revenue generated is not an indicator of increased gambling activity, because increases were observed in some domains while decreases were observed in others, potentially confounding this outcome variable. Furthermore, the government-run gambling operator and horse betting operator transfer the majority of their profits to the state through dividends and other channels rather than taxation, making direct comparisons between outcome variables impossible. We can, however, conclude that the gambling market grew at a faster rate over the course of the pandemic than it did before its onset. With the cancelation of several major sporting leagues in March and April 2020, the market share temporarily increased for horse gambling, which was hypothesized by researchers to occur during the first wave[1,2,22,23] despite previous studies finding that migrations did not occur between gambling types.[18,22] However, a similar increase in other online non-sports betting modalities was not seen until June and October 2020. This effect may indicate that sports bettors migrated to horse betting during the absence of elite-level sporting events during the initial wave. This transfer could be explained by the inherent nature of sports and horse racing being considered semi-skill gambling modalities that impulsivist gamblers tend to prefer.[7] In accordance with Blaszczynski and Nower's (2002)[45] three pathways hypothesis of pathological gambling, changes in gambling behavior among impulsivist gamblers were theoretically less likely to be influenced by fluctuations in mental health symptoms, such as pandemic-induced depression and anxiety, and more likely a simple shift because of a lack of availability for their preferred gambling outlet. Based on differences in gambling preferences and motivations between sexes, this change in availability may have impacted male gamblers to a greater degree, as females generally favor anonymous online gambling and calming luck-based forms that were affected to a lesser degree than gambling types that males prefer, namely exciting semi-skill-based sports gambling and horse betting.[46] Furthermore, age-related differences in preference and motivation may further explain the variation seen in the present study. Counterintuitively, isolation and social engagement can serve both as risk factors for the development and maintenance of disordered gambling, but only for certain groups.[5] Young gamblers typically prefer solo gambling activities like online gambling, whereas elder gamblers prefer outlets that offer social engagement such as bingo and casino tours.[47] With closures of land-based casinos forcing greater social isolation, it is possible that elders transferred to other non-gambling social activities to escape isolation. Meanwhile, the availability of online gambling for young adults and adolescents was largely unchanged, or even made more readily available during this time, providing a time of increased vulnerability for newcomers and problem gamblers to engage in gambling more frequently to combat young adult and adolescent boredom.

June 2020 was a pivotal date, as it remained unclear how the scheduled return of sports would affect the gamblers that migrated to horse racing. According to the present data set, there appears to have been no regression back to pre-COVID-19 levels in horse betting since the pandemic's inception. This is despite a significant resurgence in sports betting-driven commercial gambling, with the exception of the operator primarily active in horse racing and the state-owned operator Svenska Spel, which occurred not immediately, but around the time when COVID-19 cases began to exponentially rise in October 2020. However, it should be noted that the gambling outlet that specialized primarily in horse racing at the start of the pandemic had recently expanded their services to include other forms of gambling on their Web site,[48] so it is possible that former sports gamblers dropped horse racing and returned to sports betting later but used the new functions provided by the same horse racing vendor. We were unable to delineate these migrations precisely using the present data set. The economics literature highlights that the income elasticity of demand for horse wagering and sports betting is low but positive, indicating that an increase in personal income is associated with an increase in consumption and revenue.[49,50] With the unemployment rate rising during this period in Sweden, one would expect the demand for these modalities to decrease. However, the opposite occurred for horse betting, indicating that either sports bettors migrated to horse betting or a large number of new bettors emerged during this period. One explanation may be an increase in international sales, which according to the Swedish horse racing operator, saw an increase in 2020, particularly in countries where horse betting was prohibited (e.g., other Nordic countries).[51] Increases in horse racing tax revenue may therefore be attributable to a rise in international scales and less to intermodal migrations among domestic gamblers.

### *Strengths and limitations*

The findings from the present study should be interpreted commensurate with its limitations. First, significant demographic and motivational covariates could not be controlled for using the present methodology and revenue-based taxes did not allow us to

track within-subject changes over time nor monitor behavior change in certain groups with differing baseline characteristics. Similarly, not all statistical assumptions were met, and only monthly data were available, limiting the number of observations and level of statistical certainty. Lastly, the rise in popularity of cryptocurrency use[52] and potential migrations to unregulated offshore bookmakers, as well as the influence of differing tax rates on international gamblers in Swedish markets during this period could not be accounted for using the current data. Regarding strengths of the present study, it is one of the few to use an analysis technique that considers secular trends, which provides unique insight into pandemic-related changes in gambling behavior. Furthermore, the current analysis incorporated data from all licensed vendors in Sweden, providing a comprehensive picture of changes in gambling behavior across the country during a time of immense transformation in gambling behavior and the gambling industry.

### *Conclusions*

Although small, there were significant trend changes in the positive direction for total and sports-driven commercial online gambling over the course of the pandemic. Although less time spent at home, fewer financial and stressors, and decreased boredom may put an end to the rise of gambling newcomers, the trajectory and severity of those who began and continued gambling during the pandemic warrants further investigation. In light of the findings of this study, the macroeconomic and psychological effects of Sweden's decision to avoid lockdown strategies and introduce light restrictions on gambling activity during the pandemic may have been effective in halting significant market expansion for many, but not all gambling types, namely online gambling that does not involve sports betting.

## Author statements

### *Acknowledgements*

The authors would like to acknowledge and thank Magnus Fahlén of the Swedish Gambling Authority for his assistance in data collection. In addition, we would like to thank the reviewers for suggesting the inclusion of economics and public health literature, as well as Dr. Andrea Schaffer for her generous help with the data analysis.

### *Ethical approval*

The present study used aggregated data sets that did not contain personally identifiable information about human participants and thus did not require ethical review.

### *Funding*

This research received no direct external funding.

### *Competing interests*

The third author and his research group, which includes the primary and secondary authors, receive funding for their research from AB Svenska Spel, the state-owned Swedish gambling operator, and the regional health care system (Region Skåne). Additionally, the third author collaborates with the private company Kontigo Care to test follow-up devices for patients undergoing treatment for gambling disorder; however, this collaboration does not involve direct financial support. Lastly, the primary author has worked with Recilio Scandinavia AB in the past to develop digital health programs to prevent workplace stress and burnout. None of these organizations had any role in the study design, collection, analysis or interpretation of the data, drafting of the manuscript, or the decision to submit this paper for publication.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.07.003.

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Public Health 211 (2022) 29–36

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Themed Paper— Original Research

# Community-based response to the COVID-19 pandemic: case study of a home isolation centre using flexible surge capacity

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ARTICLE INFO

*Article history:*
Received 1 April 2022
Received in revised form
29 May 2022
Accepted 21 June 2022
Available online 13 July 2022

*Keywords:*
COVID-19
Home isolation
Incident command system
Pandemic
Surge capacity

ABSTRACT

*Objectives:* Coronavirus disease 2019 (COVID-19) has consumed many available resources within contingency plans, necessitating new capacity surges and novel approaches. This study aimed to explore the possibility of implementing the concept of flexible surge capacity to reduce the burden on hospitals by focussing on community resources to develop home isolation centres in Bangkok, Thailand.
*Study design:* A qualitative study consisted of observational and semi-structured interview data.
*Methods:* The development and activities of home isolation centres were observed, and interviews were conducted with leaders and operational workforces. Data were deductively analysed and categorised based on the practical elements necessary in disaster and emergency management.
*Results:* Data were categorised into the seven collaborative elements of the major incident medical management and support model. The command-and-control category demonstrated four subcategories: (1) coordination and collaboration; (2) staff engagement; (3) responsibility clarification; and (4) sustainability. Safety presented two subcategories: (1) patients' information privacy and treatment; and (2) personnel safety and privacy. Communication showed internal and external communications subcategories. Assessment, triage, treatment and transport followed the processes of the COVID-19 treatment protocols according to the World Health Organisation (WHO) guidelines and hospital operations. Several supply- and patient-related challenges were identified and managed during centre development.
*Conclusions:* The use of community resources, based on the flexible surge capacity concept, is feasible under restricted circumstances and reduced the burden on hospitals during the COVID-19 pandemic. Continuous education among multidisciplinary volunteer teams facilitated their full participation and engagement. The concept of flexible surge capacity may promote an alternative community-based care opportunity, irrespective of emergencies' aetiology.


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https://doi.org/10.1016/j.puhe.2022.06.025

## Introduction

The outcome of nations' responses and efforts to hamper the progression of COVID-19 seemed to rely on the levels of each country's resiliency. Some countries implemented proactive measures, while others stayed passive, hoping to emerge unaffected by the pandemic.[1–6] In contrast to contained emergencies (i.e. geographically defined events with the integral incident site, e.g. bombing or flooding), pandemics are population-based events that create new challenges and need different approaches.[7] Irrespective of the cause, the initial approach to an emergency relates to surge capacity (SC), a multidisciplinary task that aims to increase the number of staff, stuff, space and create guidelines (system) (these are the four vital elements of SC) to scale up capabilities of health care and other agencies, using available resources.[7–9]

Hospitals are an important part of the response to emergencies. In a contained emergency, the first surge in hospitals begins within the facilities by using all on-duty hospital staff, devices and spaces based on the predesigned contingency plan (intrinsic capacities).[7] The expansion of incidents necessitates a second SC,[8,10] using all off-duty staff, reserved stuff and spaces. However, further development of the incident goes beyond facilities' capabilities and requires extrinsic capacities that involve two significant fields; similar healthcare facilities within the regional and national healthcare systems or community resources.[5,7,8,11] The concept of interfacility SC has been developed over many years to facilitate integrations among diverse local, regional or national teams.[12,13] Interfacility SC aims to recruit new resources to the affected areas and facilities, or evacuate some groups of patients to other sites or facilities.

Nonetheless, there are situations when the infrastructure is affected, creating difficulties in evacuating victims, such as in war situations, or higher risks of admitting victims to hospitals, such as in pandemics. These scenarios enforce the isolation of victims within their communities or homes and indicate a need for a flexible surge capacity (FSC), which aims at both using communities' resources (i.e. facilities and staff working in specific community activities can be trained and equipped to act as voluntary individuals) and organisations to provide care for the victims either on-site or offsite at non-medical facilities. Although scarcely described in the literature, proactive SC and FSC at the community level for the use of its resources is highly advantageous when first and second SCs are neither available nor possible to deliver.[14–17] The need for flexibility in disaster and emergency response systems has been described by many; however, a descriptive concept of FSC was only introduced in 2020[14] and has proved its feasibility, applicability and transferability in different infrastructures.[15,16]

### *Theoretical framework of FSC*

The theoretical framework of FSC combines the SC framework by Bonnett et al.,[7] complexity theory by Therrien et al.[5] and the collaboration theoretical framework.[18] Bonnett et al.[7] expanded Hick et al.'s[19] concept and introduced the facility-based, community-based and extrinsic SC.[7,19] In their framework, failure in facility-based SC resulted in a search for community-based SC, and if this was insufficient, an extrinsic SC was established. Both scenarios target only medical facilities and resources.[7]

Therrien et al.[5] expanded Bonnett et al.'s[7] discussion by adding the impacts of an incident's complexity to its resilience.[5] The authors emphasised the importance of detailed and dynamic complexity to manage such complexity, as in SC. The former is updated knowledge on the risk or aetiology and management of scientific uncertainty, resources and internal decision-making and communication. The latter is the systematic management of stakeholders on municipal, regional and national levels, the disparity and inequity of the care between populations, and the risks presented by the public, policymakers and professionals. Therrien et al.,[5] suggested that these complexities can be managed by establishing a robust network and inter-organisational consistency by obtaining some common denominators within the four elements of SC.

Recognising that some factors can be common points for interaction between groups, several authors used the collaboration theoretical framework to identify such common denominators.[5] FSC uses an established practical tool in disaster and emergency management and evaluation taught as part of MIMMS (Major Incident Medical Management and Supports) courses and described as CSCATTT.[20] In CSCATTT, 'C' stands for Command and control and indicates vertical and horizontal leadership and decision-making;[21–23] 'S' for Safety clarifies self, scene and survivors' safety principles;[24,25] the second 'C' refers to Communication and encompasses both internal and external communication and information sharing;[26] 'A' relates to Assessment indicating the need for a mutual understanding of the situation;[27] and finally, 'TTT' refers to triage, treatment and transport, which follow rules of medical management in severe and restricted conditions.[27–29]

During the current pandemic, some hospitals could not admit newly diagnosed COVID-19 infected patients because of high bed occupancy and bed capacity management reasons. Therefore, some facilities created hospital-dependent home isolation centres (HICs) managed by hospital staff to provide health care and support.[30–32] Although this measure relieved hospitals from the pressure caused by the patient influx, it still consumed hospital staff, leaving community resources intact. Although limited use of community volunteers in disease screening has been reported earlier,[6,33–36] the FSC concept may offer comprehensive engagement and collaboration of communities' surge elements, which may enhance the professional care available during a crisis.

This study aimed to explore the possibility of implementing the concept of FSC to reduce the burden on hospitals by focussing on the community resources to develop HICs in Bangkok, Thailand, offering professional care to the community who were unable to attend overwhelmed hospitals for testing, care and follow-up.

## Methods

### *Study design*

A qualitative study was performed based on the perceptions and experiences of volunteers from one non-governmental organisation (NGO) led by Thai emergency physicians. This study adheres to a qualitative research design, a case study, whereby observations and individual interviews were conducted and subjected to qualitative content analysis.[37]

### *Sampling*

Interviews were conducted with purposive and snowball sampling, and the data saturation determined the sample size.[38] The purposive selections were based on the needs of a HIC, encompassing several volunteers in the response chain: professions, such as physicians, nurses and pharmacists; managerial positions, such as logistic and communication managers, public relations and senior-level managers; and model developers. In total, 13 of the 15 interviewees were women. The median age of participants was 34 years (interquartile range 5 years). Five participants were physicians, two were paramedics, three were physiotherapists, two were veterinarians and three worked in social science fields. Seven of the participants were employed in the public sector and eight in the private sector. Six participants were team leaders, while the others remained members of the teams.

*Data collection and analysis procedure*

*Observations:*

Data were collected prospectively by five observers who had experience in disaster and emergency management and the study methodology.[37,39] Each observer notified whether the participants could establish the HIC following the CSCATTT acronym used in the FSC theoretical framework (i.e. notified whether command and control were installed, safety issues and communication options were considered, a mutual assessment was achieved, and appropriate triage, treatment and transport were conducted and planned). The observers independently scrutinised the procedures and took notes throughout the study until no new information was added. The collected data were subject to deductive content analysis.[40]

*Interviews:*

Voluntary participants registered for an interview lasting approximately 60 min[38] Two interviewers performed semi-structured interviews by addressing the CSCATTT acronyms concerning the implementation and development of the HIC with open-ended questions. In addition, participants were able to critically comment on the process in a friendly environment and offer suggestions for further improvement. All interviews were recorded and transcribed by the lead author for content analysis.

*Data analysis*

A deductive content analysis explored existing theories within the data collected.[39,40] First, the texts were read through several times to obtain a sense of the entire data content. The data were subsequently divided into meaningful units and then condensed, abstracted, interpreted and sorted into subcategories based on similarities and differences, which were reflected upon and discussed by PP, AK, YS, OS and PC, and later approved by all authors. Finally, the subcategories were sorted into categories[37,41] (Table S1 in the Supplementary material).

## Results

*The home isolation centre*

An NGO led by emergency physicians initiated the HIC. Local volunteers were recruited to conduct all operating processes and obtain medical devices and inventories from the communities. The total number of patients seen at the HIC 5471, with a daily variation between 10 and 280 cases. In total, 21 patients were critically ill and were sent to a hospital within 1 h after the physicians' evaluation. Most patients survived until discharge, with the exception of three patients who chose home care to be close to their relatives and subsequently died at home. An emergency team closely monitored 275 moderate-to-severe patients; of these, 74 patients were sent to hospital for admission and all other cases were followed-up until recovery. The length of stay ranged from 14 to 21 days and patients were discharged based on the criteria given in the National Institutes of Health's (NIH) and the World Health Organisation's (WHO) guidelines.[42,43] Each patient passed through three main control stages:

1. *Registration:* Suspected patients were admitted after diagnosis was verified using a positive test from either antigen test kit or reverse transcriptase–polymerase chain reaction, as recommended by the NIH and the WHO. Patients were registered and informed about their rights and process.
2. *Treatment:* Patients were examined and treatment prioritised based on disease severity. Therapeutic protocols were adopted and constantly modified using NIH and WHO recommendations.[42,43]
3. *Logistics:* Medications and necessary devices, tests and results were delivered to secure and safe locations by local volunteers.

*The vital elements of surge capacity*

Table S1 illustrates the components (staff, stuff, space and system), subcategories and quotes based on MIMMS (CSCATTT) from observations and interviews and challenges from the interviews.

*Staff:*

A multiprofessional team of medical and allied-medical staff was recruited. The synchronisation of roles was quickly put in place to enable the necessary provision of health care. Shared goals were established and a command-and-control post was formed to emphasise collaboration between workers, patients and relatives, and foresee necessary educational initiatives. The observation and interview reports revealed four subcategories in the command-and-control category (Table S1).

The first subcategory was coordination and collaboration, recognised as essential factors for implementing and regulating all strategies. The second subcategory was workforce engagement, which indicates a positive attitude towards the centre's development and meaningful work, achieved through positive reinforcement, no blame cultures, education and public acknowledgement. The third subcategory was responsibility clarification, defined as straightforward individual tasks and responsibilities related to the given mandates.

Finally, the cultivation and sense of ownership subcategory suggested the sustainability of the volunteers, knowing that their work is for the benefit of the entire community. Table 1 presents some of the comments cited by the staff regarding these subcategories.

*Stuff:*

Medical devices required for patients in a COVID-19 home isolation programme included a pulse oximeter and a thermometer, which were provided within the community and delivered in special boxes, known as ‘happy boxes’, despite some interruptions to supply and delivery. Communication was separated into internal and external components. Internal communication was the action to propel the HIC, which was achieved by regular meetings and transparent online discussions. External communication was defined by the connection between the workforce and patients, and public communication performed through well-known mass media applications and public relations specialists (Table S1). The use of telemedicine was particularly important since the external communication depended on telemedicine and telemonitor appliances that would allow health care to be delivered at a distance, facilitating connections between healthcare providers and patients at home. The appliances entailed network connection and video communication apparatus enabled the connection, either by the hospital arrangement or by using the patients' mobile applications, taking advantage of the extensive distribution of mobile phone owners and individuals' networks.

*Space (Structure):*

Using telemedicine, the space needed in this concept was the Internet, and the physical site was used solely for inventories.

*System:*

The centre was managed by an NGO made up of private individuals with high flexibility in strategic planning and

**Table 1**
Relevant quotations and comments referred to each sub-category and categories related to surge capacity elements.

| Category | Sub-categories | Staffs' citations |
|---|---|---|
| Command and control (staff) | Coordination and collaboration | *'Even if we did not know each other, we had a common vision of an alternative way to handle the pandemic. This vision nurtured collaboration. A few of us were the initiators and others followed. We called them early adopters. Of course, there was some resistance, but I think collaboration and enthusiasm were the core driving forces.'* Leading Physician |
| | Workforce engagement | *'The difficult matters were freely discussed without negative environments or feedback, and team leaders always expressed support and positive reinforcement creating no-blame environments.'* Non-medical volunteers |
| | Responsibility clarification | *'The distribution of tasks is quite informal, but at the same time, we separate tasks that strictly belong to physicians, nurses or social workers accordingly to the professional and legal framework.'* Volunteer nurse |
| | Cultivation and sense of ownership | *'The critical processes were pre-designed, taught and discussed with volunteers; however, during operations, the ancillary flows could be discussed and modified according to volunteers' comments.'* Medical volunteer |
| Safety (stuff/system) | Telemedicine | *'The data access limitation was strictly implemented; only team leaders could give data access authorizations.'* Non-medical volunteers |
| Communications (stuff) | External communication | *'Facebook and Instagram were used to provide patients' outcomes and current knowledge with a friendly approach (colours and pictures).'* Non-medical volunteer |
| | External and internal communication | *'Line application was applied to intra-organization, inter-organization and communicate with patients, since a majority of Thai people used the channel.'* Physician volunteer |
| Assessment (system) | Patient home isolation adequacy | *'All patients were evaluated through video call with educated volunteers, and the inappropriate environments were advised to improve and wait for re-evaluation.'* Non-medical volunteer |
| Triage (system) | Patient triage – optimize resources | *'Patients were prioritized to suit the resources. At first, the triage was conducted following the Department of Medical Service which referenced the WHO guidelines. After that, the triage criteria were separated to more detailed levels to increase the number of patients' accessibility.'* Physician volunteer |
| Treatment (system) | Current standard treatment protocols | *'The treatments followed standards of care with rapid modifications as global recommendations.'* Physician volunteer |
| Transport (system) | Timely critical patient transportation | *'Critical care transports were stressful and intense. All devices needed to be prepared and arranged for patients at home until arrival to a destination hospital. The team contacted a usual referral system and facilitated the processes'* Non-medical volunteer |
| Space/stuff | Materials | *'The room is full of equipment stapled along a corridor. Paper boxes were piled marked happy with fancy colourful pictures.'* An observer at the center |

deployment. This team created interprofessional collaboration among staff and patients, and inter-organisational partnerships with governments, the Thai Red Cross and hospitals. The inter-orga-nisational partnerships were limited to shared resources, strategies and tasks' development; however, using autonomous leaders, decision-making mechanisms (with both formal and informal communications channels) were formed following the principles of the incidence command system (i.e. CSCATTT). Command and control were mainly performed by emergency physicians trained to lead the system with scarce resources through table-top exercises, live simulations and actual experiences in major incidents.

The components of safety were subcategorised as patient and personnel safety. Patient safety included privacy, cybersecurity, and medication prescription and distribution procedures (a control line was created from prescription generation to pharmacy check and delivery to the patient). The centre used an online operation that allowed healthcare services to monitor patients with reduced social contacts and hospital visits. The risk of cyber threat was attenuated by allowing only verified persons to access the data, and a login was required to view and edit any data. Staff safety was identified as physical (personal protection equipment and social distancing), mental, spiritual health and personnel privacy. Staff mental and spiritual health was achieved by providing information and enabling transparent discussion about the process and its pros and cons.

The fundamental communication principles include goal-orientated contents and a proper channel to communicate. As a simplified and accessible communication method facilitated the entire process, a popular social media platform called Line was used (see the 'Stuff' subsection). Assessment of patients was described as imitating face-to-face hospital services, starting from registration, patient examination and treatment protocols.

Patient treatment was prioritised according to clinical severity. The WHO published home isolation recommendations in August 2020, suggesting the need to thoroughly scrutinise patient eligibility, including clinical, environmental and technological aspects, before any provision of care[43] was provided. Modifications to these recommendations could be applied to suit organisational and national availability of telehealthcare.[44,45] Infectious control measures were applied by providing household evaluations, inspections and modification of guidelines to all patients. People in close contact with patients were advised to self-quarantine and monitor symptoms. After being discharged by a physician, patients were educated in self-health care to facilitate their return to work and daily activities.

In contrast to other processes, there was a paucity of evidence in patient prioritisation, and triage was one of the most adaptable processes (Table 2). Patients were categorised into eight levels to match the provision of resources; hence, many patients were able to access treatments and recovered. Moreover, patients who required intensive medical care were triaged and received an initial evaluation and treatment before being transferred to the hospital's in-patient department, which alleviated the burdens in the hospital's emergency department.[44]

## Discussion

The HIC described in this study demonstrates the operational definition of preparedness and response to public health

**Table 2**
Patient triage and management.

| Triage | Implication | Management |
|---|---|---|
| Dark red | Severely ill; dyspnea, respiratory rate >25/min<br>Pulse oximetry <90% | Pharmacists' confirmation as soon as possible,<br>and hospital contacts and referral within 1 h |
| Bright red | Dyspnea, respiratory rate>25/min<br>Pulse oximetry 90–95% | Pharmacists' confirmation as soon as possible, and<br>hospital contacts and referrals if possible.<br>Oxygen concentrator and medications delivered within 4 h.<br>24 h telemonitoring by physicians and paramedics |
| Yellow | Symptomatic patients with oxygen saturation of more<br>than 95% and risk factors; age >60 years, or diseases as follows:<br>Chronic obstructive pulmonary disease or other chronic lung diseases<br>Chronic kidney disease/cirrhosis<br>Cardiovascular disease, including congenital heart disease<br>Cerebrovascular disease<br>Uncontrolled diabetes mellitus<br>Obesity or bodyweight >90 kg<br>Immunocompromised | Pharmacists' confirmation within 2 h<br>Medication delivery within 6 h<br>Physicians followed up every day |
| Dark green | Upper respiratory tract symptoms or feeling chest discomfort or<br>feeling dyspnea and oxygen saturation of more than 95% | Pharmacists' confirmation within 6 h<br>Medication delivery within 24 h<br>Nurses followed up every day |
| Medium green | Other non-respiratory COVID-19 symptoms and oxygen saturation<br>of more than 95% | Pharmacists' confirmation within 6 h<br>Medication delivery within 24 h<br>Nurses/paramedics/dentists followed up every other day |
| Bright green | Asymptomatic and oxygen saturation of more than 95% | Paramedics/dentists followed up every two days |
| Red recovery | Once red case but clinically improved | Physicians followed up every day |
| Yellow recovery | Once yellow case but clinically improved | Physicians followed up every day |

emergencies, presented by the WHO.[46] Communities were engaged in all four phases of emergency management and necessary measures were implemented as part of the public health emergency response. Health care to protect and improve the medical condition of COVID-19 patients at home was provided and severe cases needing referral to hospitals were identified.[47–50] The successful implementation of these centres based on the FSC concept could be transferred to other causes of population-based events by emphasising the significance of community resources, strengthening fundamental individuals' rights to health care, and alternative leadership in various levels of public health and disaster management systems.[51]

The theoretical frameworks of SC in health care examine a more pragmatic aspect and the consequences of effectiveness and implementation in the actual setting, especially in the community setting under time and resources constraints,[52,53] with various degrees of integration.[13,54,55] The use of complexity theory to further develop SC enhances self-organising, diversity and interaction between the system and environment.[5] As a result, previously proposed frameworks highlighted the use of system, organisation and individual as planned or improvised manners. The FSC uses the collaboration framework, displayed as the practical tool (CSCATTT), focussing on community and multidisciplinary engagements, and is in line with previous theories yet demonstrates a more flexible and proactive resilience.[14–16,18]

This study shows that staff, stuff and space in the FSC concept develop from local communities passively and proactively, are flexible to modify and include multidisciplinary involvement, as indicated in staff quotations (see Table 1). At the same time, the need for updated knowledge on the risks and aetiology and management of scientific uncertainty, resources and internal decision-making and communication (i.e. the detailed and dynamic complexity) was met by regular meetings and educational initiatives.

Recruiting workforces from the local community to form multiprofessional teams seems to facilitate a more effortless synchronisation of roles to provide necessary health care to the patients at home. Following the principles of command and control, cooperation, coordination and collaboration were the ultimate goals for all individuals and organisations involved within a local setting, highlighting the perception of belonging and doing something for the benefit of all (shared goals).[12,13,54,55] The HIC also facilitated staff engagement and clear responsibility for given tasks, resulting in common denominators and mutual respect and acquaintances in collaboration, which built up over time during the operations[54] and resulted in achieving shared goals and consensus on the best health care provision for patients. Furthermore, continuous staff education and cultivation facilitated their response engagement, gaining the required sustainability.[15,16,56] Local staff recruitment also allowed special medical and social precautions to guarantee personnel safety and high staff performance.[23,57–59]

Communications among workers, patients and the public were significant in the achievement.[25,54,60] The rapid and complete information exchanges were widely addressed to link other elements; however, the degree and mode of communication were part of the challenges. In this study, regular, active, reciprocal and transparent communication was the leading cause of success.[61,62] Leaders arranged to communicate content among teams to ensure goal-oriented details and such information was conveyed by professional communicators.[22] Successful communications could also facilitate better assessment of the situation. The centre mirrored hospital steps from registration to drug delivery, a familiar way for all medical and allied healthcare providers to avoid misunderstandings. The process was reviewed daily and constantly improved.

Triage, treatment and transport were the three distinct sections for medical operation, described as patient prioritisation to optimise the resources (Table 2), patient medical therapies, medicines and devices inventory and delivery, and patient transfer. A triage system was designed to ensure patients received the correct triage, treatment and transport required.

### *Challenges of the home isolation centre*

Challenges in developing the HIC were either related to supply or patient care. During the initial phase of the HIC set up, difficulties in supplying medication for COVID-19 treatment appeared and were resolved through NGO-government collaboration. One patient care-related challenge was the hospital referral for critical

patients and severely ill illegal migrants. These issues were eventually managed by using local hospitals with significant input from staff.

Finally, there was insufficient economic support from the government during the COVID-19 outbreak.[6] Thus, the HIC, with operational and managerial expenses, was a donation-dependent organisation resulting in an insecure and unpredictable financial situation, despite partial support through the universal coverage scheme. Financial input was crucial for a sustainable operation; fortunately, the HIC received positive feedback through social media platforms resulting in national recognition and public acceptance, facilitating the NGO's financial contingency.[63,64]

### *Limitations*

There is a possible recall bias from the interviewees and missing data in the observational processes from the beginning of the operations due to a time difference between interviews and control and analysis of data. Moreover, the lack of similar studies does not allow a thorough analysis of this study in comparison with other investigations. Finally, the search was conducted in the English language and therefore did not consider similar research in languages other than English.

### *Conclusions*

COVID-19 infection affected national health care and socio-economic systems globally. While the usual healthcare systems were at their maximum surge, an extension of services to the community facilities, as an FSC, was feasible and applicable to reduce the burden on hospitals during the pandemic. Moreover, public health education initiatives among multidisciplinary volunteer teams overcame the participation and engagement barriers. This study represented the achievable integration of home isolation under restricted infrastructures; a similar NGO can be arranged favourably when facing dynamic global casualties. As this study emphasised reduced burden for the hospitals, future research on the application of the FSC concept needs to focus on situations where the hospital is the target of an emergency and when a hospital evacuation may be necessary. Such a scenario would enhance the capabilities of the health system in response to all threats.

## Author statements

### *Acknowledgements*

The authors would like to thank Dr Lesley Gray, University of Otago, Wellington, New Zealand, for the review and for improving the use of English in this manuscript.

### *Ethical approval*

This study was approved by the Human Research Ethics Committee, Faculty of Medicine Ramathibodi Hospital, Mahidol University (MURA2021/786).

### *Funding*

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### *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.2022.06.025.

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Public Health 211 (2022) 164–170

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Themed Paper — Original Research

# COVID-19 risk factors and predictors for handwashing, masking, and social distancing among a national prospective cohort of US older adults

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ARTICLE INFO

*Article history:*
Received 19 April 2022
Received in revised form
1 August 2022
Accepted 9 August 2022
Available online 18 August 2022

*Keywords:*
COVID
Handwash
Mask
Older adults
Public health emergency
Social distance

ABSTRACT

*Objectives:* Older adults have a disproportionately higher COVID-19 risk; however, there is limited research investigating adherence to the major COVID-19 mitigation behaviors (handwashing, masking, social distancing) for older populations. We examined COVID-19 risk factors and predictors for adherence to COVID-19 mitigation behaviors among a national sample of US older adults.

*Study design:* Data were retrieved for 3257 respondents from a nationally representative prospective sample of US Medicare beneficiaries aged ≥65 years. COVID-19 variables were collected in 2020, whereas all other data were collected in 2019.

*Methods:* We used multiple logistic regression to analyze COVID-19 risk factors and predictors for handwashing, masking, and social distancing to minimize COVID-19 spread. All models applied survey sampling weights.

*Results:* Factors significantly associated with increased odds of COVID-19 diagnosis among US older adults were Hispanic ethnicity (adjusted odds ratio [aOR] = 2.83, $P = .01$), income (aOR = 0.71, $P = .04$), residential care or nursing home (aOR = 2.62, $P = .01$), and generalized anxiety disorder (aOR = 2.38, $P = .04$). We identified multiple factors significantly associated with adherence to handwashing, masking, and social distancing. Most notably, older males had a significantly lower odds of practicing all three COVID-19 mitigation behaviors, and Black older adults had a significantly higher odds of masking (aOR = 7.94, $P < .001$) and social distancing (aOR = 2.33, $P = .01$).

*Conclusions:* When prioritizing COVID-19 prevention efforts for older adults, risk factors that should be considered are race and ethnicity, income, residential setting, and anxiety. To effectively mitigate COVID-19 disease spread, public health professionals must also recognize sociodemographic and health factors may influence whether older adults adhere to handwashing, masking, and social distancing.



## Introduction

The COVID-19 pandemic caused by severe acute respiratory coronavirus 2 (SARS-CoV-2) has reached critical levels and inundated many nations. As of April 2022, the United States leads the global community with more than 80.4 million total cases and 986,123 confirmed deaths.[1] As a result of this public health emergency, many countries, including the United States, have sought refuge in multipronged preventative public health actions, even going as far as implementing restrictive measures such as social distancing, home quarantine, and curfews to limit the spread.

Although COVID-19 affects all age groups, one group disproportionately impacted is older adults. Although those aged ≥50 years comprise only 35.7% of the US population, they account for 93.3% of the total US COVID-19 deaths.[1] Older adults have not only a higher risk for severe COVID-19 infections and hospitalization but also greater mortality compared with other age groups.[2] Older age is a major risk factor with those who get infected often needing hospitalization, critical care, or a ventilator. Older adults are generally more vulnerable because of their comorbidities and weakened immune systems.[3]

Given the limited research on COVID-19 among US older adults, few specific risk factors have been reported and elucidated.

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https://doi.org/10.1016/j.puhe.2022.08.002
0033-3506/

Nonetheless, there are multiple social determinants of health that are associated with increased risk for COVID-19. Race and ethnicity persist as a well-documented risk factor for COVID-19, especially in older adults.[4] Older adults of color compared with non-Hispanic Whites in the United States experience higher age-adjusted hospitalizations and death from COVID-19. One possible reason is differential exposure by residential setting. For instance, non-Hispanic Black older adults are disproportionately represented in US nursing homes.[4] During the pandemic, long-term care facilities commonly faced personal protective equipment and staffing shortages, which exacerbated their inability to comply with required infection control measures.[5] Even when controlling for self-reported staff and personal protective equipment shortage, US nursing homes that contained more racial and ethnic minority residents still reported higher weekly new confirmed COVID-19 cases and deaths.[6]

Similarly, living arrangement is another common COVID-19 risk factor for older adults, given the ease of transmitting the virus. In multigenerational households, older adults are more likely to live in overcrowded housing, in which there is more than one person per room.[4] When adjusting for area-level socio-economic and clinical characteristics, overcrowding in US multigenerational households remains as a risk factor for COVID-19 infection.[7] Thus, social distancing restrictions that increase house-bound populations may unintentionally increase transmission risk for COVID-19 in older adults.

Public health guidelines recommend mitigation behaviors such as masking, social distancing, and handwashing to mitigate the spread of COVID-19. Behaviors such as masking and social distancing have been shown to reduce the risk of positive cases of COVID-19.[8] In countries, including the United States, where masking is not the cultural norm, higher mask use was positively associated with the following factors: age <50 years; tertiary education; mask use before pandemic; knowing a family, friend, or colleague diagnosed with COVID-19; having cold or flu-like symptoms; self-reported adherence to local mask guidelines; and mask mandates.[9] In the same study, New York's mask use among participants aged ≥50 years was not significantly different.

Although there is limited US domestic data on handwashing during COVID-19, few specific handwashing predictors are known. In a study that included the United States among four other countries, handwashing was significantly associated with the following factors: older age, rural residence, female, and greater educational attainment.[10] The same study reported similar predictors for social distancing. In a US study, higher percentages of older adults, women, Hispanics, and Black adults self-reported that they remembered to wash their hands in multiple situations before and during the pandemic.[11]

Unlike handwashing, COVID-19–related social distancing and its predictors in the United States are more heavily researched. Social distancing varied by generational cohort, with older generations more likely to social distance despite lower risk perceptions.[12] Social distancing compliance is positively associated with perceived susceptibility of COVID-19 and perceived benefits of social distancing.[13]

Although older adults have been shown to have higher prevalence and incidence rates for COVID-19, there is limited research examining risk factors that contribute to this phenomenon using a national US sample. One prior study examined sociodemographic and health characteristics in the context of personality as a predictor for COVID-19 mitigation behaviors but did not focus on these factors primarily or to the same depth as our present research, nor did it investigate these factors as predictors of COVID-19 itself.[14] To our knowledge, this study is the most thorough analysis yet of sociodemographic and health predictors of COVID-19 diagnosis and of adherence to the three major COVID-19 mitigation behaviors (handwashing, masking, social distancing) among US older adults. Therefore, the purposes of this study were to (1) examine the risk factors for COVID-19 among US older adults and (2) examine the predictors for adherence to handwashing, masking, and social distancing as COVID-19 prevention measures.

## Methods

### *Data source*

We retrieved data from the National Health and Aging Trends Study (NHATS), a prospective longitudinal survey containing a nationally representative sample of US Medicare beneficiaries aged ≥65 years. The study oversamples persons at older ages and Black individuals. We merged data from the 2019 NHATS and the 2020 NHATS COVID-19 supplement, in which most of these self-administered questionnaires were completed in July 2020 (51.0%) or August 2020 (33.3%). There was an 82.2% response rate for the NHATS COVID-19 supplement, resulting in 3257 older adults in our final sample. Aside from the COVID-related dependent variables, all other variables were retrieved from the 2019 data.

### *Dependent variables*

#### *COVID-19 diagnosis*

Self-reported COVID-19 diagnosis was derived from two questions. First, respondents were asked, 'Has a doctor or other health professional told you that you may have had COVID-19?' and available responses were, 'Yes, definitely,' 'Yes, possibly,' and 'No.' Second, respondents were asked, 'Have you had a positive test for COVID-19?' and could answer either 'Yes' or 'No.' We defined a positive COVID-19 diagnosis as a 'Yes, definitely' or a 'Yes, possibly' diagnosis from a health professional and a 'Yes' from a COVID-19 test.

#### *COVID-19 mitigation behaviors*

Three COVID-19 mitigation behaviors included handwashing, masking, and social distancing. All three behaviors were asked under the question, 'During the COVID-19 outbreak, have you ever done the following to keep the disease from spreading?' Handwashing was measured as, 'Frequently wash your hands or use sanitizer,' and responses included 'Yes' or 'No.' Masking was measured as, 'Wear a face mask when going out,' and responses included 'Yes,' 'No,' or 'Does not apply.' Social distancing was measured as, 'Stay at least 6 feet away from people not living with you,' and responses included 'Yes,' 'No,' or 'Does not apply.' Any 'Does not apply' response was coded as missing. For one of the regression models, we constructed a composite score (range 0–3) by aggregating the number of mitigation behaviors.

### *Independent variables*

Sociodemographic and health variables were included in the regression models. Sociodemographic variables included age, gender, race, and ethnicity (non-Hispanic White [hereafter, White], non-Hispanic Black [hereafter, Black], Hispanic, or Other), highest level of education (less than high school, high school, or college), total household income, marital status (married or unmarried), metropolitan residence (metro or non-metro), and residential setting (community or residential care/nursing home).

Health variables included self-rated health (poor to excellent), body mass index (BMI), activities of daily living (no ADL limitations or at least one ADL limitation), proxy respondent, major depressive disorder in 2019, generalized anxiety disorder in 2019, dementia in

2019, history of heart attack, history of hypertension, history of diabetes, and history of stroke.

### Analysis plan

For the dependent variable of COVID-19 diagnosis, we used a series of multiple logistic regression models that first included sociodemographic variables (Model A), then added health variables (Model B), then added COVID-19 mitigation behaviors (Model C). In Model C, there were statistically significant correlations between all three COVID-19 mitigation behaviors, causing the model to automatically omit some behaviors due to multicollinearity. As a result, Model C contained only the aggregate score combining the three mitigation behaviors. The highest individual variance inflation factor (VIF) was 1.88, and the average VIF was 1.23, which indicates there is no evidence of multicollinearity.

Additional multiple logistic regression models were constructed to determine which sociodemographic and health variables were predictors for each COVID-19 mitigation behavior as a dependent variable. There was no evidence for multicollinearity since the average VIF was 1.24 for all three models.

To minimize bias due to missing data (10–15% depending on the dependent variable), multiple imputation by chained equations generated 100 imputed data files with 10 iterations each. There were no substantial differences in the results generated from multiple imputation by chained equation compared with listwise deletion. Odds ratios and 95% confidence intervals (CIs) were produced from the logistic regression models, which applied complex survey sampling weights to ensure the results are representative. Statistical analyses were performed in Stata statistical software version 16.1 (StataCorp LLC, College Station, TX, USA) with two-tailed tests at a 0.05 significance level.

## Results

### Sample characteristics

The 3257 survey respondents are described in Table 1. They ranged in age from 65 to 107 years, with a mean age of 74.2 years (standard deviation = 6.6 years), and a slight majority (57.9%) were female. White was the most common race and ethnicity (75.9%) and a high school degree being the most common highest level of education attained (48.2%). The average household income was approximately $61,090. About 80% of respondents resided in a metropolitan area, and most were community dwelling (93.1%). The average self-rated health was between good and very good (2.28 on a scale of 0–4; standard deviation = 0.98), and 15.8% had at least one ADL limitation. The most common health conditions include a history of hypertension (73.9%) and a history of diabetes (28.1%).

**Table 1**
Sample characteristics for the National Health and Aging Trends Study.

| Characteristic | Mean (SD) or % (*n*) |
|---|---|
| Age (range 65–107) | 74.18 (6.55) |
| Female | 57.94% (1887) |
| Race and ethnicity | |
| White, non-Hispanic | 75.90% (2472) |
| Black, non-Hispanic | 16.67% (543) |
| Hispanic | 4.08% (133) |
| Other | 3.35% (109) |
| Highest level of education | |
| Less than high school | 14.64% (471) |
| High school degree | 48.23% (1552) |
| College degree | 37.13% (1195) |
| Income (thousands, USD) | 61.09 (67.35) |
| Marital status | |
| Not married | 50.84% (1655) |
| Married | 49.16% (1600) |
| Household size (no. of individuals) | 1.93 (1.01) |
| Metropolitan residence | 80.14% (2610) |
| Residential setting | |
| Community dwelling | 93.12% (3033) |
| Residential care or nursing home | 6.88% (224) |
| Self-rated health (0–4; poor to excellent) | 2.28 (0.98) |
| Body mass index (kg/m$^2$) | 27.91 (6.08) |
| ADL limitations | |
| None | 84.20% (2728) |
| At least one | 15.80% (512) |
| Proxy respondent | 2.21% (72) |
| Depression | 8.91% (288) |
| Anxiety | 7.66% (248) |
| Dementia | 14.89% (485) |
| History of heart attack | 16.94% (548) |
| History of hypertension | 73.88% (2401) |
| History of diabetes | 28.10% (910) |
| History of stroke | 12.43% (402) |

ADL, activities of daily living; SD, standard deviation.

### Risk factors for positive COVID-19 diagnosis

All the COVID-19 diagnosis models were significant, including our final model [$F(24,53) = 8.54$, $P < .01$; Table 2]. Three sociodemographic characteristics were significant risk factors for COVID-19 across all models. Hispanic ethnicity increased the odds of COVID-19 by 183% (adjusted odds ratio [aOR] = 2.83, 95% CI = 1.30–6.17, $P = .01$) compared with White older adults. A log increase in household income decreased the odds of COVID-19 by 29% (aOR = 0.71, 95% CI = 0.50–0.99, $P = .04$) and residential care increased the odds by 162% (aOR = 2.62, 95% CI = 1.27–5.41, $P = .01$).

Two health-related characteristics also had significant results. Every one unit increase in BMI increased the odds of COVID-19 by 3% (aOR = 1.03, 95% CI = 1.01–1.06, $P = .02$), but the relationship was no longer significant when adjusting for mitigation behaviors. On the other hand, anxiety was initially not significantly associated with COVID-19, but the relationship did become significant after adjusting for mitigation behaviors (aOR = 2.38, 95% CI = 1.02–5.56, $P = .04$).

### Predictors for handwashing

The model for handwashing was significant [$F(23,53) = 4.46$, $P < .01$; Table 3]. Only two characteristics were significantly associated with handwashing. Being female increased the odds of handwashing by 155% (aOR = 2.55, 95% CI = 1.54–4.21, $P < .01$). In addition, older adults with dementia had a 55% significantly decreased odds of handwashing (aOR = 0.45, 95% CI = 0.24–0.85, $P = .01$).

