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Original Research

A framework for assessing the potential for a double dividend from a policy-induced reduction in alcohol consumption on the economy

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ABSTRACT

Objectives: Tax policies targeted at reducing alcohol consumption are typically understood to be associated with economic losses, including in alcohol production and trade sectors. This study sought to determine whether the overall effect of reduced alcohol consumption might be positive once improvements in productivity associated with reduced alcohol-related consumption are considered.
Study design: This study used Computable General Equilibrium economic modelling.
Methods: An economic modelling framework was developed for Scotland, which considered the fiscal and economic impacts of alcohol taxation and the economy-wide impacts. Simulation of hypothetical alcohol taxes and improvements in labour productivity calibrated on losses due to absenteeism and presenteeism in Scotland in 2017.
Results: The long-run impacts of a five pence increase in taxation alone produce negative economic impacts on jobs and Gross Domestic Product in Scotland (1189 jobs and £71.12 million). These effects are reduced by half – but remain negative – when the revenues from such policy are recycled to the economy through government spending. A small improvement in labour productivity – equivalent to 4.95% of the total productivity gap from absenteeism and presenteeism estimated for Scotland – would be sufficient to turn the economic consequence non-negative.
Conclusions: The overall macroeconomic impact of policies targeted at alcohol consumption should include consideration of the potential productivity effect and that impact studies that do not include such mechanisms are likely to overstate the negative economic impacts of alcohol policies.

Introduction

Despite efforts to combat excessive drinking, the harmful use of alcohol resulted in an estimated three million global deaths (5.3% of all deaths) in 2016.[1] In the United Kingdom, there were more than 8900 deaths in 2020 related to alcohol-specific causes, higher than in any other year since 2001.[2] Excessive alcohol consumption is also correlated with poor health outcomes, including an increased risk of some cancers and diabetes[3,4] as well as wider social harms.[5–10]

Raising the price of alcohol either through taxes or a minimum unit price (MUP) is seen as an effective public health response.[11,12] However, a pushback against these policies has been the potentially negative impact they could have on jobs and economic activity. Industry-sponsored 'economic impact studies' often show the contribution alcohol makes to the economy, both directly – in drinks manufacturing and the on/off trade sectors – and indirectly through supply-chain multiplier effects.[13–17] Policymakers are, therefore, presented with an apparent trade-off between improved health outcomes and worse economic consequences.

Such studies, however, typically focus on 'gross' economic impacts, that is, the contribution of (or loss of jobs from higher prices in) the alcohol industry itself. Some new research has, however, attempted to use the same models to assess the 'net' impacts of alcohol policy, which also accounts for the potential positive impacts on other sectors from demand shifting to non-alcohol products in response to relative price changes. Wada et al.[18] and Connolly et al.[19] show that the macroeconomic implications of increasing the price of alcohol may be less negative than first

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thought (and under certain circumstances positive) once this demand-switching is considered.

But even these recent attempts to capture the 'net' effect of demand changes ignore links between reduced alcohol consumption, public health outcomes and the associated macroeconomic benefits. This not only leads to a gap in the assessment of the 'net' economic impact of policy but also means that economic and public health debates on alcohol policy are disconnected.

There is rich evidence exploring the links between excessive alcohol consumption and economic outcomes for individuals.[20–23] But we are unaware of any peer-reviewed study that incorporates the 'supply side' effects from increased productivity from reductions in alcohol consumption into standard macroeconomic frameworks used in policy or by industry whilst also accounting for the negative impact of price policies on industry.

The purpose of this article is to set out a method to do this. To illustrate our framework, we focus on the consequences of improved labour productivity from a reduction in absenteeism and presenteeism expected to take place following a reduction in alcohol consumption.[24,25] Presenteeism reduces productive capacity while being in paid work, whereas absenteeism is the negative impact from taking off paid time from work due to health-related and other problems.[26] This study deals with presenteeism and absenteeism caused directly or indirectly due to alcohol consumption. We provide an illustrative example informed by recent data from Scotland and the United Kingdom.