### Predictors for masking

Masking also had a significant model [$F(22,52) = 7.46$, $P < .01$] and a large number of significant predictors (Table 3). Females had a significantly higher odds of masking by 251% (aOR = 3.51, 95% CI = 2.03–6.09, $P < .01$). Race and ethnicity were significant predictors as well. Black older adults were 7.9 times more likely to mask than White older adults (aOR = 7.94, 95% CI = 2.33–27.04, $P < .01$). Each unit increase in the five-point self-rated health score, meanwhile, decreased the odds of masking by 0.7 times (aOR = 0.72, 95% CI = 0.55–0.94, $P = .02$). Using a proxy respondent for the survey was associated with a decrease in masking by 0.1 times (aOR = 0.10, 95% CI = 0.02–0.53, $P < .01$), and anxiety also notably decreased the odds of masking by 0.3 times (aOR = 0.30,

**Table 2**
Adjusted odds of a positive COVID-19 diagnosis among US older adults.

| Independent variable | Model A, aOR (95% CI), *P* | Model B, aOR (95% CI), *P* | Model C, aOR (95% CI), *P* |
|---|---|---|---|
| Age | 1.00 (0.97–1.04), .96 | 1.00 (0.96–1.04), .94 | 1.00 (0.96–1.05), 1.00 |
| Female | 0.71 (0.40–1.27), .25 | 0.73 (0.40–1.34), .30 | 0.79 (0.43–1.42), .42 |
| Race and ethnicity | | | |
| White, non-Hispanic | Reference | Reference | Reference |
| Black, non-Hispanic | 1.19 (0.61–2.29), .61 | 1.15 (0.57–2.32), .69 | 1.30 (0.65–2.61), .45 |
| Hispanic | 2.67 (1.22–5.85), .02 | 2.76 (1.23–6.22), .02 | 2.83 (1.30–6.17), .01 |
| Other | 1.00 (0.29–3.43), .99 | 1.08 (0.29–3.97), .91 | 1.15 (0.30–4.39), .83 |
| Highest level of education | | | |
| Less than high school | Reference | Reference | Reference |
| High school degree | 0.90 (0.47–1.74), .75 | 1.00 (0.51–1.95), 1.00 | 1.04 (0.48–2.23), .92 |
| College degree | 1.29 (0.60–2.76), .51 | 1.68 (0.76–3.68), .20 | 1.77 (0.75–4.15), .19 |
| Income (log) | 0.69 (0.52–0.92), .02 | 0.73 (0.54–0.99), .04 | 0.71 (0.50–0.99), .04 |
| Marital status | | | |
| Not married | Reference | Reference | Reference |
| Married | 1.11 (0.61–2.01), .72 | 1.04 (0.58–1.89), .88 | 1.28 (0.72–2.30), .40 |
| Household size | 1.20 (0.99–1.45), .06 | 1.17 (0.94–1.45), .16 | 1.20 (0.97–1.49), .09 |
| Metropolitan residence | 1.37 (0.75–2.52), .30 | 1.64 (0.85–3.17), .19 | 1.82 (0.84–3.94), .13 |
| Residential setting | | | |
| Community dwelling | Reference | Reference | Reference |
| Residential care or nursing home | 3.35 (1.86–6.04), <.001 | 2.57 (1.31–5.03), .01 | 2.62 (1.27–5.41), .01 |
| Self-rated health (0–4; poor to excellent) | | 0.88 (0.68–1.14), .32 | 0.91 (0.70–1.18), .46 |
| Body mass index | | 1.03 (1.01–1.06), .02 | 1.03 (1.00–1.06), .09 |
| ADL limitations | | | |
| None | | Reference | Reference |
| At least one | | 1.46 (0.81–2.66), .21 | 1.70 (0.90–3.20), .10 |
| Proxy respondent | | 1.24 (0.36–4.32), .73 | 1.23 (0.29–5.19), .77 |
| Depression | | 0.78 (0.32–1.90), .58 | 0.76 (0.30–1.94), .56 |
| Anxiety | | 2.07 (0.92–4.64), .08 | 2.38 (1.02–5.56), .04 |
| Dementia | | 1.44 (0.76–2.70), .26 | 1.58 (0.77–3.23), .21 |
| History of heart attack | | 1.68 (0.88–3.22), .11 | 1.79 (0.93–3.46), .08 |
| History of hypertension | | 1.00 (0.59–1.71), 1.00 | 0.90 (0.51–1.58), .70 |
| History of diabetes | | 0.92 (0.53–1.61), .78 | 0.81 (0.44–1.52), .51 |
| History of stroke | | 0.60 (0.26–1.39), .23 | 0.48 (0.16–1.47), .19 |
| Adherence to COVID-19 mitigation behaviors (0–3) | | | 1.28 (0.48–3.43), .62 |
| Weighted sample size | 25,749,526 | 25,749,526 | 25,749,526 |
| Model significance | $F(12,53) = 4.73$, $P < .001$ | $F(23,53) = 12.04$, $P < .001$ | $F(24,53) = 8.54$, $P < .001$ |

ADL, activities of daily living; aOR, adjusted odds ratio; CI, confidence interval.

95% CI = 0.13–0.70, $P = .01$). Having a history of diabetes (aOR = 0.47, 95% CI = 0.31–0.72, $P < .01$) or stroke (aOR = 0.48, 95% CI = 0.24–0.97, $P = .04$) also decreased the odds of masking.

### *Predictors for social distancing*

Finally, the model for social distancing was significant [$F(23,52) = 3.29$, $P < .01$] and had several sociodemographic predictors (Table 3). Female gender significantly increased the odds of social distancing by 50% (aOR = 1.50, 95% CI = 1.08–2.08, $P = .02$), and those who self-identified as Black has 133% increased odds compared with White older adults (aOR = 2.33, 95% CI = 1.28–4.24, $P = .01$). Metropolitan residence was also significantly associated with social distancing and increased the odds by 53% (aOR = 1.53, 95% CI = 1.09–2.15, $P = .02$).

## Discussion

Three sociodemographic characteristics were shown to be consistently associated with COVID-19 in older adults across all three models: residential care or nursing home residence, Hispanic ethnicity, and income. All three of these findings are supported by current literature.[15] Older adults in nursing homes are at a greater risk due to their congregate setting and the exchange of patients with hospitals.[16] CDC data, meanwhile, report that Hispanic/Latino persons share the highest rate of COVID-19 cases in the United States with American Indian and Alaskan Native persons.[17] This association is likely due to socio-economic status, healthcare access, working frontline jobs, and multigenerational housing,[4,15,17–19] which ties into income as a COVID-19 risk factor. Neighborhoods with lower average incomes or greater income inequality are significantly correlated with higher COVID-19 incidence,[20,21] and low income is associated with higher rates of COVID-related hospitalizations.[22]

Two health characteristics were also associated with COVID-19 risk, though not consistently. BMI was significantly associated with a positive diagnosis before controlling for mitigation behaviors. Other cohorts have also seen a J-shaped association between BMI and COVID admissions, although these did not control for handwashing, masking, or social distancing.[23] Anxiety, meanwhile, only became significantly associated with COVID-19 diagnoses after adjusting for mitigation behaviors. Although the mechanism is unclear, a diagnosis of anxiety in 2019 or earlier should be especially noted for its association with COVID-19 in 2020, especially with its 138% increased odds.

Each of the mitigation behaviors had significant predictors, as well. For example, female gender was positively associated with handwashing, masking, and social distancing. This may be due to women's traditional role as caregivers, which would encourage them to do more to protect themselves and their families or it may be that women are less susceptible than men to an 'honor culture' that values the projection of strength and rejection of weakness.[24–28] Acknowledging the SARS-CoV-2 virus as a threat worth taking precautions against may indicate undesirable vulnerability and weakness in various US populations.[25] The data also found that Black older adults were more likely to mask and social distance

**Table 3**
Adjusted odds of adherence to COVID-19 Mitigation behaviors among US older adults.

| Independent variable | Handwashing, aOR (95% CI), *P* | Masking, aOR (95% CI), *P* | Social distancing, aOR (95% CI), *P* |
|---|---|---|---|
| Age | 0.99 (0.95–1.04), .80 | 1.03 (0.99–1.07), .10 | 0.97 (0.94–1.00), .06 |
| Female | 2.55 (1.54–4.21), <.001 | 3.51 (2.03–6.09), <.001 | 1.50 (1.08–2.08), .02 |
| Race and ethnicity | | | |
| White, non-Hispanic | Reference | Reference | Reference |
| Black, non-Hispanic | 2.18 (0.81–5.91), .12 | 7.94 (2.33–27.04), <.001 | 2.33 (1.28–4.24), .01 |
| Hispanic | 6.53 (0.80–53.21), .08 | NA | 2.41 (0.79–7.29), .19 |
| Other | 4.00 (0.77–20.83), .10 | 18.13 (1.90–173.21), .01 | 1.22 (0.44–3.35), .70 |
| Highest level of education | | | |
| Less than high school | Reference | Reference | Reference |
| High school degree | 0.86 (0.32–2.30), .76 | 0.95 (0.30–2.97), .92 | 0.74 (0.43–1.28), .28 |
| College degree | 1.05 (0.39–2.85), .92 | 1.81 (0.55–5.95), .32 | 1.45 (0.72–2.92), .29 |
| Income (log) | 0.93 (0.61–1.43), .74 | 1.07 (0.76–1.50), .71 | 1.02 (0.79–1.31), .87 |
| Marital status | | | |
| Not married | Reference | Reference | Reference |
| Married | 1.48 (0.66–3.35), .34 | 1.33 (0.74–2.40), .34 | 0.91 (0.56–1.48), .69 |
| Household size | 0.92 (0.73–1.17), .48 | 0.91 (0.75–1.11), .36 | 1.08 (0.86–1.37), .50 |
| Metropolitan residence | 1.32 (0.61–2.83), .47 | 1.26 (0.64–2.51), .50 | 1.53 (1.09–2.15), .02 |
| Residential setting | | | |
| Community dwelling | Reference | Reference | Reference |
| Residential care or nursing home | 0.58 (0.26–1.32), .19 | 3.00 (0.50–17.94), .22 | 1.44 (0.66–3.15), .36 |
| Self-rated health (0–4; poor to excellent) | 0.93 (0.66–1.32), .70 | 0.72 (0.55–0.94), .02 | 1.04 (0.86–1.26), .66 |
| Body mass index | 1.00 (0.97–1.04), .79 | 0.99 (0.97–1.01), .18 | 1.01 (0.99–1.04), .28 |
| ADL limitations | | | |
| None | Reference | Reference | Reference |
| At least one | 0.58 (0.24–1.41), .23 | 2.69 (0.93–7.81), .07 | 0.75 (0.43–1.32), .31 |
| Proxy respondent | 0.42 (0.12–1.39), .15 | 0.10 (0.02–0.43), <.01 | 1.43 (0.44–4.71), .54 |
| Depression | 0.64 (0.26–1.55), .32 | 1.88 (0.57–6.19), .29 | 1.47 (0.74–2.94), .27 |
| Anxiety | 1.55 (0.51–4.75), .44 | 0.30 (0.13–0.70), .01 | 0.70 (0.33–1.48), .35 |
| Dementia | 0.45 (0.24–0.85), .01 | 1.23 (0.51–3.00), .64 | 1.05 (0.64–1.71), .85 |
| History of heart attack | 0.59 (0.24–1.48), .26 | 1.02 (0.47–2.18), .97 | 1.22 (0.80–1.86), .34 |
| History of hypertension | 1.18 (0.62–2.26), .61 | 1.18 (0.60–2.31), .62 | 1.26 (0.82–1.91), .28 |
| History of diabetes | 0.99 (0.53–1.82), .96 | 0.47 (0.31–0.72), <.01 | 1.13 (0.76–1.66), .55 |
| History of stroke | 1.14 (0.56–2.30), .72 | 0.48 (0.24–0.97), .04 | 0.66 (0.42–1.04), .08 |
| Weighted sample size | 26,195,301 | 26,188,528 | 26,186,801 |
| Model significance | $F(23,53) = 4.46$, $P < .001$ | $F(22,52) = 7.46$, $P < .001$ | $F(23,52) = 3.29$, $P < .001$ |

ADL, activities of daily living; aOR, adjusted odds ratio; CI, confidence interval; NA, not available.
Hispanic was merged with 'Other' due to low statistical power.

than White older adults, and this may be because of a greater perception of risk due to health histories.[29] Black older adults may also know more family members who had been hospitalized with COVID-19, further increasing their perceived risk for the disease.[30] Finally, for sociodemographic factors, metropolitan residence was positively associated with social distancing, which may be because of higher population density in urban areas. By comparison, rural residents are less likely to have healthcare access, good health behaviors, high incomes, and higher education; inequalities that may lead to a corresponding decrease in social distancing.[31]

In general, only a small number of health variables were significantly associated with COVID-19 mitigation behaviors. Dementia decreased the odds of handwashing, which the US Alzheimer's Association posits is due to forgetfulness from impaired memory.[32] Previous research has found that although older adults with dementia have an increased COVID-19 risk and lower odds of handwashing, the relationship between dementia and COVID-19 is primarily mediated by functional impairment, income, and residential setting instead of mitigation behaviors.[33] Overall perceived health, anxiety, a history of diabetes, and a history of stroke were associated with masking. One potential reason for some of these associations may be that limited adoption of health-protective behaviors before the pandemic has now translated into limited adoption during it.[31] Because masks have been strongly polarized in the United States, they may be one of the first mitigation behaviors dropped.[34] Another possibility may be that the conditions themselves impact older adults' capacity to wear masks: individuals with certain pre-existing health concerns and their carers may be more anxious about those conditions than about COVID-19.[35] Anxiety decreasing the odds of masking is a perplexing finding because we found it is also associated with increased COVID-19 risk. Older adults with anxiety could have both lower feelings of control over their own health and lower perceived efficacy of masks,[34] suggesting that they are not only more likely to be mask resistant but that they may be especially susceptible to conspiracy theories regarding the pandemic.[36]

There are three notable limitations to this study. First, self-reported responses for all measures restrict psychometric information for the dependent variables in each model. Second, these results include only the first two waves of COVID-19 cases in the United States and therefore before other major variants that contributed to subsequent waves of infection. Third, our results are only generalizable to older adults aged ≥65 years; however, other gerontological research on COVID-19 mitigation may consider old age to begin after age 50 years.[14] Despite these limitations, to our knowledge, the findings in our study present the first examination of factors associated with COVID-19 infection and adherence to major COVID-19 mitigation behaviors using a nationally representative US older adult sample.

Future research can take an even broader view of COVID-19 risk and mitigation beyond the scope presented here. In a global pandemic, the United States is far from the only nation affected by viral infection and mitigation behavior non-adherence, and other work on these topics has been conducted in countries as disparate as Saudi Arabia, Italy, Singapore, and South Africa.[8,26–28] Although some similarities presented themselves internationally, such as the

association between female gender and mitigation behavior adherence,[26–28] absolute rates of adherence can vary dramatically between geographic regions.[26,28] Part of this may be due to differing social and political norms, such as pre-existing acceptance of masking in certain East Asian countries,[27] but some researchers suggest religion may play a role as well.[26,27] For example, cleanliness practices codified in the Islamic faith may have predisposed Saudi Arabians to regularly wash their hands and avoid anything that could be considered unclean.[26] Further work on COVID-19 and associated behaviors thus may want to analyze predictors on a global level or apply a sociocultural lens to their local populations.

### *Conclusion*

Our study of US older adults from a nationally representative sample identified numerous risk factors for COVID-19 and predictors for adhering to mitigation behaviors. Knowledge of these nuanced relationships of social, clinical, and environmental factors with infection risk will help prioritize preventative public health approaches to alleviate the public health emergency caused by COVID-19 and other future pandemics. For example, the COVID-19 vaccine supply was severely restricted during the early phase of the pandemic, and our findings indicate prioritizing prevention efforts toward underresourced communities and congregate settings may be worthwhile when new vaccines are in development during future disease outbreaks. Public health messaging should also focus on promoting adherence to disease mitigation behaviors among older males and older adults with comorbidities, which were subsequently associated with increased disease risk. Further research is warranted to investigate the connection between anxiety and elevated COVID-19 risk and reasons for racial and ethnic differences in adhering to mitigation behaviors.

## Author statements

### *Acknowledgments*

National Health and Aging Trends Study (NHATS) is sponsored by the National Institute on Aging (grant number U01AG32947) and was conducted by the Johns Hopkins University.

### *Ethical approval*

This study was approved by the SUNY Upstate Institutional Review Board for the Protection of Human Subjects (#1769765-1).

### *Funding*

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### *Competing interests*

The authors have no real or perceived competing interests to disclose.

### *Author contributions*

R.W. conceived the study and conducted the analysis. J.R.G. and M.A.L. critically contributed to data interpretation. All authors drafted the article and approved the final submitted version.

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Public Health 211 (2022) 136–143

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/puhe

Original Research

# Differences in the incidence and clinical outcomes of SARS-CoV-2 infection between Italian and non-Italian nationals using routine data

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ARTICLE INFO

*Article history:*
Received 4 April 2022
Received in revised form
21 July 2022
Accepted 22 July 2022
Available online 11 August 2022

*Keywords:*
SARS-CoV-2 infection
Incidence
Lethality
Case hospitalisation rate
Immigrants
Italy

ABSTRACT

*Objectives:* This study was to compare the incidence and clinical outcomes of SARS-CoV-2 infection between Italian and non-Italian nationals.
*Study design:* We retrospectively analysed data from the COVID-19 Italian integrated surveillance system (14 September 2020 to 17 October 2021).
*Methods:* We used multivariable Cox proportional hazards models to estimate the hazard ratio (HR) of infection and, among cases, the HRs of death, hospitalisation and subsequent admission to intensive care unit in non-Italian nationals relative to Italian nationals. Estimates were adjusted for differences in sociodemographic characteristics and in the week and region of diagnosis.
*Results:* Of 4,111,067 notified cases, 336,265 (8.2%) were non-Italian nationals. Compared with Italian nationals, non-Italians showed a lower incidence of SARS-CoV-2 infection (HR = 0.81, 95% confidence interval [CI]: 0.80–0.81). However, once diagnosed, they were more likely to be hospitalised (HR = 1.90, 95% CI: 1.87–1.92) and then admitted to intensive care unit (HR = 1.08, 95% CI: 1.04–1.13), with differences larger in those coming from countries with a lower human development index. Compared with Italian cases, an increased rate of death was observed in non-Italian cases from low–human development index countries (HR = 1.41, 95% CI: 1.23–1.62). The HRs of SARS-CoV-2 infection and severe outcomes slightly increased after the start of the vaccination campaign.
*Conclusions:* Underdiagnosis and delayed diagnosis in non-Italian nationals could explain their lower incidence compared with Italians and, among cases, their higher probability to present clinical conditions leading to worse outcomes. Facilitating early access to vaccination, diagnosis and treatment would improve the control of SARS-CoV-2 transmission and health outcomes in this vulnerable group.


## Introduction

Several studies suggest that differences in cultural, behavioural and societal characteristics (e.g. socio-economic conditions, health-seeking behaviour and intergenerational cohabitation) make migrants and ethnic minority groups more exposed to the risk of SARS-CoV-2 infection and of severe COVID-19 compared with autochthonous populations.[1–4] However, these studies were mainly conducted among ethnic minority groups, individuals who were born and living in the host country since relatively long time, failing to capture the impact of the local epidemics on more recent migrants (economic migrants, refugees and asylum seekers), who are likely to experience a higher level of exposure to the risk of infection compared with the better integrated individuals from ethnic minority groups.[5] In fact, economic migrants, refugees, and asylum seekers are more likely to live in overcrowded accommodation and to be employed in precarious and low-skilled jobs

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https://doi.org/10.1016/j.puhe.2022.07.022

associated with an increased risk of SARS-CoV-2 infection (e.g. care work, hospitality or construction)[6–8] and to be disproportionally affected by administrative, cultural and language barriers to healthcare access and to public health messaging.[9,10]

However, while migrants and ethnic minority group represent two different population groups in countries with a long migratory tradition, such as the United States and the United Kingdom, in countries where the migration process is recent, such as in Italy, these population groups partly overlap. In fact, in Italy, there was not a notable immigration flow until the 1980s, after which it progressively increased.[11]

In Italy, where almost 5.2 million foreign citizens were estimated to be living in January 2021 (8.7% of the total resident population),[12] we previously analysed, during the first epidemic wave (20 February to 19 July 2020), the difference in COVID-19–related clinical outcomes between Italian and non-Italian nationals (i.e. people with a reported non-Italian nationality, regardless of citizenship or country of birth).[13] This study showed an increased risk of hospitalisation and admission to intensive care unit (ICU) in non-Italian nationals compared with Italian nationals, as well as an increased risk of death in non-Italian nationals from countries with a low human development index (HDI).

The present study aims to integrate and update the previous analysis by comparing the incidence and clinical outcomes of SARS-CoV-2 infection between Italian and non-Italian nationals using the much larger data set of cases tested positive in the period from 14 September 2020 to 17 October 2021, who account for 94% of all cases notified in Italy since the start of the epidemic.

## Methods

### *Data sources*

We used data retrieved from the Italian national COVID-19 surveillance system, coordinated by the Italian Institute of Health, including information on the demographic and clinical characteristics and outcomes of all cases of SARS-CoV-2 infection that were laboratory confirmed by real-time polymerase chain reaction or, since 15 January 2021, detected also through an approved antigenic test (2% of cases notified up to 17 October 2021).[14] Data are collected daily using a secure online platform and checked for out-of-range values, inconsistencies, and duplicated records. The coordinating centre routinely sends a list of possible errors to regions for verification and possible corrections. We used the data set of notifications updated on 16 December 2021 and selected all cases of SARS-CoV-2 infection tested positive from 14 September 2020 to 17 October 2021 to allow at least 30 days of follow-up and 1 month of possible delay in notification of hospitalisation, admission to ICU, and death.

We also used information about the distribution of the Italian resident population in the year 2021 by citizenship (Italians vs documented foreigners as a whole), municipality of residence, sex, and age retrieved from the data sets publicly available at the Italian National Institute of Statistics (Istat) website.[12]

Information about the level of social and material vulnerability of the municipality of residence was retrieved from the *8milaCensus* platform managed by Istat.[15] This multidimensional indicator, updated to 2011, reflects contextual phenomena, measured at municipality level, that could have affected viral circulation in the community and partly individual exposure to the risk of SARS-CoV-2 infection and related outcomes (i.e. housing conditions, family size and composition, family economic discomfort, housing overcrowding, youth employment rate and welfare discomfort of families). Finally, we also used information about the level of urbanisation of the municipality of residence provided by Istat.[16] We linked these data sets through a deterministic record linkage using the municipality code as key variable.

### *Exposure, outcomes and potential confounders*

Among all notified cases of SARS-CoV-2 infection, we defined as non-Italian nationals those reporting a non-Italian nationality, regardless of citizenship or country of birth. Nationality was classified as Italian vs non-Italian in general, and according to the 2019 HDI of the country of origin.[17] Based on the tertiles of the world's countries' HDI distribution, we distinguished among non-Italian nationals from low-HDI countries (HDI $\leq$0.664), medium-HDI countries (0.664 < HDI $\leq$ 0.809), and high-HDI countries (HDI >0.809).

We analysed the associations between nationality (exposure) and different SARS-CoV-2–related end points. First, among the whole population without an infection before the starting date of the study period, we compared the incidence of SARS-CoV-2 infection, assuming it as occurred at the date of testing positive, between Italian nationals and non-Italian nationals. We then compared the death rate in all detected cases of SARS-CoV-2 infection. We considered as COVID-19–associated deaths any notified person who died within 30 days from testing positive and, according to indications from the World Health Organization, who was presenting a clinical picture suggestive of COVID-19, in the absence of a clear cause of death different from COVID-19 (e.g. trauma) and in the absence of a complete clinical recovery from the disease.[18] Finally, we compared the hospitalisation rate and, among cases who were hospitalised, the rate of admission to intensive care unit (ICU) within 30 days since testing positive for SARS-CoV-2 infection.

The analysis was conducted taking into account as potential confounders of the relationship between nationality and outcomes the following variables: sex, age (categorised as <30 years, 5-year age groups from 30–34 to 70–74, and $\geq$75 years), Italian region of diagnosis (19 regions and two autonomous provinces), social and material vulnerability index of the municipality of residence (i.e. four categories based on quartiles of the index distribution weighted by municipality population size), level of urbanisation of the municipality of residence (i.e. urban, semiurban, and rural), and calendar week of diagnosis.

### *Statistical analysis*

Of all notified cases of SARS-CoV-2 infection tested positive between 14 September 2020 and 17 October 2021, we excluded from the analysis those imported from abroad. We also excluded cases with missing or inconsistent dates of death, hospitalisation, or admission to ICU. Finally, we excluded cases with missing information about age, level of social and material vulnerability of the municipality of residence, and nationality, thus leaving only records with complete information for all outcomes and sociodemographic characteristics available for the analysis (Fig. 1).

We described the main sociodemographic characteristics by nationality using counts with percentages and median with interquartile range (IQR) for categorical and continuous variables, respectively.

We conducted a time-to-event analysis to evaluate the association between nationality and time to SARS-CoV-2 infection using the 14 September 2020 as the index date to calculate the length of follow-up, measured as the number of days elapsed from the index date to the date of infection or to 17 October 2021 for those uninfected.

Time-to-event analyses were also conducted among cases of SARS-CoV-2 infection to evaluate the association of nationality

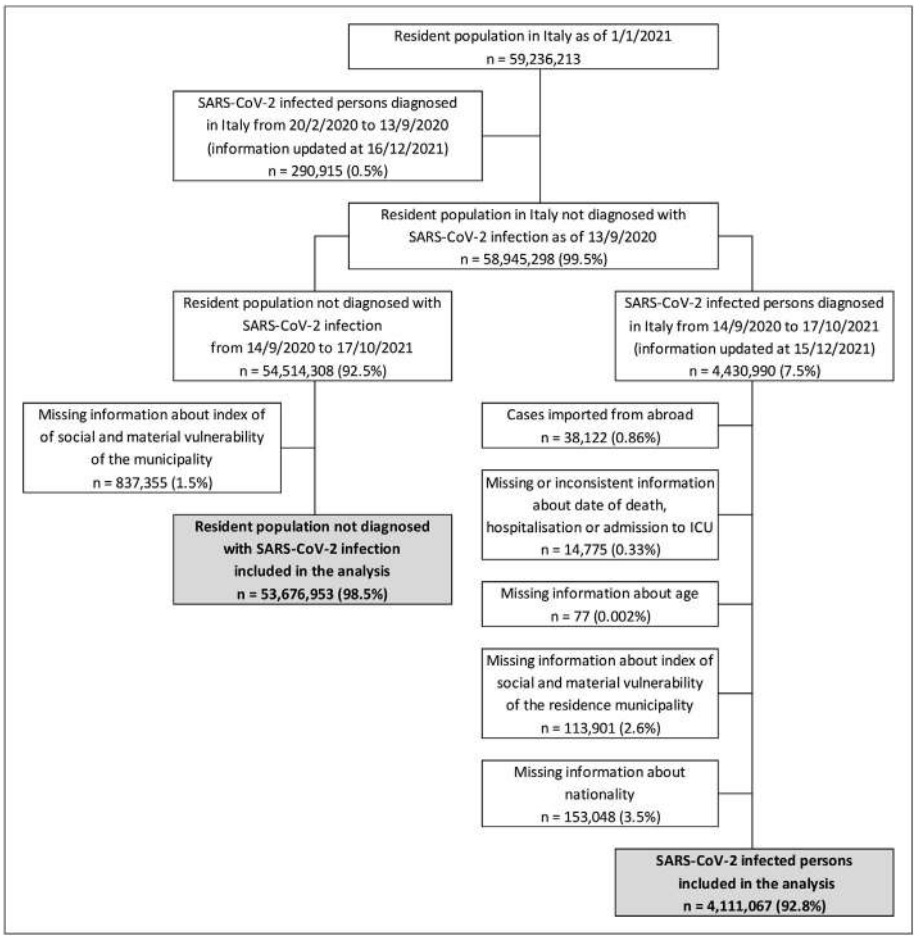


**Fig. 1.** Selection of the population included in the study. ICU, intensive care unit.

with time to COVID-19–associated death and hospitalisation and time to admission to ICU in hospitalised cases. The length of follow-up was measured as the number of days elapsed from the date of SARS-CoV-2 infection to the date of the event. Cases who did not experience the event were censored 30 days after the diagnosis of SARS-CoV-2 infection or, for the analysis of hospitalisation and admission to ICU, on the date of death if occurred earlier. We considered as died and hospitalised 0.5 days after infection all cases who were reported to have died and to have been hospitalised on the date of testing positive or within a week before it ($n = 1861$ 2.4% of deaths; $n = 125{,}798$, 41.0% of hospitalisations).

We used multivariable Cox proportional hazard models to estimate the adjusted hazard ratios (HRs) of SARS-CoV-2 infection, death, hospitalisation, and admission to ICU for non-Italian nationals compared with Italian nationals. All estimates were presented together with their 95% confidence interval (CI).

We tested the interaction between nationality and the epidemic phase through the likelihood ratio test and conducted a stratified analysis distinguishing between the epidemic phase before and after 31 January 2021. This is the date when the vaccination campaign, started in Italy on 27 December 2020, is expected to have had an impact.[19] In fact, the first second doses of the Comirnaty vaccine (the first authorised vaccine in Italy) were administered on 17 January 2021, and considering a time interval of 14 days needed to induce a full immune response, the first individuals potentially protected by a primary vaccination cycle were expected on 1 February 2021.

Finally, we conducted a sensitivity analysis using the country of birth instead of nationality to assess differences in the HRs of death, hospitalisation, and admission to ICU for foreign-born cases compared with cases born in Italy. It was not possible to evaluate differences in the incidence of SARS-CoV-2 infection because information on the population size by country of birth was unavailable.

The analyses were performed using Stata/SE version 16.1 (Stata Corp LLC, Texas, USA).

## Results

Of all the 4,430,990 notified cases of SARS-CoV-2 infection tested positive between 14 September 2020 and 17 October 2021, we excluded from the analysis 38,122 (0.86%) cases imported from abroad (Fig. 1). We also excluded 14,775 (0.33%) cases with missing or inconsistent dates of death, hospitalisation, or admission to ICU. Finally, we excluded cases with missing information about age ($n = 77$; 0.002%), level of social and material vulnerability of the municipality of residence ($n = 113{,}901$; 2.6%), and nationality ($n = 153{,}048$; 3.5%), thus leaving 4,111,067 (92.8%) cases with complete information for all outcomes and sociodemographic characteristics available for the analysis. Finally, among the 54,510,982 residents in Italy who were not diagnosed with SARS-CoV-2 infection during the study period, we excluded 834,366 (1.5%) individuals living in municipalities with missing information on the level of social and material vulnerability.

### *Sociodemographic characteristics and time of infection*

Cases of SARS-CoV-2 infection in non-Italian nationals from low-HDI countries ($n = 55{,}471$; 16.5%) were almost all from Asia

(n = 30,518; 55.0%) and south-central Africa (*n* = 24,230; 43.7%; Supplementary Fig. S1). Non-Italian cases from medium-HDI countries (*n* = 190,264; 56.6%) were mainly from European countries outside the European Union (*n* = 77,477; 40.7%), North Africa (*n* = 44,696; 23.5%), and south-central America (*n* = 41,837; 22.0%), whereas non-Italians from European Union countries (*n* = 73,975, 81.7%) accounted for most of cases from high-HDI countries (*n* = 90,530; 26.9%).

Cases of SARS-CoV-2 infection in non-Italian nationals were more frequently females (*n* = 178,159, 53.0%) compared with those in Italian nationals (*n* = 1,916,070, 50.8%), except cases from low-HDI countries who were more frequently males (*n* = 37,269, 67.2%) and relatively younger (median age: 34 years; IQR: 25–44) compared with cases in both Italian nationals (median age: 45 years; IQR: 26–60) and the whole group of non-Italian nationals (median age: 40 years; IQR: 28–50; Table 1).

Cases of SARS-CoV-2 infection in non-Italian nationals were more frequently reported in northern Italy (*n* = 254,644; 75.7%) and in urban areas (*n* = 151,965; 45.2%) compared with Italian cases (*n* = 1,947,948 [51.6%] and 1,406,421 [37.3%], respectively), particularly those in non-Italian nationals from medium and low-HDI countries. Compared with Italian cases, those in non-Italian nationals were rarely reported in municipalities with a high level of social and material vulnerability (*n* = 21,895 [6.5%] vs *n* = 1,052,476 [27.9%]).

Finally, compared with Italian cases (*n* = 1,784,181; 47.3%), those in non-Italian nationals were more frequently diagnosed during the epidemic phase following the implementation of the vaccination campaign in Italy (*n* = 177,479; 52.8%). The epidemiological curves presented in Fig. 2 show that this difference was particularly pronounced in the latest months of the study period from August to October 2021 (weeks 31–41).

### *Incidence and clinical outcomes of SARS-CoV-2 infection*

The adjusted HR of infection presented in Table 2 show that compared with Italian nationals, non-Italian nationals as a whole had a reduced risk of SARS-CoV-2 infection (adjusted HR = 0.81, 95% CI: 0.80–0.81).

By contrast, once diagnosed, they showed an increased risk of hospitalisation (HR = 1.90, 95% CI: 1.87–1.92) and, in those hospitalised, an increased risk of admission to ICU (HR = 1.08, 95% CI: 1.04–1.13). The hazard of death among cases did not differ between the two groups (HR = 1.03, 95% CI: 0.97–1.08), although it was

**Table 1**
Sociodemographic characteristics of the overall population and of SARS-CoV-2–infected cases diagnosed in Italy from 14 September 2020 to 17 October 2021.

| Sociodemographic characteristics | Italian nationals | | | | Non-Italian nationals | | | | Non-Italians from low-HDI countries | | Non-Italians from medium-HDI countries | | Non-Italians from high-HDI countries | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Population | % | Cases | % | Population | % | Cases | % | Cases | % | Cases | % | Cases | % |
| Total | 52,708,701 | 100.0 | 3,774,802 | 100.0 | 5,079,319 | 100.0 | 336,265 | 100.0 | 55,471 | 100.0 | 190,264 | 100.0 | 90,530 | 100.0 |
| Sex | | | | | | | | | | | | | | |
| Female | 27,033,641 | 51.3 | 1,916,070 | 50.8 | 2,598,342 | 51.2 | 178,159 | 53.0 | 18,202 | 32.8 | 104,554 | 55.0 | 55,403 | 61.2 |
| Male | 25,675,060 | 48.7 | 1,858,732 | 49.2 | 2,480,977 | 48.8 | 158,106 | 47.0 | 37,269 | 67.2 | 85,710 | 45.0 | 35,127 | 38.8 |
| Age group | | | | | | | | | | | | | | |
| <15 years | 6,588,262 | 12.5 | 434,788 | 11.5 | 896,278 | 17.6 | 23,652 | 7.0 | 4196 | 7.6 | 12,947 | 6.8 | 6509 | 7.2 |
| 15–19 years | 2,577,291 | 4.9 | 230,036 | 6.1 | 219,879 | 4.3 | 13,992 | 4.2 | 2723 | 4.9 | 7929 | 4.2 | 3340 | 3.7 |
| 20–24 years | 2,556,079 | 4.8 | 231,330 | 6.1 | 336,301 | 6.6 | 24,064 | 7.2 | 6387 | 11.5 | 12,457 | 6.5 | 5220 | 5.8 |
| 25–29 years | 2,563,257 | 4.9 | 227,264 | 6.0 | 413,416 | 8.1 | 29,713 | 8.8 | 7334 | 13.2 | 16,508 | 8.7 | 5871 | 6.5 |
| 30–34 years | 2,622,462 | 5.0 | 221,707 | 5.9 | 530,412 | 10.4 | 36,284 | 10.8 | 7349 | 13.2 | 20,141 | 10.6 | 8794 | 9.7 |
| 35–39 years | 2,839,989 | 5.4 | 226,748 | 6.0 | 561,485 | 11.1 | 40,151 | 11.9 | 7229 | 13.0 | 22,849 | 12.0 | 10,073 | 11.1 |
| 40–44 years | 3,362,928 | 6.4 | 259,867 | 6.9 | 548,066 | 10.8 | 42,368 | 12.6 | 6752 | 12.2 | 23,273 | 12.2 | 12,343 | 13.6 |
| 45–49 years | 4,115,110 | 7.8 | 321,371 | 8.5 | 460,958 | 9.1 | 38,313 | 11.4 | 5054 | 9.1 | 21,482 | 11.3 | 11,777 | 13.0 |
| 50–54 years | 4,311,285 | 8.2 | 331,292 | 8.8 | 385,371 | 7.6 | 32,719 | 9.7 | 3570 | 6.4 | 18,317 | 9.6 | 10,832 | 12.0 |
| 55–59 years | 4,228,349 | 8.0 | 308,309 | 8.2 | 277,795 | 5.5 | 23,117 | 6.9 | 2286 | 4.1 | 13,961 | 7.3 | 6870 | 7.6 |
| 60–64 years | 3,640,468 | 6.9 | 232,526 | 6.2 | 203,110 | 4.0 | 15,084 | 4.5 | 1328 | 2.4 | 9519 | 5.0 | 4237 | 4.7 |
| 65–69 years | 3,263,963 | 6.2 | 179,240 | 4.7 | 118,770 | 2.3 | 7869 | 2.3 | 589 | 1.1 | 5276 | 2.8 | 2004 | 2.2 |
| 70–74 years | 3,288,133 | 6.2 | 169,178 | 4.5 | 65,031 | 1.3 | 3925 | 1.2 | 274 | 0.5 | 2658 | 1.4 | 993 | 1.1 |
| ≥75 years | 6,751,125 | 12.8 | 401,146 | 10.6 | 62,447 | 1.2 | 5014 | 1.5 | 400 | 0.7 | 2947 | 1.5 | 1667 | 1.8 |
| Median age (IQR) | 49 | (27–65) | 45 | (26–60) | 36 | (22–48) | 40 | (28–50) | 34 | (25–44) | 40 | (29–51) | 42 | (31–51) |
| Level of urbanisation[a] | | | | | | | | | | | | | | |
| Urban | 18,557,114 | 35.2 | 1,406,421 | 37.3 | 2,238,480 | 44.1 | 151,965 | 45.2 | 24,602 | 44.4 | 92,983 | 48.9 | 34,380 | 38.0 |
| Semiurban | 25,405,107 | 48.2 | 1,810,695 | 48.0 | 2,180,242 | 42.9 | 145,264 | 43.2 | 24,161 | 43.6 | 78,120 | 41.1 | 42,983 | 47.5 |
| Rural | 8,746,480 | 16.6 | 557,686 | 14.8 | 660,597 | 13.0 | 39,036 | 11.6 | 6708 | 12.1 | 19,161 | 10.1 | 13,167 | 14.5 |
| Level of social and material vulnerability[a] | | | | | | | | | | | | | | |
| Low | 6,571,273 | 12.5 | 532,719 | 14.1 | 554,080 | 10.9 | 44,534 | 13.2 | 6438 | 11.6 | 23,426 | 12.3 | 14,670 | 16.2 |
| Medium-low | 11,482,259 | 21.8 | 906,761 | 24.0 | 1,303,275 | 25.7 | 105,513 | 31.4 | 18,163 | 32.7 | 58,997 | 31.0 | 28,353 | 31.3 |
| Medium-high | 19,116,265 | 36.3 | 1,282,846 | 34.0 | 2,396,879 | 47.2 | 164,323 | 48.9 | 25,971 | 46.8 | 98,466 | 51.8 | 39,886 | 44.1 |
| High | 15,538,904 | 29.5 | 1,052,476 | 27.9 | 825,085 | 16.2 | 21,895 | 6.5 | 4899 | 8.8 | 9375 | 4.9 | 7621 | 8.4 |
| Geographical macroarea of Italy | | | | | | | | | | | | | | |
| North-West | 13,938,966 | 26.4 | 1,054,776 | 27.9 | 1,760,765 | 34.7 | 136,260 | 40.5 | 19,976 | 36.0 | 82,939 | 43.6 | 33,345 | 36.8 |
| North-East | 10,063,788 | 19.1 | 893,172 | 23.7 | 1,282,328 | 25.2 | 118,384 | 35.2 | 22,140 | 39.9 | 64,763 | 34.0 | 31,481 | 34.8 |
| Centre | 10,428,111 | 19.8 | 697,468 | 18.5 | 1,296,284 | 25.5 | 69,309 | 20.6 | 10,725 | 19.3 | 37,597 | 19.8 | 20,987 | 23.2 |
| South and Islands | 18,277,836 | 34.7 | 1,129,386 | 29.9 | 739,942 | 14.6 | 12,312 | 3.7 | 2630 | 4.7 | 4965 | 2.6 | 4717 | 5.2 |
| Period of diagnosis (epidemic phase) | | | | | | | | | | | | | | |
| Phase 1 (14 September 2020–31 January 2021) | NA | NA | 1,990,621 | 52.7 | NA | NA | 158,786 | 47.2 | 28,280 | 51.0 | 89,733 | 47.2 | 40,773 | 45.0 |
| Phase 2 (1 February 2021 to 17 October 2021) | NA | NA | 1,784,181 | 47.3 | NA | NA | 177,479 | 52.8 | 27,191 | 49.0 | 100,531 | 52.8 | 49,757 | 55.0 |

HDI, human development index; IQR, interquartile range; NA, not applicable.
[a] The level of urbanisation and the level of social and material vulnerability refer to the municipality of residence.

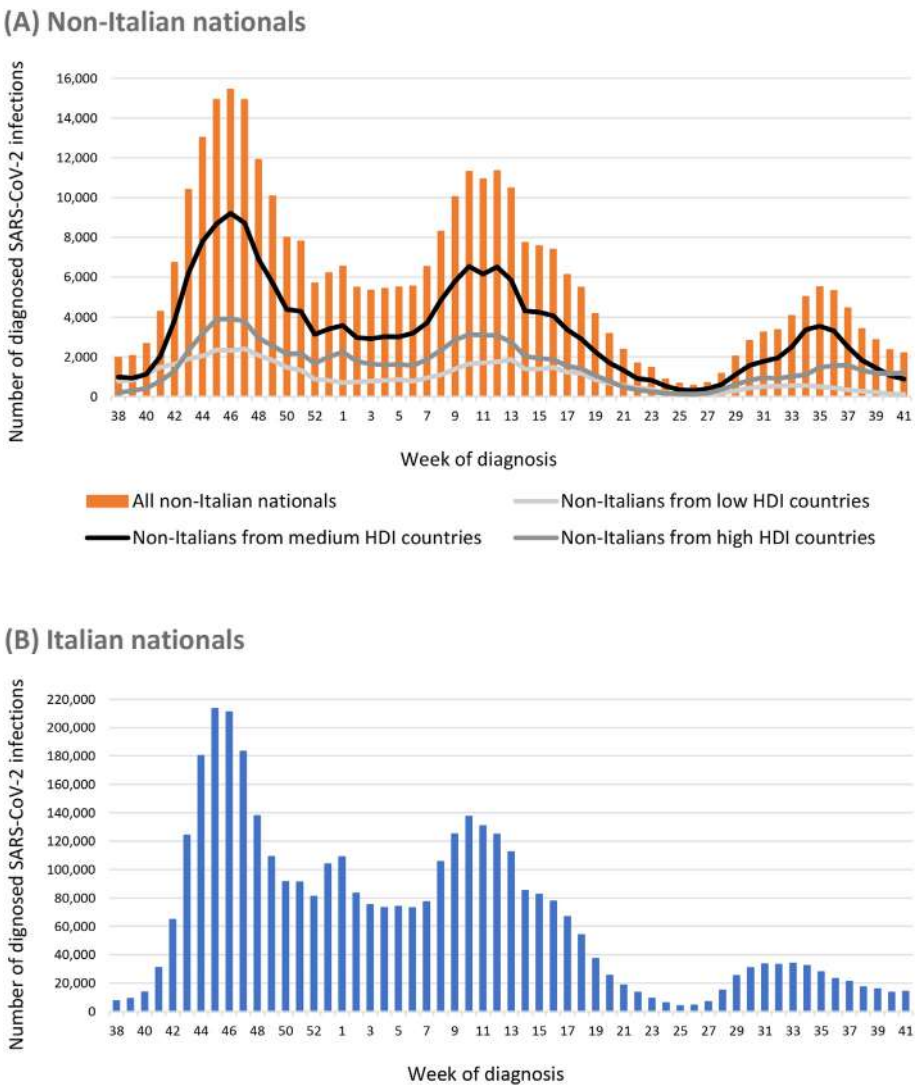


**Fig. 2.** SARS-CoV-2 infection epidemiological curves in non-Italian nationals (A) and Italian nationals (B), week 38/2020 (14–20 September) to week 41/2021 (11–17 October). HDI, human development index.

increased in non-Italian cases from low-HDI countries (HR = 1.41, 95% CI: 1.23–1.62). In general, all the considered clinical outcomes among cases showed an inverse gradient by which the hazard of these events increased as the HDI level of the country of origin decreased.

We found an interaction between nationality and the epidemic phase for all the considered events (likelihood ratio tests, $P < 0.05$). The analysis stratified by epidemic phase presented in Fig. 3 showed how, relative to Italian nationals, the risk of all events in non-Italian nationals slightly increased from the first period (from 14 September 2020 to 31 January 2021) to the second period following the implementation of the COVID-19 vaccination campaign in Italy (from 1 February to 17 October 2021).

The sensitivity analysis conducted using the country of birth instead of nationality as exposure variable showed very similar results (Supplementary Table S1).

## Discussion

We found that non-Italian nationals were less likely to be diagnosed with SARS-CoV-2 infection compared with the Italian population. Once diagnosed, however, they were more likely to be hospitalised and to be admitted to ICU, also showing a higher risk of COVID-19–associated death in those from low-HDI countries. The risks of hospitalisation, admission to ICU, and death were found to increase with decreasing HDI of the country of origin. We also found that, relative to Italian nationals, the risk of infection, death, hospitalisation, and admission to ICU slightly increased after the implementation of the COVID-19 vaccination campaign in Italy (from 1 February to 17 October 2021).

It is possible that non-Italian nationals were at lower risk of infection because of the smaller social networks that migrants have been described to experience.[20] However, this would not explain why when diagnosed, non-Italian cases showed worse clinical outcomes than their Italian counterpart. For this reason, we believe it is more likely that non-Italian nationals were not at lower risk of being infected but rather less likely to be diagnosed unless the disease progressed to more severe symptoms requiring hospitalisation. This hypothesis is supported by findings from a seroprevalence survey conducted in a social housing neighbourhood in Milan, northern Italy, showing a prevalence of SARS-CoV-2 antibodies in non-Italians about twice that in Italians.[24] Underdiagnosis in non-Italian nationals could be partly explained by the fact that in Italy, although all non-Italian nationals have free access to

**Table 2**
Hazard ratio of diagnosis with SARS-CoV-2 infection and subsequent death, hospitalisation and admission to ICU by nationality.

| Diagnosis of SARS-CoV-2 infection | Population | Cases | PD | Incidence per 100,000 PD | Crude HR | (95% CI) | Adjusted HR[a] | (95% CI) |
|---|---|---|---|---|---|---|---|---|
| Nationality (1) | | | | | | | | |
| Italian | 52,708,701 | 3,774,802 | 20,069,606,450 | 18.8 | Ref. | | Ref. | |
| Non-Italian | 5,079,319 | 336,265 | 1,946,192,112 | 17.3 | 0.92 | (0.92–0.92) | 0.81 | (0.80–0.81) |
| **Death** | **Cases** | **Deaths** | **PD** | **Death rate per 100,000 PD** | **Crude HR** | **(95% CI)** | **Adjusted HR[a]** | **(95% CI)** |
| Nationality (1) | | | | | | | | |
| Italian | 3,774,802 | 74,781 | 111,928,756 | 66.8 | Ref. | | Ref. | |
| Non-Italian | 336,265 | 1511 | 10,062,137 | 15.0 | 0.23 | (0.21–0.24) | 1.03 | (0.97–1.08) |
| Nationality (2) | | | | | | | | |
| Italian | 3,774,802 | 74,781 | 111,928,756 | 66.8 | Ref. | | Ref. | |
| Low-HDI countries | 55,471 | 202 | 1,660,556 | 12.2 | 0.18 | (0.16–0.21) | 1.41 | (1.23–1.62) |
| Medium-HDI countries | 190,264 | 907 | 5,692,805 | 15.9 | 0.24 | (0.22–0.25) | 1.00 | (0.94–1.07) |
| High-HDI countries | 90,530 | 402 | 2,708,776 | 14.8 | 0.22 | (0.20–0.25) | 0.95 | (0.86–1.05) |
| **Hospitalisation** | **Cases** | **Hospitalised patients** | **PD** | **Hospitalisation rate per 100,000 PD** | **Crude HR** | **(95% CI)** | **Adjusted HR[a]** | **(95% CI)** |
| Nationality (1) | | | | | | | | |
| Italian | 3,774,802 | 278,741 | 105,481,161 | 264.3 | Ref. | | Ref. | |
| Non-Italian | 336,265 | 28,256 | 9,303,341 | 303.7 | 1.15 | (1.13–1.16) | 1.90 | (1.87–1.92) |
| Nationality (2) | | | | | | | | |
| Italian | 3,774,802 | 278,741 | 105,481,161 | 264.3 | Ref. | | Ref. | |
| Low-HDI countries | 55,471 | 5912 | 1,496,539 | 395.0 | 1.48 | (1.44–1.52) | 2.88 | (2.81–2.96) |
| Medium-HDI countries | 190,264 | 16,728 | 5,245,203 | 318.9 | 1.20 | (1.18–1.22) | 1.90 | (1.87–1.93) |
| High-HDI countries | 90,530 | 5616 | 2,561,600 | 219.2 | 0.84 | (0.82–0.86) | 1.41 | (1.38–1.45) |
| **Admission to ICU** | **Hospitalised cases** | **Admitted to ICU** | **PD** | **ICU admission rate per 100,000 PD** | **Crude HR** | **(95% CI)** | **Adjusted HR[a]** | **(95% CI)** |
| Nationality (1) | | | | | | | | |
| Italian | 278,741 | 40,775 | 6,637,420 | 614.3 | Ref. | | Ref. | |
| Non-Italian | 28,256 | 2871 | 763,321 | 376.1 | 0.66 | (0.64–0.69) | 1.08 | (1.04–1.13) |
| Nationality (2) | | | | | | | | |
| Italian | 278,741 | 40,775 | 6,637,420 | 614.3 | Ref. | | Ref. | |
| Low-HDI countries | 5912 | 479 | 163,556 | 292.9 | 0.52 | (0.48–0.57) | 1.09 | (0.99–1.19) |
| Medium-HDI countries | 16,728 | 1765 | 451,098 | 391.3 | 0.69 | (0.65–0.72) | 1.10 | (1.04–1.15) |
| High-HDI countries | 5616 | 627 | 148,667 | 421.7 | 0.73 | (0.68–0.79) | 1.05 | (0.97–1.13) |

CI, confidence interval; HDI, human development index; HR, hazard ratio; ICU, intensive care unit; PD, person-days; ref., reference category.
[a] Adjusted for sex, age, geographical region of diagnosis, level of urbanisation of the municipality of residence, level of social and material vulnerability of the municipality of residence and calendar week of diagnosis.

emergency services and some outpatient services,[21] only documented immigrants have access to additional services, including the assignment to a general practitioner, who is the most likely mediator for diagnosis. Moreover, informal barriers (language, administrative, cultural, and social) might have hindered the access to healthcare services regardless of status.[9,10] It is worthwhile to note that in Italy, in January 2021, the case definition for surveillance purposes was extended to include cases who were laboratory confirmed through an antigenic test. The execution of this kind of test was also made available for pay in pharmacies and laboratories outside the public circuit,[22] thus facilitating the access to diagnosis, especially where public services were overcrowded. The access to this diagnostic service, however, was likely higher in Italian nationals compared with non-Italian nationals, the former being probably more informed about the service and more prone to sustain its cost. This possibly led to a more pronounced increase in the number of diagnosed infections, especially those asymptomatic or paucisymptomatic, in Italian nationals compared with non-Italians. Finally, non-Italian nationals, particularly those engaged in precarious works, might have avoided diagnosis fearing the isolation/quarantine and the consequent impact on their economic income.[23]

All this suggests that non-Italian nationals infected with SARS-CoV-2 were more likely to be undiagnosed or diagnosed less timely than Italian nationals, possibly when the disease was more advanced, thus explaining the increased risk of severe outcomes observed in non-Italian nationals, especially in those from low-HDI countries. This hypothesis is consistent with findings from a study conducted in northern Italy showing that immigrant women were more likely to be tested for SARS-CoV-2 infection only when presenting severe symptoms.[25] Overall, we did not observe a difference in the hazard of death between Italian and non-Italian nationals, although it was increased in non-Italian cases from low-HDI countries. This result is consistent with findings from a study conducted in Milan, northern Italy, where in-hospital mortality was found to not significantly differ between Italian and immigrant patients.[26]

A reduced access to vaccination could partly explain the slight increase in the HRs of infection and severe clinical outcomes in non-Italians compared with Italian nationals that was observed during the epidemic phase following the implementation of the vaccination campaign. Although the available data did not allow us to adequately assess the COVID-19 vaccination coverage by nationality, a recent study conducted in the metropolitan area of Milan in the Lombardy region showed, in the period January to September 2021, an estimated risk of missed vaccination in non-Italian nationals more than twice that estimated in Italian nationals, both overall and among individuals aged $\geq$50 years.[27] A lower COVID-19 vaccination coverage in migrants and ethnic minorities compared with the autochthonous population was also observed elsewhere in Europe.[8]

In general, our findings are consistent with those from other European countries. Although sometimes designed in different ways, studies conducted in Spain, Norway, Denmark, and Sweden

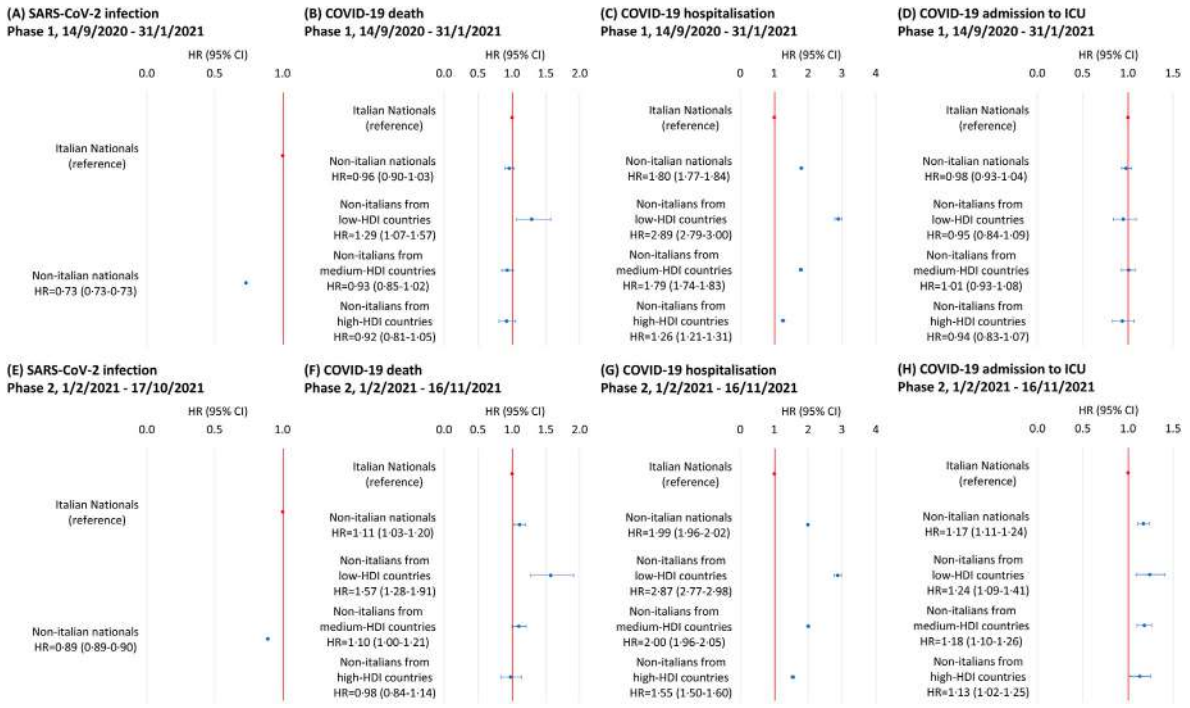


**Fig. 3.** Hazard ratio of SARS-CoV-2 infection and subsequent death, hospitalisation, and admission to ICU by nationality and epidemic phase. HR, hazard ratio adjusted for sex, age, geographical region of diagnosis, level of urbanisation of the municipality of residence, level of social and material vulnerability of the municipality of residence and calendar week of diagnosis; CI, confidence interval; HDI, human development index; ICU, intensive care unit.

also showed an increased risk of hospitalisation and admission to ICU due to COVID-19 in migrants compared with autochthonous populations.[28–31] In Norway, it was observed a higher rate of hospitalisation in cases born abroad compared with those born in Norway (4.7% vs 3.2%),[28] and in Madrid, Spain, an increased risk of admission to ICU in hospitalised patients from non-European countries compared with those from European countries (odds ratio adjusted for age/gender = 1.43, 95% CI: 1.03–1.98).[29] In Denmark, it was observed a higher proportion of non-Western migrants (15%) in COVID-19–hospitalised cases than in the general population (9%),[30] and in Sweden, among the whole population, a higher rate of admission to ICU in foreign-born persons compared with natives.[31] Consistently with our findings on lethality, a stratified analysis from Sweden showed an increased risk of COVID-19–associated death in migrants from low- or middle-income countries compared with nationals,[32] whereas no excess mortality by migrant status was observed in Denmark.[30] However, in contrast with findings from these countries, we did not observe an increased risk of SARS-CoV-2 infection in non-nationals compared with nationals. As discussed previously, this could be explained by a higher rate of missed diagnosis in non-Italian cases compared with Italian cases, especially in those asymptomatic or paucisymptomatic, possibly leading to estimates of severe clinical outcomes in this population group greater than elsewhere.

Our study has the strength to be highly representative of the population living in Italy, including all cases of SARS-CoV-2 infection notified to the national surveillance system over more than 1 year.

However, this analysis also has some limitations. Differences in the incidence of SARS-CoV-2 infection should be interpreted with caution because the population size at risk to develop the disease was assessed using estimates of the population residing in Italy at the beginning of the year 2021. Therefore, it does not account for deaths unrelated to COVID-19 that occurred thereafter, as well as for population movements to/from abroad that, given their higher mobility, are expected to have been more frequent among foreigners than among Italians.

It was not possible to adjust our estimates for the presence of pre-existing comorbidities since this information was available only for 58% of all the cases notified to the Italian integrated surveillance system. However, based on data from the six Italian regions where the percentage of missing information about pre-existing comorbidities was below 5% (accounting for 2,220,194 [54%] of the notified cases included in the study), the models adjusted for the presence of comorbidities yielded estimates of the HRs of severe clinical outcomes in non-Italian nationals compared with Italian nationals very close to those presented in the main analysis (Supplementary Table S2).

Finally, we cannot adjust for individual socio-economic conditions nor stratify the analysis grouping non-Italian nationals by length of stay in Italy, both factors likely affecting COVID-19–associated morbidity and mortality. Although we adjusted the analysis for social and material vulnerability measured at municipality level, this indicator may suffer from ecological fallacy, given that, especially in large municipalities, the contextual social and material vulnerability may differ among subareas and poorly reflect individual conditions. In conclusion, the results suggest that, in Italy, there was both underdiagnosis and delayed diagnosis of SARS-CoV-2 infection in non-Italian nationals compared with the autochthonous population, possibly explaining the lower incidence but worse clinical outcomes in this population group. If non-nationals are hindered in accessing healthcare services in a timely manner, vaccination, diagnosis, and treatment can be in turn delayed with a possible negative impact on individual outcome as well as on disease prevention and control at population level. Removing healthcare access barriers is, therefore, essential to control SARS-CoV-2 transmission, preserve health services, and improve the health outcomes in this vulnerable group as well as in the whole population living in Italy.

## Author statements

### Acknowledgements

*Members of the Italian Integrated Surveillance of COVID-19 study group*: Antonino Bella, Alberto Mateo Urdiales, Martina Del Manso, Massimo Fabiani, Matteo Spuri, Chiara Sacco, Stefano Boros, Maria Cristina Rota, Antonietta Filia, Marco Bressi, Maria Fenicia Vescio, Daniele Petrone, Marco Tallon, Corrado Di Benedetto, Paola Stefanelli, Flavia Riccardo, Patrizio Pezzotti.

*Regional representatives of the Italian Integrated Surveillance of Covid-19 network:* Antonia Petrucci (Abruzzo); Michele La Bianca (Basilicata); Anna Domenica Mignuoli (Calabria); Pietro Buono (Campania); Erika Massimiliani (Emilia-Romagna); Fabio Barbone (Friuli Venezia Giulia); Francesco Vairo (Lazio); Camilla Sticchi (Liguria); Danilo Cereda (Lombardia); Lucia Di Furia (Marche); Francesco Sforza (Molise); Annamaria Bassot (P.A. Bolzano); Pier Paolo Benetollo (P.A. Trento); Chiara Pasqualini (Piemonte); Lucia Bisceglia (Puglia); Maria Antonietta Palmas (Sardegna); Salvatore Scondotto (Sicilia); Emanuela Balocchini (Toscana); Anna Tosti (Umbria); Mauro Ruffier (Valle D'Aosta); Filippo Da Re (Veneto).

### Ethical approval

Dissemination of COVID-19 surveillance data was authorised by Decree Law number 24 on March 2022 (article 13).

### Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### 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.2022.07.022.

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Public Health 211 (2022) 157–163

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

# Effect of ontological insecurity on vaccination behavior against COVID-19: a hospital-based cross-sectional study

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ARTICLE INFO

*Article history:*
Received 8 March 2022
Received in revised form
7 July 2022
Accepted 10 July 2022
Available online 18 July 2022

*Keywords:*
COVID-19
Ontological insecurity
Vaccination behavior
China

ABSTRACT

*Objective:* Coronavirus disease 2019 (COVID-19) has brought great uncertainty to our society and it may have disrupted people's ontological security. Consequently, this hospital-based study concerns the impact of ontological insecurity on vaccination behavior against COVID-19.
*Study design:* This cross-sectional study was conducted among hospital inpatients.
*Methods:* A questionnaire survey addressing inpatient ontological insecurity and vaccination behavior against COVID-19 was administered in Taizhou, China. A total of 1223 questionnaires were collected; specifically, 1185 of them were credible, for a validity rate of 96.9%.
*Results:* The score of ontological insecurity was 13.27 ± 7.84, which was higher in participants who did not recommend vaccination for others than those who did (12.95 ± 8.25 vs 14.00 ± 6.78, $P = 0.022$). There was no difference between the vaccinated and unvaccinated groups (13.22 ± 7.96 vs 13.35 ± 7.67, $P = 0.779$). Lower ontological insecurity (odds ratio [OR] = 1.40, 95% confidence interval [CI]: 1.08–1.81) and being inoculated with COVID-19 vaccines (OR = 2.17, 95% CI: 1.67–2.82) were significantly associated with recommendation of COVID-19 vaccines to others after adjusting for sex, age, education, and occupation. Associations between low ontological insecurity and recommendations for COVID-19 vaccines were observed in men, adults aged 18–59 years, non-farmers, and vaccine recipients.
*Conclusions:* This study suggests that the ontological insecurity of participants affects their behavior of recommending the COVID-19 vaccination to others rather than getting vaccinated themselves. This promotion of vaccination can be considered from the perspective of improving ontological security in China.



## Introduction

The coronavirus disease 2019 (COVID-19) pandemic has caused thousands of deaths and severely affected the global economy and healthcare systems. Many countries have adopted social distancing and lockdown policies to control the disease's spread. In China, a high-intensity 'joint prevention and control' strategy has played an important role in containing epidemics; nevertheless, people's social and living conditions are affected by this approach. In several countries, discrimination and violence broke out after limiting social distancing for long periods.[1,2] These results indicate that people's sense of ontological security is disrupted by changes in social and living environments.[3] The concept of ontological security

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https://doi.org/10.1016/j.puhe.2022.07.008
0033-3506/

proposed by Anthony Giddens,[4] following psychologist Robert Laing (1960),[5] was described as the 'confidence that most human beings have in the continuity of their self-identity and in the constancy of the surrounding social and material environments.' Once a positive COVID-19 case is identified, a series of tightened measures for the prevention and control of COVID-19 such as taking body temperature, wearing face masks, social distancing, checking health codes, and enforcing travel codes would heighten people's concerns about the situation and increase their sense of insecurity.

Recent research has suggested serious illness potentially threatens people's sense of ontological security.[6] Hospitalized patients often experience more complex diseases, resulting in a sense of insecurity. In addition, hospitals are high-risk places for the spread of the epidemic, which may further reduce people's sense of security. Illness narratives relying on perceptions of emotional and ontological security can in turn elicit adaptive responses to threats.[7,8] A systematic review found positive changes in health-promoting behaviors through narrative interventions.[9] However, few studies have focused on the influence of perceived scarcity of ontological security on the possible behavioral changes of individuals.

To date, vaccination against COVID-19 has been the primary preventive measure. Nonetheless, our previous study found that a significant proportion of people are still reluctant to receive vaccinations.[10] In the present study, we further examine the relationship between ontological insecurity and health-promoting behaviors in hospitalized patients, including self-vaccination and recommendations for vaccination against COVID-19.

## Methods

### *Study design and data collection*

A face-to-face hospital-based cross-sectional questionnaire survey was administered in Taizhou, China, by uniformly well-trained and qualified nurses using the WeChat-Inc Wen-Juan-Xing platform. The target population were inpatients admitted to Taizhou Hospital during routine COVID-19 epidemic prevention and control. The inpatients were invited to answer the questionnaire voluntarily by scanning the quick response (i.e. 'QR') code on WeChat when they first arrived between July 11 and August 9, 2021. A total of 1223 questionnaires were collected. Redundant questionnaires identified by duplicate identity numbers were removed and only those submitted for the first time were retained. The questionnaires that contained unreasonable information or were answered too quickly were excluded. Finally, 1185 interviewees with valid data were included, thus corresponding to an eligibility rate of 96.9% (1185/1223). The present study was exempted from the requirement for written informed consent and was approved by the Ethics Committee of Taizhou Hospital of Zhejiang Province (approval number: K20210521) in China. All procedures were performed in accordance with the guidelines of the institutional ethics committee of the authors and adhered to the tenets of the Declaration of Helsinki.

### *Structured questionnaires and measurement*

A structured questionnaire comprising several parts was constructed. Its preface described the background and purpose of the survey; also, it would be answered anonymously and voluntarily following informed consent. Demographic information included age, sex, residence, educational level, and occupation. The questionnaire's content also included patients' knowledge about COVID-19 and its prevention and control measures, individual behaviors of prevention and control both before and after admission, and evaluation of the implementation of prevention and control measures in the hospital. The major topics were ontology insecurity and health behaviors, including self-vaccination and recommendations of others for COVID-19 vaccines. The underlying condition of primary ontological insecurity was measured using the first subscale of the newly developed Ontological Insecurity Scale (OIS) with 34 items (OIS-34 scale).[11] The primary ontological insecurity subscale comprises nine items. Responses were scored on the following 5-point Likert scale:0 = *Not at all like me*; 1 = *A little like me*; 2 = *Moderately like me*; 3 = *Very much like me*; or 4 = *Completely like me*. The total score ranges from 0 to 36, where the higher the score, the stronger the ontology insecurity, indicating the lack of a secure sense is more severe. Vaccination behaviors were measured by the following two questions: 'Have you been vaccinated against COVID-19?' (response options: 'yes' or 'no') and 'Have you recommended anyone for the COVID-19 vaccines?' (response options: 'yes' or 'no'). All questions were close-ended, with boxes provided for checked responses.

### *Statistical analysis*

We performed a logical check of the data, excluding those who were under 18 years of age and those who answered within 120 s. Categorical variables regarding basic demographic characteristics and vaccination behaviors were expressed as counts and percentages. The mean and standard deviation were calculated for ontological insecurity. The relationship between vaccination behaviors and ontological insecurity was tested using the Chi-squared test. After classifying high and low ontological insecurity according to the mean score, binary logistic regression models were used to analyze the impact of ontological insecurity on vaccination behavior and the behavior of recommending vaccination to anyone, and the odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were calculated. All data were analyzed using IBM's SPSS version 22.0 and the differences were considered statistically significant at $P < 0.05$.

## Results

Of the 1223 collected questionnaires, 27 were excluded due to patients' ages being under 18 years old; notably, one was excluded because of too short a time (less than 120 s) to complete the questionnaire. In addition, 10 redundant questionnaires were excluded owing to duplicate submissions. Finally, 1185 qualified questionnaires were analyzed in this study. The mean (±SD) age was 51.7 ± 16.6 years with 54.3% being female.

### *Distribution of two vaccination behaviors including vaccination for themselves and recommendations to anyone for COVID-19 vaccination*

Overall, 707 participants (59.7%) had been vaccinated against COVID-19 and 819 (69.1%) reported they recommended others for COVID-19 vaccines. The percentage of those who recommended anyone for COVID-19 vaccination was significantly higher in vaccinated patients than in unvaccinated ones (75.2% vs 60.0%, $\chi^2 = 30.89$, $P < 0.001$). The rate of COVID-19 vaccination was higher in men (63.7% vs 56.3%, $\chi^2 = 6.61$, $P = 0.01$) and workers (73.7% vs 58.4%, $\chi^2 = 8.892$, $P = 0.003$) than in their counterparts. The behavior of recommending COVID-19 vaccines to anyone was

**Table 1**
The relationship between sociodemographic characteristics, ontological insecurity and COVID-19 vaccination behavior.

| Characteristics | Classification | *N* (%) | Have you been vaccinated against COVID-19? | | | Do you recommend anyone for the COVID-19 vaccines? | | |
|---|---|---|---|---|---|---|---|---|
| | | | Yes | No | *P* | Yes | No | *P* |
| | | | (*n* = 707, 59.7%) | (*n* = 478, 40.3%) | | (*n* = 819, 69.1%) | (*n* = 366, 30.9%) | |
| Sex | | | | | **0.010** | | | **0.026** |
| | Men | 542 (45.7) | 345 (63.7) | 197 (36.3) | | 357 (65.9) | 185 (34.1) | |
| | Women | 643 (54.3) | 362 (56.3) | 281 (43.7) | | 462 (71.9) | 181 (28.1) | |
| Age (years) | | | | | 0.657 | | | **<0.001** |
| | 18−59 | 787 (66.3) | 466 (59.2) | 321 (40.8) | | 584 (74.2) | 203 (25.8) | |
| | ≥60 | 398 (33.6) | 241 (60.6) | 157 (39.4) | | 235 (59.0) | 163 (41.0) | |
| Residence | | | | | 0.416 | | | 0.108 |
| | Urban | 253 (21.4) | 143 (56.5) | 110 (43.5) | | 183 (72.3) | 70 (27.7) | |
| | Town | 303 (25.6) | 188 (62.0) | 115 (38.0) | | 218 (71.9) | 85 (28.1) | |
| | Rural | 629 (53.1) | 376 (59.8) | 253 (40.2) | | 418 (66.5) | 211 (33.5) | |
| Education | | | | | 0.087 | | | **<0.001** |
| | Primary and below | 487 (41.1) | 301 (61.8) | 186 (38.2) | | 296 (60.8) | 191 (39.2) | |
| | Junior Secondary | 343 (28.9) | 201 (58.6) | 142 (41.4) | | 239 (69.7) | 104 (30.3) | |
| | Senior Secondary | 171 (14.4) | 109 (63.7) | 62 (36.3) | | 136 (79.5) | 35 (20.5) | |
| | College and above | 184 (15.5) | 96 (52.2) | 88 (47.8) | | 148 (80.4) | 36 (19.6) | |
| Occupation | | | | | **0.014** | | | **<0.001** |
| | Civil servants, staff or professionals | 158 (13.3) | 87 (55.1) | 71 (44.9) | | 129 (81.6) | 29 (18.4) | |
| | Workers | 99 (8.4) | 73 (73.7) | 26 (26.3) | | 68 (68.7) | 31 (31.3) | |
| | Farmers | 465 (39.2) | 267 (57.4) | 198 (42.6) | | 273 (58.7) | 192 (41.3) | |
| | Others | 463 (39.1) | 280 (60.5) | 183 (39.5) | | 349 (75.4) | 114 (24.6) | |
| Ontological insecurity score | | | | | 0.781 | | | **0.008** |
| | ≤13 | 609 (51.4) | 361 (59.3) | 248 (40.7) | | 442 (72.6) | 167 (27.4) | |
| | >13 | 576 (48.6) | 346 (60.1) | 230 (39.9) | | 377 (65.5) | 199 (34.5) | |
| Have you been inoculated with the COVID-19 vaccine | | | | | – | | | **<0.001** |
| | Yes | 707 (59.7) | – | – | | 532 (75.2) | 175 (24.8) | |
| | No | 478 (40.3) | – | – | | 287 (60.0) | 191 (40.0) | |
| Do you recommend anyone for the COVID-19 vaccine | | | | | **<0.001** | | | – |
| | Yes | 819 (69.1) | 532 (65.0) | 287 (35.0) | | – | – | |
| | No | 366 (30.9) | 175 (47.8) | 191 (52.2) | | – | – | |

The bold values indicate that $P < 0.05$, which is statistically significant.

**Table 2**
Factors associated with the behavior of recommending anyone for COVID-19 vaccines.

| Variables | Categories | *P* | OR | 95% CI |
|---|---|---|---|---|
| Ontological insecurity score | | | | |
| | <13 vs ≥13 | **0.011** | 1.40 | 1.08–1.81 |
| Have you been inoculated with the COVID-19 vaccine | | | | |
| | Yes vs no | **<0.001** | 2.17 | 1.67–2.82 |
| Sex | Women vs men | 0.197 | 1.19 | 0.91–1.56 |
| Age | ≥60 vs 18–59 years | **0.048** | 0.73 | 0.53–0.99 |
| Education | Primary and below | – | 1.00 | – |
| | Junior Secondary | 0.277 | 1.21 | 0.86–1.70 |
| | Senior Secondary | 0.053 | 1.60 | 0.99–2.59 |
| | College and above | 0.132 | 1.51 | 0.88–2.59 |
| Occupation | Civil servants, staff or professionals | – | 1.00 | – |
| | Workers | 0.095 | 0.57 | 0.29–1.10 |
| | Farmers | **0.020** | 0.51 | 0.29–0.90 |
| | Others | 0.383 | 0.80 | 0.48–1.33 |

The bold values indicate that $P < 0.05$, which is statistically significant.

**Table 3**
Associations between low ontological insecurity and the behavior of recommending anyone for COVID-19 vaccines in different models.

| Model | Stratification | *P* | OR | 95% CI |
|---|---|---|---|---|
| 1 | Total | **0.011** | 1.40 | 1.08–1.81 |
| 2 | Men | **0.018** | 1.57 | 1.08–2.29 |
| | Women | 0.202 | 1.26 | 0.88–1.81 |
| 3 | 18–59 years | **0.003** | 1.65 | 1.18–2.30 |
| | ≥60 years | 0.944 | 1.02 | 0.67–1.54 |
| 4 | Farmers | 0.931 | 1.02 | 0.69–1.49 |
| | Non-farmers | **<0.001** | 1.86 | 1.30–2.65 |
| 5 | Vaccinated | **0.005** | 1.66 | 1.16–2.37 |
| | Unvaccinated | 0.502 | 1.14 | 0.78–1.67 |

Model 1: adjusted for sex, age, education, occupation, and self-vaccination status.
Model 2: adjusted for age, education, occupation, and self-vaccination status.
Model 3: adjusted for sex, education, occupation, and self-vaccination status.
Model 4: adjusted for sex, age, education, and self-vaccination status.
Model 5: adjusted for sex, age, education, and occupation.
The bold values indicate that $P < 0.05$, which is statistically significant.

related to sex, age, education level, occupation, and vaccination (Table 1).

*Ontological insecurity and two vaccination behaviors*

The mean (±SD) score of ontological insecurity was 13.27 ± 7.84, and was higher in those who did not recommend others for vaccination than in those who did (12.95 ± 8.25 vs 14.00 ± 6.78, $P = 0.022$). The patients were divided into high and low ontological insecurities, with a cutoff of 13. The results of the univariate analysis (Table 1) revealed that patients with a lower score of primary ontological insecurity were significantly more likely to recommend vaccination against COVID-19 than those with higher scores of ontological insecurity (72.6% vs 65.5%, $P = 0.008$).

We further calculated the magnitude of the association between ontological insecurity and the behavior of recommending COVID-19 vaccines to anyone in a binary logistic regression model. As shown in Table 2, ontological insecurity (low vs high: OR = 1.40, 95% CI: 1.08–1.81, $P = 0.011$) and vaccination themselves (yes vs no: OR = 2.17, 95% CI: 1.67–2.82, $P < 0.001$) were significantly associated with the behavior of recommending anyone for COVID-19 vaccines after adjusting for the demographic variables. Moreover, the elderly and farmers were not likely to recommend vaccination against COVID-19.

Contrariwise, there was no difference in the score of ontological insecurity between the vaccinated and unvaccinated groups (13.22 ± 7.96 vs 13.35 ± 7.67, $P = 0.779$). Therefore, vaccination behavior was not associated with ontological insecurity ($P = 0.781$; Table 1).

*Associations between ontological insecurity and behavior of recommending vaccination in different subgroups*

We further performed multiple logistic regression models with different stratifications according to sex, age, occupation, and vaccination status. As displayed in Table 3, overall low ontological insecurity increased the likelihood of recommending COVID-19 vaccination behavior (OR = 1.40, 95% CI: 1.08–1.81, $P = 0.011$). Specifically, the associations were only observed in men (OR = 1.57, 95% CI: 1.08–2.29, $P = 0.018$), adults aged 18–59 years (OR = 1.65, 95% CI: 1.18–2.30, $P = 0.003$), non-farmers (OR = 1.86, 95% CI: 1.30–2.65, $P < 0.001$), and the vaccinated subgroups (OR = 1.66, 95% CI: 1.16–2.37, $P = 0.003$).

## Discussion

*COVID-19 has brought great uncertainty to society and triggered people's ontological insecurity*

A model of ontological insecurity constructed from a sociological perspective showed that social uncertainty plays a growing role within a general framework of subjective insecurity.[12] Individuals' ontological security is often integrated unperceived into their daily lives. However, imperceptible concepts become easier to perceive

when the external environment is threatened by drastic changes. The perceived scarcity of ontological security diminishes confidence in the continuity of self-identity and disturbs a sense of trust and stability.[13] COVID-19 has brought great uncertainty to society, broken people's daily life order, and elicited much COVID-19-related stress and mental health problems like sleep shortness, shortness in temper, family discord,[14] and suicide.[15] During the COVID-19 crisis, many households experienced the lockdown in vulnerable situations and their ontological security was severely weakened.[16] Research in Australia also illustrated that the uncertainties created by the COVID-19 pandemic triggered ontological insecurity.[17]

*Ontological security influences people's behavior in a crisis*

Research suggests that ontological security is a better predictor of the impact of social and environmental changes on personal security during a pandemic; moreover, it is also a better predictor of people's behavioral trends during a crisis.[18] A study on migrant workers found that people who feel insecure are more likely to engage in risk-taking behaviors.[19] Our recently published study also suggested that ontological insecurity mediated the effects of pandemic-induced disruption to inpatients' lives on their prevention behavior—including washing their hands, wearing facial masks, and social distancing.[20] We also found the more ontologically secure people were, the more inclined they were to choose the behavior of recommending vaccination. This was found especially in men, adults aged 18–59 years, non-farmers, and vaccinated groups.

Ontological security is 'not simply a matter of self-preservation or self-interest,' but relies on 'the well-being of others as well.'[21] As ontological security is essentially a form of trust in continuity, the sense of insecurity reflects a lack of trust and poor relationships. Actively encouraging peers, relatives, and friends to get vaccinated is a sign of good social relations. A discrete choice experiment showed that peer influence and social norms are critical in vaccine decision-making.[22] The behavior of recommending vaccination to others is not only beneficial to others but also to oneself. For most patients with contraindications to vaccines, encouraging others to receive vaccines can build up immunity in the vaccinated individuals and provide a benefit to others in the community via herd immunity, which uses the altruistic nature of vaccines to reduce the opportunity of infection. From a public health perspective, one of the effective vaccination strategies relies on altruistic motivations rather than self-interested goals.[23]

*Ontological security, individual risk attitudes and vaccination decisions*

As discussed earlier, a perceived scarcity of ontological security can drive people to adopt risk-taking behaviors; conversely, perception of ontological security may influence people to choose risk-averse behaviors. Risk aversion may affect a decision to be vaccinated in two opposite ways: some choose vaccination because they fear the consequences of an infectious disease, whereas others choose not to be vaccinated because they worry about the vaccine's side effects.[24] The research involving the econometric model based on bounded rationality shows that risk aversion has a positive effect on the decision to be vaccinated, a finding that implies that the impact of perceived effectiveness of vaccination outweighs the impact of its perceived side effects.[24,25] Another study also found that risk-averse French general practitioners were more inclined to vaccinate against influenza—both for themselves and their patients.[26]

The results of this study showed that ontological security was associated with the behavior of recommending COVID-19 vaccines to others, although the association with self-vaccination behavior was not statistically significant. Participants with higher levels of ontological insecurity were less likely to recommend others for vaccination against COVID-19. As a risk-averse behavior, encouraging others to get vaccinated can both prevent them from suffering from adverse reactions to the vaccine and protect them from infection caused by the altruistic nature of the vaccine. Accordingly, our results are consistent with established theories of ontological security and decision-making under risk. Therefore, the findings suggest that improving people's perception of ontological security is helpful in promoting and encouraging them to receive COVID-19 vaccines.

*Public health implication*

The prospect theory states that individuals are inclined to make risk-seeking or risk-averse choices based on how a health-related message is presented. Therefore, because of the phenomena of risk aversion, information framing that emphasizes the positive aspects (i.e. gain frames) leads to more risk aversion, whereas that which emphasizes equivalent negative aspects (i.e. loss frames) leads to riskier decisions.[27,28] Consequently, to boost vaccine uptake, the government should vigorously promote the effectiveness of vaccines in a positive way, so that people—especially the elderly and those with underlying diseases—understand the benefits of vaccination and are more likely to make risk-averse choices. Meanwhile, the accessibility and orderliness of vaccination is also critical to increase the perception of ontological security, thereby increasing the tendency of recommending others for COVID-19 vaccines.

The dramatic threat posed by COVID-19 not only disrupts people's sense of ontological security but also triggers adaptive responses from governments, institutions, and individuals. As an adaptive response, vaccination is an effective measure to control epidemics that many governments are vigorously promoting. Vaccination is viewed not only as self-interested, but more importantly as altruistic because some vaccines are more beneficial to society than to vaccine recipients, who experience related adverse effects.[29] In the present study, 75.2% of the COVID-19 vaccine recipients recommended others for vaccination. Interestingly, 60% of the participants who were not yet vaccinated reported that they would also recommend others to get vaccinated. Most of the unvaccinated participants (70.7%) had contraindications to vaccination. Given this, to promote vaccination among this group, multidisciplinary treatment and integrated disease management are needed to improve their fulfillment of the vaccination requirements. Moreover, unvaccinated participants with vaccine contraindications were more likely to recommend vaccination than those who were not vaccinated for other reasons (65.1% vs 47.9%, $P < 0.001$). We argue that unvaccinated people, because of contraindications, may not be willing to be self-vaccinated. However, further evidence is needed in the future. From the perspective of evolutionary game theory, those who disregard preventive measures, including vaccination, can be seen as free riders[30] and their motivation for free-riding behavior may be dominated by their peers.[31] Finally, it is necessary for policymakers to use altruistic motivations[23] and peer persuasion[32] to encourage and promote vaccination.

*Methodological considerations*

To the best of our knowledge, this study is the first to explore the influence of ontological insecurity on vaccination behavior against

COVID-19 among hospitalized patients in Taizhou, China. The results demonstrated that the hospitalized patients' sense of ontological security was not too low in the context of the COVID-19 epidemic. Individuals with a high sense of ontological security had greater confidence in the sustainable stability of their environment and a greater sense of self-identity. Their self-vaccination behavior was not influenced, but they were more likely to have good practices in the recommendation of vaccination to others.

Nevertheless, this study has some limitations. First, the study sample was only inpatients at a regional hospital, likely indicating a selection bias. The results of this study may have limited generalizability, but they are useful for promoting vaccination strategies. Second, more poorly educated farmers and workers were included who might not have fully understood the content of the questionnaire. The accuracy of their information may not be guaranteed, although uniformly trained nurses have explained some obscure items of the questionnaire. Third, the bias resulting from unknown factors may have confounded the results. More relevant clinical variables were unavailable owing to the anonymity of the questionnaire. Finally, our data were collected only at one time point and we could not investigate the impact of an outbreak on ontological security. Further longitudinal studies are needed to verify the causal relationship between ontological security and health-promoting behaviors.

### *Conclusions*

In summary, this study presented the level of ontological security of hospitalized patients and found a positive association between their ontological security and behavior of recommending the COVID-19 vaccination to others. The results provided a reasonable theoretical basis for the development of vaccine promotion strategies. Accordingly, people's perceptions of ontological security and vaccination altruism can be used to promote vaccination plans through peer persuasion.

## Author statements

### *Acknowledgements*

We would like to thank participants for their cooperation and support, and Editage (*www.editage.cn*) for English language editing.

### *Ethical approval*

This study was exempted from the requirement for written informed consent and was approved by the Ethics Committee of Taizhou Hospital of Zhejiang Province (approval number: K20210521) in China. All procedures were performed in accordance with the guidelines of the institutional ethics committee of the authors and adhered to the tenets of the Declaration of Helsinki.

### *Funding*

This study is supported by grants from the National Natural Science Foundation of China (72074189).

### *Competing interests*

All authors declare that they have no conflict of interest.

### *Author contributions*

H-X Chen and T-H Tung conceived the study. M-X Zhang, G-F Shi, X–Y Wu and T-H Tung designed the questionnaire. W-Z Wang and F-M Cheng collected the data. M-X Zhang, C Luo and T-H Tung analyzed and interpreted the data. M-X Zhang and G-F Shi wrote the first draft of the paper and interpreted the relevant literature. C Luo, X–Y Wu, W-Z Wang, F-M Cheng, H-X Chen, and T-H Tung edited and approved the final manuscript.

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Public Health 211 (2022) 122–127

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

# ‘Give us the real tools to do our jobs’: views of UK stakeholders on the role of a public health objective for alcohol licensing

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ARTICLE INFO

*Article history:*
Received 14 April 2022
Received in revised form
30 June 2022
Accepted 10 July 2022
Available online 14 September 2022

*Keywords:*
Alcohol
Licensing
Public health policy
Regulation
Local authorities

ABSTRACT

*Objectives:* This study ascertains the views of UK stakeholders on the actual, and possible, impact of a public health licensing objective in their day-to-day work.
*Study design and methods:* Twenty-eight interviews were conducted with members of public health teams who were actively engaged in alcohol licensing in their local area between 2017 and 2019. Six teams were based in Scotland (where there is a public health licensing objective) and 14 in England (where there is no similar objective).
*Results:* Scottish participants reported that while challenges remained in applying the public health licensing objective, progress had been made and the objective was beneficial to their work. Participants in England felt that an objective would increase the legitimacy, value and impact of their contributions. In both Scotland and England, constructive relationships between PHTs, licensing authorities and other key stakeholders were developing suggesting that PHTs could have a sustainable and positive role in licensing.
*Conclusions:* In many Scottish areas, the alcohol licensing system is evolving to take constructive account of its public health objective. In England, PHTs that have invested resources in engaging in this area have demonstrated an ability to work effectively within licensing systems. Strong support for the adoption of a public health licensing objective among these PHTs adds weights to calls for the UK Government to reconsider its previous decision not to introduce such an objective.