Our approach – which we illustrate using a macroeconomic model of Scotland – means that we capture not just the impact of demand-switching following an increase in the relative price of alcohol but also any change in productivity when a fiscal intervention on alcohol consumption is introduced.[d] We show that the potential impacts of such productivity effects are large, suggesting that any assessment of the economic costs from increased taxes, or a MUP, ignore a crucial benefit to the economy that will impact any 'net' assessment of outcomes.

Methods

We use an applied macroeconomic model of Scotland (AMOS) – see Lecca et al.[27] for a guide. It is a dynamic forward-looking Computable General Equilibrium model. AMOS has been used to assess a variety of policy issues (including Brexit and studies of the value of higher education, see Figus et al.[28] and Hermannson et al.,[29] respectively).

Computable General Equilibrium models are widely used by policymakers, including national governments and international organisations such as HM Treasury and the World Bank. A variant of AMOS is used by the Scottish Government for policy development.[30] They are quantitative models designed to evaluate the impact of policy shocks in a country or region. They begin by emulating the structure of that economy and the interactions and dependencies among various agents (e.g. households, firms, the government, etc.; see Fig. 1). A change in the level of alcohol consumed by households due to a higher tax would ripple through the economy through various channels, thus having macroeconomic impacts.

The key elements of AMOS used here are provided in Lisenkova et al.[33] with a full listing in Emonts-Holley et al.[34] The economy is assumed to be in equilibrium before the introduction of "shocks" (in this case, sequentially, an excise duty on alcohol and a labour

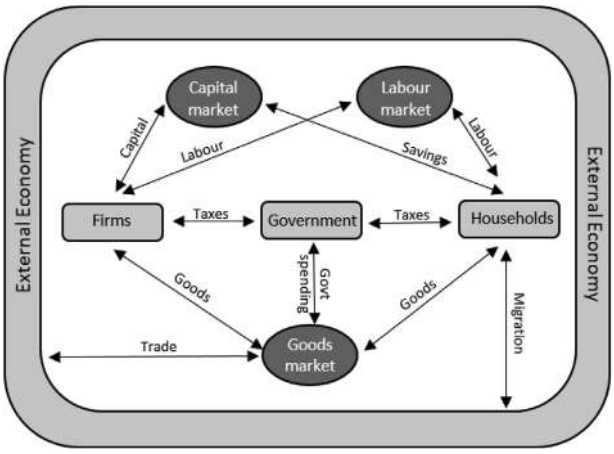

Fig. 1. Interactions among the agents within the AMOS model.

productivity increase) so that economy-wide changes can be attributed to the shocks introduced. Fig. 1 shows how the model captures the relationships between production and consumption across the economy and so can be used to simulate how the economy responds under specific assumptions. In the short run, sectoral capital stocks are assumed to be fixed but in the long run adjust to their desired levels through changes in investment. In the short run, the stock of labour force is also fixed so that employment adjusts through increasing the employment rate. However, unlike capital, in the short run, labour can move freely between sectors. Migration into Scotland (or out) is also possible and responds to differences in real wages and unemployment between Scotland and the (exogenous) rest of the UK economy. The effect of these dynamics is that changes from shocks take time to fully materialise, but a long-run equilibrium reflects where all markets have fully adjusted to the change in policy. We concentrate on the long-run equilibria.

The model is calibrated on real economic data, in our case, a 2016 Social Accounting Matrix database for Scotland developed from the Input-Output tables produced by the Scottish Government. For our purposes, we aggregate to 14 sectors (which are listed in Appendix 1) to focus on the appropriate sectors affected directly and indirectly. We introduce three shocks, which are summarised in Fig. 2. In this figure, text in a diamond indicates the disturbances introduced in each simulation, whereas text in rectangles indicates the key consequences, which are determined endogenous in our modelling framework.

The first shock is an illustration of the economic impacts of an increase in alcohol tax. We assume a rise of five pence in all alcohol taxes, which raises prices paid by domestic households and so reduces demand (Fig. 2, row 1). We show how our results are affected by the use by government of these additional tax revenues in the second shock (Fig. 2, row 2). The third is a change in the supply side of the economy – modelled as an improvement in labour productivity – from the elimination of current days lost each year from absence and presenteeism at work from alcohol consumption (Fig. 2, row 3).[e]

To capture the economy-wide impact of these effects, we make use of the methodology by the Scottish Government (2010).[35] Workers are estimated to turn up at work with the negative effects of excessive alcohol consumption, on average, two and a half

[d] Scotland is an interesting case study because of the policy interest in reducing alcohol consumption and the importance of the industry for investment, jobs and exports.[31,32]

[e] Note these improvements do not consider other avenues through which productivity might be impacted, for example, reinvesting savings in health expenditures in pro-growth policies.

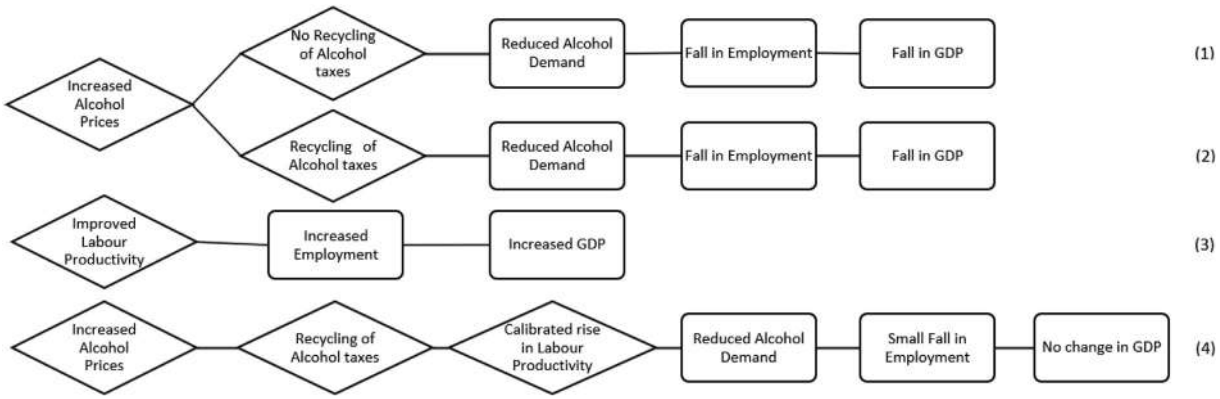

Fig. 2. Shocks introduced into the Computable General Equilibrium model.

days per year, with an efficiency hit of 27% compared with normal days. In effect, the output from 0.68 full working days was lost per employee annually due to presenteeism.[36] For absenteeism, it is estimated that an average of 4.4 days were lost per worker in the United Kingdom each year.[37] A study by Leontaridi[38] showed that 6%–15% of all sick days can be attributable to alcohol-related sickness in the United Kingdom. The midpoint of this range (10.5% of 4.4 days) is used here as an illustration of the sick days lost each year from excessive alcohol consumption. To note, these specific scenarios are simply to illustrate the value of such a modelling framework: specific empirical data on pricing and productivity losses, if available, could be used instead.

Finally, we model the impact if such presenteeism and absenteeism productivity losses from excessive consumption were to be eliminated. Based on these data and assumptions, we estimate that eliminating these losses would be equivalent to 0.493% improvement in national labour productivity.

Results

We first look at the impact of an increase in alcohol taxes. Table 1 summarises the estimated long-run economic impacts of a five pence increase in tax applied to all alcohol products sold in Scotland. We show the impact that this has across a range of economic variables, including Gross Domestic Product (GDP), employment, real wages and output.