## Introduction

In the UK, alcohol retail is regulated through a system of local licensing. In England and Scotland, separate primary legislation empowers local authorities to decide whether to grant licences, and what conditions to place on licences that are approved. Although England and Scotland introduced similar reforms to licensing in 2003 and 2005 respectively, recent alcohol policy in Scotland has adopted a stronger public health focus.[1–4] This has led to key policy divergences, including the adoption of minimum unit pricing for alcohol in Scotland, that reflect not only greater political consensus on the need to tackle alcohol-related harms (which have historically been higher in Scotland) but also a desire on the part of the devolved administration to adopt distinctive public health policies relative to the rest of the UK.[5–7] The legislation introduced in 2003 and 2005 established the principle that licence applications should be approved unless they risk contravening specific ‘licensing objectives’. In England and Wales, those objectives are as follows: the prevention of crime and disorder; the protection of children from harm; the protection of public safety; and the prevention of public nuisance. Scottish licensing has four similar objectives, but also ‘protecting and improving public health’. The inclusion of this ‘fifth’ licensing objective in the 2005 Licensing (Scotland) Act is an early example of alcohol policy divergence in regard to the role of public health, which has created a significant difference in the operational framework for licensing between the two nations. Both systems create ‘responsible authorities’ (RAs) who have a formal role as respondents to individual licensing applications and as key

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https://doi.org/10.1016/j.puhe.2022.07.006

consultees in the development of local licensing policies. Local public health teams (PHTs) were included as RAs from 2011 in Scotland and 2012 in England.[8,9] The addition of PHTs as RAs led to regional and national action to support public health involvement in licensing.[10–12]

In 2018, 97% of licence applications in both England and Scotland were successful.[13,14] Nevertheless, the 2003 and 2005 Acts set out instruments to address high alcohol outlet densities. Every five years licensing authorities must produce Statements of Licensing Policy (SLP) establishing the policy framework for licensing decisions. In Scotland, SLPs must include a statement identifying any areas considered 'overprovided' with alcohol outlets.[1] In England, local authorities may, but are not required to, create Cumulative Impact Zones (CIZ) following consultation.[2] In overprovision areas and CIZs, the presumption that new licences will not undermine licensing objectives is reversed, and applicants must demonstrate that this will not be the case. In 2012, the UK Government committed to exploring the introduction of a public health licensing objective in England and Wales specifically linked to cumulative impact policies.[15] However, the proposal was dropped following consultation on the grounds that 'local processes and data collection are insufficient, meaning that it is unclear how this proposal could be implemented in practice'.[16]

In Scotland, implementation of the public health licensing objective is supported by advocacy and structured guidance from Alcohol Focus Scotland (AFS), a national organisation campaigning for policies to reduce alcohol harm.[10,17–19] It produces key reports, national events and guidance aimed at ensuring PHTs play an active role in licensing practice. In England and Wales, regional advocacy organisations have supported local PHTs in licensing activity while also campaigning for the establishment of a public health objective.[20,21] Public Health England (PHE) and the Local Government Association (LGA) have both actively supported public health involvement in licensing.[12,22,23] PHE also supported pilots to test the feasibility of a public health objective following the creation of Local Action Alcohol Areas in 2016.[24–26]

Previous research has found that the omission of a public health objective from English legislation undermined PHT's influence on licensing.[27–30] PHTs in England reported experiencing low status within the licensing system, though some had developed working relationships with other RAs. In Scotland, some PHTs reported difficulties applying the public health objective, partly due to naïve expectations around how public health evidence would impact decision-making within a complex licensing system.[31,32] Wright (2019) found some Scottish PHTs felt that the failure of licensing boards to routinely prioritise health considerations showed insufficient accountability to the intentions of the primary legislation.[33] Public health engagement in Scotland has varied, with influence often dependent on the support of local champions within the licensing system.[34] Grace et al. (2016) found that English PHTs struggled to make their input relevant to individual outlets, and so have tended to focus more on area-level interventions such as SLPs and CIZs.[35] Among more active PHTs, a range of approaches to engagement have emerged ranging from 'challenging' engagement, aimed primarily at reducing availability, to more pragmatic, collaborative forms of partnership working aimed at ensuring best use is made of local public health data to improve local outcomes.[20,36,37]

This article focuses on findings from a multisite study of stakeholder opinions using qualitative research methods, which forms part of the Exploring the impact of licensing in England and Scotland (ExILEnS) study.[38] One focus of this study was PHT views on the role of a public health objective in supporting engagement with licensing teams. This is the first qualitative study of this question covering, and comparing, both England and Scotland.

## Methods

In 2017–18, with support from PHE and AFS, all PHTs in England and Scotland were informed of the proposed study via email and invited to participate.[38] Of 44 PHTs who expressed an interest, 40 were selected to ensure the sample was representative of 1) diversity of regionality and urban/rural setting, and 2) relative intensity of PHT activity in licensing in the period 2012–8. The profile of participating areas is summarised in Table 1. The relative intensity of PHT activity was ascertained through desk research (local policies and published case studies) advice from expert partners (e.g. PHE) and scoping interviews with potential participants. Our study protocol, including the sampling strategy, was published at the start of the project.[38] At the sampling stage, 'higher' activity was determined broadly through actions such as allocating dedicated PHT resources to licensing issues, routine analysis of relevant data, having contributed to reviews of licensing policy, or having made representations regarding premises licence applications. A detailed measure of activity intensity was developed postrecruitment to allow quantitative assessment of the relationship between PHT licensing input and health outcomes, which is reported elsewhere[40] The sample was split into 20 'high' and 20 'low' intensity areas, though one lower activity area did not participate in data collection leaving 39 areas in total. For this study, the 20 'high' intensity areas were selected to qualitatively explore the experiences of professionals where efforts towards engagement had occurred. Of these, 14 PHTs were in England and six in Scotland.

For each study area, potential interviewees were identified through direct contact, site visits and snowball sampling. We aimed to recruit participants with strategic leadership roles in regard to PHT engagement with licensing in their area. Twenty-eight participants were recruited across the 20 areas (1 PHT interviewee in 20 areas; 2 in 7 areas, 3 in 1 area). In single areas where relevant roles were split or shared across posts, we aimed to speak to all key individuals. A topic guide was developed based on preliminary desk research and following discussions within the research team (Supplementary file 1).

Participants took part in an in-depth, audio-recorded, one-to-one interview lasting between 32 and 156 min (median: 72 min). Interviews were transcribed, anonymised and imported into NVivo 12 for analysis. Coding against thematic categories was carried out using deductive (reviewing research questions and topic guide) and inductive (transcript analysis) approaches. Codes were developed iteratively, with ongoing refinements based on data re-examination and reflective team discussions.

All participants were provided with an information sheet and had the opportunity to discuss the study with the team before consenting to take part. A consent form was completed on behalf of the team by the lead professional, usually the Director of Public Health. Individuals participating in in-depth interviews received a separate information sheet about participation and completed separate written consent forms.

## Results

### *Making public health an equal partner in the licensing system*

The premises-based focus of licensing means that PHTs face challenges in influencing decisions, especially compared to the police – who have routine involvement with licensed premises in their area.[30] English interviewees consistently described feeling that public health remained, at best, a junior partner in the licensing process. The lack of a public health objective exacerbated this perception:

**Table 1**
Profile of participating areas.

| England (n = 27) | Scotland (n = 12) |
|---|---|
| London and South East 11 | West 6 |
| North West 6 | East 4 |
| North East and Yorkshire 4 | Northeast 2 |
| South West 3 | |
| East 3 | |
| **Local authority type** | Type of local authority is not applicable in Scotland. |
| Unitary: 13 | |
| Lower tier: 14 | |
| **Urban-rural classification** | Urban rural classification not provided for Scotland as it would be likely to identify participating areas. |
| 1 (most rural): 1 | |
| 2: 2 | |
| 3: 5 | |
| 4: 13 | |
| 5: 0 | |
| 6 (most urban): 6 | |

*Having health as a licensing objective is not the be all and end all, but I think it would help significantly in terms of Public Health's role as a responsible authority. And I think that's the key issue. If we're a responsible authority, then give us the real tools to do our jobs effectively […] It feels like we're a responsible authority without any teeth really. (Area 23, England)*

*If health or public health was a licensing objective […] it would strengthen the amount of work that goes on. It would raise the profile and it would also mean that we would be probably respected as much as if the police put in […] a representation. (Area 16, England)*

Scottish interviewees, while recognising the ongoing limitations of their role, noted the positive operational impact of having a public health objective, with many feeling it was essential to their work:

*I can't underestimate the value of it being written down […] with it being within a law. […] It probably does make it easier in one sense to certainly quote something when you're challenging an application, and it gives it the weight of the research. That's behind why that's an objective in the first place (Area 28, Scotland)*

Previous research has highlighted the challenges in applying the public health objective in Scotland.[31,34,41] Participants remained conscious of limitations in the applicability of the public health objective, especially when there was a need to make claims about causal links between individual premises and health outcomes. However, participants also reported that it gave their engagement a vital degree of statutory weight. There was evidence that early challenges were being resolved in some areas, and modes of practice were adopted, which made the application of the objective more practical and meaningful. Several Scottish PHTs reported that involvement in the development of local SLP, including the establishment of 'overprovision' areas, had improved over time as more sustainable structures for advanced planning with partners developed. In other cases, PHTs felt that they had established stronger working relationships within key bodies, such as the Local Licensing Forums:

*One of the things that's been really successful is, first of all, the Local Licensing Forums: our role in the Local Licensing Forums. It's been consistent from the very start, and we've had Public Health representation … I really think that's helped drive the public, the licensing forum forward (Area 19, Scotland)*

While not leading to the kind of availability reductions that some people within Scottish PHTs may have initially hoped for, there was a growing sense that PHT engagement could contribute in less direct ways to improvements in licensing practice.

### *Moving upstream*

Early experiences of Scottish PHTs highlighted the difficulty of establishing causal relationships between single outlets and public health outcomes.[35,41,42] Consequently, it became clear, in both England and Scotland, that public health engagement was likely to be most relevant to area-level considerations – even while premises-specific input remained an option. This meant moving the focus upstream to look at overprovision, CIZs and SLPs.

*I think for a while people thought we were talking about removing licenses. And that's obviously not something that's possible through legislation. But what we can do is say 'Actually we have enough, and we don't think there is a requirement for any more.' So, and again it's that shift isn't it: from looking at it from a case-by-case basis to actually thinking about the wider, whole population approach (Area 34, Scotland)*

While PHT involvement at area level was expected to have a tangible impact – through, for instance, supporting the establishment of overprovision and cumulative impact policies – interviewees also saw a key role for public health in 'setting the scene' for licensing decision-making. That is, providing the broader health-related evidence needed to place individual applications, or policy decisions, in context:

*So, we just generally […] set the scene. So, we'll talk about issues in that particular area, in that particular ward, where the licence application's coming from; look at deprivation, health related information, and any particular concerns we've got with the application. (Area 26, England)*

For English interviewees, the capacity to have an impact at a strategic level was constrained by the lack of a public health objective. By contrast, Scottish interviewees felt the existence of a

public health objective made a significant difference to their ability to influence area-level planning:

> *Getting people to start thinking, or boards to start thinking, a bit wider than just the case by case. So, I think that has been a challenge. But to be fair, having that objective in there has really been supportive for us. (Area 34, Scotland)*

> *[The public health objective] probably does make it easier […] it probably adds to the confidence of an individual licensing board. (Area 28, Scotland)*

Interviewees in England also felt that placing public health considerations on a more formal statutory footing would help applicants and, potentially, reduce the need for representations to be made:

> *It would help in terms of supporting us making the case from the health perspective. But actually, I think if it was actually there, it's that more upstream effect. So, when people are actually putting the licence application in, they're going to be thinking themselves about what they're doing. (Area 39, England)*

A public health objective was not, therefore, seen in narrow terms as an instrument by which to prevent licence applications from being approved. Rather it was viewed as a means of further embedding public health considerations within the licensing systems, ensuring they were given equal weighting with crime prevention, nuisance and the protection of children.

*Developing partnerships with responsible authorities*

Interviewees in both England and Scotland reported establishing partnerships, or working collaboratively, with other RAs. For some, this was experienced as an inevitable consequence of PHT involvement rarely being, by itself, sufficient to generate action. It was reported variously that the lack of a public health objective is a 'frustration' (Area 16, England) that 'hinders [PHT activities] to a degree' (Area 26, England) and causes representations to 'feel a little contrived' (Area 27, England).

> *From the start, we're tied into that grid that we don't actually fit in, and we've come in with a crime and disorder hat because we had some data that helped. So, I think that has been restricted. (Area 25, England)*

For others, however, collaboration was seen as enabling stronger representations to be developed, while helping to ensure that public health considerations were established as routine within the thinking of key decision-makers:

> *I think the most successful way to manage or regulate alcohol under a Licensing Act is actually to have several responsible authorities working together. And that's where you get your real success in the Licensing Committee: when, rather than going as just one Responsible Authority, you get three or four coming. (Area 38, England)*

In areas in England where PHTs had made efforts to engage in a sustained way, collaboration and coordination not only helped provide a route for public health evidence to influence decision-making but also established PHTs as trusted and constructive partners in the wider network of RAs and other key stakeholders.

*Developing a meaningful role in the licensing system*

Interviewees in England reported finding pragmatic ways to develop a meaningful role within the licensing system, albeit without having the degree of autonomy and power that they may have preferred. Some were satisfied with the role as it stood under the current legislation. Most, however, reported that while such arrangements were constructive, they were workarounds put in place to mitigate the limitations caused by the lack of a public health objective.

> *Not having a licensing public health objective doesn't stop us doing what we do. But, just having a public health objective, would make it easier. So, when I say it's a frustration, it would just be that it would give us the ability to make things easier for us. But actually, what we do is that we use those licensing objectives that we've got and use them creatively. (Area 38, England)*

Therefore, while frustrated by the lack of a public health objective, pragmatic strategies were being developed that allowed for a level of meaningful engagement. Interviewees understood that the realistic impacts were constrained not only by the lack of a public health objective but also by well-established norms of decision-making in this setting. They did not see a public health objective as uniquely transformational, but rather as a necessary contribution to a broader strengthening of public health considerations in this area.

## Discussion

*Main findings of this study*

Our findings show strong support among participating PHTs in England for the introduction of a public health objective for licensing in England and Wales. Interviewees felt it would raise the profile of public health within the licensing system, enable a more proactive consideration of how premises could operate more responsibly, and provide structure and legitimacy to both representations and strategic engagement. Many felt that a public health licensing objective would also better enable the use of health data – such as alcohol-related harm trends, A&E visits, or ambulance call-outs – to inform planning and policy. The adoption of a public health objective in Scotland, and its significance as part of a broader public health-oriented suite of alcohol policies, clearly provided an aspirational model for public health professionals in England. Participants were pragmatic, however, in regard to what was achievable. Few felt such an objective would (or necessarily should) significantly reduce outlets in a given area, especially in the short term; rather it would help develop a practice culture in which public health was a routine consideration. Interviews demonstrated that strong and constructive partnership-working between PHTs, licensing authorities and other Responsible Authorities was possible despite differences in approach, priorities and the uses of evidence.

*What is already known on this topic*

Previous studies have found that public health professionals experience frustration when engaging with alcohol licensing, and that they often feel undervalued in the process.[27–30,33,35] Some PHTs have held naïve, or overly optimistic, expectations about their potential impact, while others have taken a more pragmatic view of their role in a complex system that applies different approaches to evidence.[20,31,32,43,44] Previous reviews of the operations of the public health licensing objective in Scotland have found that

implementation was often hampered by lack of clear understanding of how the objective could be applied in practice and friction between PHTs and licensing teams.[17,31,34,45]

*What this study adds*

This is the first study of the debate over a public health objective to compare experiences of Scottish and English PHTs in the context of changes over time. Responses from Scottish participants here suggest early challenges have, to some degree, been addressed: PHTs in Scotland routinely provide input into local SLPs and have become increasingly confident in establishing a sustainable and constructive role, making use of the public health objective – including in support of the establishment of 'overprovision' areas. English PHTs also reported developing increasingly constructive relationships with other Responsible Authorities. However, in England, there remains a widespread perception that the ability to influence both decision-making and strategic policy is hampered by the lack of a public health objective.

*Limitations of this study*

Interviews on this topic were only carried out with PHTs that were deemed to have been actively engaged with licensing during the study period. Therefore, they represent the experiences of teams that had invested significant capacity and resource into licensing activity. The experiences of PHTs that were not actively engaged in licensing, whether due to lack of capacity, resource or motivation cannot be inferred directly from this data. The selection of only 'high' intensity areas creates a risk of participant responses being biased towards either emphasising success or providing information useful to a study perceived as oriented towards supporting the creation of a public health licensing objective. To mitigate this, our interview questions invited reflection on both positive and negative experiences, including unintended consequences; and participants were not guided specifically to comment, or take a position on, a public health licensing objective (though it was a prompt option for a general question on possible changes to the licensing system). Possible biases within the research team were considered throughout the data analysis and interpretation stage, and we sought to address these through reflective discussion.

*Conclusions*

These findings suggest relationships between diverse stakeholders in licensing in Scotland are developing constructively. However, while relationships are also developing in England, active PHTs continue to express frustration that their contribution is hampered by the lack of a public health objective, which necessitates procedural workarounds that create unnecessary barriers and blockages. These barriers, and the lack of presumed legitimacy, may partly account for the number of areas in England where engagement among PHTs remains low – though there remain areas of low engagement in Scotland too. At the same time, this study demonstrates that public health evidence can be usefully deployed in the licensing context, and that in many areas a culture of collaborative working has developed, which has allowed public health considerations to become a core feature of licensing activity. In 2013, the reason given by the UK Government for not implementing its proposal to create a health-based licensing objective for cumulative impact assessment was that 'more work is required at local level to put in processes to underpin it'.[16] This research suggests that such work is underway, and that in areas where this has occurred, PHTs are keen for the UK Government to reconsider following Scotland in putting public health considerations on a statutory footing.

## Author statements

*Acknowledgements*

This study has received grant funding from the UK National Institute for Health Research (Public Health Research programme, project number 15/129/11). The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health. The study funders had no role in the study design.

*Ethical approval*

The study was approved by the University of Stirling Ethics Committee for NHS, Invasive or Clinical Research (NICR 16/17 – 64) and the Research Ethics Committee at London School of Hygiene and Tropical Medicine (LSHTM 14283/RR/8365).

*Funding*

This study has received grant funding from the UK National Institute for Health Research (Public Health Research programme, project number 15/129/11).

*Competing interests*

James Nicholls was previously employed by Alcohol Change UK and has worked with Public Health England in an unpaid advisory role on alcohol licensing issues.

Laura Mahon is employed as Deputy Chief Executive of Alcohol Focus Scotland (AFS). AFS is a registered Scottish charity (SC009538) with the stated aim of reducing the harm caused by alcohol in Scotland.

Niamh Fitzgerald has received research or other support from charities and other organisations working to reduce harm from alcohol or on related issues including Scottish Health Action on Alcohol Problems, the Institute of Public Health in Ireland, Public Health Scotland, the Society for the Study of Addiction, and Alcohol Change UK.

*Authors' contributions*

JN, writing (original draft preparation); ROD, NF and LM, writing (editing and reviewing); NF, ROD, JN and LM, conceptualisation and methodology; NF, ROD and the ExILEnS Consortium, investigation, data collection and formal analysis; and NF, JN, LM and the ExILEnS Consortium, funding acquisition. All authors have approved this submitted version.

*Data availability*

All data requests should be submitted to the corresponding author for consideration. Access to anonymised data may be granted following review.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.07.006.

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Public Health 211 (2022) 1–4

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Short Communication

# Making integration foundational in population health intervention research: why we need 'Work Package Zero'

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ARTICLE INFO

*Article history:*
Received 7 March 2022
Received in revised form
22 June 2022
Accepted 26 June 2022
Available online 16 August 2022

*Keywords:*
Population health interventions
Evaluation
Integration
Public health
Policy

ABSTRACT

*Objectives:* We aimed to identify when and how integration should take place within evaluations of complex population health interventions (PHIs).
*Study design:* Descriptive analytical approach.
*Methods:* We draw on conceptual insights that emerged through (1) a working group on integration and (2) a diverse range of literature on case studies, small-n evaluations and mixed methods evaluation studies.
*Results:* We initially sought techniques to integrate analyses at the end of a complex PHI evaluation. However, this conceptualization of integration proved limiting. Instead, we found value in conceptualizing integration as a process that commences at the beginning of an evaluation and continues throughout. Many methods can be used for this type of integration, including process tracing, realist evaluation, congruence analysis, general elimination methodology/modus operandi, pattern matching and contribution analysis. Clearly signposting when integrative methods should commence within an evaluation should be of value to the PHI evaluation community, as well as to funders and related stakeholders.
*Conclusions:* Rather than being a tool used at the end of an evaluation, we propose that integration is more usefully conceived as a process that commences at the start of an evaluation and continues throughout. To emphasize the importance of this timing, integration can be described as comprising 'Work Package Zero' within evaluations of complex PHIs.


## Introduction

Population health interventions (PHIs) are upstream interventions with the potential to impact a large number of people at once, often with a focus on the prevention of disease and/or reducing inequalities in health outcomes.[1] Examples include sugar-sweetened beverage (SSB) taxes, large-scale infrastructure interventions to promote physical activity, minimum unit pricing for alcohol and restrictions on tobacco advertising.

Complex interventions are defined either by the nature of the intervention (e.g. number of components, range of pathways, etc.) or the nature of 'interactions between the intervention and its context.'[2] Given the importance of context to PHIs,[3] most can reasonably be thought of as complex interventions.

Evaluations of complex intervention often ask a research question that is some form of 'did it work?'[2] Although this is a crucial question, decision makers also need to know: 'should we do more of this or more of that?' and 'what happened? what did the PHI contribute?'[4] Addressing these questions often necessitates the use of multiple types of evidence and study types.

Accordingly, evaluations of PHIs typically include multiple methodologically distinct 'work packages' (WPs), each with specific research questions which together aim to deliver a holistic perspective on the intervention. Each WP corresponds to a distinct research question within the evaluation (e.g. concerning health-related outcomes, processes, economics, etc.) and usually involves the collection and analysis of different kinds of data. There is then often a WP with the aim of 'integrating' the different strands to answer a summative question about the PHI under study. This WP

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https://doi.org/10.1016/j.puhe.2022.06.028

is critical since 'without integration, questions are left unanswered and possibilities for deeper insights unexplored.'[5] In practice, this 'integration' WP is usually undertaken at the end of the study.

There are several challenges associated with 'integration' as a final WP. First, the evaluation team may find it challenging to know what to do with multiple findings at the end of a study, particularly when impending project deadlines limit time and resources available in the final months of an evaluation. Second, it might become clear that key 'bridging' analyses are missing, limiting the depth or nuance that can be brought out. Third, there may be a tendency for quantitative results to dominate qualitative ones in the final 'bringing together' process.[6]

We suggest that conceptualizing integration as 'Work Package Zero' will help embed integration within PHI evaluations, support evaluation teams to make the most of diverse types of evidence and produce holistic and complexity-informed insights regarding PHIs.

## Main text

### *What do we mean by 'integration'?*

The term 'integration' has many meanings.[7] We build on Woolley's definition and suggest that integration entails bringing together multiple components 'in such a way as to be mutually illuminating, thereby producing findings that are greater than the sum of parts.'[8]

Although integration is sometimes thought of as the mixing of quantitative and qualitative approaches, we posit that integration is relevant whenever multiple sources or types of data are used.[5]

We differentiate between integration and synthesis. Synthesis can be thought of as bringing together similar types of studies, each focused on different instances of a similar intervention. Integration can be thought of as bringing together different types of studies, each focused on the same instance of a specific intervention.

### *What methods can be used for integration in evaluations of population health interventions?*

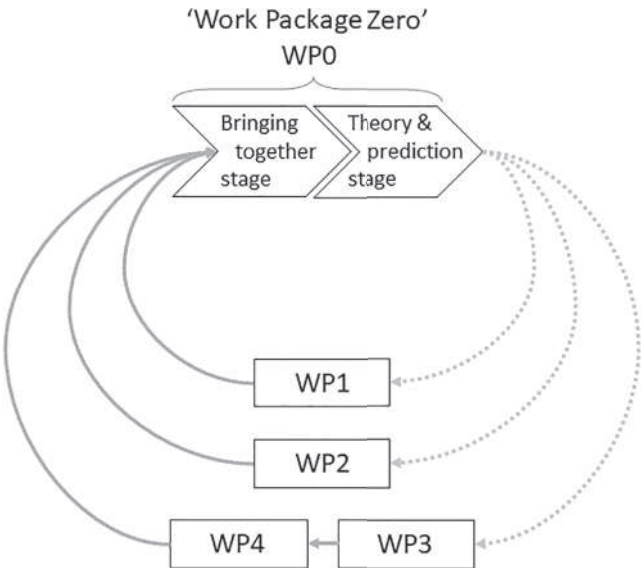
There are many methods available for integration in evaluations of PHIs, including process tracing, realist evaluation, congruence analysis, general elimination methodology/modus operandi, pattern matching and contribution analysis.[5,9] We summarize these methods in more detail in Table 1 and provide key references to methodological guidance and applied examples.

To varying degrees, all the aforementioned methods emphasize theory as the foundation for bringing together multiple types of findings. Some methods focus on the intervention's theory of change (e.g. contribution analysis, pattern matching). Others emphasize greater engagement with the broader theoretical literature (e.g. process tracing, realist evaluation) through middle-range theory[10] and theories about social mechanisms, and may enrich PHI evaluations by encouraging evaluators to think beyond intervention theory. This engagement with higher-level theory would enable evaluators to build on, test and refine theories related to underlying causal mechanisms with broader applicability.

**Table 1**
Integrative methods for evaluation of population health interventions.

| Integrative Methods | Description | References | Applied Example in Evaluation |
|---|---|---|---|
| Contribution analysis | "aims to compare an intervention's postulated theory of change against the evidence […] to critically construct a 'contribution story' which builds up evidence to demonstrate the contribution made by an intervention, while also establishing the relative importance of other influences on outcomes"[9] | Methods: Mayne 2008,[11] Mayne 2012[12]<br>Examples: Belcher et al., 2017,[13] Befani & Mayne 2014[14] | A sustainable forestry management program in the Congo Basin.[13] |
| General elimination methodology/Modus operandi/Congruence analysis | "The methodology entails systematically identifying and then ruling out alternative causal explanations of observed results."[9]<br>Used to ask "which explanatory approach provides more/new insights?" and to compare "the descriptive and explanatory merits of different theories"[15] | Methods: Blatter 2012,[15] Scriven 2008[16]<br>Examples: Wauters and Beach 2018[17] | A career coaching program with Flemish adults.[17] |
| Pattern matching | "Pattern matching involves the specification of a hypothesized pattern, the acquisition of an observed pattern using empirical data, and an attempt to match the two. This moves beyond single hypothesis testing because the complexity of the pattern is important."[18] | Methods: Trochim 1989[19]<br>Examples: Foley et al., 2022[18] | Travel behaviours (amount, mode of choice) in Africa, with a focus on gender and socioeconomic differences.[18] |
| Process tracing | "Process tracing (PT) is a form of within-case analysis that makes inferences to the best explanation of a case based on evidence, including the temporal sequence of events."[20] | Methods: Beach and Pedersen 2019,[21] Bennett and Checkel 2014,[22] Fairfield and Charman 2017[23]<br>Examples: Raimondo 2020,[24] Alvarado et al., 2021,[25] Wauters and Beach 2018,[17] Befani & Mayne 2014[14] | A risk signalling effect around sodas and sugar-sweetened juices following the introduction of the Barbados SSB tax[25] |
| Realist evaluation | "Sets out to test a Middle Range Theory (MRT), detailing how the mechanisms initiated by a programme should cause desired outcomes. […] Pawson and Tilley (1997) sum this up as 'mechanisms + context = outcomes'"[9] | Methods: Pawson and Tilley 1997,[26] Pawson and Tilley 2009[27]<br>Examples: Renmans et al., 2020,[28] Marchal et al. 2010[29] | A performance-based financing intervention focused on health centres and hospitals in Western Uganda.[28] |

Note: The methods listed in this table are not exhaustive, but are provided as an indicative list of potentially integrative methods that can be useful for population health intervention (PHI) evaluators.




*Notes: WP = work package. Dotted grey lines correspond to the ways WP0 informs subsequent WPs; solid grey lines correspond to the data, analyses and findings resulting from the empirical WPs which become inputs into the second stage of WP0.*

**Fig. 1.** Conceptualizing integration as 'Work Package Zero' within evaluations of population health interventions.

*Integration as 'Work Package Zero'*

We suggest that PHI evaluations would benefit from conceptualizing integration as a process that commences at the start of an evaluation — the so-called 'Work Package Zero' or WP0.

In practice, many of the PHI evaluations that we have worked on position integration as something to be done at the conclusion of a project (e.g. the final WP). However, many integrative methods (such as those listed earlier) are more appropriately seen as 'umbrella methods' which encompass the entire evaluation. These methods require substantial up-front work before any empirical evidence is collected or analysed and involve continued appraisal/updating throughout the evaluation.

As Fig. 1 illustrates, WP0 is both central to an evaluation and inclusive of both the starting and endpoint within an evaluation. Although the specific approach will vary depending on the integrative method chosen, the early stages of WP0 tend to involve the identification or development of theory and predictions about the corresponding evidence that may be found. Dotted grey lines highlight the ways this stage of WP0 helps to identify, prioritize and justify the choice of empirical analyses (represented here as WP1–4).

The solid grey lines depict the empirical analyses being brought together in the context of the theory and predictions identified previously. The initial work completed within WP0 provides guidance on how to analyse data from multiple sources or analyses, interpret findings and revise, refine or refute the initial theory or theories. Emergent hypotheses not explicitly identified at the outset may also be developed and inform the revised theory within WP0, and lead to further analyses. Additional interconnections between WPs likely exist — for simplicity, we have streamlined the figure.

*What are the benefits of, and barriers to conceptualising integration as 'Work Package Zero'?*

Conceptualising integration as WP0 may strengthen evaluations of PHI in several ways. First, this may reduce the chances of coming to the end of the evaluation without a clear idea of how to 'bring it all together.' Positioning integration as the first step in planning an evaluation will encourage researchers explicitly to consider and select an appropriate over-arching method at the start of a PHI evaluation. There are many methodological approaches that may be appropriate — we are not suggesting a new approach, but rather a further legitimization of best practices and a clear label (WP0) to communicate this to researchers, funders and other stakeholders.

Second, prospectively considering how various kinds of evidence will come together provides an opportunity for researchers to focus limited resources on the types of analyses with the greatest potential to discriminate between theories or increase understanding.

Third, identifying an approach for interpreting diverse types of evidence up-front gives each type a 'seat at the table,' putting qualitative insights on fairer footing in relation to quantitative insights.[6]

There are also challenges. Many of the methods described in Table 1 will be less familiar to population health evaluators, and require additional training, resources and time to conduct. These methods are infrequently published in population health journals, and some sensitization around these methods with peer reviewers, editors and funders may also be necessary.

However, if population health evaluators hope to elucidate the ways in which PHIs contribute to change and produce evidence to inform 'what next? and how should we improve the PHI?' it will be important to use multiple types of evidence and an over-arching integrative method.

*Conclusion*

In developing the idea for this commentary, we set out to identify methods to integrate different types of data at *the end* of a multicomponent PHI evaluation.[30] However, we found this conceptualization of integration did not bear out the promise of effective integration, namely producing insights that are greater than the sum of its individual parts. Rather than looking for a tool for use at the end of an evaluation, we found value in conceptualizing integration as something that starts at the planning stage and continues throughout an evaluation (WP0).

There are many methods that can be deployed in this type of integration. It will be instructive to compare and assess the relative strengths and limitations of these methods when applied in evaluations of PHIs. It will also be crucial to assess the extent to which 'integrative findings' are useful to decision makers in practice.

In some cases, especially for high-profile PHIs, multiple evaluations may be designed in parallel, with or without coordination. As a result, there may be multiple types of evidence available both within and across study teams that shed light on a particular aspect of the PHI under consideration, and the extent to which integration is feasible under these circumstances remains an open question.

We have focused on integration within evaluations of PHIs, but it will be valuable to consider whether this framing is useful in other evaluation contexts. Finally, it will be important for funders to recognize integrative methods as a valuable component of evaluation proposals and allocate resources as appropriate.

To highlight the importance of integration to both funders and researchers, we recommend the inclusion of a 'Work Package Zero' in future evaluations of PHIs.

## Author statements

### *Acknowledgements*

The authors would like to thank David Ogilvie, Louise Foley and Judith Green for very useful comments on early drafts of the figure and/or text.

### *Ethical approval*

This work did not require ethical approval.

### *Funding*

MA, HF, MW and JA are supported by the Medical Research Council (MRC) Epidemiology Unit, University of Cambridge [grant number MC/UU/00006/7]. MW and JA hold grants for evaluations of complex interventions from the National Institute of Health Research (PHR 16/130/01) and Biology and Biotechnology Research Council (BB/V004832/1), which also fund HF. MA is supported by the Wellcome Trust (218629/Z/19/Z), and TP and CA acknowledge research support from York University.

### *Competing interests*

The authors have no competing interests to declare.

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Public Health 211 (2022) 5–13

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

# Non-adherence to COVID-19 lockdown: who are they? A cross-sectional study in Portugal

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ARTICLE INFO

*Article history:*
Received 4 October 2021
Received in revised form
21 June 2022
Accepted 4 July 2022
Available online 11 July 2022

*Keywords:*
COVID-19
Lockdown
Adherence
Prevention
Non-pharmacological interventions

ABSTRACT

*Objectives:* The SARS-CoV-2 virus has spread worldwide, leading governments to implement mitigation measures. Understanding the reluctance to adhere to non-pharmacological interventions might help promote adherence to these measures. This study aimed to identify factors associated with non-adherence to the first lockdown in Portugal.
*Study design:* Cross-sectional study.
*Methods:* This study used data from a Portuguese community-based survey entitled 'COVID-19 Barometer: Social Opinion'. Data were collected on risk perception, health status and social experiences using a snowball sampling technique. The event of interest corresponded to participants who reported not staying home during the lockdown period, serving as a proxy for non-adherence to lockdown. Logistic regression was used to identify factors associated with non-adherence to the first lockdown.
*Results:* Responses from 133,601 individual questionnaires that were completed during the first week of the first lockdown in 2020 were analysed. A minority of participants (5.6%) reported non-adherence to lockdown (i.e. leaving home for reasons other than essential situations). Working in the workplace was the factor with the strongest association of non-adherence to the lockdown. Several other factors were also associated with non-adherence to the first lockdown; namely, being a man, being a student, having a low level of education, having a low income, living alone or with a high-infection-risk professional (e.g. doctor, nurse, pharmaceutical, health technician, firefighter, police officer, military, essential services worker), perceiving the risk of getting COVID-19 to be high, not having social support in case of infection, feeling agitated, sad or anxious every day, and considering the preventive measures to be unimportant or inadequate.
*Conclusions:* Non-adherence to lockdown was associated with socio-economic, trust and perception factors. Future research should investigate the mechanisms underlying these associations to help identify the population groups who are most at risk of non-adherence.


## Introduction

At the end of 2019, a new coronavirus (SARS-CoV-2), which causes COVID-19, was found and rapidly spread worldwide. As of 19 May 2022, 519, 467, 357 cases and 6,277,833 deaths have been reported due to the SARS-CoV-2 virus.[1] Restrictive measures were implemented to control the transmission of the virus, such as banning gatherings, closing public spaces, limiting working hours, introducing remote working as the preferred work environment, and promoting infection control measures, such as respiratory etiquette, frequent hand washing, reduction of facial touch and physical distancing.[2] These measures reduced further COVID-19 transmission and mortality in several countries,[3–5] including Portugal.[6]

Lockdowns have been one of the most widely implemented non-pharmaceutical interventions adopted by governments to help reduce the spread of SARS-CoV-2.[7,8] In Portugal, the first national lockdown started on 22 March 2020 and people were asked to stay at home and leave only for essential reasons. Although the

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https://doi.org/10.1016/j.puhe.2022.07.001

effectiveness of lockdowns relies on community adherence,[9–11] citizens behave differently to restrictions.[12,13] However, few studies have investigated which factors are associated with adherence to lockdown. To the best of the authors' knowledge, only a few studies have explored factors associated with non-adherence to lockdown.[14,15] These studies identified several factors related to stay-at-home order adherence, including age, education, geographical location, religious/spiritual beliefs, number of children, perceptions of physical health and social-emotional support.

In addition, several studies have explored the role of adherence to protective behaviours, such as the use of a mask,[16] handwashing[17] and social distancing.[18] Several factors associated with non-adherence to protective behaviours were similar to those identified in studies exploring non-adherence to lockdown. Some of the factors found associated with protective behaviours were gender,[14,19–22] age,[21–23] geographical location,[21,24] education level,[22,24,25] household composition,[14,20] income,[19,24] work status,[21,24,26] health status,[20,27] health-related risk perception,[11,20,22] perceived effectiveness of government 'lockdown' measures[14] and trust in government and health authorities.[28] Beliefs in specific conspiracy theories and political ideology, voting and political identification were also associated with less compliance with social distancing measures.[29] In qualitative exploratory research, non-adherence to social distancing and social isolation during the COVID-19 pandemic was associated with financial losses, unclear government communication about physical distancing, observation of non-adherence in other individuals, and uncertainty about social reintegration and the future.[19]

The development and availability of a vaccine against COVID-19 and a high vaccination acceptance in several countries led to a reduction of non-pharmaceutical interventions. However, vaccination coverage varies between countries and continents.[30] In addition, the need for a booster vaccination and the emergence of new variants might impact the current epidemiological situation. Thus, understanding adherence to non-pharmaceutical interventions remains crucial in the case of new outbreaks. A better understanding of the factors that are associated with compliance to lockdown measures could also help target health promotion messages to those non-adhering.[31,32] Hence, this study aimed to assess and identify factors associated with non-adherence to the first lockdown in Portugal.

## Methods

### *Study design and participants*

Data were collected from the community-based survey entitled 'COVID-19 Barometer: Social Opinion'.[33] The questionnaire was administered online through the Microsoft Forms software program (Microsoft Corp). Invitations to participate were sent to existing contact networks and mailing lists, posted and promoted on social networks, and promoted to vulnerable groups through partnerships with patient associations, public health doctors and other healthcare professional groups. A snowball sampling technique was used, asking participants to forward the link to the questionnaire. The questionnaire was pretested to verify response times, ensure comprehensibility and resolve operational errors.

The survey asked questions on risk perception, health status and social experiences. Participants who answered the questionnaire between 21 and 27 March 2020 were included; participants not living in Portugal or who were aged <16 years were excluded.

### *Instruments*

This study was interested in the responses to the question regarding preventive measures (i.e. 'What recommendations from the health authorities did you take to prevent COVID-19 infection?'). The multiple option choice answers were: 'No recommendations adopted'; 'Leave home only in essential cases'; 'Avoid touching common surfaces, such as handrails and door handles'; 'Wash hands regularly'; 'Cover mouth and nose when sneezing or coughing'; 'Avoid contact with feverish or ill people'; 'Avoid touching face'; 'Avoid sharing food or personal utensils'; 'Cook food properly'; 'and 'Prefer not to answer'. The dependent variable corresponds to the option 'Leave home only in essential cases'. The outcome was categorised into two categories: 'Yes', corresponding to participants who stayed at home, and 'No', corresponding to participants who did not stay home (serving as a proxy for non-adherence to lockdown), which was the event of interest in this study. The questionnaire had another question assessing whether individuals stayed at home: 'Are you at home, leaving only in situations of absolute necessity', which was considered for a sensitivity analysis.

Independent variables were divided into five dimensions: demographic, social, labour, health and perceptions (see Supplementary Table S1). These variables were selected based on the literature review on adherence to preventive measures during a pandemic.[23,34–37]

### *Statistical analyses*

Variables were described using absolute and relative frequencies, and multicollinearity was checked using the variance inflation factor. Logistic regression was fitted for each dimension (Supplementary Table S1). We estimated crude odds ratios (ORs) and adjusted odds ratios (aORs), and their corresponding 95% confidence intervals (95% CIs). Each regression was adjusted for the demographic dimensions of age, gender, education and region. A complete case analysis was performed because there was very little missing data.

The questionnaire had two questions whose interpretation could be similar (i.e. 'What recommendations from the health authorities did you take to prevent COVID-19 infection' and 'Are you at home, leaving only in situations of absolute necessity'). Thus, a sensitivity analysis was carried out only using data from individuals who answered the first question with 'Leave home only in essential cases' and the second question positively.

The level of significance considered for all analyses was 5%. The data analysis was performed using SPSS Statistics 26 Software (IBM).

### *Ethical approval*

Before completing the questionnaire, participants read the informed consent. Only participants who gave their informed consent could see the questionnaire and were included in the study. Participation in this study was voluntary and anonymous. Participants were not asked for personal information. The study was conducted in agreement with the Declaration of Helsinki, and the Ethics Committee of the National School of Public Health approved the protocol (approval number: CE/ENSP/CREE/3/2020).

## Results

Data from 133,601 individuals were obtained from a community-based survey. Only 5.6% of participants reported non-adherence to lockdown (i.e. leaving home for reasons other than essential situations). Supplementary Table S2 presents the characteristics of the study population. Overall, more women (64.3%) and individuals with a university degree (69.0%) participated in the study. The majority of participants were aged between 26 and 65 years (86.4%) and lived in the Lisbon and Tagus Valley (47.5%) and the North (24.1%).

### *Demographic dimension*

Men were more likely to non-adhere to lockdown than women (aOR: 1.43, 95% CI: [1.36; 1.50]). Individuals living in the Centre region were more likely to non-adhere to lockdown than individuals living in the Lisbon and Tagus Valley (aOR: 1.16, 95% CI: [1.08; 1.24]). Working-age adults (aged 26–65 years) were less likely to non-adhere to lockdown than young adults (aged 16–25 years) (aOR: 0.87, 95% CI: [0.80; 0.94]). Individuals with a higher level of education were also less likely to non-adhere to lockdown than individuals without education or with only a basic education (see Fig. 1 and Table 1).

In the sensitivity analysis, different results were observed regarding age and region. Older individuals were less likely to non-adhere to lockdown than young adults (Table 2).

### *Health dimension*

Individuals who felt agitated, sad or anxious some days were less likely to non-adhere to lockdown than individuals who never experienced these feelings (aOR: 0.87, 95% CI: [0.89; 0.93]). On the other hand, individuals who felt agitated, sad or anxious every day were more likely to non-adhere to lockdown than those who had never experienced these feelings (aOR: 1.22, 95% CI: [1.12; 1.33]). Individuals with a reasonable or good perception of their health status were less likely to non-adhere than individuals who perceived their health status as very bad (Fig. 1 and Table 1).

In the sensitivity analysis, health perception was no longer significant. However, we found that participants with comorbidities were less likely to non-adhere than participants without comorbidities (Table 2).

### *Social dimension*

Individuals living alone or with high-infection-risk professionals were more likely to non-adhere to lockdown (aOR: 1.27, 95% CI: [1.18; 1.36] and aOR: 1.35, 95% CI: [1.26; 1.44], respectively). Individuals without social support or who do not need social support were more likely to non-adhere to lockdown than individuals who would receive social support in case of infection (aOR: 1.44, 95% CI: [1.19; 1.74] and aOR: 1.26, 95% CI: [1.02; 1.55], respectively) (Table 1).

The results were similar in the sensitivity analysis. Individuals living with the elderly or with people with chronic diseases were less likely to non-adhere to lockdown than individuals who were not living with the elderly or with people with chronic diseases (Table 2).

### *Labour dimension*

Individuals with higher monthly household incomes were less likely to non-adhere to lockdown than individuals with a monthly household income below €650 (Fig. 2 and Table 1). Individuals who were slightly concerned about losing income were less likely to non-adhere to lockdown than individuals who were not concerned about losing income (aOR: 0.83, 95% CI: [0.76; 0.91]). Retired individuals and students were more likely to non-adhere to lockdown than workers (aOR: 1.83, 95% CI: [1.40; 2.40], and aOR: 1.69, 95% CI: [1.43; 1.99], respectively). High-infection-risk professionals were less likely to non-adhere to lockdown than non–high-infection-risk professionals (aOR: 0.92, 95% CI: [0.86; 0.99]). This study also found a strong association between working at the workplace and remote work (aOR: 4.80, 95% CI: [4.47; 5.15]). Individuals working at the workplace were more likely to non-adhere to lockdown than individuals who were working remotely. Individuals who suspended their working activities were also more likely to non-adhere to lockdown than individuals who were working remotely (aOR: 1.23, 95% CI: [1.12; 1.34]) (Fig. 2 and Table 1).

The results were similar in the sensitivity analysis. No evidence was found of an association for individuals who suspended their work activities and retired individuals (Table 2).

### *Perceptions dimension*

Individuals who perceived the measures implemented by the health authorities as very important were less likely to non-adhere

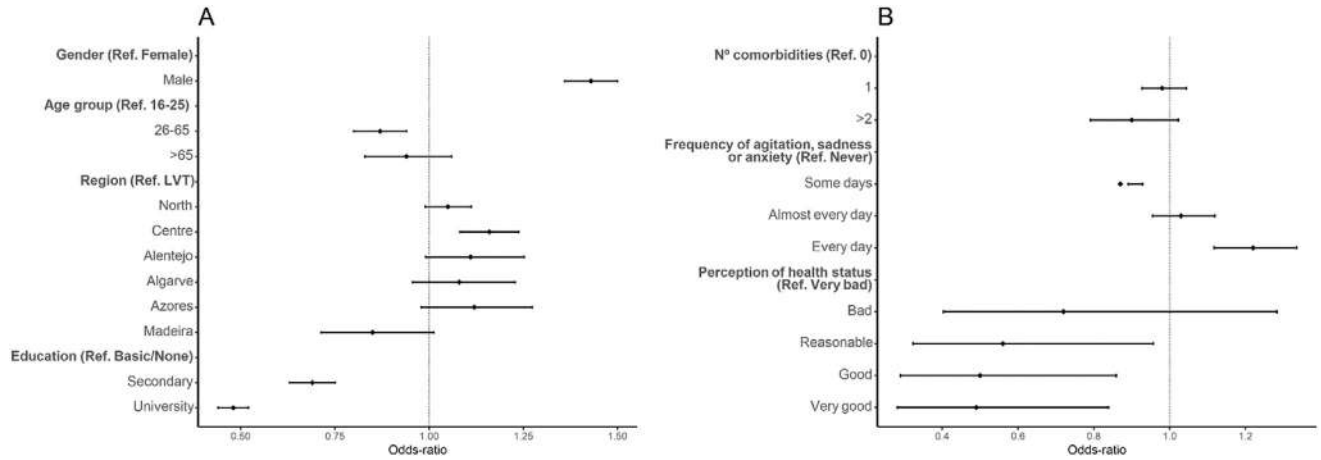


**Fig. 1.** Forest plot for non-adherence to lockdown. Adjusted odds ratio (adjusted for gender, age group, education and region) and the respective 95% confidence intervals are denoted by black dots and black lines, respectively. A — Forest plot of the demographic dimension. B — Forest plot of the health dimension.