In line with the first shock outlined in Section Methods previously, column 1 in Table 1 assumes any taxation raised by the government is saved. In other words, the 'gross' impacts of a policy to increase alcohol tax. This is implicitly the assumption underpinning industry-led 'economic impact' assessments. The increase in tax leads to a reduction in alcohol purchased. Unsurprisingly, the effects on the economy are all negative. The impacts, whilst small in percentage terms, are not insignificant. For example, the −0.05% hit to employment equates to a loss of jobs of 1189 FTE in the Scottish economy. GDP is smaller by 0.058%, or £71.12 million. Household consumption falls (government consumption remains fixed by assumption), and net trade deteriorates through a loss in competitiveness (in part, from the increase in after-tax prices).

Column 2 illustrates the estimated economic impact when the additional alcohol tax revenues raised are recycled through higher government spending. The 'net' impact is still negative, but the effects are reduced, often by around 50%. For example, the fall in employment, in the long run, is reduced to −0.030% or 686 jobs. The fall in GDP is reduced by a similar magnitude to −0.033%, a loss of £41.61 million. Household consumption continues to fall, but by less, whereas government spending rises by 0.002%. The 'net' negative impacts reflect, in part, the importance of the industry to Scotland's economy, particularly exports.

We next look at the impact from eliminating absenteeism and presenteeism losses from labour productivity resulting from the consumption of alcohol in Table 2.

Unsurprisingly, with a more productive workforce, we see a boost to economic activity, equivalent to 0.675% of Scottish GDP, or £839.95 million. Employment would rise by 0.211%, or by 4838 FTE. One way of interpreting this is to say that Scottish GDP is currently over 0.67% lower than would otherwise be the case if the labour supply effects of excessive alcohol consumption were eliminated.

Discussion

The estimates mentioned earlier reveal the different – and often conflicting – impacts on the economy of changes in alcohol policy, notably to increase in the price of alcohol. Crucially, these findings

Table 1
Economic impact of a 5p increase in alcohol taxes on the Scottish economy, % changes from base in long run.

Variable	(1)	(2)
GDP	−0.058%	−0.033%
Employment	−0.052%	−0.030%
Output	−0.051%	−0.030%
Household consumption	−0.032%	−0.019%
Investment	−0.045%	−0.026%
Government spending	0.000%	0.002%
Exports	−0.043%	−0.025%
Imports	−0.018%	−0.010%
Real wages	0.000%	0.000%
Consumer price index	0.048%	0.028%

Table 2
Economic impact of the elimination of costs to the economy from alcohol-induced absenteeism and presenteeism, % changes from base in long run.

Variable	(3)
GDP	0.675%
Employment	0.211%
Output	0.629%
Household consumption	0.165%
Investment	0.547%
Government spending	0.666%
Exports	0.686%
Imports	0.066%
Real wages	0.000%
Consumer price index	−0.265%