**Table 1**
Crude and adjusted odds of non-adherence to lockdown. Odds ratios were adjusted for the demographic dimensions (i.e. gender, age group, education and region)[a].

| Dimension | Crude OR | 95% CI | Adjusted OR | 95% CI |
|---|---|---|---|---|
| **Demographic dimension (N = 132,888)** | | | | |
| Gender (Ref. Female) | **1.51** | **[1.44; 1.58]** | **1.43** | **[1.36; 1.50]** |
| Age group, in years (Ref. 16–25) | | | | |
| 26–65 | **0.83** | **[0.77; 0.90]** | **0.87** | **[0.80; 0.94]** |
| >65 | 1.01 | [0.90; 1.14] | 0.94 | [0.83; 1.06] |
| Region (Ref. Lisbon and Tagus Valley) | | | | |
| North | **1.07** | **[1.01; 1.14]** | 1.05 | [0.99; 1.11] |
| Centre | **1.19** | **[1.12; 1.28]** | **1.16** | **[1.08; 1.24]** |
| Alentejo | **1.14** | **[1.02; 1.28]** | 1.11 | [0.99; 1.25] |
| Algarve | 1.11 | [0.98; 1.26] | 1.08 | [0.96; 1.23] |
| Azores | **1.19** | **[1.05; 1.36]** | 1.12 | [0.98; 1.27] |
| Madeira | 0.85 | [0.72; 1.02] | 0.85 | [0.71; 1.01] |
| Education (Ref. Basic/No education) | | | | |
| Secondary | **0.67** | **[0.62; 0.73]** | **0.69** | **[0.63; 0.75]** |
| University | **0.44** | **[0.41; 0.48]** | **0.48** | **[0.44; 0.52]** |
| **Social dimension (*N* = 130,119)** | | | | |
| Living alone (Ref. No) | **1.23** | **[1.15;1,32]** | **1.27** | **[1.18; 1.36]** |
| Living with the elderly or people with chronic illness (Ref. No) | 0.98 | [0.93; 1.03] | 1.01 | [0.95; 1.06] |
| Living with a high-infection-risk professional (Ref. No) | **1.31** | **[1.23; 1.40]** | **1.35** | **[1.26; 1.44]** |
| Social support in case of infection (Ref. Yes) | | | | |
| None | **1.53** | **[1.27; 1.84]** | **1.44** | **[1.19; 1.74]** |
| Unsure | 1.13 | [0.97; 1.32] | 1.10 | [0.94; 1.28] |
| Not needed | **1.29** | **[1.05; 1.58]** | **1.26** | **[1.02; 1.55]** |
| Other | **1.25** | **[1.05; 1.48]** | **1.22** | **[1.02; 1.46]** |
| **Labour dimension (*N* = 99,574)** | | | | |
| Monthly household income (Ref. <650€) | | | | |
| 651–1000€ | **0.83** | **[0.74; 0.93]** | **0.81** | **[0.72; 0.91]** |
| 1001–1500€ | **0.59** | **[0.53; 0.66]** | **0.62** | **[0.55; 0.70]** |
| 1501–2000€ | **0.51** | **[0.45; 0.57]** | **0.57** | **[0.51; 0.65]** |
| 2001–2500€ | **0.46** | **[0.41; 0.53]** | **0.53** | **[0.47; 0.61]** |
| > 2501€ | **0.48** | **[0.42; 0.53]** | **0.57** | **[0.51; 0.65]** |
| Unknown | **0.71** | **[0.59; 0.85]** | 0.85 | [0.70; 1.04] |
| Fear of losing income (Ref. Not concerned) | | | | |
| Slightly concerned | **0.74** | **[0.68; 0.81]** | **0.83** | **[0.76; 0.91]** |
| Concerned | **0.88** | **[0.81; 0.95]** | 0.95 | [0.88; 1.04] |
| Very concerned | **0.91** | **[0.84; 0.98]** | 0.97 | [0.88; 1.05] |
| Occupation (Ref. Worker) | | | | |
| Self-employed | **0.81** | **[0.75; 0.87]** | 0.93 | [0.86; 1.01] |
| Homemaker | **0.94** | **[0.58; 1.54]** | 1.01 | [0.60; 1.72] |
| Retired | 1.18 | [0.92; 1.52] | **1.83** | **[1.40; 2.40]** |
| Unemployed | **0.89** | **[0.69; 1.15]** | 1.05 | [0.79; 1.41] |
| Student | 0.99 | [0.88; 1.14] | **1.69** | **[1.43; 1.99]** |
| Other | 1.06 | [0.95; 1.19] | 1.08 | [0.95; 1.22] |
| Working mode (Ref. Remote work) | | | | |
| At workplace | **4.75** | **[4.48; 5.04]** | **4.80** | **[4.47; 5.15]** |
| Suspended professional activity | **1.32** | **[1.22; 1.43]** | **1.23** | **[1.12; 1.34]** |
| High-infection-risk professional (Ref. No) | **1.96** | **[1.85; 2.08]** | **0.92** | **[0.86; 0.99]** |
| **Health dimension (*N* = 129,691)** | | | | |
| Number of comorbidities (Ref. 0) | | | | |
| 1 | 1.04 | [0.98; 1.10] | 0.98 | [0.93; 1.04] |
| ≥2 | 1.08 | [0.95; 1.21] | 0.90 | [0.79; 1.02] |
| Frequency of agitation, sadness or anxiety (Ref. Never) | | | | |
| Some days | **0.84** | **[0.79; 0.89]** | **0.87** | **[0.89; 0.93]** |
| Almost every day | 1.02 | [0.95; 1.10] | 1.03 | [0.95; 1.12] |
| Every day | **1.22** | **[1.12; 1.33]** | **1.22** | **[1.12; 1.33]** |
| Perception of health status (Ref. Very bad) | | | | |
| Bad | 0.60 | [0.35; 1.01] | 0.72 | [0.40; 1.28] |
| Reasonable | **0.44** | **[0.27; 0.71]** | **0.56** | **[0.32; 0.96]** |
| Good | **0.37** | **[0.23; 0.61]** | **0.50** | **[0.29; 0.86]** |
| Very good | **0.35** | **[0.22; 0.58]** | **0.49** | **[0.28; 0.84]** |
| **Perceptions dimension (*N* = 126,301)** | | | | |
| Perception of the importance of the measures implemented by health authorities (Ref. Not important) | | | | |
| Not very important | **0.63** | **[0.46; 0.86]** | 0.76 | [0.54; 1.07] |
| Important | **0.48** | **[0.36; 0.64]** | 0.75 | [0.54; 1.02] |
| Very important | **0.25** | **[0.19; 0.34]** | **0.44** | **[0.33; 0.61]** |
| Perception of the adequacy of measures implemented by the government (Ref. Not adequate) | | | | |
| Not very adequate | **0.44** | **[0.38; 0.50]** | **0.67** | **[0.56; 0.79]** |
| Adequate | **0.32** | **[0.28; 0.37]** | **0.64** | **[0.54; 0.76]** |
| Very adequate | **0.29** | **[0.25; 0.34]** | **0.61** | **[0.50; 0.74]** |

**Table 1** (*continued*)

| Dimension | Crude OR | 95% CI | Adjusted OR | 95% CI |
|---|---|---|---|---|
| Confidence in the government's response to the pandemic (Ref. Not confident) | | | | |
| Not very confident | **0.60** | **[0.54; 0.65]** | **0.86** | **[0.77; 0.97]** |
| Confident | **0.47** | **[0.43; 0.52]** | **0.81** | **[0.71; 0.92]** |
| Very confident | **0.49** | **[0.44; 0.56]** | **0.83** | **[0.70; 0.98]** |
| Confidence in the capacity of health services to respond to the pandemic (Ref. Not confident) | | | | |
| Not very confident | **0.64** | **[0.57; 0.71]** | 0.91 | [0.80; 1.04] |
| Confident | **0.61** | **[0.55; 0.67]** | 1.00 | [0.88; 1.15] |
| Very confident | **0.69** | **[0.60; 0.78]** | 1.12 | [0.96; 1.31] |
| Self-perceived risk to get COVID-19 infection (Ref. Low/No risk) | | | | |
| Moderate | **1.34** | **[1.25; 1.41]** | **1.38** | **[1.29; 1.47]** |
| High | **2.40** | **[2.25; 2.57]** | **2.37** | **[2.21; 2.55]** |
| Unknown | **1.21** | **[1.11; 1.32]** | **1.22** | **[1.10; 1.35]** |
| Self-perceived risk to develop severe disease (Ref. Low/No risk) | | | | |
| Moderate | **1.14** | **[1.07; 1.20]** | 1.00 | [0.94; 1.06] |
| High | **1.36** | **[1.28; 1.45]** | 0.97 | [0.90; 1.05] |
| Unknown | 1.05 | [0.97; 1.14] | 0.95 | [0.86; 1.04] |
| Perceived risk to the population (Ref. Low/No risk) | | | | |
| Moderate | **0.43** | **[0.35; 0.53]** | **0.50** | **[0.41; 0.62]** |
| High | **0.40** | **[0.33; 0.48]** | **0.45** | **[0.36; 0.55]** |
| Unknown | **0.43** | **[0.33; 0.55]** | **0.52** | **[0.39; 0.69]** |

OR, odds ratio; CI, confidence interval.
[a] Bold indicates significant result.

to lockdown than individuals who perceived them as not important (aOR: 0.44, 95% CI: [0.33; 0.61]). Individuals who perceived the measures implemented to be inadequate were more likely to non-adhere than individuals who found them adequate or not very adequate. Similarly, individuals without any confidence in the government's response to the pandemic were more likely to non-adhere than individuals who had some level of confidence. Regarding the risk of getting COVID-19, individuals who perceived their risk to be moderate, high or were unsure were more likely to non-adhere to lockdown than those who perceived their risk as low or null. On the other hand, individuals who perceived the population risk of getting COVID-19 as moderate, high or unsure were less likely to non-adhere than those who perceived the population risk as low or null (Fig. 2 and Table 1).

Results were similar in the sensitivity analysis (Table 2).

## Discussion

The main objective of this study was to identify factors associated with non-adherence to the first lockdown in Portugal. The present study found that a minority of participants (5.6%) reported non-adherence to lockdown (i.e. leaving home for reasons other than essential situations). The study found that the following factors were associated with non-adherence to lockdown: being a man, having a lower level of education, living alone, living with a professional at high risk of getting infected, having no support in case of infection, belonging to a low-income household, being a student, continuing to work at the workplace, having a higher risk perception of becoming infected, feeling agitated, sad or anxious every day, not having confidence in the government and considering mitigation measures as unimportant or inappropriate.

### *Demographic, social and labour dimensions*

Participants who continued working at the workplace had an almost five-fold increased likelihood of non-adherence to lockdown than participants who worked from home. Other studies have also indicated that work-related conditions might influence preventive behaviours.[26] Workers who cannot transition to remote working were less likely to adhere to lockdown or adopt preventive behaviours, such as social distancing.[24,38] It could be hypothesised that travelling to work could lead to other unnecessary trips. This idea could also be corroborated by the fatalism effect, in which an individual believes that their exposure to risk makes it practically inevitable that they will be infected, thereby reducing the adoption of preventive behaviours.[39–41] As remote working was one of the most implemented lockdown measures, further studies should replicate the present study findings to ascertain the real effect of remote working on adherence to lockdown.

Individuals with lower household incomes were also more likely to non-adhere to the lockdown, which is in line with results from other studies.[24,34] This finding could represent individuals with lower incomes who might work in precarious conditions and who were unable to work from home or those who have fewer savings to help them during lockdowns.[24,34] Providing support or means of subsistence for certain families can be a way of mitigating these differences. The literature shows that compliance with public health recommendations is higher when living standards are maintained. Governments that provide economic reassurance (e.g. wage compensation or temporarily suspending reimbursements to the state),[26] food support[19] or free Internet access at home[25] might experience higher rates of adherence to lockdown. Similarly, individuals with lower levels of education were also more likely to non-adhere to the lockdown. However, this association was not found in all studies.[22,24,42] The present study also showed that students were more likely to non-adhere to lockdown, and men were more likely to non-adhere. Both findings have been documented in other studies.[14,19,20,23,24,26]

Socially, individuals without a support system in case of infection or individuals living alone were more likely to non-adhere to the lockdown. These results were corroborated by other studies.[14,26] Surprisingly, living with a high-infection-risk professional (e.g. doctor, nurse, pharmaceutical, health technician, firefighter, police officer, military, essential services worker) increased the odds of non-adherence, which might be explained by the increased exposure to risk and the fatalism effect discussed previously.[39–41]

### *Health and perception dimensions*

A strong association was found between the self-perceived risk of getting infected and non-adherence to lockdown. This

**Table 2**
Crude and adjusted odds of the sensitivity analysis of non-adherence to lockdown. Odds ratios were adjusted for the demographic dimensions (i.e. gender, age group, education and region)[a].

| Dimension | Crude OR | 95% CI | Adjusted OR | 95% CI |
|---|---|---|---|---|
| **Demographic dimension (N = 120,975)** | | | | |
| Gender (Ref. Female) | **1.81** | **[1.69; 1.94]** | **1.76** | **[1.64; 1.89]** |
| Age group, in years (Ref. 16–25) | | | | |
| 26-65 | 0.91 | [0.81; 1.04] | 0.95 | [0.84; 1.08] |
| >65 | **0.30** | **[0.23; 0.39]** | **0.26** | **[0.20; 0.34]** |
| Region (Ref. Lisbon and Tagus Valley) | | | | |
| North | 1.02 | [0.94; 1.12] | 0.98 | [0.89; 1.07] |
| Centre | **1.23** | **[1.11; 1.36]** | **1.17** | **[1.06; 1.29]** |
| Alentejo | **1.30** | **[1.10; 1.53]** | **1.23** | **[1.04; 1.45]** |
| Algarve | 1.05 | [0.86; 1.27] | 0.99 | [0.82; 1.20] |
| Azores | 1.12 | [0.91; 1.37] | 1.00 | [0.82; 1.23] |
| Madeira | **0.49** | **[0.35; 0.69]** | **0.46** | **[0.33; 0.65]** |
| Education (Ref. Basic/No education) | | | | |
| Secondary | **0.75** | **[0.66; 0.86]** | **0.73** | **[0.64; 0.84]** |
| University | **0.44** | **[0.39; 0.50]** | **0.45** | **[0.40; 0.51]** |
| **Social dimension (*N* = 118,481)** | | | | |
| Living alone (Ref. No) | **1.26** | **[1.14; 1.39]** | **1.25** | **[1.12; 1.39]** |
| Living with the elderly or people with chronic illness (Ref. No) | **0.83** | **[0.77; 0.91]** | **0.86** | **[0.79; 0.94]** |
| Living with a high-infection-risk professional (Ref. No) | **1.40** | **[1.27; 1.54]** | **1.44** | **[1.30; 1.60]** |
| Social support in case of infection (Ref. Yes) | | | | |
| None | **1.71** | **[1.31; 2.22]** | **1.62** | **[1.23; 2.12]** |
| Unsure | **1.24** | **[1.00; 1.54]** | 1.22 | [0.97; 1.53] |
| Not needed | **1.40** | **[1.03; 1.89]** | 1.34 | [0.98; 1.83] |
| Other | 1.09 | [0.83; 1.43] | 1.08 | [0.82; 1.44] |
| **Labour dimension (*N* = 107,076)** | | | | |
| Monthly household income (Ref. <650€) | | | | |
| 651–1000€ | 0.96 | [0.82; 1.13] | 0.94 | [0.79; 1.11] |
| 1001–1500€ | **0.61** | **[0.52; 0.72]** | **0.66** | **[0.55; 0.78]** |
| 1501–2000€ | **0.55** | **[0.47; 0.65]** | **0.67** | **[0.56; 0.81]** |
| 2001–2500€ | **0.49** | **[0.41; 0.59]** | **0.62** | **[0.51; 0.75]** |
| >2501€ | **0.50** | **[0.42; 0.59]** | **0.68** | **[0.56; 0.81]** |
| Unknown | **0.61** | **[0.46; 0.81]** | 0.95 | [0.69; 1.29] |
| Fear of losing income (Ref. Not concerned) | | | | |
| Slightly concerned | **0.66** | **[0.59; 0.74]** | **0.78** | **[0.68; 0.88]** |
| Concerned | **0.72** | **[0.65; 0.81]** | **0.81** | **[0.72; 0.92]** |
| Very concerned | **0.73** | **[0.66; 0.81]** | 0.88 | [0.78; 1.00] |
| Occupation (Ref. Worker) | | | | |
| Self-employed | **0.66** | **[0.59; 0.74]** | 0.90 | [0.80; 1.02] |
| Retired | **0.27** | **[0.14; 0.55]** | 0.58 | [0.29; 1.20] |
| Unemployed | **0.35** | **[0.20; 0.60]** | 0.88 | [0.47; 1.63] |
| Student | **0.59** | **[0.47; 0.74]** | **2.29** | **[1.73; 3.03]** |
| Other | **0.97** | **[0.82; 1.14]** | 1.03 | [0.85; 1.24] |
| Working mode (Ref. Remote work) | | | | |
| At workplace | **19.5** | **[17.49; 21.74]** | **21.89** | **[19.32;24.81]** |
| Suspended professional activity | 1.14 | [0.96; 1.36] | 1.15 | [0.95; 1.39] |
| High-infection-risk professional (Ref. No) | **2.96** | **[2.74; 3.21]** | **0.74** | **[0.67; 0.81]** |
| **Health dimension (*N* = 118,140)** | | | | |
| Number of comorbidities (Ref. 0) | | | | |
| 1 | **0.81** | **[0.74; 0.89]** | **0.82** | **[0.74; 0.90]** |
| ≥2 | **0.66** | **[0.53; 0.83]** | **0.66** | **[0.52; 0.83]** |
| Frequency of agitation, sadness or anxiety (Ref. Never) | | | | |
| Some days | **0.73** | **[0.67; 0.80]** | **0.77** | **[0.70; 0.84]** |
| Almost every day | 0.98 | [0.87; 1.09] | 1.01 | [0.89; 1.13] |
| Every day | **1.25** | **[1.11; 1.41]** | **1.28** | **[1.13; 1.46]** |
| Perception of health status (Ref. Very bad) | | | | |
| Bad | 0.57 | [0.21; 1.51] | 0.66 | [0.22; 1.94] |
| Reasonable | 0.66 | [0.27; 1.63] | 0.80 | [0.29; 2.19] |
| Good | 0.63 | [0.26; 1.54] | 0.75 | [0.27; 2.04] |
| Very good | 0.64 | [0.26; 1.57] | 0.76 | [0.28; 2.07] |
| **Perceptions dimension (*N* = 115,046)** | | | | |
| Perception of the importance of the measures implemented by health authorities (Ref. Not important) | | | | |
| Not very important | **0.64** | **[0.42; 0.96]** | 0.74 | [0.47; 1.19] |
| Important | **0.48** | **[0.33; 0.70]** | 0.79 | [0.51; 1.21] |
| Very important | **0.20** | **[0.13; 0.28]** | **0.37** | **[0.24; 0.57]** |
| Perception of the adequacy of measures implemented by the government (Ref. Not adequate) | | | | |
| Not very adequate | **0.35** | **[0.30; 0.42]** | **0.56** | **[0.45; 0.70]** |
| Adequate | **0.23** | **[0.19; 0.27]** | **0.54** | **[0.43; 0.69]** |
| Very adequate | **0.17** | **[0.14; 0.21]** | **0.49** | **[0.37; 0.64]** |

**Table 2** (*continued*)

| Dimension | Crude OR | 95% CI | Adjusted OR | 95% CI |
|---|---|---|---|---|
| Confidence in the government's response to the pandemic (Ref. Not confident) | | | | |
| Not very confident | **0.53** | **[0.47; 0.61]** | 0.87 | [0.73; 1.03] |
| Confident | **0.36** | **[0.32; 0.41]** | **0.77** | **[0.64; 0.93]** |
| Very confident | **0.28** | **[0.23; 0.34]** | **0.67** | **[0.51; 0.87]** |
| Confidence in the capacity of health services to respond to the pandemic (Ref. Not confident) | | | | |
| Not very confident | **0.59** | **[0.50; 0.69]** | 0.91 | [0.76; 1.09] |
| Confident | **0.51** | **[0.44; 0.59]** | 1.02 | [0.85; 1.23] |
| Very confident | **0.52** | **[0.43; 0.63]** | 1.15 | [0.91; 1.44] |
| Self-perceived risk to get COVID-19 infection (Ref. Low/No risk) | | | | |
| Moderate | **2.06** | **[1.85; 2.29]** | **2.22** | **[1.98; 2.48]** |
| High | **5.00** | **[4.49; 5.56]** | **5.49** | **[4.89; 6.18]** |
| Unknown | **1.18** | **[1.00; 1.39]** | **1.26** | **[1.04; 1.52]** |
| Self-perceived risk to develop severe disease (Ref. Low/No risk) | | | | |
| Moderate | **1.19** | **[1.10; 1.31]** | 0.94 | [0.86; 1.03] |
| High | 1.05 | [0.94; 1.16] | **0.64** | **[0.60; 0.72]** |
| Unknown | 0.88 | [0.78; 1.00] | **0.85** | **[0.73; 0.99]** |
| Perceived risk to the population (Ref. Low/No risk) | | | | |
| Moderate | **0.39** | **[0.29; 0.51]** | **0.43** | **[0.32; 0.58]** |
| High | **0.32** | **[0.25; 0.42]** | **0.34** | **[0.26; 0.46]** |
| Unknown | **0.32** | **[0.22; 0.46]** | **0.41** | **[0.27; 0.64]** |

OR, odds ratio; CI, confidence interval.
[a] Bold indicates significant result.

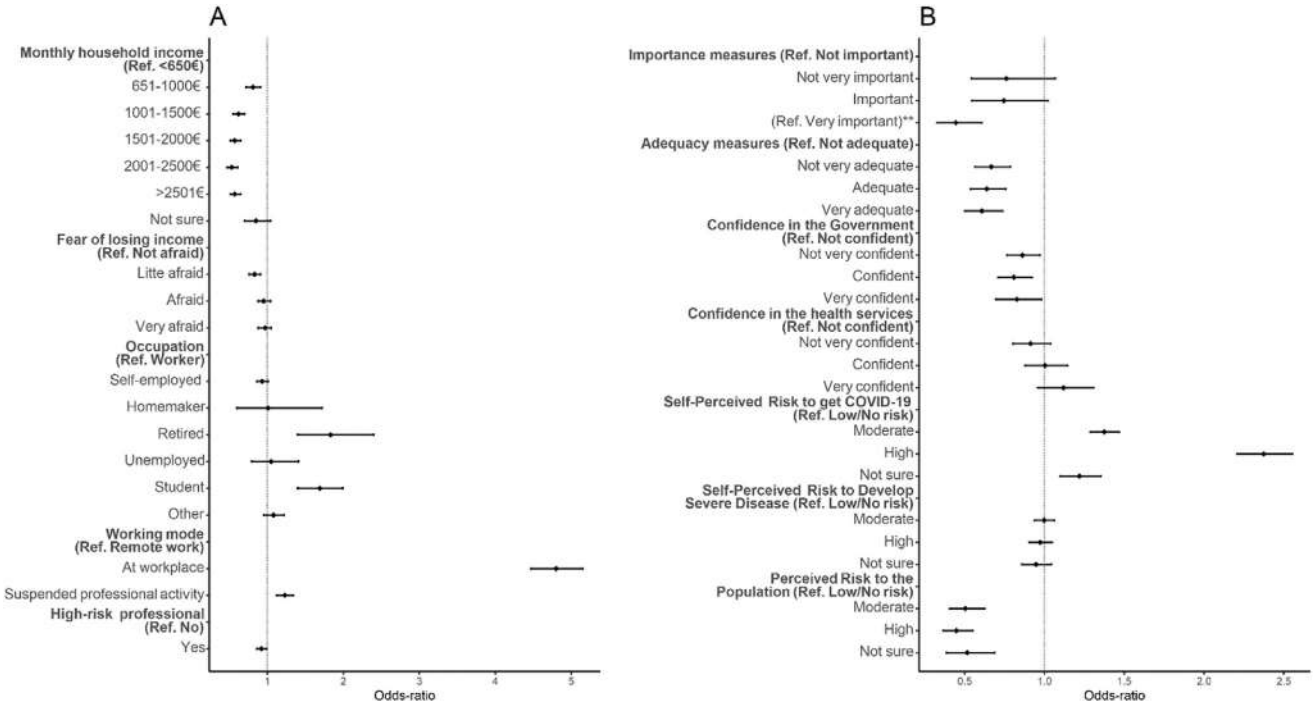


**Fig. 2.** Forest plot for non-adherence to lockdown. Adjusted odds ratio (adjusted for gender, age group, education and region) and the respective 95% confidence intervals are denoted by black dots and black lines, respectively. A — Forest plot of the labour dimension. B — Forest plot of the perceptions dimension.

association has been shown in other studies and could also be related to the fatalism effect.[39–41] Having a high self-perceived risk of getting infected, or being unsure of their risk, seems intuitively more associated with adopting protective behaviours. However, the literature shows that fear associated with a higher perception of risk can trigger paradoxical actions, exacerbate already existing stressors of the COVID-19 pandemic and produce unintended consequences, such as denial, backlash, avoidance, defensiveness, depression, anxiety, increased risk behaviour and a feeling of lack of control.[43] Nevertheless, fear is a natural response to the pandemic. Thus, communication messages should explore fear using an optimistic approach. Some studies suggest that exploiting the fear of being infected can be helpful in certain situations, such as pandemics, especially alongside effective messages by the health authorities encouraging the adoption of preventive behaviours.[45]

The idea of infecting vulnerable people can trigger the adoption of behaviours such as physical distancing.[46] In this situation, people are more likely to make sacrifices, such as staying at home to protect individuals they can relate to. This idea is corroborated by the 'Victim Effect', which refers to the likelihood of helping

strangers with whom we empathise compared with unknown individuals. This effect persists even when anonymity is maintained,[47] for instance, personalising risk communication referring to our grandparents instead of individuals aged >65 years.[47–49]

Individuals who did not trust the government were found to have an increased likelihood of non-adherence to the lockdown. This association has been shown in other studies[14] and during the H1N1 influenza outbreak.[50] According to the Trust and Cooperation Model, trust is an important factor in risk management because it affects public judgment when assessing the harm and benefits of a measure. Hence, people with high levels of trust in institutions are more likely to accept recommendations.[51] A lack of confidence in the capability of authorities to manage a public health crisis can feed uncertainty and scepticism about their recommendations.[52] Risk communication should therefore focus on building trust in close collaboration with health services and the media.[11]

The present study also suggests that poor health perception was positively associated with non-adherence to lockdown. This is in line with other analyses that showed that neither having a previous medical condition increased the adoption of preventive behaviours[24] nor having a previous health problem was a significant factor in self-protection.[53]

### *Limitations and strengths*

The present study does not represent the Portuguese population because more women, participants living in Lisbon and Tagus Valley and participants with higher levels of education responded to the questionnaire, which does not correspond to the national demographics.[54] The results may also be subject to sampling bias as some households in Portugal do not have access to the Internet (or have only limited access). The present study sample is likely to include more respondents sensitive to health issues (i.e. a non-response bias). Another limitation of this work is related to the dependent variable. Participants might have understood 'essential cases' differently. These limitations might affect the generalisability of the current results. Nevertheless, the study included a large sample, allowing a better understanding of non-adherence to lockdown in the studied population. The dissemination of an online questionnaire is a safe and effective way to reach the population, which is an essential factor to consider during a pandemic. Another advantage relates to the variety of themes analysed in the questionnaire, which provides a better view of how these factors might be interconnected and should be further explored.

### *Future work and challenges*

Although several countries have a high COVID-19 vaccination rate, the need for booster vaccinations and the emergence of new strains might bring further restrictions. Some authors have studied COVID-19 vaccine booster hesitancy and found that acceptance decreases over time.[55–57] Thus, it is important to fully understand non-adherence to lockdowns and other preventive measures. Although the present study sheds some light on certain factors associated with non-adherence, human intentions change over time, especially during a pandemic. A longitudinal study is essential to assess changes in the population responses to the pandemic (i.e. the factors associated with non-adherence to the lockdown identified in the present study may not be present at other stages of the pandemic).

### *Conclusion*

Understanding the factors associated with non-adherence to lockdown can support the development of specific policies to mitigate social and economic inequalities and communication messages tailored to priority populations.

## Author statements

### *Acknowledgements*

We thank all the participants who answered the questionnaire for their contribution to this study.

### *Ethical approval*

The study was conducted in agreement with the Declaration of Helsinki, and the Ethics Committee of the National School of Public Health approved the protocol (approval number: CE/ENSP/CREE/3/2020).

### *Funding*

None declared.

### *Competing interests*

None declared.

### *Data availability statement*

The data underlying this article will be shared on reasonable request to the corresponding author.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.07.001.

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Public Health 211 (2022) 81–84

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Short Communication

# Outbreak of SARS-CoV-2 in a teenage discotheque in Northern Ireland—November 2021

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ARTICLE INFO

*Article history:*
Received 14 April 2022
Received in revised form
20 June 2022
Accepted 21 June 2022
Available online 28 June 2022

*Keywords:*
COVID-19
Outbreak
Teenagers
COVID-19 vaccination

ABSTRACT

*Objectives:* To report key findings associated with an outbreak of SARS-CoV-2 following a teenage disco in Northern Ireland.
*Study design:* Observational case series.
*Methods:* A case was defined as an individual who attended the event with a positive SARS-CoV-2 result between 6th and 20th November 2021. Demographic and clinical information, including symptom status, date of onset and school attended, were recorded during contact tracing. Vaccination status was derived from the COVID-19 Vaccine Management System. Forty-five samples associated with the outbreak were sequenced as part of the NI Whole Genome Sequencing (WGS) programme.
*Results:* Only 2.4% (5/205) of cases received a COVID-19 vaccine more than 14 days before the event. 84.9% (174/205) had received no vaccine at the time of the event and 12.7% (26/205) had been vaccinated within 14 days, offering only limited disease protection. The AY4.2.2 lineage of two cases who attended the event after symptom onset was found in 69% of sequenced outbreak cases.
*Conclusions:* This study demonstrates extensive COVID-19 transmission in largely unvaccinated teenagers in an indoor venue with limited social distancing, close social contact and mixing, limited ventilation and singing and shouting. Public Health authorities developing COVID-19 entertainment regulations should consider congregations of teenagers in these settings, especially if vaccination rates are low in this group or they are not eligible for vaccination at that time. Public communications should be developed to ensure young people with COVID-19 symptoms follow public guidance regarding self-isolation and in particular avoid indoor events with larger numbers.


## Introduction

On 8th November 2021, the Public Health Agency (PHA) became aware of an outbreak of SARS-CoV-2 associated with an under-18s disco held on 5th November 2021 in a nightclub in County Antrim, Northern Ireland (NI). The closed ticketed teenage disco was held in a nightclub complex in the Mid-Ulster Local Government District (LGD) from 8 pm to midnight on 5th November 2021. Event organisers reported that attendees were not required to wear face masks or provide COVID-19 vaccination status or evidence of negative antigen tests before entry. This study reports the key characteristics associated with this outbreak, which is the largest COVID-19 point source event in a non-workplace setting in NI to date.

## Methods

The outbreak was first identified on 9th November 2021 (4 days after the event) with seven cases associated by a member of the Contact Tracing (CT) clinical team, using the CT data capture software system, which allows for rapid establishment of new outbreaks and clusters in real time. A common name and a unique ID were assigned to the venue and this information was immediately circulated among all Contact Tracers and the CT surveillance team. Cases were then actively associated with the outbreak both by

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https://doi.org/10.1016/j.puhe.2022.06.023

tracers and by the CT surveillance team as soon they became known. Tracers could actively associate cases with the outbreak in real time while on the CT call, and this was supported by CT surveillance staff who examine all reported data on settings attended daily. Although cases were not specifically asked about attendance at the venue, extensive media coverage at the time likely raised public awareness and may have led to increased case ascertainment. The Incident Management Team confirmed that 1000 tickets were sold online and that the event was fully attended. Although it would have been desirable to obtain detailed exposure histories from all attendees and to develop an analytical epidemiological study, this was not possible because of very limited staff resources and confidentiality concerns related to obtaining a full list of teenage attendees.

An observational case series study design was used with routinely collected COVID-19 contact tracing data. A case was defined as an individual who attended the event with a real-time polymerase chain reaction (RT-PCR) SARS-CoV-2 positive result between 6th and 20th November 2021. The episode start date was defined as the date of onset of symptoms, or date of first positive test in the asymptomatic. All RT-PCR confirmed cases are reported to the Contact Tracing Service (CTS) via the National Testing Initiative Laboratory Network and Health and Social Care (HSC) Trust Laboratories.

Case demographic, potential exposure settings and clinical information, including symptom status, date of onset, vaccination status and school attended, were recorded. Vaccination status for cases was derived from the COVID-19 Vaccine Management System.[1] In addition, 45 samples associated with the outbreak were sequenced as part of the NI Whole Genome Sequencing (WGS) programme. The incubation period was determined as the time, in days, between the event and the date of reported symptoms onset.

## Results

### *Demographic and clinical information*

Two hundred and six cases were associated with the outbreak of whom 59.9% were female ($n = 124$). The median age was 14 years, ranging from 10 to 21 years. Ninety-six percent of cases (197/206) were aged between 12 and 15 years. Although cases travelled up to 40 miles to the event, case residences were clustered in towns close to the venue in Mid-Ulster (MU) and Causeway Coast and Glens (CCG) LGDs and along arterial roads to Derry City/Limavady and Coleraine. Forty-six percent of cases ($n = 96$) resided in Mid-Ulster LGD and 29% ($n = 59$) in Causeway Coast and Glens LGD.

### *Microbiological analysis*

Forty-five samples associated with the outbreak were sequenced as part of the NI WGS programme, with all cases identified as Delta variant, the dominant variant in NI at this time. Six lineages were identified as AY 4.2.2 accounting for 69% of samples (31/45) and AY4.2 accounting for 22% (10/45). The two cases who attended the event after symptom onset were both sequenced as AY 4.2.2 (Fig. 1) and had an epidemiological link outside the venue.

Owing to constraints in the local sequencing laboratory system, only a proportion of positive samples (22% (45/206)) associated with the outbreak had WGS undertaken. This was in line with WGS testing in NI at the time. However, no selection of cases occurred and the 45 cases could be considered a random sample from the 206 cases. The mean age for those sequenced ($n = 45$) was 14.4 years (SD = 3.5 years) and for those not sequenced ($n = 161$) was 13.7 years (SD = 1.1 years), while the female:male ratio was 1.4:1 and 1.5:1 for those sequenced and non-sequenced, respectively.

### *Incubation period*

Table 1 shows information on the incubation period. For the 171 cases with a reported date of onset (171/204), the mean incubation period was 4.1 days (SD = 2.4 days, median = 3 days, range = 1–13 days). The mean incubation period for females was 4.0 days (SD = 2.6 days, median = 3 days) and 4.4 days for males (SD = 2.2 days, median = 4 days). The mean incubation period for different age cohorts is shown in Table 1 and ranged from 2.8 days in those aged 16 years to 4.6 in those aged 15 years, but with no obvious pattern by age. The median incubation period was 3 days for all cohorts except those aged 13 years, where it was 4 days. The mean incubation period for cases with no vaccine was 4.2 days (SD = 2.4 days, median = 3 days) and for those who have had any dose of vaccine ($n = 31$) was 3.6 days (SD = 2.3 days, median = 3 days).

### *Vaccination status*

Vaccination status, which required the cases' Health and Care Number (HCN) for linkage, was available for 205 cases.[1] There was one case where HCN was not available. Only 2.4% of cases (5/205) had one dose more than 14 days before 5th November, with 12.7% (26/205) having had one dose within 14 days and 84.9% (174/205) having no vaccination at the time of the event.

### *Associated schools*

Of the 201 cases associated with 20 secondary schools, 43% (87/201) reported attending three schools in the Mid Ulster LGD area and 57% (115/201) attending schools located in MU and CCG area. Case numbers in each school ranged from 1 to 35, with an average of 10 cases per school (SD = 10 cases, median = 5 cases).

### *Background disease rate*

In the 4 weeks before the event case numbers in the 12- to 16-year group across Northern Ireland declined with 7 day cumulative case rates per 100,000 of 1551, 1306, 1044 and 990 for the 7 days up to 15/10/21, 22/10/21, 29/10/21 and 5/11/21 (date of event), respectively.

## Discussion

Transmission of COVID-19 is a function of biological, behavioural and environmental factors.[2] Our initial investigation suggests rapid and extensive transmission in a largely unvaccinated group of teenagers in a crowded indoor venue where conditions conducive to transmission prevailed including limited social distancing, close social contact and mixing, limited ventilation and likely singing and shouting. As the vaccination programme in Northern Ireland for 12- to 15-year-olds only began on 27th November 2021,[3] the majority of those who attended the event on 5th November 2021 would not have been eligible for COVID-19 vaccination. Indeed, only 2.4% had their first vaccination dose at least 14 days previously. Whole genome sequencing of 45 cases identified the majority as AY4.2.2, including both cases who attended the event after symptom onset. If we assume non-sequenced case samples would follow these WGS findings, the pattern is suggestive of super-spreading type transmission of SARS-CoV-2 in a largely unvaccinated cohort.

As part of the relaxation of COVID restrictions in NI, nightclubs were permitted to reopen on 31st October 2021.[4] COVID restrictions in entertainment settings such as nightclubs were probably designed with adults consuming alcohol in mind and the opening of the vaccination programme to over 18s from May 2021 (and for 16- and 17-year-olds from August 2021)[5–7] coupled with high adult

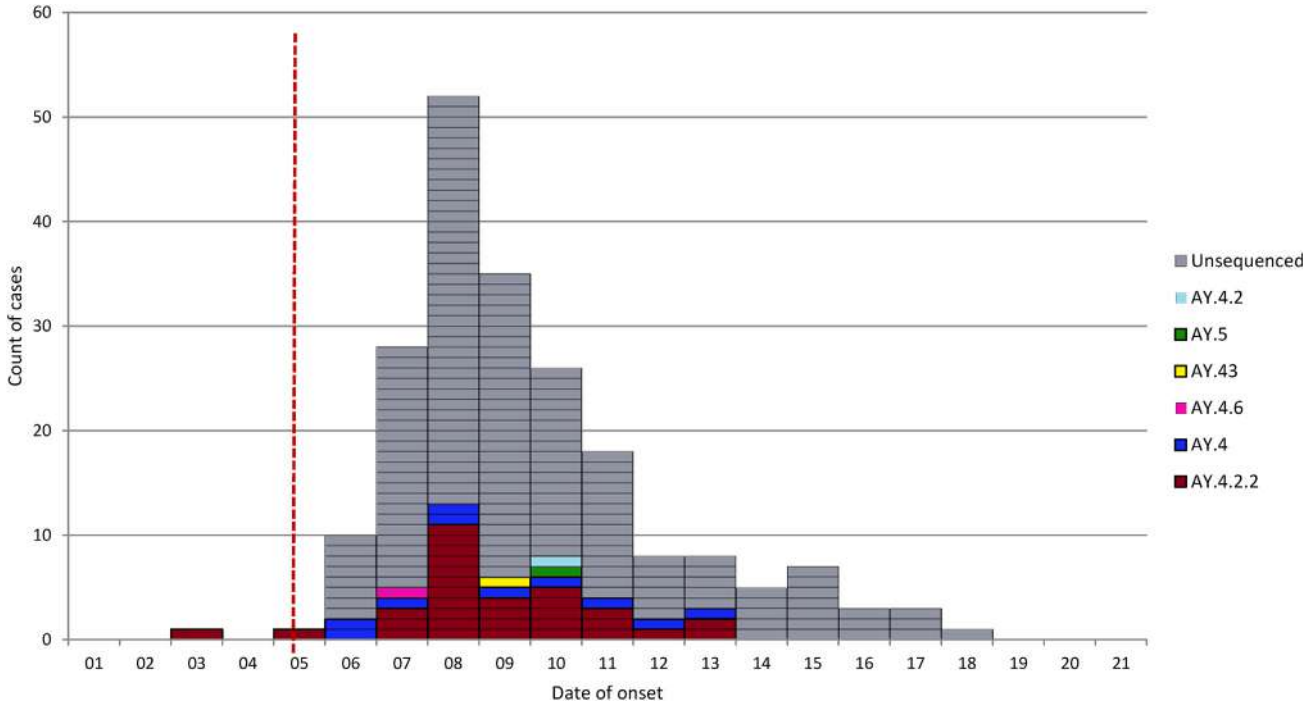


**Fig. 1.** Cases of SARS-CoV-2 associated with teenage nightclub outbreak, Northern Ireland, November 2021, by WGS lineage (Excel file.)

vaccination uptake by the start of November 2021 would have informed decisions to relax restrictions. By 6th November 2021, good vaccination rates had been achieved by adults in NI with 18-24-year-olds having uptake rates of 77% (first dose) and 70% (second dose) and 25-29-year-olds having uptake rates of 70% (first dose) and 68% (second dose) uptake, with higher vaccination rates among older age cohorts.[8] Between 8th and 22nd November 2021, 12 clusters associated with nightclubs and bars across NI were identified by the CTC. For the two nightclubs identified, there were seven total associated cases (mean = 4 cases, median = 4 cases, range = 3–4 cases). For the 10 bars, there were 52 total associated cases (mean = 5 cases, median 4 cases, range 2–11 cases). These licensed premises are generally attended by adults over 18 years of age, who at the time of the teenage disco (5th November 2021) had good vaccination uptake rates with 71%, 78%, 87% and 93% of 18–29, 30–39, 40–49 and 50–59 years, respectively, having had two doses of vaccine, at least 14 days previously.[8] During this period, large outbreaks and clusters associated with nightclubs and bars were not reported, which may have been due to the high levels of vaccination in the adult population.

**Table 1**
Incubation period for cases with recorded date of symptom onset by age, gender and vaccination status.

| | Mean incubation period (SD) [days] | Median incubation period (range) [days] |
|---|---|---|
| Total ($n$ = 171) | 4.1 (2.4) | 3 (1–13) |
| Age range (years) | | |
| 10–12 ($n$ = 26) | 3.7 (1.9) | 3 (1–9) |
| 13 ($n$ = 45) | 4.5 (2.3) | 4 (1–11) |
| 14 ($n$ = 53) | 3.9 (2.3) | 3 (1–12) |
| 15 ($n$ = 40) | 4.6 (3.1) | 3 (1–13) |
| 16 ($n$ = 4) | 2.8 (1.3) | 3 (1–4) |
| ≥18 ($n$ = 2) | 3.0 (1.4) | 3 (2–4) |
| Gender | | |
| Female ($n$ = 97) | 4.0 (2.6) | 3 (1–13) |
| Male ($n$ = 69) | 4.4 (2.2) | 4 (1–11) |
| Vaccination status | | |
| Vaccinated ($n$ = 29) | 3.6 (2.3) | 3 (1–10) |
| Not vaccinated ($n$ = 142) | 4.2 (2.4) | 3 (1–13) |

However, the nightclub event organised for 5th November was targeted at teenagers who at this time had much lower vaccination rates, especially as the general vaccination programme for 12- to 15-year-olds had not opened at the time of the event and only began on 27th November 2021.[3] By 6th November 2021, only 16% of all 12- to 15-year-olds in NI had received the first vaccine, with 3% having received their second vaccine.[8] As the general vaccination program only opened for this group on 27th November 2021, the majority of these children were likely to be either in a high-risk group or in a household of close contact of a Clinically Extremely Vulnerable (CEV) person.

In our study, case vaccination rates were very similar to regional rates with 16.4% of cases having received one vaccine by November 5th. Also, at the time of the event, 14% of the outbreak cases were less than 14 days postvaccination and thus had only limited disease protection, which again highlights the need to co-ordinate lifting of restrictions with vaccine eligibility and uptake. Congregation of teenagers in these settings, with no licence to serve alcohol, was probably not considered by authorities and represents a gap in COVID mitigation planning at entertainment venues. Norwegian authorities banned or restricted alcohol sales in bars and restaurants during the pandemic and in December 2021 could only remain open if not serving alcohol, a measure introduced in response to a super-spreading event involving a group of vaccinated adults in an Oslo entertainment venue.[9,10] Our report demonstrates why public health authorities must also consider younger people who congregate in entertainment venues, especially if vaccination rates are low in this group or they are not eligible for vaccination at that time. Our study also found at least two cases who attended the event after their date of reported symptoms, which illustrates the need to reinforce public messaging regarding the importance of self-isolation when symptomatic and in particular not attending large indoor events.

The under-18s disco is traditionally attended by pre-GCSE (General Certificate of Secondary Education) secondary school-aged teenagers from the wider local area. Indeed, we found that the vast majority of cases (94%) were aged between 12 and 15 years, correlating with four discrete school year groups (year 9 to year 12). Cases were associated with 20 different secondary schools, with 43% of cases associated with just three schools. Initial investigation suggests possible onward transmission to other school-aged children, but further work is required to investigate this.

The incubation period of COVID-19 has been reported as averaging 5–6 days, ranging from 2 to 14 days, but shorter incubation periods have been reported for both Delta (4 days) and Omicron variants (3 days).[11] The mean incubation period in this study was 4.1 days (median = 3 days, range 1–13 days), which is similar to that reported for the Delta variant, which was the main lineage found in this study.

Limitations of this study include the inability to offer testing or to undertake enhanced questionnaires regarding exposures to all attendees. Also, only a proportion of positive samples associated with the outbreak had WGS undertaken (22% (45/206)), but this was in line with WGS testing in NI at the time.

### *Conclusion*

Initial investigations found that SARS-CoV-2 was highly transmissible among unvaccinated young people in a crowded indoor nightclub venue with limited social distancing, close social contact and mixing, limited ventilation and associated singing and shouting. Further investigation to assess onward/secondary transmission is ongoing. Governments and public health authorities should consider the possible congregation of younger people in entertainment settings, when alcohol is not being served, especially if vaccination rates in this group are low or they are not eligible for vaccination at that time. Cases were found to have attended the event after they had developed symptoms, which illustrates the need to develop public communication reinforcing the importance of self-isolation when symptomatic and to ensure young people with COVID symptoms follow public health guidance regarding self-isolation and avoid indoor events with large numbers.

## Author statements

### *Acknowledgements*

Thanks to all members of the Contact Tracing (CT) Data Team for collating data and to the tracing staff for conducting contact tracing interviews. Thanks also to Regional Diagnostic Laboratories for rapid diagnostics and variant screening for national surveillance purposes.

### *Ethical approval*

This study was undertaken using routine COVID-19 contact tracing data collected for the purpose of public health outbreak response. Research ethics approval was not required.

### *Funding*

None declared.

### *Competing interests*

None declared.

### *Authors' contributions*

DB, PS, PMcA, ER, CR, CMcK, CT, CA and MD designed the study. PMcA, DB, ER, CR, CMcK, CT, CA, MD, EDK, HS and PS implemented the study and collated data in collaboration with the CT service. PMcA, DB, ER, CR, CMcK, CT, CA, MD, EDK, HS and PS analysed and interpreted the data. DB, PMcA, ER, CR, CMcK, CT and CA wrote the first draft of the manuscript. All authors revised the manuscript and approved the final version.

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Public Health 211 (2022) 88–96

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

# Pros and cons factors influence population attitudes toward non-pharmaceutical interventions and vaccination during post–COVID-19

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ARTICLE INFO

*Article history:*
Received 22 February 2022
Received in revised form
9 July 2022
Accepted 15 July 2022
Available online 11 August 2022

*Keywords:*
COVID-19
Non-pharmaceutical interventions
Vaccination
Structural equation model
Bayesian

ABSTRACT

*Objectives:* Population compliance greatly influences the effectiveness of vaccination and non-pharmaceutical interventions (NPIs) for the curtaining of COVID-19 transmission. We aimed to determine the conceptual framework of potential factors that influence compliance.
*Study design:* This was a cross-sectional study.
*Methods:* Questionnaires were used to survey population attitudes toward vaccination and NPIs in China. Confirmatory factor analysis of the survey data by structural equation model was used to define the pros and cons factors of attitudes. The strength and direction of each factor's effect on population attitudes were illustrated by Bayesian network analysis.
*Results:* A total of 1700 respondents aged 18–70 years were surveyed with a panel of 34 questionnaires. Of these questionnaires, the confirmatory factor and structural equation model analysis identified five categories contributing to positive attitudes, including response efficiency, willingness and behavior, trust, cues to action, and knowledge, as well as four categories contributing to negative attitudes, including autonomy, perceived barriers, threat, and mental status. Bayesian networks revealed that cues to action produced a driving force for positive attitudes, followed by willingness and behavior, trust, response efficiency, and knowledge, whereas perceived barriers produced a driving force for negative attitudes, followed by autonomy and threat.
*Conclusions:* This study established a concise and representative list of questionnaires that could be applied to investigate the conceptual framework of potential pros and cons factors of attitudes toward vaccination and NPIs for COVID-19 prevention. The factors with driving forces should be addressed with a priority to effectively improve population compliance.


## Introduction

As of November 2021, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been raging globally. Many countries are experiencing multiple waves of high COVID-19 transmission.[1] Infectious diseases and human behaviors are generally intertwined. People's movements and interactions are the engines of transmission.[2] The COVID-19 pandemic has significantly changed our daily activities, which in turn greatly influence the development of the pandemic.[3] So far, although vaccination has been administered in many parts of the world, no satisfactory drugs have been developed to curtail the rapid transmission of COVID-19. Most countries have implemented administrative measures to timely contain the spread of COVID-19. These measures are usually referred to as non-pharmaceutical interventions (NPIs), such as quarantine and lockdowns, social distancing measures, community use of facemasks, and travel restrictions.[4,5] Vaccines are also given high expectations to effectively contain the pandemic. However, these measures have resulted in the significant impairment of physical and psychosocial well-being of people. Such impairment and often existing vaccine hesitancy among subgroups of people led to declined compliance to abide requirements, which drastically affected the effectiveness of control of COVID-19 transmission.[6,7]

Earlier studies have identified a few underlying factors that might influence population compliance with NPIs and vaccination

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https://doi.org/10.1016/j.puhe.2022.07.010

through questionnaire surveys designed on the basis of several psychological theories, such as health belief model,[8] perceived stress,[9] protection motivation theory,[10] theory of planned behavior,[11] as well as sociodemographic factors.[12] These previous studies were independently implemented, often focusing on individual aspects of potential factors, although the actual factors were usually interrelated to affect people's decisions. In the realistic world, several manifesting variables can form a latent variable that, despite the difficulty to be measured, is often more representative of people's overall attitude and social status.[13] As to the psychological survey for attitudes toward COVID-19 prevention, a latent variable approach that integrates several aspects of influencing factors to obtain a comprehensive conclusion is more applicable in judging population attitudes. Routine statistical methodology is often incapable to dig out the representative latent variables and their complex interrelationships.

Investigating factors affecting population compliance with vaccination and NPIs by survey often yields a multitude of categorical data, which needs more specialized mathematical tools to analyze. Structural equation model (SEM) combines latent variable approach, path analysis, and framework analysis,[14] achieving simultaneous analysis of complex relationships of categorical factors. Another mathematical technology is Bayesian paradigm that can provide information about effect direction and causal inference of a series of factors that influence people's attitudes.[15]

People were reported to display varied overall attitudes toward vaccination and NPIs for the prevention of COVID pandemic;[16] we hypothesized there were distinctive factors resulting in positive and negative responses. We aimed to apply SEM and Bayesian methods to analyze the conceptual framework and driving force of factors that affected population attitudes. This study would develop a concise and representative list of questionnaire items, which could be applied to investigate the comprehensive factors resulting in positive and negative responses toward NPI and vaccination for COVID-19 prevention.

## Methods

### *Study design and setting*

We conducted a face-to-face questionnaire survey about population attitudes toward NPIs and vaccination of COVID-19 from August 1 to August 20, 2021, in Ningbo city, China. The participants were aged 18–70 years. The sample size was calculated based on the online Raosoft sample size calculator (http://www.raosoft.com/samplesize.html), which used a response rate of 80%, a confidence interval of 99%, a largest population of 20,000, and a margin of error of 5%; the required sample size was 416. Accordingly, this study included 1700 subjects that were enough for the present study. We recruited participants via convenience sampling at three communities, a college, a park, and an outpatient department. The participants were interviewed by a trained surveyor. The process comprised five phases: involving questionnaire item definition and validity, reliability validity, structure validity of confirmatory factor analysis, strength and direction of factorial effect, and finally, interpretation by experts. The survey raters were trained with knowledge about the meaning of questions and the way of communication with participants.

### *Questionnaire items and surveys*

The questionnaire items consisted of contents based on three theories: perception of severity and susceptibility of COVID-19, perception of benefit and barriers of NPI and vaccine, and knowledge about COVID-19 based on the health belief model;[8] threat assessment of COVID-19 and response efficiency based on the protection motivation theory;[10] as well as cues to action, and willingness and behavior based on the theory of planned behavior.[11] The questionnaire items also included assessment of mental anxiety and depression; trust of medicine, government, and vaccine; as well as autonomy of respondents. These items were reviewed by a panel of experts, including two psychologists, a statistician, and an epidemiologist. Except that 2-item Patient Health Questionaire (PHQ-2) and 2-item Generalized Anxiety Disorder (GAD-2) were 4-point (0–3) scales,[17,18] each item developed in the present study was 5-point (0–4) Likert scale with answers of strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree.[19] The consistency between the statement in the questionnaire and the theoretical indicative meaning was assessed by experts. The questionnaires were amended according to the comments of the experts and pilot tested by a small group of candidates ahead of the large-scale formal investigation. The demographic information of the participants consisted of age, sex, occupation, education, marriage, and residence. The questions and their abbreviations were supplied in Supplement 1.

### *Analysis*

Reliability of the data was considered acceptable when Cronbach's alpha exceeded 0.8.[20] The sampling adequacy for factor analyses was verified using Kaiser–Meyer–Olkin test (at least >0.7).[21] Each category of factors was denoted as a latent variable that was represented by three to four questionnaire items. The confirmatory factor analysis was applied to verify and illustrate the conceptual framework using SEM in the lavaan R package.[22] The final component items of a latent variable were determined according to five metrics of SEM, including Chi-squared (<0.05), standardized root mean square residual (<0.1), comparative fit index (>0.9), root mean square error of approximation (<0.1), and loadings (>0.6). We used the psych R package[23] to compute the polychoric correlation network and the qgraph R package to demonstrate the network.[24] The qgraph package produced regularized partial correlations using the lasso method by the glasso R package.[25] Edges of the network ranging from 0.4 to 0.9 were accepted as reliable associations. The thickness of edges indicated the magnitude of association between two nodes.

To create a Bayesian network of directed acyclic graphs (DAGs), we applied the Bayesian hierarchical model using the bnlearn R package.[26] The fit process of Bayesian network involved the specification of edges, strength of connections, and probability of direction. The edges were determined using a hill climbing algorithm to learn the structure of network and its parameters. The bootstrap function computed the structure of network represented by edges according to goodness-of-fit target score (e.g. Bayesian information criterion [BIC]).[27] The BIC was used as a criterion for edge strength. The smaller the BIC value, the stronger the connection. The direction of connection between nodes was represented by a probability.[28] Each edge had a strength value and a direction value, both of which were expressed in a rate of 0–1. We kept the edges with strength >0.8. The thickness of an edge reflected the magnitude of its strength value. The software codes were supplied in Supplement 2.

### *Statistical analysis*

The answers were represented by numbers of 0 through 3 or 4. Their prevalence was calculated. Categorical variables of demographic information were expressed as absolute values and percentages, and the differences in their distribution were tested by the Chi-squared test when necessary. Age was classified into three groups of 18–29, 30–50, and >50 years. Income was classified into

three categories of <4000, 4000–8000, and ≥8000 Chinese Yuan. Residence was denoted as urban and rural. Job status was classified as medical staff, other employed, retired, student, and unemployed. Education levels were denoted as below college and at least college.

## Results

### *Questions and latent variables*

Descriptive demographic characteristics of the respondents are provided in Table 1 and Fig. 1. Of 1700 respondents who were aged 18–70 years, 49.5% were female (n = 842), and 61.5% (n = 1046) were married. 75% (n = 1276) held a college or higher academic degree. The job status comprised medical staff (n = 233 [13.7%]), other employed (n = 1070 [62.9%]), retired (n = 53 [3.1%]), student (n = 187 [11%]), and unemployed (n = 157 [9.2%]). The distribution of monthly income was under 4000 (n = 338, 19.9%), 4000–8000 (n = 685, 40.3%), and ≥8000 (n = 677, 39.8%) Chinese Yuan. Overall, 81.2% (n = 1380) lived in urban areas, and 18.8% (n = 320) in rural areas. Fig. 1 illustrates the composition percentages of answers to 34 questions among 1700 respondents in terms of Likert scale, showing the distribution of answers for each question was distinctive. We classified the people into three age groups of 18–29, 30–50, and >50 years and compared the Likert scores among the age groups. Generally, the comparison showed that young people had a higher prevalence of depression and anxiety and a higher level of knowledge, whereas the older people had a higher level of autonomy (Table 2). Other categories of questions were the same or only one question showed different responses.

Before exploratory factorial analysis, we inspected the correlation matrix of the questionnaire items. Bartlett's Chi-squared was 4751.2 ($P < 0.001$), indicating that the correlation matrix was not an identity matrix. The mean value of Kaiser–Meyer–Olkin test was 0.86 (ranging from 0.71 to 0.96) that was more than 0.7 as required for adequate sampling for factor analysis. Cronbach's alpha was 0.94, indicating reliability of the survey data. Finally, 34 questionnaire items were defined and grouped into nine categories, which were referred to as the following latent variables: mental depression and anxiety, willingness and behavior, knowledge, perceived barriers, response efficiency, cues to action, autonomy, trust, and threat (Supplement 1 and Fig. 2). To fit variable labels inside the nodes of network, we used the abbreviations for the questions.

**Table 1**
Demographic characteristics.

| Feature | Number (percentage) |
|---|---|
| Sample number | 1700 |
| Sex | |
| Female | 842 (49.5) |
| Male | 858 (50.5) |
| Marriage | |
| Married | 1046 (61.5) |
| Unmarried | 654 (38.5) |
| Age | |
| 18–29 years | 614 (36.1) |
| 30–50 years | 818 (48.1) |
| >50 years | 268 (15.8) |
| Education level | |
| College and over | 1276 (75) |
| Bellow college | 424 (25) |
| Job status | |
| Medical staff | 233 (13.7) |
| Other employed | 1070 (62.9) |
| Retired | 53 (3.1) |
| Student | 187 (11) |
| Unemployed | 157 (9.2) |
| Income (Chinese yuan/month) | |
| <4000 | 338 (19.9) |
| 4000–8000 | 685 (40.3) |
| ≥8000 | 677 (39.8) |
| Residence | |
| Urban | 1380 (81.2) |
| Rural | 320 (18.8) |

### *Confirmatory factor analysis*

Confirmatory factor analysis by SEM showed that nine latent variables composed of 34 items were classified into two classes (Fig. 2). One class contained five latent variables contributing to positive responses, the loadings of which were greater than zero: response efficiency (loading = 1), willingness and behavior (loading = 0.97), trust (loading = 0.85), cues to action (loading = 0.76), and knowledge (loading = 0.59). Another class contained the remaining four latent variables contributing to negative responses: autonomy (loading = 0.94), perceived barriers (loading = 0.9), threat (loading = 0.3), and mental (loading = 0.28). The present results proved that willingness and behavior, response efficiency, and trust had a larger positive effect than cues to action and knowledge, whereas perceived barriers and autonomy had a massively negative effect.

### *Network*

The polychoric correlation network depicted the associations between nine latent variables or categories of 34 questions (Fig. 3). The edges with correlation coefficient between 0.4 and 0.9 were kept. The thickness of the edges represented the correlation magnitude. The number of edges linking a node reflected the centrality degree (strength). Based on the magnitude and strength of correlation, we identified that willingness and behavior, trust, cues to action, and response efficiency had the core influence and prominent interrelationship in the correlation network, whereas autonomy and perceived barriers had negative correlation with the network core. The mental status, knowledge, and threat seemed to be isolated from the central correlation network.

As to the Bayesian network in the appearance of DAG, its primary difference from the polychoric correlation network was that the Bayesian network had a feature of direction. This feature represented a causal relationship or effect direction in the network (Fig. 4). The present DAG showed that the mental status (Nodes 1–4 in Fig. 4) was an isolated factor without an evident effect on other latent variables. Three nodes (Nodes 22, 23, and 21) belonging to cues to action were on the top of the DAG, implying that these factors were the original driving force of the DAG. The subsequent effect chains stretched in an order of willingness and behavior (Nodes 6, 5, 7, and 8), trust (Nodes 30, 28, and 29), response efficiency (Nodes 18, 17, 19, and 20), and, finally, knowledge (Nodes 9–12). On the right segment of the DAG, three items belonging to perceived barriers had the original negative effect of the DAG, followed by autonomy and threat. To be noteworthy, one item of perceived barriers, that is, difficult to get self-protection, was at the end of the DAG. The strength and direction values of links between every two nodes were provided in Supplement 3.

## Discussion

The present study coined a panel of 34 questionnaire items and determined their conceptual framework and interrelationship that might affect the population attitudes toward NPI measures and vaccination for prevention of the COVID-19 pandemic. SEM and confirmatory factorial analysis of the survey results of 1700 respondents showed that five categories of questionnaire items producing positive effects and four categories producing negative

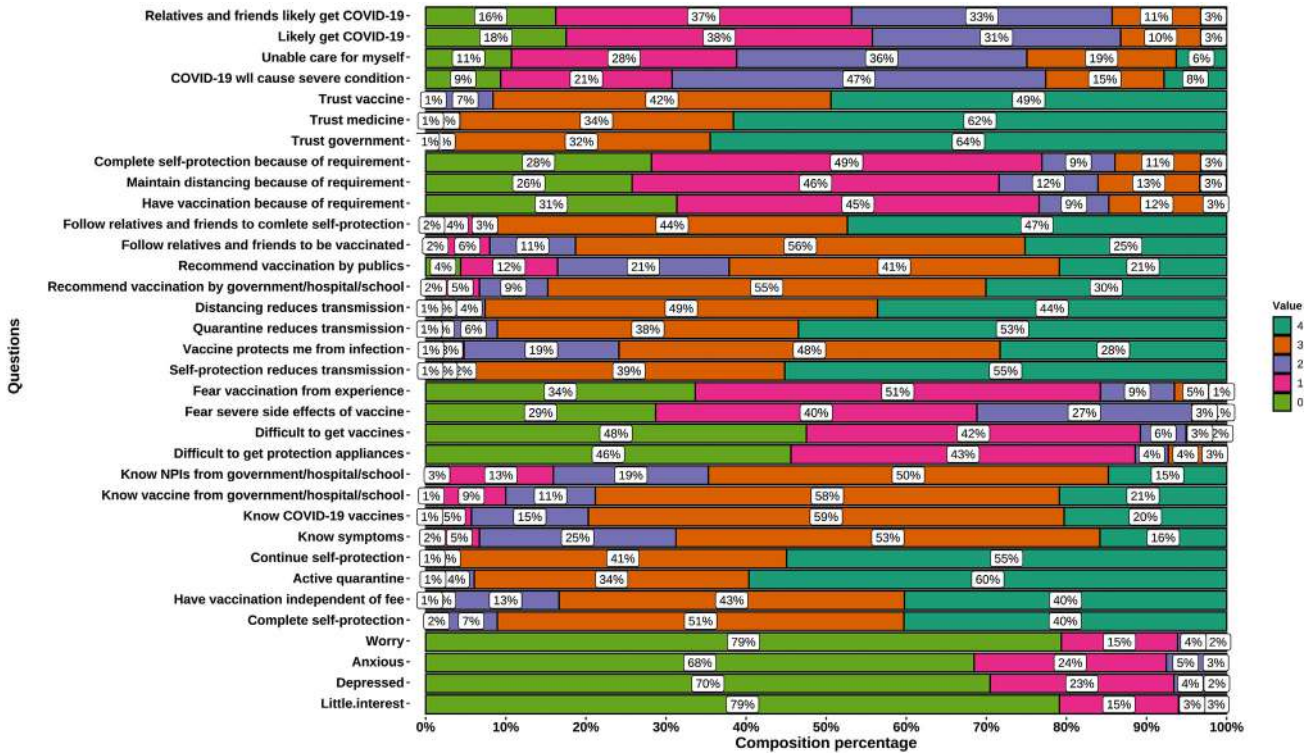


**Fig. 1.** Composition percentages of answers to 34 questions among 1700 respondents. Note: Except for four mental items are 4-point scale, ranging from 0 to 3, and the other items are 5-point scale, ranging from 0 to 4.

effects on the overall population attitudes. The Bayesian network approach proved that cues to action produced a positive driving force of the network, whereas perceived barriers produced a negative driving force of the network.

So far, a number of preceding studies investigated potential factors that affected people's attitude toward NPIs and vaccination.[29,30] These factors were related to multidisciplinary fields that could be largely generalized into three theories: including health belief model, protection motivation theory, and the theory of planned behavior. However, these studies failed to clarify the conceptual framework of numerous factors, their interrelationship, and effect direction. The present study applied three approaches to disentangle the complex factorial network: involving the definition of latent variables, confirmatory factor analysis by SEM, and Bayesian network approach.

We classified these factors into nine categories of concepts based on the three theories and previous literature. Although age is an important factor that influences people's attitude in many ways, our results by age stratification showed difference only in depression and anxiety, knowledge, and autonomy (Table 2). Other categories of questions were the same or only one question showed different responses (Table 2). These categories were depicted by SEM and referred to as latent variables. Latent variables are inferred variables representing a centralized value shared by the observed variables or the degree to which observed variables congregate in meaning.[31] Observed variables, which appear as components of a latent variable, must correlate with each other to some extent. Too low the correlation coefficient between observed variables means they do n'ot belong to the same latent variable, whereas too high the correlation coefficient means they are redundant.[32] We specified a correlation coefficient of 0.4–0.9 as the threshold value for the observed variables in a latent variable (Fig. 3). This correlation network showed how close the categories were interlinked. The network showed that response efficiency, willingness and behavior, cues to action, and trust formed the center of the positive response segment, whereas autonomy and perceived barriers formed the negative response segment.

The SEM analysis of latent variables successfully fitted the survey data to yield a conceptual framework consisting of positive and negative categories of items (Fig. 2). This fitted structure of latent variables vividly depicted the relative effectiveness of potential factors leading to positive and negative responses toward NPI and vaccination and answered our hypothesis. In the SEM path diagram, the loading values on the edges illustrated the extent to which the observed variables were correlated with the latent variable they belonged to. Regarding the five categories contributing to positive responses, the order according to their loadings was response efficiency (loading = 1), willingness and behavior (loading = 0.97), trust (loading = 0.85), cues to action (loading = 0.76), and knowledge (loading = 0.59). When we define 0.6 as the threshold value of loading, only knowledge was slightly below 0.6. The top-ranked response efficiency contained four questions about the effectiveness of self-protection, vaccination, quarantine, and distancing, suggesting belief in the effectiveness of NPIs and vaccination was most important to increase the compliance of NPIs among people. The following categories were willingness and behavior, as well as cues to action that were related to action, behavior, and recommendation of actions.

Although among the four latent variables contributing to negative responses, autonomy (loading = 0.94) and perceived barriers (loading = 0.90) had the evident negative effectiveness as indicated by loadings. Autonomy can be defined as the ability of a person to make his or her own decisions. This faith in autonomy is the central premise of the concept of informed consent and shared decision-making.[33] This result proved that respect for people's decision-making rights deeply affected their adherence. Preceding literature described that autonomy leading to inability to abide by NPIs

**Table 2**
Likert scores of survey questions stratified by three age groups.

| Questions | Age group | | | |
|---|---|---|---|---|
| | 18–29 | 30–50 | >50 | Overall *P* |
| | ***N* = 614** | ***N* = 818** | ***N* = 268** | |
| Little interest | 0.36 (0.70) | 0.29 (0.67) | 0.15 (0.47) | <0.001[a] |
| Depressed | 0.46 (0.71) | 0.39 (0.70) | 0.22 (0.54) | <0.001[a] |
| Anxious | 0.49 (0.76) | 0.43 (0.72) | 0.22 (0.51) | <0.001[a] |
| Worry | 0.34 (0.69) | 0.29 (0.65) | 0.16 (0.48) | 0.001[a] |
| Complete self-protection | 3.29 (0.71) | 3.29 (0.72) | 3.27 (0.66) | 0.893 |
| Have vaccination independent of fee | 3.18 (0.87) | 3.20 (0.82) | 3.18 (0.74) | 0.862 |
| Active quarantine | 3.51 (0.70) | 3.52 (0.66) | 3.52 (0.61) | 0.987 |
| Continue self-protection | 3.51 (0.62) | 3.50 (0.66) | 3.41 (0.59) | 0.058 |
| Know symptoms | 2.77 (0.84) | 2.80 (0.82) | 2.63 (0.86) | 0.011[a] |
| Know COVID-19 vaccines | 2.96 (0.78) | 2.94 (0.80) | 2.84 (0.79) | 0.119 |
| Know vaccine from government/hospital/school | 2.94 (0.85) | 2.89 (0.90) | 2.74 (0.88) | 0.007[a] |
| Know NPIs from government/hospital/school | 2.58 (0.96) | 2.58 (1.00) | 2.74 (0.96) | 0.057 |
| Difficult to get protection appliances | 0.73 (0.92) | 0.76 (0.94) | 0.82 (0.96) | 0.484 |
| Difficult to get vaccines | 0.70 (0.88) | 0.72 (0.85) | 0.65 (0.78) | 0.582 |
| Fear severe side-effects of vaccine | 1.05 (0.91) | 1.11 (0.88) | 1.07 (0.84) | 0.454 |
| Fear vaccination from experience | 0.87 (0.88) | 0.91 (0.86) | 0.91 (0.84) | 0.613 |
| Self-protection reduces transmission | 3.43 (0.81) | 3.46 (0.77) | 3.43 (0.60) | 0.753 |
| Vaccine protects me from infection | 2.94 (0.93) | 3.00 (0.85) | 3.03 (0.70) | 0.256 |
| Quarantine reduces transmission | 3.40 (0.79) | 3.43 (0.76) | 3.37 (0.76) | 0.491 |
| Distancing reduces transmission | 3.25 (0.83) | 3.36 (0.72) | 3.34 (0.63) | 0.023[a] |
| Recommend vaccination by government/hospital/school | 3.03 (0.92) | 3.09 (0.84) | 3.04 (0.82) | 0.347 |
| Recommend vaccination by publics | 2.60 (1.08) | 2.68 (1.07) | 2.50 (1.07) | 0.054 |
| Follow relatives and friends to be vaccinated | 2.97 (0.92) | 2.98 (0.88) | 2.88 (0.87) | 0.272 |
| Follow relatives and friends to complete self-protection | 3.36 (0.81) | 3.32 (0.87) | 3.17 (0.87) | 0.009[a] |
| Have vaccination because of requirement | 1.03 (1.06) | 1.12 (1.04) | 1.16 (1.08) | 0.117 |
| Maintain distancing because of requirement | 1.12 (1.00) | 1.24 (1.10) | 1.39 (1.12) | 0.002[a] |
| Complete self-protection because of requirement | 1.02 (0.94) | 1.08 (1.05) | 1.46 (1.17) | <0.001[a] |
| Trust government | 3.59 (0.61) | 3.60 (0.60) | 3.62 (0.55) | 0.715 |
| Trust medicine | 3.55 (0.65) | 3.56 (0.61) | 3.57 (0.60) | 0.932 |
| Trust vaccine | 3.43 (0.69) | 3.37 (0.73) | 3.36 (0.64) | 0.218 |
| COVID-19 causes severe condition | 1.92 (1.04) | 1.88 (1.01) | 1.93 (0.99) | 0.703 |
| Unable care for myself | 1.79 (1.06) | 1.82 (1.06) | 1.86 (1.05) | 0.692 |
| Likely get COVID-19 | 1.31 (0.99) | 1.45 (0.98) | 1.64 (1.03) | <0.001[a] |
| Relatives and friends likely get COVID-19 | 1.41 (1.03) | 1.50 (0.98) | 1.59 (0.96) | 0.049[a] |

The Likert scores are expressed in mean (SD).
[a] Likert scores are statistically different among three groups.

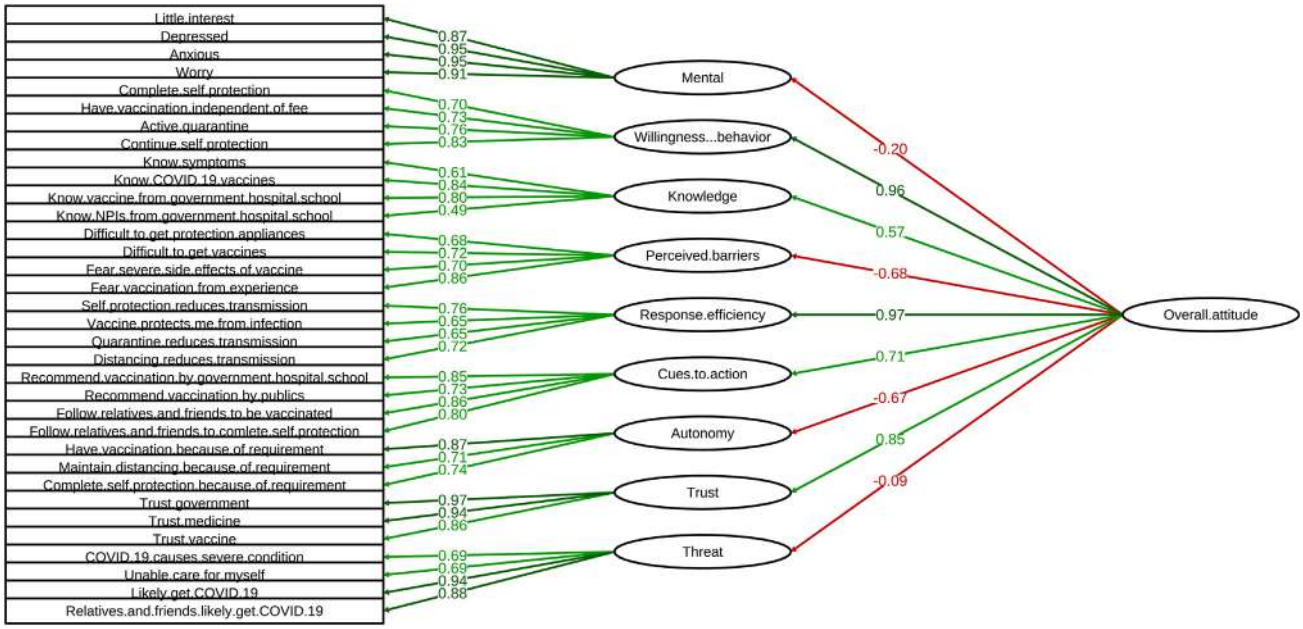


**Fig. 2.** SEM illustrates the framework of 34-item instrument including nine latent variables.

was a significant predictor of higher infection rates among certain groups.[3] The questions of perceived barriers were about the difficulty to get protection appliances, vaccines, and worry about side-effects of vaccination. They were the common cause of vaccine hesitancy. As a previous study indicated, healthcare provider–related barriers and institutional barriers affected

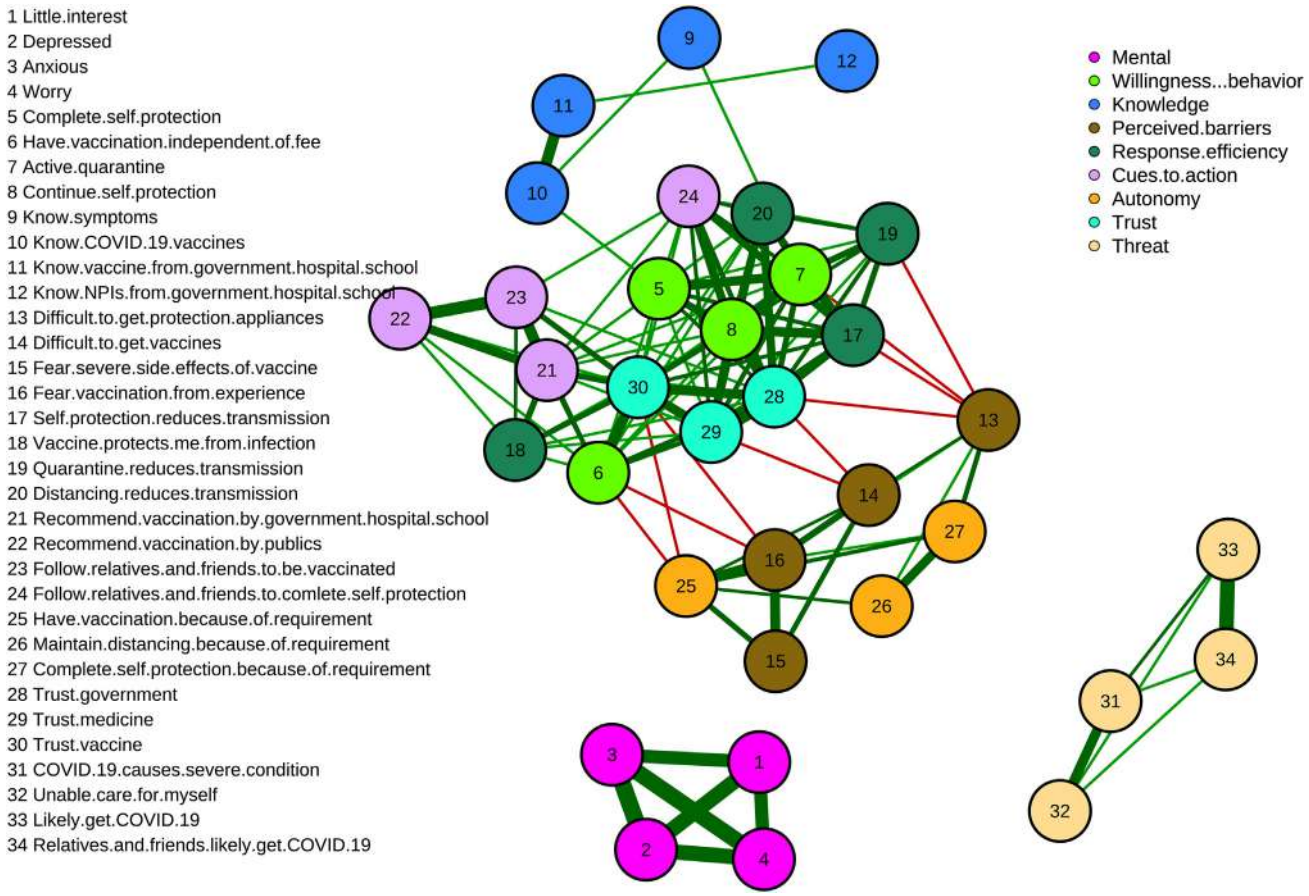


**Fig. 3.** Polychoric correlation network of 34 items in nine categories.

preventive measures.[34] Although the correlation network (Fig. 3) did n'ot establish causation, it could provide proof to the following Bayesian network in terms of the link strength between nodes.

SEM analysis of latent variables and correlation network hereto did n'ot tell the direction of effectiveness. In other words, the above technologies did n'ot answer what factors had the most driving force and how they affected each other in a directed way. DAG produced by Bayesian network is a probabilistic graphical model with a direction, which represents a set of variables and their conditional dependencies.[35] It can infer the likelihood of possible causes, which show the contributing strength to a status. This approach was used in identifying the most effective policy to control COVID-19 transmission.[36] In the present study, the survey data of 34 questions were analyzed by Bayesian network method to derive the direction of action that shaped the population attitudes (Fig. 4). We reached several interesting conclusions from the findings of DAG analysis: mental depression and anxiety was an isolated factor staying clearly away. There were largely two primary effect paths with direction: the positive response path and the negative response way. The positive response path started from cues to action (Nodes 22, 23, and 21), to trust (Nodes 30, 28, and 29), to willingness and behavior (Nodes 6–8), and to response efficiency (Nodes 17, 19, and 20) and knowledge (10–12). This path revealed that cues to action were the driving force that directly affected trust and willingness and behavior, and subsequently, the affected two factors further influenced response efficiency and the last factor of knowledge. As to the negative response path that appeared in a simpler manner, it originated from perceived barriers (Nodes 15, 16, and 14) and moved to autonomy (Nodes 25–27). Meanwhile, threat had moderate linkage with one item of the last positive and negative categories. The primary application of the DAG was to suggest what factors should be the primary targets of government intervention. Upstream factors that were close to the top of the network, such as cues to action, should be the primary targets, as it appeared to be the source of activation driving. These findings imply that the critical point of increasing compliance with NPI and vaccination is to address the factors that locate at the beginning of Bayesian network, such as items of cues to action and perceived barriers. The items that show a direct link with willingness and behavior are also should be paid attention to.

Our study has several strengths and weaknesses. One aspect of strength is that our study was designed to systematically decipher the pros and cons of factors that influenced population's attitudes from a broad scope of potential factors based on classical psychological theories. Another aspect of strength is the quantitative results that provide clues to the causal direction of the relationship between potential factors. The weak is that the demographic characteristics of participants might differ from other countries or in different stages of the pandemic. Second, the generalization of our findings to the general population is limited, as voluntary participation option and convenience sampling method may lead to selection bias. Another limitation is that people aged beyond 70 years are not included in this study, which requires a special study to investigate these people, as they may have different pros and cons factors toward their attitude. Yet, by classifying people into three age groups, we demonstrated that the age affects few aspects of factors. Moreover, the analysis procedure gains light to how to decipher the pros and cons of

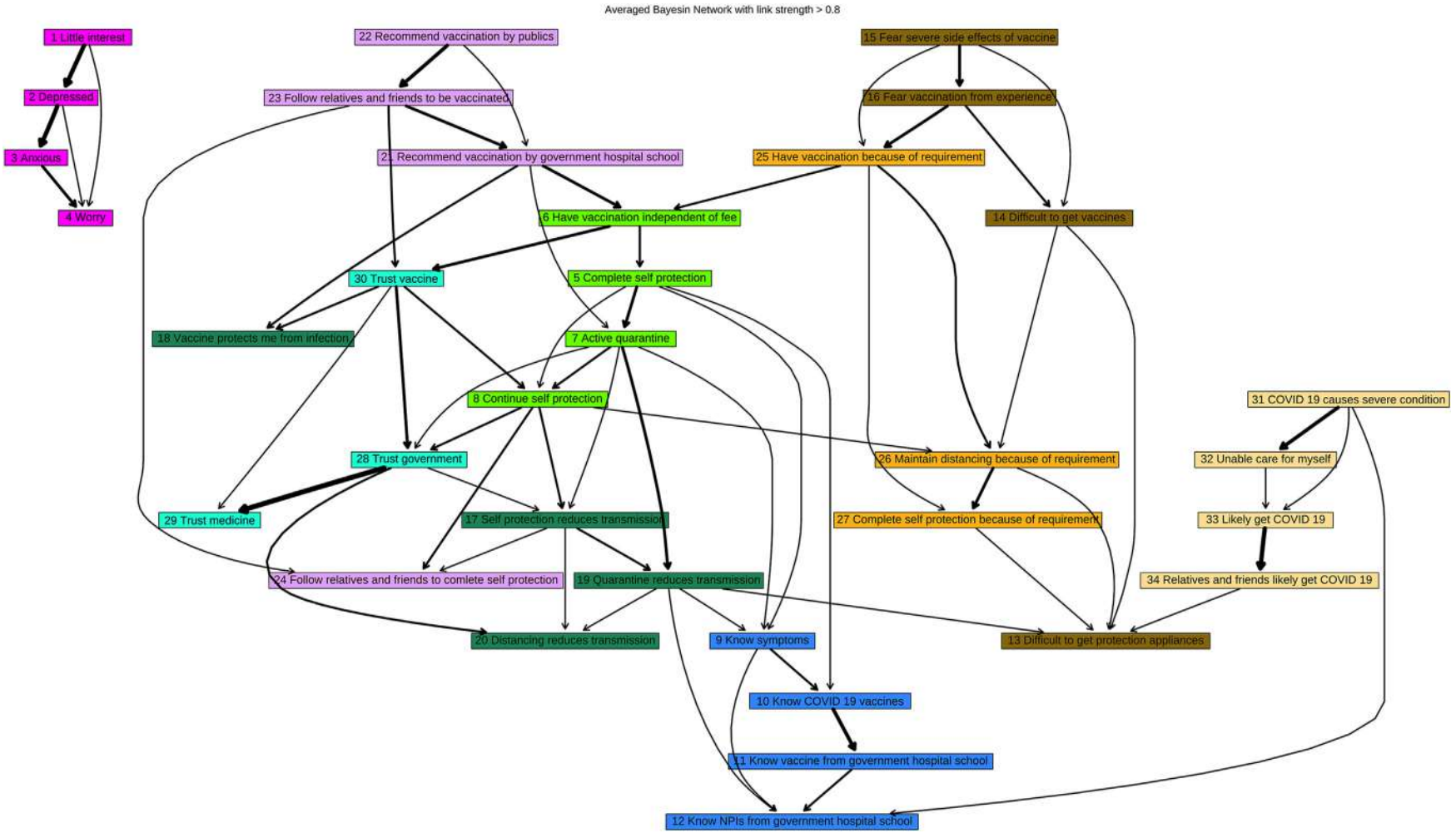


**Fig. 4.** Bayesian network of 34 items in nine categories. Note: the group color is the same with that in Fig. 3.

factors that influence population attitudes toward NPIs and vaccination during post–COVID-19.

*Conclusion*

To summarize, the present study successfully creates a panel of 34 questionnaire items that can be used to investigate the pros and cons attitudes toward NPIs and vaccination for COVID-19 prevention. The study unravels that response efficiency, willingness and behavior, cues to action, trust, and knowledge contribute to positive responses, whereas autonomy, perceived barriers, mental, and threat contribute to negative responses. Bayesian network analysis suggests that factors located near the top of the DAG of Bayesian network, such as cues to action and perceived barriers, should be addressed with a priority to efficiently increase the compliance with NPIs and vaccination.

## Author statements

*Acknowledgements*

The authors would like to thank the participants of this study.

*Ethical approval*

The protocol has been approved by the ethics committee of Ningbo University School of Medicine (approval number: NBU-2021-066).

*Funding*

This research was funded by Natural Science Foundation of Ningbo (No. 2021J270) and Public Welfare Fund of Zhejiang Province, China (No. LGF22G030010).

*Competing interests*

None to declare.

*Author contributions*

Q.S. designed the study, analyzed the data, and wrote the article. Y.M. wrote the article and designed the questions. L.R. provided the fund and revised the article.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.07.010.

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Public Health 211 (2022) 85–87

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Short Communication

# Risk of hospitalisation or death in households with a case of COVID-19 in England: an analysis using the HOSTED data set

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ARTICLE INFO

*Article history:*
Received 11 April 2022
Received in revised form
16 July 2022
Accepted 19 July 2022
Available online 8 August 2022

*Keywords:*
COVID-19
SARS-CoV-2
Household contacts
Hospitalisation
Mortality
Household transmission
England
Surveillance
Secondary user service
HOSTED

ABSTRACT

*Objective:* To determine whether household contacts of confirmed cases of COVID-19 have an increased risk of hospitalisation or death.

*Methods:* We used the HOSTED data set of index cases of COVID-19 in England between June and November 2020, linked to Secondary Uses Service data on hospital episodes and Office for National Statistics' mortality data. Multivariable logistic regression models of the odds of household contacts being hospitalised or dying within six weeks of an index case, adjusted for case type, age, sex and calendar month were calculated. Excess risk was determined by comparing the first six weeks after the index case with 6–12 weeks after the index case in a survival analysis framework.

*Results:* Index cases were more likely to be hospitalised or die than either secondary cases or non-cases, having adjusted for age and sex. There was an increased risk of hospitalisation for non-cases (adjusted hazard ratio (aHR) 1.10; 95% confidence interval (CI) 1.04, 1.16) and of death (aHR 1.57; 95% CI 1.14, 2.16) in the first six weeks after an index case, compared to 6–12 weeks after.

*Conclusion:* Risks of hospitalisation and mortality are predictably higher in cases compared to non-cases. The short-term increase in risks for non-case contacts following diagnosis of the index case may suggest incomplete case ascertainment among contacts, although this was relatively small.



## Introduction

The Household Transmission Evaluation Dataset (HOSTED)[1] provides a unique opportunity to explore the risk of hospitalisation and death in household contacts of confirmed cases of COVID-19 to determine if there is any excess risk to them, regardless of whether they are diagnosed with COVID-19 themselves. This is particularly important in the scenario of limited testing where cases may be missed, as was the case in England early in the pandemic.

## Methods

The HOSTED methodology has been described elsewhere[1]; in brief, it is an ongoing surveillance system that has identified the residential household contacts of laboratory-confirmed cases in England since 20th April 2020, including both Pillar 1 (testing of persons for a clinical need in healthcare or as part of a public health investigation) and Pillar 2 (community-based testing accessible to members of the public). Linkages with hospital episodes from Secondary Uses Service (SUS) data (a national administrative dataset based on healthcare providers' clinical activities) and ONS (Office for National Statistics) mortality data for all anonymised cases and contacts within HOSTED enable us to investigate whether there is any increased risk in hospitalisation or death for household contacts of confirmed cases of COVID-19.