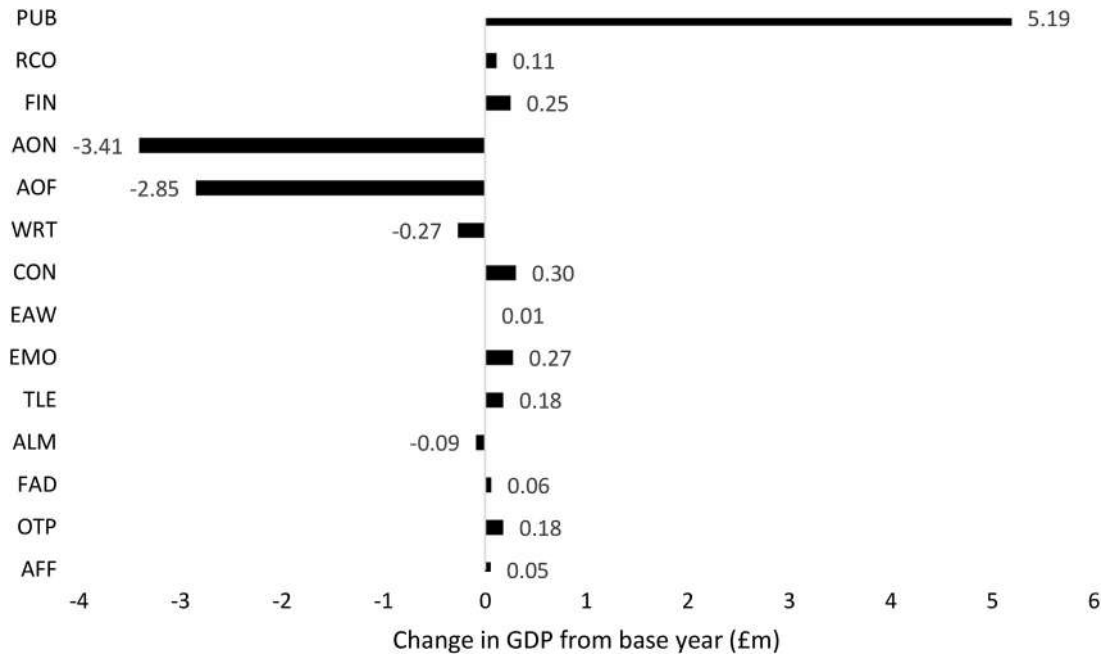

Fig. 3. Net GDP impact by sector from 5p increase in alcohol tax, recycled government revenue and improvement in productivity from a reduction in alcohol-associated labour market outcomes.

are more complex than in industry-led impact studies and are used to highlight the risk of taxes or MUP.

First, we do find that an increase in taxes, with the subsequent revenues saved by the government, leads to a loss in economic activity and employment (Column 1, Table 1).

Second, however, a significant amount of that negative loss is ameliorated when revenues raised are recycled back into the economy (Column 2, Table 1). The net effect, however, in an economy such as Scotland, with a large alcohol manufacturing and successful on- and off-trade sector, is still negative. A trade-off between economic impacts and alcohol consumption for policymakers would appear to exist.

But third, we show that the economy would benefit greatly from an improvement in productivity from a reduction of absenteeism and presenteeism in the workforce. Increases in the price of alcohol, if successful in reducing alcohol-induced illness amongst workers, could be expected to produce benefits from higher productivity. We show that these effects could be significant. Clearly, the 'overall' impact depends on how rates of absenteeism and presenteeism respond to any given change in tax, and this is an important area of further research. Our final contribution, however, is to demonstrate that the net reduction in Table 1 – both to employment and GDP – will definitely be reduced (and could be positive) once recognition is given to productivity channels through which public health will be improved (Fig. 2, Row 4). In our example, an improvement in national labour productivity of just 0.024% – equivalent to around 4.95% of the total productivity gap originating from absenteeism and presenteeism would be sufficient to ensure that the overall impact on Scottish GDP from a five pence increase in alcohol taxes would be zero.

Note that in this case, we still find a negative impact on economic activity in sectors tied to the alcohol industry. Fig. 3 shows the net sectoral impact of a five pence increase in alcohol taxes and a productivity improvement sufficient to ensure that the net impact on the economy (as measured by GDP) as a whole is zero.

Although this simulation constrains the overall change in GDP to be zero, economic activity does fall across the on- and off-trade sectors (AON & AOF), and there is a slight fall in alcohol manufacturing (ALM) too. The smaller fall reflects the export-intensive nature of these sectors. But note the increases in most other sectors of the economy. Increased government spending boosts activity in the public sector for example. But there is also demand-switching benefitting other sectors too. In short, there is a realignment of activity within the economy.

In summary, our contribution is to analytically demonstrate, using frameworks common for policymakers and industry bodies, that assessing the impact of changes in alcohol policy on economic outcomes must look beyond simply the gross impacts on the industry itself. Whilst the impacts on the industry of price policies are likely to be negative, positive boosts to the rest of the economy through recycled tax revenues and greater productivity make the total effect of such a policy ambiguous. Indeed, if a relatively small share of the productivity improvements can be secured, the impact – even in Scotland with a large alcohol sector – is likely to be positive.