There is very limited evidence on hospitalisation and deaths of household contacts of confirmed COVID-19 cases. Data from a cohort study in Scotland have shown that between 1st March and 6th June 2020, household contacts of cases of COVID-19 in the general public had a risk of admission with COVID-19 of 0.05%; it was higher for healthcare workers and their household contacts.[2]

We considered individuals in households where the index case occurred between 1st June 2020 and 8th November 2020, extracted on the 31st January 2021, to allow for complete follow-up of hospitalisations within six weeks of the index case, and a further six weeks buffer in case of reporting delays in the SUS

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https://doi.org/10.1016/j.puhe.2022.07.013

data. Hospitalised individuals were grouped using ICD-10 codes into 'COVID' (U07 and derivatives), 'pneumonia (B97 and J12) and possible interest', and 'other' (all other ICD-10 codes). ICD-10 codes of 'possible interest' were comorbidities thought to be risk factors for adverse outcomes of COVID-19 on discussion with clinicians. This predominantly included diseases of the cardiovascular, cerebrovascular, respiratory and renal systems, cancer, diseases that cause immunosuppression or require treatment with immunosuppressives, diabetes and obesity. The pneumonia codes were selected in case of misdiagnosis of a COVID-19 case as another viral pneumonia. This grouping together captured people in whom a diagnosis of COVID-19 could have been missed. We had data on whether the person had died, but not their cause of death.

*Statistical analysis*

The proportion hospitalised or dying within 6 weeks of the index case testing positive (starting from the specimen date of the positive test) was modelled using logistic regression; covariates included case category (index case, secondary case, contact without positive test), age group (0–34, 35–54, 55–69 and 70+ years) and sex. Time trends were considered by including calendar month, and age-specific trends. To ascertain whether there was any excess risk of hospitalisation in non-cases, we examined hospitalisation rates in the first six weeks after the index case compared to 6–12 weeks in a survival analysis framework. Hazards were assumed constant within each time interval and estimated hazard ratios (HRs) adjusted for age, sex and calendar time. Analysis was restricted to patients with 18 weeks observable follow-up.

*Ethics approval*

The HOSTED surveillance system was reviewed and approved by the PHE Research Ethics Governance Group. The data were collected and linked by NHS Digital. The data were processed lawfully under GDPR Article 6(1)e and 9(2)i and shared under Regulation 3(4) of the Health Service (Control of Patient Information) Regulations 2002.

## Results

In England, there were 1.68 million individuals living in a household in which a confirmed case occurred between 1st June and 8th November 2020. The median household size was 4 (interquartile range (IQR): 3–5); the median age of individuals in the data set was 32 years (IQR 19–50 years), with 326,606 children younger than 16 years (19.4%) and 63,994 older than 70 years (3.8%). In 74.5% of the data for this period, the index case occurred in October/November, when cases were increasing rapidly in England, but before the emergence of the Alpha variant.

*Hospitalisation*

A total of 49,516 individuals (2.95%) were hospitalised within 42 days of the index case date. 28,843 of 477,034 (6.05%) index cases were hospitalised, and 4685 of 92,243 (5.08%) secondary cases were hospitalised. In comparison, among household contacts without laboratory-diagnosed COVID-19, 13,876 were hospitalised out of 1.05 million (1.32%).

In logistic regression of all persons in the data set, index cases were most likely to be hospitalised (aOR 4.49; 95% CI 4.40, 4.59) compared to non-cases, after adjusting for age and sex, as were secondary cases (aOR 3.54; 95% CI 3.40, 3.65). Rates of hospitalisation increased with age, as did the risk associated with being a case compared to a contact, regardless of reason for admission. Of those aged over 70 years, 27.9% were admitted with COVID-19 within six weeks of laboratory confirmation and 4.14% were admitted with pneumonia or other potentially relevant ICD-10 code, compared to 1.26% and 0.35%, respectively, in index cases aged 0–34 years. Among household contacts who were not laboratory-confirmed COVID-19 cases, 0.35% of those aged over 70 years were admitted with COVID-19, 3.18% with pneumonia or other relevant condition and 0.58% for other reasons, according to the SUS data. For every age group, the percentages of non-COVID-19 admissions are higher in COVID-19 cases than in those not diagnosed with COVID-19.

Hospitalisations due to any cause in index cases of COVID-19 fell in all age groups from June to October 2020, though the risks decreased most for those younger than 35 years. Hospitalisation in non-cases also fell slightly in every age group between June- and October 2020, and younger age groups were consistently more likely to be hospitalised for reasons other than COVID-19/pneumonia.

Examining only the non-COVID-19 admissions, both index and secondary cases were more likely to be admitted to hospital in the six weeks following a positive test for SARS-CoV-2, particularly if they were older than 70 years, both for pneumonia/other relevant conditions or for another reason.

*Mortality*

A total of 6414 individuals (0.38%) died within 42 days of the index case date. 5230 of 477,034 index cases died (1.10%), 596 of 92,243 secondary cases died (0.65%), and 419 of 1.05 million non-cases died (0.04%).

Death was considerably more likely in index cases (aOR 22.9; 95% CI 20.7, 25.3) and secondary cases (aOR 13.1; 95% CI 11.5, 14.8) than in individuals not diagnosed with COVID-19, having adjusted for age and sex. In terms of trends, the risk of death in index cases reduced over time with a similar pattern to hospitalisation, with the greatest reduction over time in the younger groups. Trends are more stable for secondary cases, although data are sparse and confidence intervals wide. For those not diagnosed, there are declining trends in the youngest and oldest age groups, similar to hospitalisations, but confidence intervals are wide and the results are not significant.

*Excess risk*

The adjusted HR for hospitalisation within six weeks vs. 6–12 weeks was 1.10 (95% CI 1.04, 1.16), indicating a modest increase in hospitalisation rates in non-cases around the time of the index case. For mortality, the adjusted HR was 1.57 (95% CI 1.14, 2.16) for the first six weeks after the index case compared to 7–12 weeks after. As shown in Fig. 1, this was driven by increased hospitalisation and deaths in those older than 55 years.

## Discussion

Index cases had the highest risk of hospitalisation and death followed by secondary cases compared to household contacts who did not become laboratory-confirmed cases (non-cases). The higher

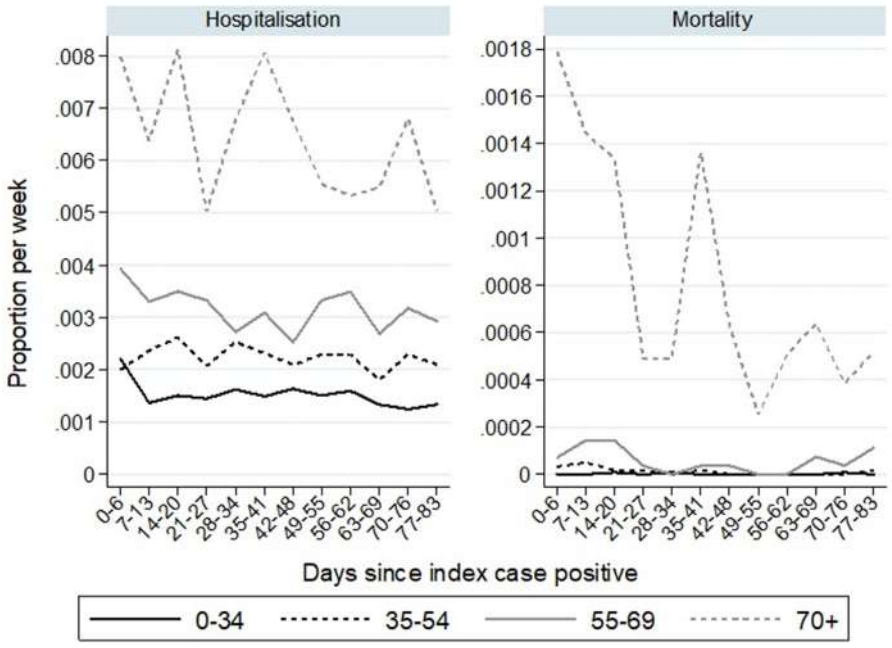


**Fig. 1.** Proportion of non-diagnosed contacts hospitalised (any cause) or dying per week since date of index case positive, by age. Y-axis scales vary between panels.

risk in index cases could be due to testing being biased towards more severe index cases, whereas case ascertainment may be less dependent on severity for secondary cases.

We found some evidence of a modestly increased risk of hospitalisation in household contacts of laboratory-confirmed cases of COVID-19 who did not become laboratory-confirmed cases themselves. This suggests that, over the timeframe considered, case ascertainment has been good, if not complete. We found a higher risk of admission than the Scottish study, which is likely because we included all hospitalisations, not only those for COVID-19(2).

Mortality may be increased by around 50% in non-cases immediately following the index case, although absolute mortality rates remain low and confidence intervals for any excess risk were relatively wide. This may indicate incomplete case ascertainment if a person died before being tested. Routine postmortem testing for SARS-CoV-2 could reveal the true burden of the disease.[3]

### *Strengths and limitations*

The HOSTED data set is large, covering all laboratory-confirmed cases and their household contacts in England. However, as a passive surveillance system, the data are subject to several limitations, including incomplete case ascertainment and a lack of information on testing uptake which could introduce bias. Without genomics data, we cannot confirm household transmission versus secondary cases having acquired their infection elsewhere. However, self-isolation of households following COVID-19 symptoms even before confirmation reduces the likelihood of acquiring an infection outside of the household. Previous sensitivity analysis showed that secondary attack rates within the household were robust to changing the definition of a secondary case from 2–14 days after the index case to 4–14 days after the index case.

## Author statements

### *Acknowledgements*

The authors wish to thank Heather Pinches, Phillip Bowker and Paul Ellingham as well as the rest of the NHS Digital team whose hard work and dedication enabled the creation of these data during the UK COVID-19 pandemic response. The authors also wish to thank Sarah Woodhall for her integral role in developing the HOSTED project.

### *Data availability statement*

The data underlying this article cannot be shared publicly due to the legal and policy controls placed on data used as part of the government's response to the COVID-19 pandemic.

### *Funding*

This work was undertaken as part of the core functions of Public Health England in relation to the surveillance of communicable diseases and outbreak response.

### *Competing interests*

None declared.

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Public Health 211 (2022) 53–61

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

# Route to diagnosis of colorectal cancer and association with survival within the context of a bowel screening programme

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ARTICLE INFO

*Article history:*
Received 29 January 2022
Received in revised form
21 June 2022
Accepted 29 June 2022
Available online 23 August 2022

*Keywords:*
Colon
Rectum
Diagnosis
Neoplasms

ABSTRACT

*Objectives:* Bowel cancer screening has been introduced to improve colorectal cancer outcomes; however, a significant proportion of cases continue to present with TNM Stage III-IV disease and/or emergently. This study analyses the prior interaction with screening of patients diagnosed with colorectal cancer and factors associated with non-screening diagnosis.

*Study design:* This was a retrospective observational study.

*Methods:* All patients diagnosed with colorectal cancer in the West of Scotland from 2011 to 2014 were identified. Through data linkage to the Scottish Bowel Cancer Screening Programme, we analysed patient interaction with screening within 2 years before cancer diagnosis.

*Results:* In total, 6549 patients were diagnosed with colorectal cancer, 1217 (19%) via screening. Screening participation was associated with earlier TNM stage, reduced emergency presentations and improved 3-year survival (all $P < 0.001$). Failure to diagnose through screening was predominantly due to non-invitation (37%), non-return of screening test (29%) or negative test (13%). Three hundred fifty-one patients were below screening age, 79% of whom were aged 40–49 years and 2035 patients were above screening age. Factors associated with non-return of screening test included age, sex, SIMD (all $P < 0.001$) and raised Charlson score ($P = 0.030$). Factors associated with negative screening result included sex, anaemia, differentiation, right-sided tumours and venous invasion ($P < 0.001$).

*Conclusion:* Within Scotland, <20% of colorectal cancer is diagnosed through screening despite the existence of a population screening programme. Measures must be taken to improve screening participation including encouragement of those of routine screening age and those age ≥75 years in good health to participate in screening with consideration given to extending screening to under 50s. A significant false-negative rate of testing was observed in the present study and this requires further investigation within a population undergoing screening through faecal immunochemical testing.



## Introduction

Colorectal cancer, the third most commonly diagnosed malignancy worldwide remains a significant cause of morbidity and mortality.[1] The majority of new cases of colorectal cancer are diagnosed electively; however, a significant proportion (10–30%) continue to present emergently, predominantly with obstructive symptoms.[2,3] TNM stage remains the main factor influencing long-term outcomes; however, significantly worse short- and long-term outcomes have been reported in the emergency compared to the elective population even after adjustment for the TNM stage.[3–5]

Bowel cancer screening programmes are now well established within the Developed World[6,7] with the aim of both identifying early-stage disease and reducing the proportion of emergency presentations. Available modalities of screening have been summarised in a recent review.[8] Currently, the most common first-line screening test is through the detection of blood in faecal samples, either through guaiac-based faecal occult blood testing (gFOBT) or, increasingly, faecal immunochemical testing (FIT). In a previous Cochrane review, screening programmes were reported to have a colorectal cancer mortality relative risk reduction of 15% overall and 25% following exclusion of non-responders.[9] The European guidelines for quality assurance in colorectal cancer screening and diagnosis recommend a minimum uptake to screening of 45% and

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https://doi.org/10.1016/j.puhe.2022.06.032

desirable uptake of 65%[10] of the target population; however, to date participation has remained suboptimal at 50–60%. Some subsets of the population, particularly those of low socio-economic status, have been shown to have particularly poor engagement with screening.[11–14]

Within Scotland, all adults aged between 50 and 74 years are routinely invited to participate in biennial bowel screening. This programme was rolled out nationally from 2007 and aims to have a minimum uptake of 60%.[14] Before 2017, gFOBT was the first-line screening test with positive results progressing to endoscopic investigation and borderline results progressing to FIT testing. Since 2017, FIT testing has been used as the first-line investigation. Previous literature suggests that the current participation rate is approximately 57% with a further 8% of patients with a positive screening sample failing to undergo further investigation.[15] Despite this, a significant reduction in both the proportion of patients diagnosed with late-stage disease and the proportion of emergency presentations following introduction of the bowel cancer screening programme has been reported — 20% prescreening versus 13% in the postscreening cohort ($P < 0.001$).[13] However, a recent study that excluded individuals who did not participate in the bowel screening programme has suggested that the rate of emergency presentation could be reduced to as low as 5%;[16] therefore, there remains potential for significant improvement within the screening service.

Multiple studies have examined screening cohorts as a whole; however, the majority of these have failed to capture patients diagnosed with colorectal cancer out with screening. In the present study, we aim to investigate the relationship between patients diagnosed with colorectal cancer in the West of Scotland and their involvement in the most recent round of screening within 2 years before diagnosis. Furthermore, we aim to identify which clinicopathological characteristics are associated with failure to progress through each stage of the screening programme and examine the relationship between screening diagnosis and TNM stage, mode of presentation and long-term outcomes in colorectal cancer.

## Methods

The West of Scotland Colorectal Cancer Managed Clinical Network (MCN) maintains a prospectively collected data set of all patients diagnosed with colorectal cancer in the West of Scotland and contains basic clinicopathological data. This covers four health boards (Ayrshire and Arran, Forth Valley, Lanarkshire and Greater Glasgow and Clyde) and includes almost half of the population of Scotland. These patients receive treatment and follow-up in line with national guidelines.

Patients diagnosed with colorectal cancer between January 2011 and December 2014 within the West of Scotland were identified from the MCN database and additional data were obtained from electronic patient records. All patients were included within the present study regardless of disease stage, mode of presentation or subsequent treatment. Tumours were staged using the TNM classification system. Emergency presentation was defined as an unplanned admission requiring a definitive procedure within 72 h. Those patients who did not undergo a procedure did not have a recorded mode of presentation. Socio-economic deprivation has been stratified using the Scottish Index of Multiple Deprivation (SIMD).[17] Comorbidity status was classified using the Charlson Index (Royal College of Surgeons Modification).[18] Preoperative anaemia was included if a preoperative haemoglobin was available, for elective patients within 1 month before surgery and for emergency patients from the date of admission. Survival was updated through data linkage to the National Records of Scotland (NRS) deaths data until the end of 2018. Overall survival (OS) was defined as the time from the date of surgery until the date of death of any cause. Cancer-specific survival (CSS) was defined as the time from the date of surgery until the date of death due to recurrent/metastatic colorectal cancer. A death was considered the result of colorectal cancer if this was the primary cause of death recorded on the death certificate. All patients were followed up for a minimum of 4 years from the date of diagnosis.

Through data linkage to the Scottish Bowel Screening Programme (SBoSP) data set, the interaction of each patient with the most recent round of screening (within 2 years before diagnosis of colorectal cancer) was analysed. Engagement with the bowel screening programme was categorised as: invited (yes/no), return of screening sample (yes/no), return of valid screening sample (yes/no), screening stool sample result (positive/negative), further investigation (yes/no) and diagnosis of cancer (yes/no). Further data were also available including the date of investigation and screening test used (gFOBT/FIT). Being before 2017, this patient population underwent first-line screening through the gFOBT test. Patients with positive tests progressed to endoscopic investigation. Patients with a borderline gFOBT underwent FIT with positive FIT subsequently progressing to endoscopic investigation. Screening was routinely offered to patients aged between 50 and 75 years. Patients aged 75 years and older were not routinely sent screening tests but were able to request them.

Ethical approval was granted for this project from the Public Benefit and Privacy Panel (NHS Scotland) for Health and Social Care (PBPP) and Caldicott Guardian Approval.

### *Statistical analysis*

The relationship between clinicopathological characteristics and interaction with each stage of the bowel screening programme was analysed using the Chi-squared test. Three-year survival was calculated using a life table approach and results were displayed as percentage 3-year survival and percentage standard error. Statistical significance was calculated using the log-rank test.

Statistical analysis was carried out using IBM SPSS Statistics for Windows Version 27 (IBM Corporation, Armonk, New York USA). A two-tailed $P$ value of $<0.05$ was considered significant throughout.

## Results

Within the study period of January 2011–December 2014, 6549 patients were diagnosed with colorectal cancer in the West of Scotland, 4113 of whom were invited to participate in the bowel screening programme. Most patients presented electively (83%) with TNM Stage II (29%) or TNM Stage III (30%) disease. Seventy-seven percent of patients underwent either a curative or palliative procedure. During the follow-up period, there were 3519 deaths, 69% of which were cancer related.

As shown in Fig. 1, 6549 patients were diagnosed with colorectal cancer in the West of Scotland from January 2011 to December 2014. Nineteen percent of these patients ($n = 1217$) were diagnosed through screening. Reasons for failure to diagnose through screening included: no invitation to screening (37%, $n = 2436$), patient invited to screening but no valid sample returned (29%, $n = 1884$), valid sample returned however negative result (13%, $n = 844$), positive sample returned but no further investigation (2%, $n = 137$) or further investigation but no malignancy found (0.5%, $n = 31$).

The association between screening diagnosis and clinicopathological factors including mode of presentation, treatment type and survival is shown in Table 1. Of host factors, screening diagnosis was associated with age <75 years, male sex, lower socio-economic deprivation, less comorbid status (as measured by both ASA and

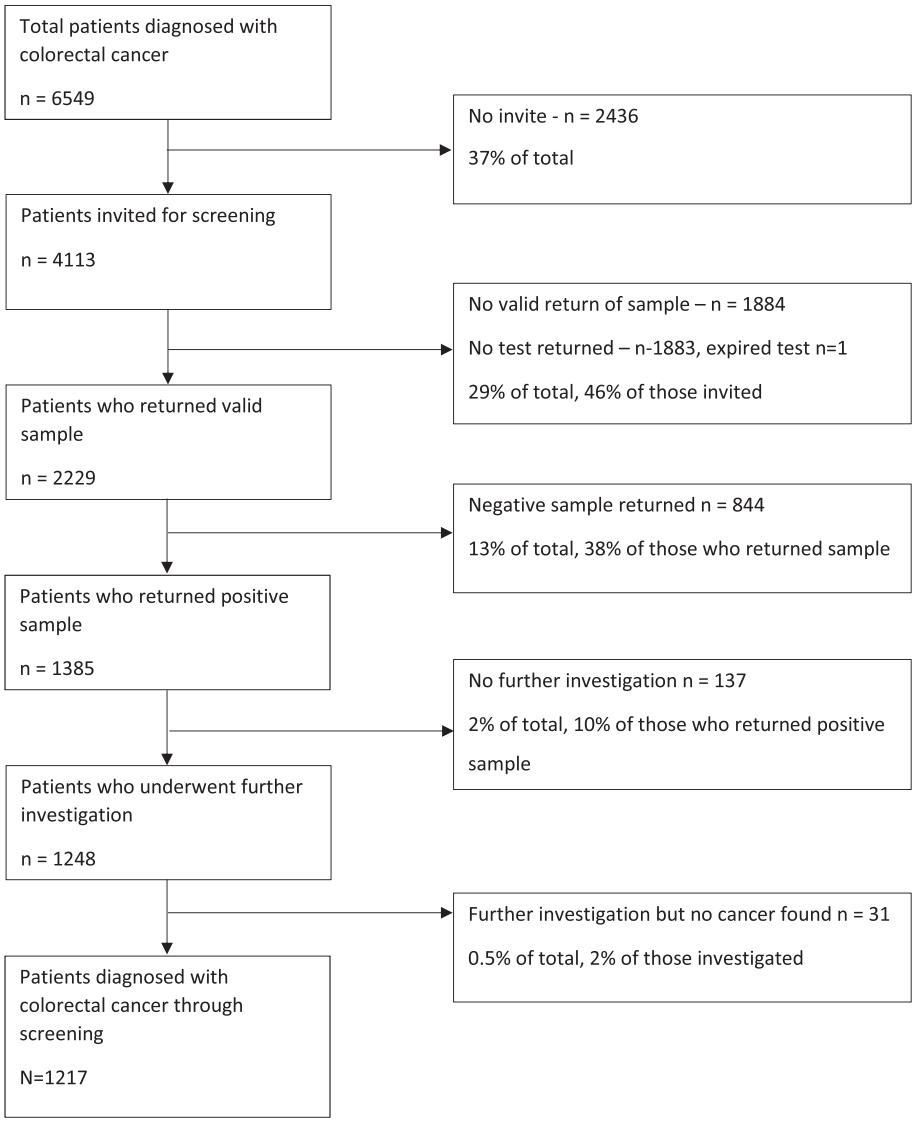


**Fig. 1.** Patient involvement with Bowel Cancer Screening Programme within the screening round immediately before colorectal cancer diagnosis.

Charlson score) and non-smokers (all $P \leq 0.001$). Of tumour factors, patients diagnosed through screening had less advanced, well-moderately differentiated tumours without extramural venous invasion (all $P < 0.001$). Right-sided tumours were less likely to be diagnosed through screening ($P < 0.001$). Those patients diagnosed through screening were more likely to undergo elective procedures with resectional surgery (both $P < 0.001$). Diagnosis through screening was associated with a significantly improved 3-year overall (86% vs 51%, $P < 0.001$) and CSS (90% vs 58%, $P < 0.001$) (Fig. 2).

Of the 6549 patients diagnosed with colorectal cancer during the study period, 37% ($n = 2436$) had not been invited to participate in screening. As shown in Table 2, of those patients not invited, 14% ($n = 350$) were below the age threshold for screening of whom 79% were aged between 40 and 49 years ($n = 277$). Eighty-four percent of patients ($n = 2035$) were above the upper limit of routine invitation to screening. When patient age was categorised by decade, 27%, 64% and 9% were aged 75–79, 80–89 and 90+ years, respectively. The reason for non-invitation to screening of the remaining 51 patients (2%) was uncertain.

Of 4113 patients invited to participate in the bowel cancer screening programme, 46% ($n = 1884$) of patients failed to return a valid stool sample. One patient returned a screening test; however, the sample container had expired and the remaining 1883 patients failed to return a test. The association between clinicopathological factors and return versus non-return of the screening test is shown in Table 3. Patients aged between 65 and 74 years ($P < 0.001$), female patients ($P < 0.001$), patients of a higher socio-economic status ($P < 0.001$), patients with a less comorbid status as measured by both ASA and Charlson score ($P < 0.001/0.030$, respectively), non-smokers ($P < 0.001$) and patients with an increased BMI ($P = 0.007$) were more likely to return a screening test. No significant association was seen between ethnicity and non-return of screening test ($P = 0.574$).

Of the 2229 patients who returned a valid stool sample, 38% ($n = 844$) returned a negative sample. The association between clinicopathological factors and screening test result is shown in Table 4. Female sex ($P < 0.001$), BMI <30 kg/m$^2$ ($P = 0.002$), increased comorbidity as measured by Charlson Score ($P = 0.002$), preoperative anaemia ($P < 0.001$), poorly differentiated tumours, extramural venous invasion ($P = 0.001$), right-sided cancers

**Table 1**
Association between screening diagnosis and tumour stage, mode of presentation, treatment type and survival.

| Variable | All patients | Non-screening diagnosis | Screening diagnosis | *P*-value |
|---|---|---|---|---|
| **Total** | **6549** | **5332 (81%)** | **1217 (19%)** | |
| **Age (years)** | **6549** | **5332 (81%)** | **1217 (19%)** | **<0.001** |
| <50 | 350 (5%) | 350 (7%) | 0 (0%) | |
| 50–74 | 3943 (60%) | 2727 (51%) | 1216 (>99%) | |
| 75+ | 2256 (34%) | 2255 (42%) | 1 (<1%) | |
| **Sex** | **6549** | **5332 (81%)** | **1217 (19%)** | **<0.001** |
| Male | 3643 (56%) | 2887 (54%) | 756 (62%) | |
| Female | 2906 (44%) | 2445 (46%) | 461 (38%) | |
| **SIMD** | **6549** | **5332 (81%)** | **1217 (19%)** | **<0.001** |
| 1 | 1871 (29%) | 1570 (29%) | 301 (25%) | |
| 2 | 1509 (23%) | 1251 (24%) | 258 (21%) | |
| 3 | 1129 (17%) | 923 (17%) | 206 (17%) | |
| 4 | 1004 (15%) | 782 (15%) | 222 (18%) | |
| 5 | 1036 (16%) | 806 (15%) | 230 (19%) | |
| **ASA** | **4440** | **3425 (77%)** | **1015 (23%)** | **<0.001** |
| 1 | 474 (11%) | 330 (10%) | 144 (14%) | |
| 2 | 2342 (53%) | 1706 (50%) | 636 (63%) | |
| 3 | 1395 (31%) | 1171 (34%) | 224 (22%) | |
| 4 | 223 (5%) | 213 (6%) | 10 (1%) | |
| 5 | 6 (<1%) | 5 (<1%) | 1 (<1%) | |
| **Smoking** | **3523** | **2724 (77%)** | **799 (23%)** | **0.001** |
| Non-smoker | 1638 (47%) | 1256 (46%) | 382 (48%) | |
| Ex-smoker | 1353 (38%) | 1025 (38%) | 328 (41%) | |
| Smoker | 532 (15%) | 443 (16%) | 89 (11%) | |
| **BMI (kg/m$^2$)** | **2498** | **1874 (75%)** | **624 (25%)** | **<0.001** |
| <18.5 | 58 (2%) | 51 (3%) | 7 (1%) | |
| 18.5–24.9 | 795 (32%) | 644 (34%) | 151 (24%) | |
| 25–29.9 | 897 (36%) | 679 (36%) | 218 (35%) | |
| 30–34.9 | 492 (20%) | 337 (18%) | 155 (25%) | |
| 35+ | 256 (10%) | 163 (9%) | 93 (15%) | |
| **Charlson score** | **2657** | **1990 (75%)** | **667 (25%)** | **<0.001** |
| 0 | 1561 (59%) | 1104 (56%) | 457 (69%) | |
| 1 | 737 (28%) | 572 (29%) | 165 (25%) | |
| 2 | 289 (11%) | 255 (13%) | 34 (5%) | |
| 3+ | 70 (3%) | 59 (3%) | 11 (2%) | |
| **Ethnicity** | **3341** | **2688 (81%)** | **653 (20%)** | **0.655** |
| White British | 3283 (98%) | 2640 (98%) | 643 (99%) | |
| Other | 58 (2%) | 48 (2%) | 10 (2%) | |
| **Preoperative anaemia** | **3051** | **2377 (78%)** | **674 (22%)** | **<0.001** |
| None | 1701 (56%) | 1168 (49%) | 533 (79%) | |
| Mild | 761 (25%) | 654 (28%) | 107 (16%) | |
| Severe | 589 (19%) | 555 (23%) | 34 (5%) | |
| **Differentiation** | **5740** | **4564 (80%)** | **1176 (21%)** | **<0.001** |
| Well-mod | 4688 (82%) | 3664 (80%) | 1024 (87%) | |
| Poor | 1052 (18%) | 900 (20%) | 152 (13%) | |
| **EMVI** | **4350** | **3325 (76%)** | **1025 (24%)** | **<0.001** |
| Negative | 2579 (59%) | 1856 (56%) | 723 (71%) | |
| Positive | 1771 (41%) | 1469 (44%) | 302 (30%) | |
| **Tumour site** | **6549** | **5332 (81%)** | **1217 (19%)** | **0.450** |
| Colon | 4611 (70%) | 3765 (71%) | 846 (70%) | |
| Rectal | 1938 (30%) | 1567 (29%) | 371 (31%) | |
| **Colon tumour side** | **4524** | **3684 (81%)** | **840 (19%)** | **<0.001** |
| Right | 2363 (52%) | 2038 (55%) | 325 (39%) | |
| Left | 2161 (48%) | 1646 (45%) | 515 (61%) | |
| **Screening test type** | **2229** | **1012 (45%)** | **1217 (55%)** | **<0.001** |
| gFOBT | 1188 (53%) | 822 (81%) | 366 (30%) | |
| FIT | 1041 (47%) | 190 (19%) | 851 (70%) | |
| **TNM** | **5402** | **4268 (79%)** | **1134 (21%)** | **<0.001** |
| I | 1195 (22%) | 732 (17%) | 463 (41%) | |
| II | 1575 (29%) | 1281 (30%) | 294 (26%) | |
| III | 1598 (30%) | 1284 (30%) | 314 (28%) | |
| IV | 1034 (19%) | 971 (23%) | 63 (6%) | |
| *Unknown* | | | | |
| **Metastatic at presentation** | **6382** | **5175 (81%)** | **1207 (19%)** | **<0.001** |
| No | 5002 (78%) | 3877 (75%) | 1125 (93%) | |
| Yes | 1380 (22%) | 1298 (25%) | 82 (7%) | |
| **Mode of presentation** | **5193** | **4033 (78%)** | **1160 (22%)** | **<0.001** |
| Elective | 4307 (83%) | 3161 (78%) | 1146 (99%) | |
| Emergency | 886 (17%) | 872 (22%) | 14 (1%) | |
| **Type of procedure** | **6542** | **5325 (81%)** | **1217 (19%)** | **<0.001** |
| No procedure | 1516 (23%) | 1452 (27%) | 64 (5%) | |
| Bypass/stent/defunctioning surgery | 358 (6%) | 345 (7%) | 13 (1%) | |
| Local resection | 337 (5%) | 199 (4%) | 138 (11%) | |
| Formal resection | 4331 (66%) | 3329 (63%) | 1002 (82%) | |
| **3-year survival (all patients)** | **6549** | **5332** | **1217** | |
| OS | 58% (SE 1%) | 51% (SE 1%) | 86% (SE 1%) | <0.001 |
| CSS | 64% (SE 1%) | 58% (SE 1%) | 90% (SE 1%) | <0.001 |

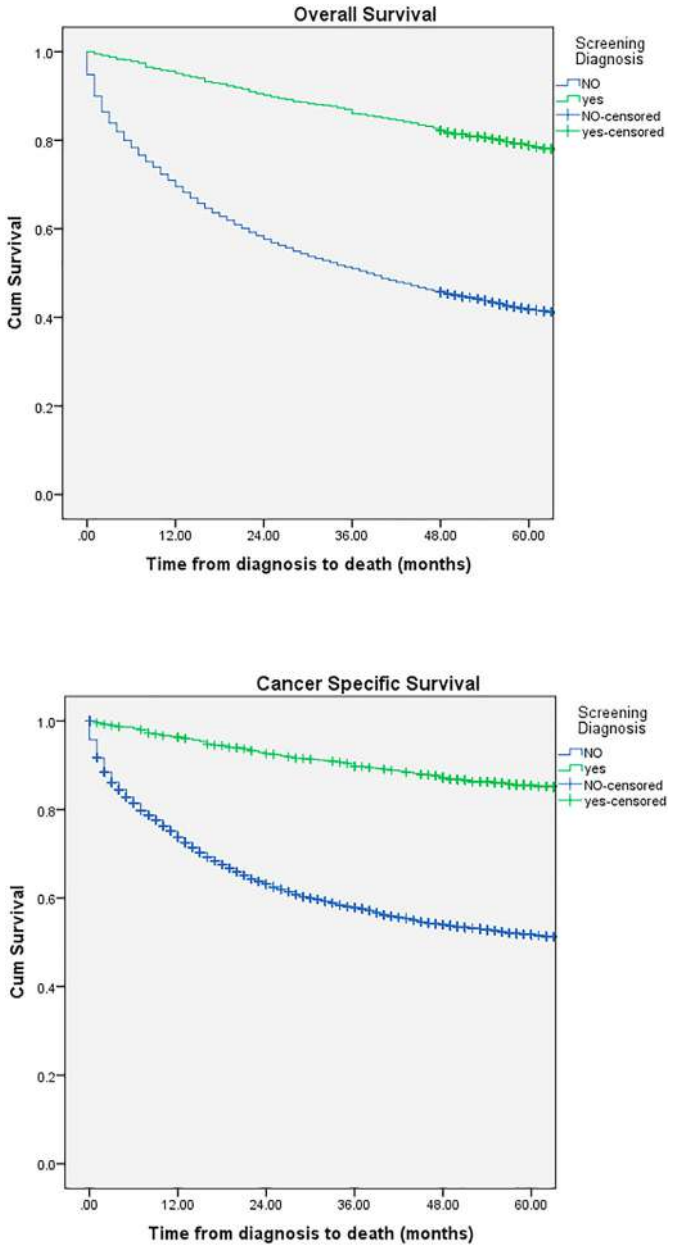


**Fig. 2.** Kaplan-Meier chart for survival stratified by type of diagnosis (screening vs non-screening) — (a) overall survival and (b) cancer-specific survival.

($P < 0.001$) and patients screened using gFOBT ($P < 0.001$) were associated with negative screening results.

Of the 1385 patients who had a positive screening test, 90% underwent further investigation. Of the 10% of patients ($n = 137$) who did not undergo further investigation, the reason for this could not be established in 51 patients. As shown in Table 4, for the remaining 86 patients, this was either a patient decision (44%, $n = 38$), patient did not attend (21%, $n = 18$), patient already under endoscopic surveillance (19%, $n = 16$), clinician decision (15%, $n = 13$) or the patient died while waiting for further investigation (1%, $n = 1$).

Thirty-one patients (2%) had a negative colonoscopy after a positive screening test. Colonoscopies were complete in 20 patients, incomplete in three patients and results not available for the remaining eight patients.

**Table 2**
Characteristics of patients not invited to participate in screening ($n = 2436$).

| | |
|---|---|
| **Total number of patients** | **2436** |
| **Below screening age (<50 years)** | **351** |
| 18–29 | 24 (7%) |
| 30–39 | 49 (14%) |
| 40–49 | 277 (79%) |
| **Above screening age (75+ years)** | **2035** |
| 75–79 | 543 (27%) |
| 80–89 | 1311 (64%) |
| 90+ | 181 (9%) |
| **Unknown** | **51** |

## Discussion

The results of the present study show that during the study period, only 19% of colorectal cancer in the West of Scotland was diagnosed through screening, and 50% of patients invited to screening fully participated in the screening process. Patients diagnosed through the bowel cancer screening programme were more likely to present electively with early-stage (TNM Stage I-II) disease and undergo curative resectional surgery with significantly better oncological outcomes than patients diagnosed outwith screening.

The present results show that despite the current stool-based bowel cancer screening programme being simple, safe and non-invasive, engagement with screening within the West of Scotland remains poor. Uptake to screening within Scotland is similar to that in England and Wales as reported in the National Bowel Cancer Audit 2020 — 60% and 57%, respectively.[19] However, within the present study, a higher proportion of patients were diagnosed through the Bowel Screening Programme than reported within the National Bowel Cancer Audit 2020 within England and Wales (19% vs 10%) likely due to the wider age range eligible for screening within Scotland compared to England and Wales (50–74 vs 60–74 years). Nonetheless, the proportion of patients diagnosed with colorectal cancer at TNM Stage I-II remains far short of the 75% target set within the NHS Long Term Plan;[20] therefore, optimisation of services are required to meet this target. Within the present study, one in five patients had metastatic disease at the time of diagnosis and of those with full TNM staging, 50% of patients had TNM Stage III-IV disease. The incidence of colorectal cancer (currently 1.9 million cases each year globally) has been predicted double over the next 10–20 years.[21] A significant survival advantage was seen in patients diagnosed through screening (3-year CSS — 90% vs 58%, $P < 0.001$). Optimisation of the screening service remains perhaps the most promising way of improving outcomes in patients with colorectal cancer.

Although traditionally considered a disease of high HDI (Human Development Index) nations, likely due to dietary and lifestyle factors, the incidence of colorectal cancer in low HDI countries has more recently been reported to be increasing, likely due to Western lifestyle changes. Meanwhile, within some high HDI countries, the incidence has been reported to be decreasing, in part due to the introduction of screening programmes aimed not just at diagnosing colorectal cancer at an early malignant stage but also within the premalignant polyp phase.[22] Outcomes have been reported to be significantly worse in low compared to high HDI nations. This is, amongst other factors the result of limited access to healthcare and late stage at diagnosis (in part due to the absence of screening programmes).[23] As summarized in a recent review, the implementation of screening programmes within low HDI nations undoubtedly carries additional challenges;[24] however, remains an opportunity to increase the proportion of patients diagnosed at early stage with improved oncological outcomes, particularly where access to adjuvant/palliative chemotherapy may be limited.

**Table 3**
Association between clinicopathological characteristics and return vs non-return of screening sample in patients invited to screening ($n = 4113$).

| Clinicopathological factor | Missing | Total *n* (%) | Returned screening test *n* (%) | Non-return of screening test *n* (%) | *P*-value |
|---|---|---|---|---|---|
| **Total** | **0** | **4113** | **2230 (54%)** | **1883 (46%)** | |
| **Age (years)** | **0** | **4113** | **2230 (54%)** | **1883 (46%)** | **<0.001** |
| <65 | | 1604 (39%) | 859 (39%) | 745 (40%) | |
| 65–74 | | 2026 (49%) | 1155 (52%) | 871 (46%) | |
| 75+ | | 483 (12%) | 216 (10%) | 267 (14%) | |
| **Sex** | **0** | **4113** | **2230 (54%)** | **1883 (46%)** | **<0.001** |
| Male | | 2422 (59%) | 1252 (56%) | 1170 (62%) | |
| Female | | 1691 (41%) | 978 (44%) | 713 (38%) | |
| **SIMD** | **0** | **4113** | **2230 (54%)** | **1883 (46%)** | **<0.001** |
| 1 | | 1207 (29%) | 559 (25%) | 648 (34%) | |
| 2 | | 948 (23%) | 474 (21%) | 474 (25%) | |
| 3 | | 685 (17%) | 371 (17%) | 314 (17%) | |
| 4 | | 630 (15%) | 390 (18%) | 240 (13%) | |
| 5 | | 643 (16%) | 436 (20%) | 207 (11%) | |
| **ASA** | **1024** | **3089** | **1784 (58%)** | **1305 (42%)** | **<0.001** |
| 1 | | 348 (11%) | 234 (13%) | 114 (9%) | |
| 2 | | 1752 (57%) | 1090 (61%) | 662 (51%) | |
| 3 | | 884 (29%) | 434 (24%) | 450 (35%) | |
| 4 | | 101 (3%) | 25 (1%) | 76 (6%) | |
| 5 | | 4 (<1%) | 1 (<1%) | 3 (<1%) | |
| **Smoking** | **1696** | **2417** | **1413 (59%)** | **1004 (42%)** | **<0.001** |
| Non-smoker | | 1085 (45%) | 670 (47%) | 415 (41%) | |
| Ex-smoker | | 913 (38%) | 568 (40%) | 345 (34%) | |
| Smoker | | 419 (17%) | 175 (12%) | 244 (24%) | |
| **BMI (kg/m$^2$)** | **2304** | **1809** | **1093 (60%)** | **716 (40%)** | **0.007** |
| <18.5 | | 33 (2%) | 13 (1%) | 20 (3%) | |
| 18.5–24.9 | | 521 (29%) | 293 (27%) | 228 (32%) | |
| 25–29.9 | | 655 (36%) | 401 (37%) | 254 (36%) | |
| 30–34.9 | | 378 (21%) | 242 (22%) | 136 (19%) | |
| 35+ | | 222 (12%) | 144 (13%) | 78 (11%) | |
| **Charlson score** | **2292** | **1821** | **1108 (61%)** | **713 (39%)** | **0.030** |
| 0 | | 1157 (64%) | 729 (66%) | 428 (60%) | |
| 1 | | 459 (25%) | 271 (25%) | 188 (26%) | |
| 2 | | 166 (9%) | 86 (8%) | 80 (11%) | |
| 3+ | | 39 (2%) | 22 (2%) | 17 (2%) | |
| **Ethnicity** | **1990** | **2123** | **1196 (56%)** | **927 (44%)** | **0.574** |
| White British | | 2090 (98%) | 1179 (99%) | 911 (98%) | |
| Other | | 33 (2%) | 17 (1%) | 16 (2%) | |

Furthermore, although the establishment of such programmes will increase the burden on endoscopy services, increased detection and management of premalignant polyps may reduce the number of people requiring resectional surgery ± adjuvant therapy. The present findings are therefore applicable to both high and low HDI nations.

In 1966, Wilson and Jungner described multiple factors that must be considered when establishing a screening service, both in terms of the health condition screened for and the population in whom to screen.[25] Many of these factors lie outwith the scope of this study. Nonetheless, within the present study, 351 patients (5%) were diagnosed with colorectal cancer below screening age of whom 79% were aged 40–49 years. It has been reported that an increasing number of younger people (age <50 years) are developing colorectal cancer,[26,27] often with poorer outcomes and it would therefore seem reasonable to consider lowering the minimum age for screening within Scotland. Indeed, several sources including the American Cancer Society[28] and the US Preventative Services Task Force[29] advocate the inclusion of patients aged between either 45–50 or 40–50 years into bowel cancer screening. Furthermore, a large proportion of patients diagnosed with bowel cancer were above the upper age limit for the routine invitation to screening although these patients were still eligible to request screening tests. As described by Nee and colleagues,[30] the inclusion of older people within screening is more complex and the benefits of screening depend on several factors including comorbid and functional status. Within the present study, fewer than 10% of patients over 75 years returned a screening sample. Despite this, a large proportion of these patients subsequently underwent curative resectional surgery and it therefore seems reasonable that older individuals in good health should be encouraged to continue to participate in screening.