Conclusions

Health concerns have prompted governments to seek to reduce excessive alcohol consumption. Whilst widely supported to improve public health, it is frequently argued that reducing the sale of alcohol products will have a detrimental economic impact. This concern is understandable, given the importance of manufacturing and on- and off-trade for jobs and investment. This is particularly true in Scotland.

Unfortunately, debates over the health harms of alcohol consumption and the economic benefits from industry take place in parallel to each other. Public health officials typically focus on human and societal costs, whereas economists build macroeconomic models that capture links between GDP and jobs.

In this article, we have outlined a framework that seeks to bring these different agendas together. Our macroeconomic framework can capture not just the impacts of reduced demand on the alcohol industry from higher prices but also the impacts of recycling tax

revenues and improvements in productivity from better public health outcomes. This provides a systematic framework with which to better understand the full effects of changes in tax policies.

Our results confirm that an increase in alcohol taxation alone, without considering any other effect, would have negative effects on the Scottish economy. This broadly captures the approach of conventional 'impact studies'.

However, it is the 'overall' impact that matters for the macroeconomic consequences. Our key takeaway is that the assumption that increasing alcohol taxes is unambiguously bad for the economy and therefore that a trade-off exists between health and the economy does not necessarily hold. Indeed, our study shows that once consideration is given to further channels (labour productivity), then claims over significant aggregate job losses are likely to be overblown.

Future research could look to develop microeconomic evidence on how specific percentage changes in taxes feed through to levels of absenteeism and presentism. These could be incorporated into specific point estimates for the likely productivity boost from a given change in tax. In this article, we have focussed on one aspect of productivity – attendance at work – and it is entirely possible to extend this to other areas. Such an analysis is likely to reveal higher level 'dividends' of policies directed at moderating harmful alcohol consumption.

Author statements

Ethical approval

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Competing interests

None declared.

Appendix 1. Sectoral aggregation of the Social Accounting Matrix for Computable General Equilibrium modelling

Sector	Description	SIC classification (2007)
AFF	Agriculture, forestry and fishing	1-3
OTP	Other primaries	5-9, 19-21
FAD	Food and drink	10,11.07,12
ALM	Alcohol manufacturing	11.01-06
TLE	Textiles, leather, wood, rubber, cement and glass	13-18, 22-25
EMO	Electrical, mechanical and other manufacturing	26-33
EAW	Electricity and water	35-39
CON	Construction	41-43
WRT	Wholesale and retail trade, transportation	45-56
AOF	Alcohol Off-trade	46 – Alcohol
AON	Alcohol On-trade	55, 56 – Alcohol
FIN	Financial services	64-66, 69.2-70, 73, 74, 82
RCO	Real Estate, communication and other services	58-63, 68-69.1, 71, 72, 75-81, 90-97
PUB	Public services including education and healthcare	84-88

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Original Research

Age-dependent changes in the risk of weight gain in Chinese adults: results from the Kailuan cohort study

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ABSTRACT

Objectives: Over the past decades, China has seen a dramatic epidemic of overweight and obesity. However, the optimal period for interventions to prevent overweight/obesity in adulthood remains unclear, and little is known regarding the joint effect of sociodemographic factors on weight gain. We aimed to investigate the associations of weight gain with sociodemographic factors, including age, sex, educational level, and income.

Study design: This was a longitudinal cohort study.

Methods: This study included 121,865 participants aged 18–74 years from the Kailuan study who attended health examinations over the period 2006–2019. Multivariate logistic regression and restricted cubic spline were used to evaluate the associations of sociodemographic factors with body mass index (BMI) category transitions over two, six, and 10 years.

Results: In the analysis of 10-year BMI changes, the youngest age group had the highest risks of shifting to higher BMI categories, with odds ratio of 2.42 (95% confidence interval 2.12–2.77) for a transition from underweight or normal weight to overweight or obesity and 2.85 (95% confidence interval 2.17–3.75) for a transition from overweight to obesity. Compared with baseline age, education level was less related to these changes, whereas gender and income were not significantly associated with these transitions. Restricted cubic spline analyses suggested reverse J-shaped associations of age with these transitions.