Within the present study, non-return of screening sample was a major factor precluding screening diagnosis — fewer than 55% of patients invited for screening returned a screening sample and this remains below international guidelines.[10] The reason for non-engagement in screening is likely to be multifactorial. Although the precise reason for non-engagement requires more detailed qualitative investigation, the present study described several factors associated with non-return of screening test in particular: older age, male sex, less affluent socio-economic status, current smokers, patients with a low-normal BMI and patients with an increased comorbid status. Prior research has investigated factors influencing return versus non-return of bowel screening samples and factors including: lower educational achievement, lower socio-economic status, fear of cancer diagnosis, reluctance to handle faecal samples and a lack of knowledge regarding the benefits of early asymptomatic detection were reasons for non-engagement with screening.[31–35] It is of interest that this association with socio-economic status remains within the free at point of care National Health Service. The effect of sex on screening participation remains unclear. Although the present results show that females are more likely to engage with screening, a previous review by Mosquera and colleagues[36] reported significant variation between studies and offered several hypotheses for the discrepancies observed. Despite screening aiming to identify colorectal cancer

**Table 4**
Association between clinicopathological factors and screening test result in those who returned valid screening test ($n = 2229$).

| Clinicopathological factor | Missing | Total | Negative screening test *n* (%) | Positive screening test *n* (%) | *P*-value |
|---|---|---|---|---|---|
| **Total** | | **2229** | **844 (38%)** | **1385 (62%)** | |
| **Age (years)** | **0** | **2229** | **844 (38%)** | **1385 (62%)** | **0.147** |
| <65 | | 859 (39%) | 304 (36%) | 555 (40%) | |
| 65–74 | | 1154 (52%) | 452 (54%) | 702 (51%) | |
| 75+ | | 216 (10%) | 88 (10%) | 128 (9%) | |
| **Sex** | **0** | **2229** | **844 (38%)** | **1385 (62%)** | **<0.001** |
| Male | | 1251 (56%) | 402 (48%) | 849 (61%) | |
| Female | | 978 (44%) | 442 (52%) | 536 (39%) | |
| **SIMD** | **0** | **2229** | **844 (38%)** | **1385 (62%)** | **0.764** |
| 1 | | 558 (25%) | 208 (25%) | 350 (25%) | |
| 2 | | 474 (21%) | 175 (21%) | 299 (22%) | |
| 3 | | 371 (17%) | 147 (17%) | 224 (16%) | |
| 4 | | 390 (18%) | 141 (17%) | 249 (18%) | |
| 5 | | 436 (20%) | 173 (21%) | 263 (19%) | |
| **ASA** | **445** | **1784** | **644 (36%)** | **1140 (64%)** | **0.336** |
| 1 | | 234 (13%) | 80 (12%) | 80 (12%) | |
| 2 | | 1090 (61%) | 381 (59%) | 381 (59%) | |
| 3 | | 434 (24%) | 174 (27%) | 174 (27%) | |
| 4 | | 25 (1%) | 9 (1%) | 9 (1%) | |
| 5 | | 1 (<1%) | 0 | 0 | |
| **Smoking** | **817** | **1412** | **520 (37%)** | **892 (63%)** | **0.408** |
| Non-smoker | | 669 (47%) | 246 (47%) | 423 (47%) | |
| Ex-smoker | | 568 (40%) | 202 (39%) | 366 (41%) | |
| Smoker | | 175 (12%) | 72 (14%) | 103 (12%) | |
| **BMI (kg/m$^2$)** | **1137** | **1092** | **390 (36%)** | **702 (64%)** | **0.002** |
| <18.5 | | 13 (1%) | 6 (2%) | 7 (1%) | |
| 18.5–24.9 | | 293 (27%) | 118 (30%) | 175 (25%) | |
| 25–29.9 | | 400 (37%) | 159 (41%) | 241 (34%) | |
| 30–34.9 | | 242 (22%) | 69 (18%) | 173 (25%) | |
| 35+ | | 144 (13%) | 38 (10%) | 106 (15%) | |
| **Charlson score** | **1121** | **1108** | **372 (34%)** | **736 (66%)** | **0.002** |
| 0 | | 729 (66%) | 228 (61%) | 501 (68%) | |
| 1 | | 271 (25%) | 91 (25%) | 180 (25%) | |
| 2 | | 86 (8%) | 45 (12%) | 41 (6%) | |
| 3+ | | 22 (2%) | 8 (2%) | 14 (2%) | |
| **Preoperative anaemia** | **1038** | **1198** | **442 (37%)** | **756 (63%)** | **<0.001** |
| None | | 858 (72%) | 276 (62%) | 582 (77%) | |
| Mild | | 230 (19%) | 104 (24%) | 126 (17%) | |
| Severe | | 110 (9%) | 62 (14%) | 48 (6%) | |
| **Differentiation** | **19** | **2110** | **778 (37%)** | **1332 (63%)** | **<0.001** |
| Mod/well | | 1764 (84%) | 604 (78%) | 1160 (87%) | |
| Poor | | 346 (16%) | 174 (22%) | 172 (13%) | |
| **EMVI** | **441** | **1788** | **633 (35%)** | **1155 (65%)** | **0.001** |
| Negative | | 1189 (67%) | 388 (61%) | 801 (69%) | |
| Positive | | 599 (34%) | 245 (39%) | 354 (31%) | |
| **Tumour site (for colon cancer)** | **701** | **1528** | **580 (38%)** | **948 (62%)** | **<0.001** |
| Right | | 733 (48%) | 359 (62%) | 374 (40%) | |
| Left | | 795 (52%) | 221 (38%) | 574 (61%) | |
| **Screening test type** | **0** | **2229** | **844 (38%)** | **1385 (62%)** | **<0.001** |
| gFOBT | | 1188 (53%) | 748 (89%) | 440 (32%) | |
| FIT | | 1041 (47%) | 96 (11%) | 945 (68%) | |

within the asymptomatic population, there have been reports of a public perception that screening is only required if symptoms are experienced.[37] It seems likely that improved education may increase the participation rate with screening and prior research is supportive of this hypothesis.[38] The Scottish Bowel Screening Programme has recently transitioned from using gFOBT (requiring two stool samples on three separate occasions) to FIT (requiring a single stool sample). This may result in an increased uptake to screening although this effect is likely to be modest.[39] Further measures are required to encourage patient participation, and these should be targeted at particular groups including those of increased socio-economic deprivation. However, there is potential to significantly improve screening uptake across the entire population and measures should not be restricted to such individuals. A recent study summarised barriers and facilitators to screening[40] and addressing these factors with measures including reminder letters and improved education is likely to improve screening participation.

The present results show that a significant proportion of screening tests returned within 2 years before colorectal cancer diagnosis were negative. Although some of these may represent true-negative tests (and therefore true interval cancers), it seems likely that the majority of these are false-negative results. It is recognised that gFOBT (used as the first-line investigation in the era of the present study) is less sensitive than FIT (first-line investigation since 2017), particularly in right-sided disease.[41,42] Therefore, it would be of interest to repeat the present study in the screening via FIT era. One would expect the false-negative rate to be significantly lower in such a study. Unlike Scotland, countries including Germany and the USA use periodic endoscopic evaluation in addition to stool sampling within their screening programmes. Should false-negative rates remain high within a population who had previously underwent screening via FIT such periodic endoscopic evaluation may be worth considering or a reduction in the abnormal threshold level of FIT used for screening. Within the present results, poorly differentiated tumours and extramural

venous invasion were associated with cancers diagnosed outwith of bowel screening. This is likely to be due to the increased proportion of right-sided cancers and more advanced diseases within these patients.

Data, predominantly from the USA, have described an association between ethnic minority status and reduced likelihood of participation within screening. Owing to the healthcare system in the USA, socio-economic deprivation may be a confounding factor in these studies; therefore, the routine to diagnosis of colorectal cancer across ethnicities was of interest in the free at point of care health service in Scotland. However, because of the small proportion of patients who were non-white British, it was not possible to accurately analyse this. Ninety-two percent of the Scottish population in the 2011 census identified as white British. It has been shown that colorectal cancer is less common within several ethnic minority groups;[43] however, it is unclear whether this is sufficient to explain the lower proportion of patients diagnosed with colorectal cancer within this study. Notably, there was a significant quantity of missing ethnicity data raising the possibility of reporting bias particularly as a recent study within Scotland did find lower screening uptake within ethnic minority populations.[44] Nonetheless, because of the small proportion of patients of ethnic minority status, the present study is likely underpowered to reliably make the comparison between ethnic minority status and screening involvement before cancer diagnosis.

The present study has several limitations. The cohort of patients included within the present study were from an era where gFOBT was used as the first-line screening test. Scotland has now transitioned from gFOBT to FIT although many countries worldwide still use gFOBT for screening. Although it would be of interest to repeat such a study in patients screened using FIT, the results of the present study remain applicable to current practice. However, there is likely to be a smaller proportion of 'false-negative' screening tests and potentially an improved uptake of screening as a result of this transition. Within the present study, we have analysed the results of the screening round within 2 years before diagnosis of colorectal cancer. In our comparison of factors associated with negative screening test results, negative results have been assumed to be 'false-negatives'. Bowel screening aims to detect not just carcinomas but additionally advanced polyps. Given the duration of the adenoma-carcinoma sequence, this assumption is likely to be predominantly correct; however, it is impossible to know which of these tests were false-negative results and which were true interval cancers. Given the association seen between screening test result and the type of test used (gFOBT/FIT), this would be in keeping with this assumption as FIT has been widely reported to have a higher sensitivity than gFOBT. However, given that the majority of patients who received a FIT test had a prior borderline gFOBT as opposed to being randomly allocated either FOBT or FIT, this assumption may be biased.

In conclusion, the present study shows that colorectal cancer diagnosed through screening is associated with improved oncological outcomes; however, less than one in five cases of colorectal cancer within the West of Scotland were diagnosed through screening. Thirty-seven percent of patients were not invited for screening, predominantly those above the age for routine invitation (75+ years) or within the 40–49 years age group. Twenty-nine percent of patients had not returned a screening sample, in particular: males, patients with increased socio-economic deprivation or more comorbid patients. Thirteen percent of patients had returned a negative screening sample (likely false negative) within 2 years before diagnosis, in particular: females, patients with a BMI $< 30$ kg/m$^2$, patients with anaemia, right-sided tumours, patients who had a gFOBT test and patients with poorly differentiated tumours or tumours with extramural venous invasion. Further measures are required to educate the population about the benefits of screening to increase engagement with the screening process and to encourage patients aged 75+ years who are in otherwise good health to continue to participate in screening. Consideration should be given to extending screening to individuals aged between 40 and 50 years. Finally, further analysis should be carried out within a FIT (as opposed to gFOBT) screening cohort to determine whether the false-negative rate remains high.

## Author statements

### *Ethical approval*

Ethical approval was granted for this project from the Public Benefit and Privacy Panel (NHS Scotland) for Health and Social Care (PBPP) and Caldicott Guardian Approval.

### *Funding*

None declared.

### *Competing interests*

No conflicts of interest to declare.

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Public Health 211 (2022) 114–121

Contents lists available at ScienceDirect

Public Health

journal homepage: www.elsevier.com/locate/puhe

Original Research

# Voluntary early retirement and mortality in patients with and without chronic diseases: a nationwide Danish Registry study

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ARTICLE INFO

*Article history:*
Received 9 February 2022
Received in revised form
26 June 2022
Accepted 25 July 2022
Available online 8 September 2022

*Keywords:*
Voluntary early retirement
Early Retirement
Mortality
COPD
Diabetes
Heart failure

ABSTRACT

*Objective:* This study explores how the choice of voluntary early retirement (VER) affects mortality in a population where VER is available 5 years before regular retirement age.
*Study design:* This retrospective cohort study uses a registry-based follow-up design with access to Nationwide Danish Registry Data.
*Methods:* The study includes all Danish individuals who between 2000 and 2015 were part of an unemployment insurance fund and working at the time of their 60th (P60) or 62nd (P62) birthday. Those alive 1 year from their 60th or 62nd birthday were included in the mortality analysis. Individuals were registered as VER recipients if they chose the benefit within 1 year from P60 or P62. Three-year mortality likelihood following the first year from inclusion was explored for both cohorts separately. Multiple subgroups were explored in the mortality analysis, including individuals with chronic obstructive pulmonary disease (COPD), heart failure, and diabetes.
*Results:* P60 included 627,278 individuals, and VER was chosen by 22.5%. P62 included 379,196 individuals, and VER was chosen by 33.4%. The likelihood of VER in the P60 was lower in healthy individuals (odds ratio [OR] 0.87, confidence interval [CI] 0.85–0.88) and higher in COPD (OR 1.15, CI 1.07–1.22) and heart failure patients (OR 1.15, CI 1.05–1.25). Three-year mortality was significantly higher in those choosing VER in P60 (OR 1.28, CI 1.22–1.34), which was also found for all health subgroups (healthy, OR 1.18, CI 1.07–1.30; COPD, OR 1.55, CI 1.16–2.07; heart failure, OR 1.42, CI 1.02–1.98; diabetes, OR 1.36, CI 1.12–1.65). The increased mortality risk was not found in the P62 cohort.
*Conclusion:* The choice of VER is more likely in patients with COPD and heart failure. VER in the P60 cohort is associated with an increased mortality likelihood, which was not found in the P62 cohort, which may be explained by health selection bias.


## Introduction

To remain attached to the workforce is, from a societal perspective, highly important to minimize public spending and increase tax revenue. Multiple reasons for not participating in the workforce exists, such as disability pension, unemployment, and early retirement, which to varying degrees are associated with poor self-assessed health, poor mental health, and chronic diseases.[1] In contrast to the previously mentioned benefits voluntary early retirement (VER) recipients actively chooses to leave the workforce. The voluntary part may suggest that the general negative effects associated with unemployment do not apply to this subpopulation.[2] In contrast, the choice in itself may be driven by poor health status due to chronic diseases, such as heart failure, chronic obstructive pulmonary disease (COPD), or diabetes, all known to predispose a poor workforce connection.[3–6]

Various studies have explored the effect of early retirement on mortality with contradicting results, as some studies indicate beneficial effects and others indicate harmful effects, as demonstrated in the metanalysis by Sewdas et al.[7] The explanation may be

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https://doi.org/10.1016/j.puhe.2022.07.019

that there are in fact both positive and negative effects on self-reported health status, physical activity, and morbidity in those who retire from the workforce.[8–15]

VER benefit is unique to the Danish social system where similar benefits exist in other countries. It is in Denmark available from age 60 years, and an increase in the benefit is available if VER is postponed till the age of 62 years. VER is available to working individuals who are part of an unemployment insurance fund, paying into the VER scheme, and not receiving sick leave benefit. The availability of VER where the absence of sick leave is required raises the question whether the overall effect of VER is associated with a positive or negative effect on health outcome. We hypothesize that the effect of VER represents an overall negative effect on mortality, making it a prognostic tool for clinicians to identify vulnerable individuals.

Thus, the aim of this study was to explore whether people with comorbidity are more likely to choose VER at both ages 60 and 62 years. We will furthermore explore whether the choice of VER at age 60 and 62 years is associated with an increased mortality.

## Methods

### *Study setting*

#### *Danish social security system*

During the study period, Denmark had between 5.3 and 5.6 million citizens. In Denmark, health care, education, and retirement benefits are funded through the Danish taxpaying system.

#### *Danish VER*

VER is available to people who were members of an unemployment insurance fund and who contributed to the VER benefit fund. In addition, contributions to the VER benefit fund must start before the age of 30 years, and access to VER from the age of 60 years is not available if you are on sick leave or in other ways incapable of working. Furthermore, a minimum salary during a period of 3 years before detachment is required to ensure that the only individuals actively working are eligible. Changes to the VER benefit during the study period did not affect the individuals included.

### *Study population*

The study included all Danish citizens who reached the age of 60 years between January 1, 2000, and December 31, 2015. Two study populations were created, one including people at their 60th (P60) birthday and one consisting of people still part of the workforce at their 62nd (P62) birthday.

#### *Exclusion*

Identical exclusion criteria were used for both groups; individuals receiving any type of public support (e.g. unemployed, sick leave, disability pension; see Table S1), as well as individuals not part of an unemployment insurance or with either missing values on educational level or income were excluded.[16] Patients alive 1 year from P60 and P62 were included in the mortality analysis.

#### *Subgroups*

Health status subgroups (healthy, heart failure, COPD, diabetes) and demographic subgroups (male, female, income [low/high], and education level [short and medium/long/very long]) and combinations hereof were created for the mortality analysis.

### *Data sources*

A pseudonymized version of the unique Danish Civil Personal Number was used to identify individuals across different registries.[17] Multiple different national Danish registries were accessed for the purpose of this study. The following registries were accessed: The National Patient Registry, which contains information on all hospital contacts with access to diagnosis codes;[18] The Danish National Prescription Registry, with information on prescriptions redeemed from the pharmacy;[19] the Danish Cause of Death registry, with access to time of death;[20] the Statistics Denmark, with access to age, sex, income, and educational level;[17,21] and the Danish Labour Market Registry, with access to workforce connection.[16]

Retrospective registry studies do not require ethical approval or informed consent in Denmark. Access to data was granted by the Capital Region of Denmark (approval nr. P-2019-191).

### *Outcomes*

The outcome VER was defined as individuals choosing it within 1 year from inclusion in the P60 and P62 cohorts. Three-year mortality 1 year from inclusion was furthermore explored for both cohorts.

### *Variable definitions and covariates*

#### *Health subgroups*

Citizens were categorized as suffering from a disease if they had a hospital contact within the past 5 years, or, in the case of diabetes, had redeemed a prescription of antidiabetics within the past year. Diagnosis of COPD (International Classification of Diseases, 10th Revision [ICD-10], DJ44), heart failure (ICD-10, DI42 DI43, DI50), and diabetes (ICD-10, DE10-14; ATC, A10) was used for the group analysis. Individuals were defined as healthy if they did not have any diagnosis (as listed in Table S2) and no redeemed prescriptions in the past 6 months.

#### *Comorbidity*

Charlson comorbidity index was used in the analysis as a factor to adjust for comorbidity excluding the healthy subpopulation.[22] Diagnosis codes used for Charlson is shown in Table S2.

#### *Demographics*

Highest achieved educational level was categorized into four groups, corresponding to the following International Standard Classification of Education levels: short, 0–2 (early childhood education level to lower secondary education level); medium, 3 (upper secondary education level); long, 5–6 (short-cycle tertiary education level to bachelor or equivalent level); very long, 7–8 (masters/doctoral degree or equivalent).[23]

Income was defined as low, medium, and high corresponding to the 0–25%, 25–75%, and 75–100% percentile in the study population.

### *Statistical analysis*

Continuous variables are presented using means and standard deviations when normally distributed and median with 25 and 75 percentiles when not normally distributed.

Cumulative incidence plots were used to visualize the age at which individuals choose VER.

#### *VER as outcome*

Choosing VER within 1 year in both cohorts was treated as a dichotomous variable. Logistic regression was used to explore odds

ratios for choosing VER adjusting for sex, education level, and Charlson comorbidity index.

*VER as exposure*

Logistic regression for each health status subgroup was used to explore 3-year mortality for both P60 and P62. VER was also treated as a dichotomous variable to avoid introducing knowledge on individuals not choosing VER health status (e.g. disability pension, sick leave). Covariates included in the analysis were workforce connection, sex, Charlson comorbidity index, income, and educational level. Subgroup analysis was performed on demographic variables, income (low/high), and education level (short and medium/long/very long) to explore if VER association with mortality is different in relation to demographic characteristics.

Comparison of P60 and P62 characteristics and mortality rates between the groups choosing VER and those not choosing VER made done using Chi-squared test.

SAS (version 9.4, SAS Institute Inc, Cary, NC, USA) and R (version 4.0. 3, R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.) were used for data management and analysis.

## Results

*Population*

Fig. 1 shows inclusion of individuals for P60 and P62. Table 1 shows baseline data and events in the population at both time points.

*Voluntary early retirement*

In the P60 cohort, 22.5% (141,271/627,278) had left the workforce due to VER, and 0.2% (1232/627,278) died during the first 12 months. In the P62 cohort, 33.4% (126,782/379,196) had left the workforce due to VER, and 0.2% (886/379,196) died during the first 12 months. The percentages of individuals choosing VER in different subgroups are displayed in Table 2 for both cohorts.

The cumulative incidence from age 60 years is displayed in Fig. 2, revealing two waves of individuals choosing VER at age 60 and 62 years.

The likelihood of choosing VER is displayed in Fig. 3. Males, individuals with higher education level and high income, and people categorized as healthy have a decreased likelihood of choosing VER in both the P60 and P62 cohorts. People with low income have an increased likelihood of choosing VER, and patients with either heart failure or COPD have an increased likelihood of choosing VER in the P60 cohort. Diabetes is, in the P62 cohort, associated with a decreased chance of VER.

*Three-year mortality*

In the P60 cohort, from age 61 to 64 years, 1.5% (9373/626,046) died and in the P62 cohort, from age 63 to 66 years, 1.7% (6456/378,310) died, accounting for the 3-year mortality analyzed. Estimates of odds ratios of mortality likelihood in people choosing VER compared with people not choosing early voluntary retirement, according to healthy or disease-specific strata, are presented in Fig. 4 for both cohorts. VER was not significantly associated with improved survival in any subgroup in neither the P60 nor in the P62 cohort. On the contrary, the majority of the subgroups in the P60 cohort had a significant higher 3-year mortality likelihood compared with the P62 cohort, in which only one group had significant higher 3-year mortality (COPD subgroup with medium or higher education level). All point estimates are lower for the female subgroups compared with the male subgroups, apart from the diabetes subgroup in the P62 cohort. In most disease subgroups, the point estimated mortality likelihood for the high-income subgroups is higher than that for the low-income subgroups. This trend is less clear in the education subgroups.

The complete models reveal a higher likelihood of dying among males, people with low income and with increasing Charlson comorbidity index, and a lower likelihood with increasing education level and high income in most models.

Comparison of individuals choosing VER in P60 and P62 is displayed in Table 3. Significantly more males, higher educated, and

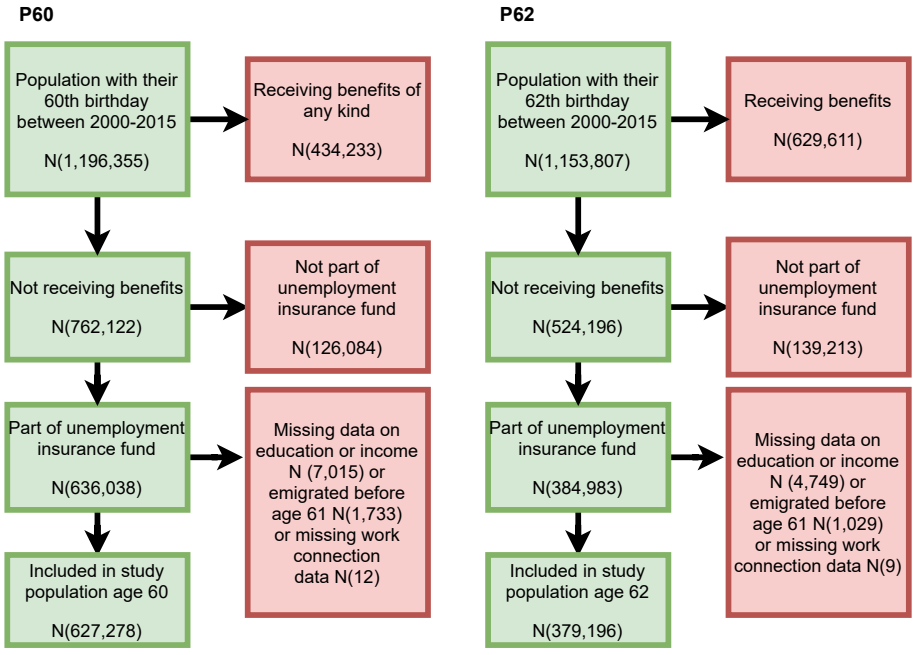


**Fig. 1.** Flow chart of inclusion for populations age 60 (P60) and age 62 (P62).

**Table 1**
Population frequency table.

| Variable | Level | Age 60 total | Age 62 total |
|---|---|---|---|
| Male | | 328,591 (52.4) | 221,006 (58.3) |
| Education level | | | |
| | Short | 156,815 (25.0) | 84,513 (22.3) |
| | Medium | 289,670 (46.2) | 176,339 (46.5) |
| | Long | 139,860 (22.3) | 87,287 (23.0) |
| | Very long | 40,933 (6.5) | 31,057 (8.2) |
| Income | | | |
| | 25% | 154,938 (24.7) | 94,799 (25.0) |
| | 25%–75% | 317,397 (50.6) | 189,598 (50.0) |
| | 75% | 154,943 (24.7) | 94,799 (25.0) |
| Status 1 year from inclusion | | | |
| | No VER | 484,775 (77.3) | 251,528 (66.3) |
| | VER | 141,271 (22.5) | 126,782 (33.4) |
| | Died | 1232 (0.2) | 886 (0.2) |
| Died during follow-up | | 10,605 (1.7) | 7342 (1.9) |
| Charlson comorbidity | | | |
| | 0 | 547,192 (87.2) | 326,381 (86.1) |
| | 1 | 51,424 (8.2) | 33,275 (8.8) |
| | 2 | 22,202 (3.5) | 14,867 (3.9) |
| | 3 | 3767 (0.6) | 2750 (0.7) |
| | 4 | 915 (0.1) | 638 (0.2) |
| | 5 | 216 (0.0) | 173 (0.0) |
| | 6 | 1308 (0.2) | 898 (0.2) |
| | 7 or above | 254 (0.0) | 214 (0.1) |
| COPD | | 4769 (0.8) | 3002 (0.8) |
| Heart failure | | 3232 (0.5) | 2375 (0.6) |
| Diabetes | | 21,854 (3.5) | 14,734 (3.9) |
| Healthy | | 188,131 (30.0) | 110,082 (29.0) |

VER, voluntary early retirement; COPD, chronic obstructive pulmonary disorder.

people with higher income choose VER at the age of 62 years. Differences in comorbidity distribution are minimal.

Significant differences between the P60 and P62 cohorts were seen when comparing the raw mortality rates in those choosing VER. All significant P-values indicated higher mortality rates in the P60 group. Significant differences between the P60 and P62 cohorts were also seen when comparing the raw mortality rates in those not choosing VER. All significant P-values indicated higher mortality rates in the P62 group (see Tables S3 and S4).

## Discussion

This study indicates that individuals with low income, short education, COPD, and heart failure are more likely to choose VER, whereas people who are healthy, have longer education, and have higher income are less likely to choose VER. This indicates that the choice of VER in the total population is influenced by individual's social status and comorbidities. The choice of VER furthermore comes with an increased mortality likelihood in individuals choosing VER at age 60 years and not in patients choosing VER at age 62 years.

It is seen that the likelihood estimates of choosing early voluntary retirement for medium, long, and very long education move toward one when comparing the P60 and P62 groups. The explanation for this tendency may be that the individuals in the lower education group are prone to leaving the workforce at 60 years. As a result of this, a survivorship bias is introduced in the P62 lower education group. This is supported by the demographic data, where the percentages of individuals with a shorter education is higher in P60 than in P62.

The time relation of the self-assessed health to unemployment has been explored by Bockerman, who found that unemployment does not decrease individuals' self-assessed health and that individuals with low self-assessed health are more likely to become unemployed.[24] This may also apply to individuals choosing VER with the choice associated with health status as shown in this study. Multiple studies have shown an increased likelihood of VER in individuals with poor self-perceived health status.[1,25] Individuals within disease subgroups are likely to have a poorer self-rated health compared with healthy due to their chronic diseases.[26] Poor self-rated health has previously been found to be associated with the choice of VER in Denmark in both people with and without chronic diseases.[27] Our finding that patients with COPD and heart failure have a higher likelihood of choosing VER and healthy have a lower likelihood indicates that this is also the case in our population.

The behavior and any possible beneficial and harmful effects associated prospectively with VER are expected to be the same in both P60 and P62 or we at least have no reason to believe that this should change over time. The mortality increases in those choosing voluntary retirement in the age 60 years cohort must therefore likely be explained by something else than the VER status itself. The most obvious explanation for this is that VER at age 60 years is the first option to retire voluntarily with public support for health reasons in people finding it difficult to remain in the workforce. This hypothesis is supported by aforementioned literature on self-perceived health status association with the choice to retire and by the increased mortality risk in people within working age with poor self-perceived health.[28]

Gender differences were seen in terms of a significant association between choosing VER and mortality in females; however, when looking at the health-related subgroups in women, no significant associations were seen. Furthermore, point estimates are lower for females than for males in almost all subgroups. The effect of the difference between men and women may be found in either their motivation for early retirement or their behavior following

**Table 2**
Voluntary early retirement status one year after inclusion (age 60 [P60] and 62 [P62]).

| P60 | | | | |
|---|---|---|---|---|
| Variable | No VER | VER | Dead | Total (n = 627,278) |
| Health | 150,344 (79.9%) | 37,518 (19.9%) | 269 (0.1%) | 188,131 (100%) |
| COPD | 3407 (76.1%) | 1327 (27.8%) | 35 (0.7%) | 4769 (100%) |
| Heart failure | 2458 (76.1%) | 746 (23.1%) | 28 (0.8%) | 3232 (100%) |
| Diabetes | 16,796 (76.9%) | 4972 (22.8%) | 86 (0.3%) | 21,854 (100%) |
| P62 | | | | |
| Variable | No VER | VER | Dead | Total (n = 379,196) |
| Healthy | 76,060 (69.1%) | 33,875 (30.1%) | 147 (0.1%) | 110,082 (100%) |
| COPD | 1862 (62.0%) | 1106 (36.8%) | 34 (1.1%) | 3002 (100%) |
| Heart failure | 1571 (66.1%) | 783 (33.0%) | 21 (0.9%) | 2375 (100%) |
| Diabetes | 9970 (67.7%) | 4688 (31.8%) | 76 (0.5%) | 14,734 (100%) |

VER, voluntary early retirement; COPD, chronic obstructive pulmonary disorder.

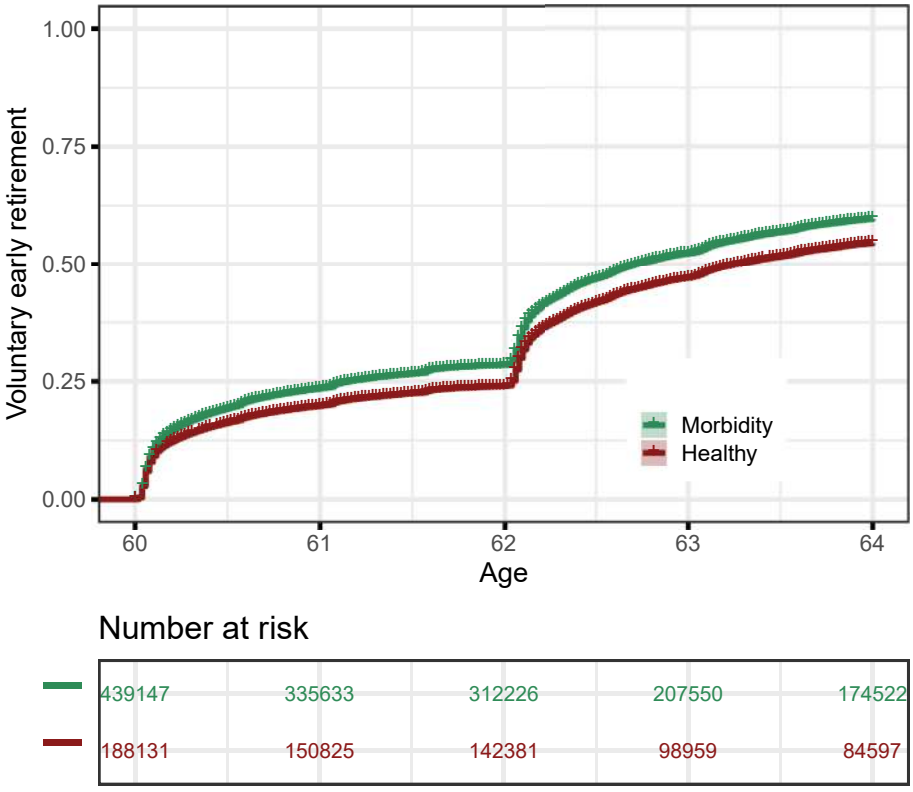


**Fig. 2.** Cumulative incidence from age 60 till early voluntary retirement in weeks using the P60 cohort.

early retirement. Patients' intentions to retire early have previously revealed gender differences, as men with poor perceived health have a higher likelihood of reporting an intention to retire.[29] Hypothetically, the differences in poor perceived health may explain some of the differences seen in the mortality in the male and female subgroups. The negative effect on physical activity seen in men retiring from strenuous work may furthermore add to these differences.[15]

Patients with COPD and heart failure in the P60 cohort have an increased likelihood of choosing VER. This implies that the choice at

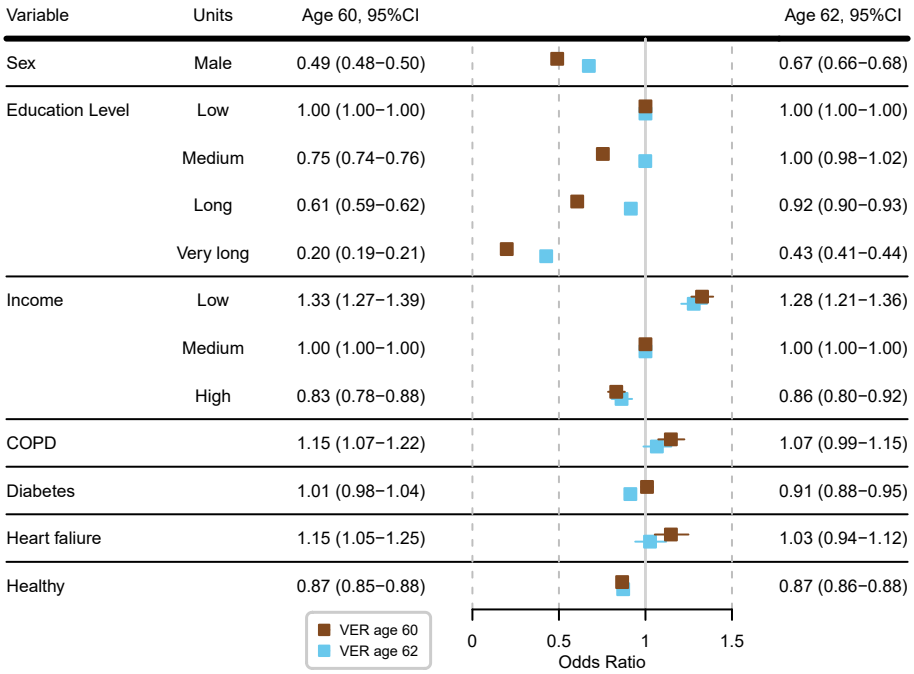


**Fig. 3.** Logistic regression model of the likelihood of choosing voluntary early retirement (VER) benefit with all variables displayed included in the model. Estimates are odds ratios.

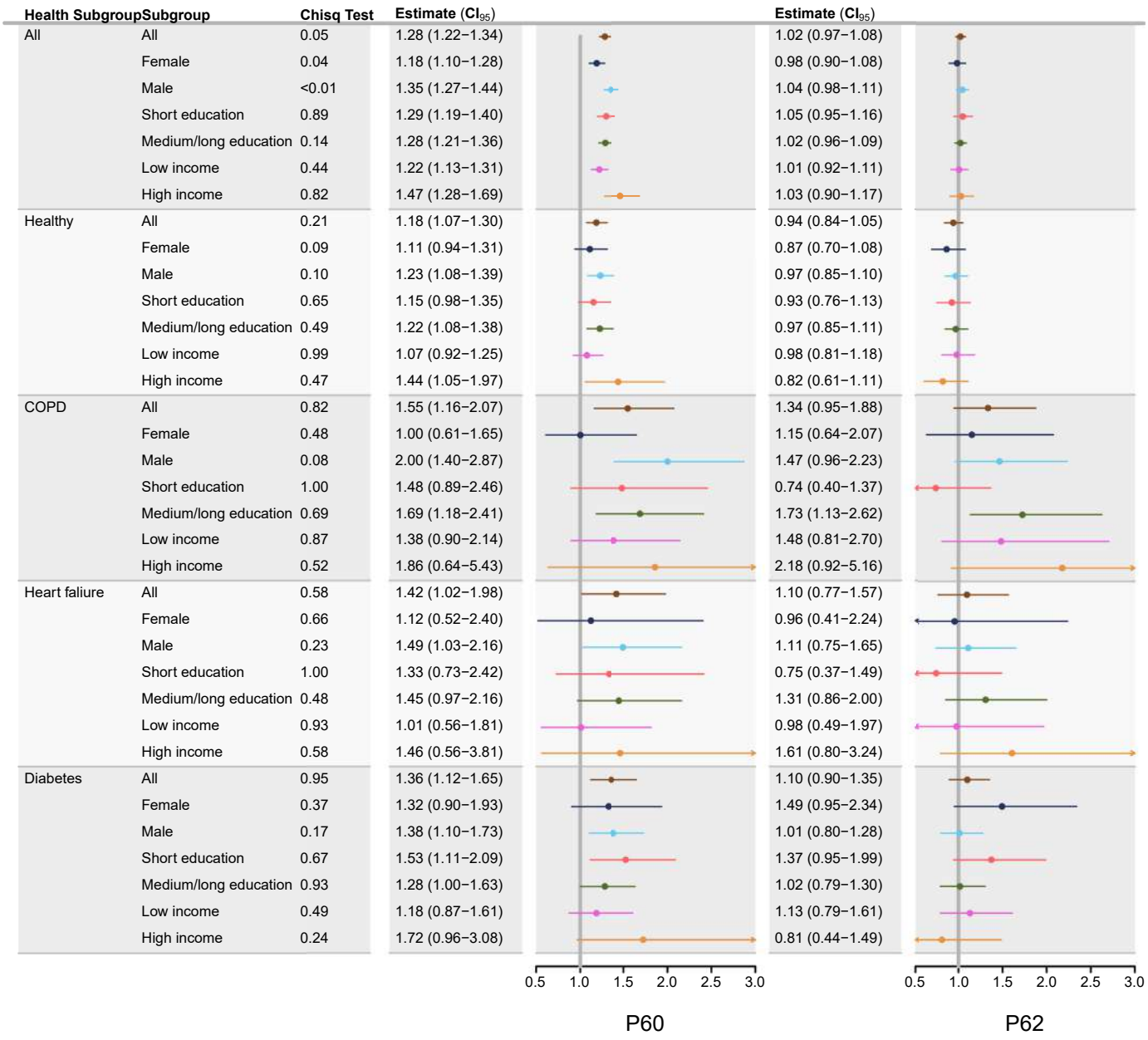


**Fig. 4.** Logistic regression model of the likelihood of 3-year mortality in the P60 and P62 cohorts stratified according to disease categories and subgroups of male, female, low/medium education level and long/very long education level. All models are adjusted for education level, sex, and Charlson comorbidity index in accordance with subgroup division. Estimates are displayed as odds ratios. Chi-squared test show the *p*-value of the group difference comparing voluntary early retirement rates in the two cohorts and their death rate. All significant *P*-values indicate a favorable outcome for those choosing voluntary early retirement at age 62 years. Subgroup colors; gray = all; pink = female; blue = male; yellow = education level low and medium; green = education level long and very long. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

this time point is to some extent driven by health status. These subgroups remain insignificant for the P62 cohort. This tendency may help explain why a higher mortality is observed with VER in the P60 and not in the P62 cohort. The choice to retire at age 60 years may represent a cumulative poor health as the first time point where it is possible to retire voluntarily, which to some extent is eliminated at age 62 years. This information may increase attention toward patients choosing to leave the workforce to VER when possible.

In Denmark, the access to VER is granted without any healthcare involvement, and therefore, health personnel has the possibility of intervention on any negative health behavior in direct relation to retirement. Different availability of VER between countries may affect the generalizability of our results. However, the identification of individuals choosing to leave the workforce voluntarily as a vulnerable subgroup is expected to translate to populations from other countries.

The association of VER and early retirements (disability pension) with mortality has previously been explored in the Danish registries by Quaade et al.[30] The results from this study suggest that VER compared with all other patients is associated with a lower relative mortality risk. These findings are in contrast with our findings, where no beneficial effects and mainly harmful effects of VER are observed. The study by Quaade et al. also compared VER to employed, which revealed an increased mortality risk for VER in accordance with our study. However, the selection of individuals

**Table 3**
Voluntary early retirement status at 60 and 62 years.

| Variable | Level | VER at age 60 years (n = 141,271) | VER at age 62 years (n = 126,782) | p-value |
|---|---|---|---|---|
| Sex | Male | 53,519 (37.9) | 65,200 (51.4) | <1e-04 |
| Education level | | | | |
| | Short | 48,078 (34.0) | 30,322 (23.9) | |
| | Medium | 65,150 (46.1) | 62,069 (49.0) | |
| | Long | 25,992 (18.4) | 29,277 (23.1) | |
| | Very long | 2051 (1.5) | 5114 (4.0) | <1e-04 |
| Income | | | | |
| | 25% | 50,431 (35.7) | 33,662 (26.6) | |
| | 25–75% | 72,582 (51.4) | 68,960 (54.4) | |
| | 75% | 18,258 (12.9) | 24,160 (19.1) | <1e-04 |
| Died during follow-up | | 2578 (1.8) | 2183 (1.7) | 0.045365 |
| Charlson comorbidity | | | | |
| | 0 | 121,939 (86.3) | 108,742 (85.8) | |
| | 1 | 12,288 (8.7) | 11,296 (8.9) | |
| | 2 | 5431 (3.8) | 5142 (4.1) | |
| | 3 | 973 (0.7) | 987 (0.8) | |
| | 4 | 241 (0.2) | 207 (0.2) | |
| | 5 | 49 (0.0) | 55 (0.0) | |
| | 6 | 301 (0.2) | 278 (0.2) | |
| | 7 or above | 49 (0.0) | 75 (0.1) | <1e-04 |
| COPD | | 1327 (0.9) | 1106 (0.9) | 0.071101 |
| Heart failure | | 746 (0.5) | 783 (0.6) | 0.002308 |
| Diabetes | | 4972 (3.5) | 4688 (3.7) | 0.013849 |
| Healthy | | 37,518 (26.6) | 33,875 (26.7) | 0.346834 |

VER, voluntary early retirement; COPD, chronic obstructive pulmonary disorder.

compared between studies are different, as disability pension patients are included, and we only include only working patients and do not differentiate on work status after inclusion.

It is important to emphasize that it is not the authors' opinion that VER is harmful because there is no logical way that receiving a voluntary public benefit can have a harmful biological effect. Any harmful effects of VER must be derived from either poor health status before VER as suggested in this study or harmful behavior enforced by VER such as sedentary behavior. The value of the study is therefore that the time of VER is a unique way of identifying individuals at risk of dying at a young age. The access to VER differs between countries, but it is expected that the problem of individuals leaving the workforce for health reasons in no way is unique to the Danish setting.

*Strengths and limitations*

This study has several strengths. Both cohorts include all individuals at the same time point in their lives, at the age of 60 or 62 years. This for the purpose of analysis eliminates age, which is highly correlated with death, as a confounder. The inclusion of all individuals aged 60 and 62 years over a 15-year period, complete follow-up on all participants, and the use of multiple administrative registries ensures not only large cohorts but also high-quality data with good accuracy.[17–20]

The choice to include and record health status on the birth date at the age of 60 and 62 years is done to ensure comparability in the groups. This does, however, create the possibility that some individuals will have accumulated more diseases at the time where they choose VER. This is not expected to change the results significantly in this relatively young cohort, as the majority of VER recipients choose to activate the benefit in close relation to their birthday.

However, there are also limitations to the study. All individuals included are part of an unemployment insurance fund. The access to VER is limited to members who actively had paid a monthly fee, and the number of contributors has declined during the study period. This may, in our study, force some patients to work, who otherwise would have had a desire to retire and may hereby contribute to the mortality risk in the control groups and limit the effects seen. This may introduce selection bias into the study. However, it does show that in a setting as with the Danish VER, it is still possible to identify those who chose VER at the time it becomes available as vulnerable individuals. The study design also makes the study cohorts very large compared with the existing studies exploring the subject of early retirement.[7]

Fluctuations in the unemployment rates historically may influence the availability and motivation for choosing VER. However, no major fluctuations have occurred in unemployment rates during the study period.

The linear relationship of the time dependency of VER on mortality was not explored. It is possible that the effect of choosing VER on mortality at the age of 60 years wears off more quickly than within the first year of the benefit being available. This may underestimate the effect on mortality for those choosing VER immediately at their 60th birthday who chooses this because of more severe health issues. However, our study contributes with new knowledge regarding how VER is associated with mortality in a social system where VER is a possibility and therefore holds a unique possibility of identifying atrisk patients.

The choice of treating VER as a dichotomous variable and not as all the levels of employment was chosen to avoid introducing health selection bias. People not choosing VER will be registered with sick leave, disability pension, and so on, which are events that may also be warranted for the individuals who have chosen VER. The Danish Labour Market Registry does not record this for patients on voluntary retirement. Therefore, if these patients were excluded, health selection bias would be introduced. The group of patients receiving disability pension at age 61 and 63 years in their respective cohort analysis will to some extent account for patients choosing VER due to health status because the benefit is only available to people not able to work. This choice is hereby expected to limit some of the health bias related to VER; however, it is unlikely to account for it all. Therefore, despite trying to account for the potential health bias selection, the study still clearly indicates residual health bias between the P60 and P62 cohorts. However, the

study still provides important health information on people who voluntarily leave the workforce. Although the access to VER varies between countries, the VER populations around the world remain unexplored, and this study indicates that the health of this population group should be focus for further studies.

The interpretation of the differences seen in the VER mortality estimates between subgroups should be done with caution. With the subgroup divisions creating much smaller groups and events as shown in Tables S3 and S4, the uncertainty of the point estimates of the results are affected. This makes the relatively small changes in the point estimates difficult with overlapping confidence intervals and point estimates in many subgroups. The systematic differences seen in gender, as described previously, do however indicate that some differences between groups exist that are not fully explained by chance. Furthermore, the relatively small changes within the P60 and P62 population subgroups indicate that VER generally represents a negative effect in the P60 cohort and a neutral effect in the P62.

*Conclusion*

The choice of VER at the age of 60 years is associated with an increased mortality. This effect is most likely explained by an unhealthy selection bias because the association is not found for people choosing to retire at the age of 62 years. Our results indicate that patients leaving the workforce at first given possibility are a vulnerable group regarding mortality. This study hereby adds to the existing knowledge on how VER is associated with health outcomes, revealing a time-dependent association with mortality not previously described to the authors' knowledge.

## Author statements

*Ethical approval*

None sought.

*Funding*

No funding was obtained for this article.

*Competing interests*

C.T.P. has received grants for studies from Bayer and Novo Nordisk unrelated to the present study. K.K. has received research grants from The Laerdal Foundation and speaker's honoraria from Novartis, both unrelated to the present work.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.07.019.

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