Conclusions: The risk of weight gain in Chinese adults is age dependent, and clear public healthcare messaging is needed for young adults who are at the highest risk of weight gain.

Introduction

Overweight and obesity have become a major global public health problem,[1,2] with more than 1.9 billion adults having overweight and more than 650 million adults having obesity worldwide in 2016.[3] Between 1975 and 2016, the global prevalence of obesity in adults increased from 3% to 11% in men and from 6% to 15% in women.[4] Alongside the rapid economic and demographic shifts that have occurred in China, the prevalence of obesity has been increasing, rising from 3.1% in 2004 to 8.1% in 2018.[5,6] It is predicted that the prevalence of overweight/obesity in Chinese adults will reach 65.3% by 2030.[7] Obesity is a recognized risk factor for major non-communicable diseases,[8] including cardiovascular disease, diabetes, and cancer,[9,10] and is also associated with higher risks of osteoarthritis, sleep apnea, kidney disease, hepatobiliary disease, and depression.[11,12] This emphasizes the importance of identifying and modifying the factors that determine the onset and progression of overweight and obesity.

A large number of studies have shown that the risk factors for overweight and obesity include an unhealthy diet, physical inactivity, certain medications, and inadequate sleep, which interact

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with genetic susceptibility to cause weight gain and ultimately lead to overweight and obesity.[13–15] However, the critical period for controlling risk factors for overweight and obesity in adulthood remains unclear. Although preliminary observations suggest that young adults are at a higher risk of weight gain than older people,[16] available evidence is lacking from Asian countries accounting for the majority of the global population. In addition, there have been no large-scale cohort studies analyzing the associations of weight gain with age and other important sociodemographic characteristics in China.

In the present study, we used longitudinal data from a large population-based cohort study to examine the joint effect of age, sex, educational level, and income on the risk of weight gain in China.

Material and methods

Study population

The Kailuan study is an ongoing community-based prospective cohort study in Tangshan, China. The detailed study design and procedures have been described previously.[17,18] From 2006 to 2007, employees of the Kailuan Group were recruited to participate in comprehensive biennial health examination at 11 hospitals affiliated with the Kailuan Group. Data were obtained by questionnaire interview, physical examination, and laboratory tests. Participants were eligible for inclusion in this study if they attended at least two health examinations in Kailuan between 2006 and 2019. The exclusion criteria were a diagnosis of pregnancy or viral hepatitis during the follow-up period, age ≥75 years, and missing body mass index (BMI) values at the beginning or end of all three follow-up intervals.

The Ethics Committee of Kailuan Hospital approved this cohort study, and written informed consent was provided by all the participants.

Assessment of sociodemographic variables

Sociodemographic characteristics used in these analyses, including age, sex, family monthly income, and educational level, were obtained using data from the questionnaires at each health examination. We regarded the time at which each participant first attended for a medical examination as the baseline, and according to the ages of the participants at baseline, they were placed into six age groups: 18–24, 25–34, 35–44, 45–54, 55–64, and 65–74 years. With respect to socio-economic status, the educational level of the participants was categorized as primary or below, secondary, or tertiary or above; and family monthly income was categorized as <¥1000, ¥1000–¥3000, or >¥3000.

Assessment of BMI status

For each participant, height and body weight are measured by trained medical staff according to standardized methods. The measurements of height and body mass were made to precisions of 0.1 cm and 0.1 kg, respectively. BMI was calculated as body weight (kilogram) divided by height (meter) squared. The classification of BMI was based on the World Health Organization guidelines (underweight, BMI <18.5 kg/m^2; normal weight, BMI 18.5–24.9 kg/m^2; overweight, BMI 25.0–29.9 kg/m^2; and obesity, BMI ≥30 kg/m^2).[19] We used the baseline BMI and the BMI measurements made at subsequent visits two, six, and 10 years after initial physical examination for the assessment of transitions between BMI categories.

Assessment of covariates

Data regarding covariates were collected using questionnaires and laboratory tests at a health examination and updated every two years. These included smoking status, alcohol consumption status, physical activity, the use of antidiabetic drugs or diuretics, self-reported medical history (of hypertension, diabetes, atherosclerotic cardiovascular disease [ASCVD], chronic kidney disease, and cancer), and total serum cholesterol and triglyceride concentrations. Participants who currently smoked (smoked cigarettes in the past 30 days) or with a history of smoking (smoked ≥100 cigarettes in lifetime) were defined as smokers (i.e. ever-smokers), and those who currently drank (alcohol consumption at least three times per week and more than one cup of alcohol each time during the last month) or who had a history of drinking (alcohol consumption a month ago) were defined as drinkers (i.e. ever-drinkers).[20] Physical activity was defined using a frequency of exercise of more than three times a week, with a duration of >30 min on each occasion. ASCVD was defined using a history of myocardial infarction or stroke. Participants were evaluated after an eight hour fast using calibrated equipment, and the total cholesterol and triglyceride concentrations were measured using an automated analyzer (Hitachi 747, Hitachi, Tokyo, Japan).

Statistical analysis

We summarized baseline characteristics of the participants by follow-up interval and presented them as mean (standard deviation) or median (interquartile range) for continuous variables and number (percentage) for categorical variables. While the longitudinal transitions of BMI status are diverse, the focus of our study is on the onset and progression of overweight and obesity, diseases with shared pathophysiology and adverse long-term clinical consequences. Thus, two unhealthy BMI transition statuses in each time interval were examined in our study: transition from underweight or normal weight to overweight or obesity and transition from overweight to obesity. We used multivariate logistic regression models to calculate odds ratios (ORs) and corresponding 95% confidence intervals (CIs) for the relationships of age and other sociodemographic factors (sex, educational level, and income) with transition to higher BMI categories over two year, six year, and 10 year periods, with adjustment for the potential confounders. In addition to mutual adjustments for sociodemographic factors, the covariates that were also included in the model were baseline BMI, smoking status, drinking status, physical activity, myocardial infarction, stroke, hypertension, diabetes, chronic kidney disease, cancer, the use of diuretics and antidiabetic drugs, and the total cholesterol and triglyceride concentrations. To further illustrate the correlation between age and BMI status transitions in the three time intervals, we also used a restricted cubic spline with four knots located at the 5th, 35th, 65th, and 95th percentiles to flexibly model the possible non-linear relation. The maximum age was chosen as a reference.

Moreover, we performed subgroup analyses according to smoking status (smoker vs non-smoker), drinking status (drinker vs non-drinker), and physical activity (physical activity vs physical inactivity). To assess the robustness of our findings, we performed a series of sensitivity analyses. First, we did a complementary analysis using classification of BMI based on the Chinese criteria (underweight, BMI <18.5 kg/m^2; normal weight, BMI 18.5–23.9 kg/m^2; overweight, BMI 24.0–27.9 kg/m^2; obesity, BMI ≥28 kg/m^2).[21] Second, we excluded individuals with ASCVD at baseline. Third, we excluded individuals with diabetes or hypertension at baseline. Fourth, we excluded individuals with chronic kidney disease at baseline. Fifth, we excluded individuals with cancer. Sixth, to maximize statistical power and minimize bias that might occur if

participants who attend only one health examination were excluded from analyses, we repeated our analyses with the data sets with imputed variables from multiple imputation by chained equations. Finally, we also conducted a sensitivity analysis without excluding participants aged ≥75 years. Data analyses were conducted using SAS software (version 9.4, SAS Institute, Cary, NC, USA). Two-sided statistical testing was performed, and $P < 0.05$ was considered to represent statistical significance.

Results

Participant characteristics

Of the 132,540 participants who attended at least two health examinations in Kailuan between 2006 and 2019, a total of 121,865 individuals of age 18–74 years were finally included in the study (Fig. 1). The demographic and clinical characteristics of participants are presented in Table 1. Participants for whom an assessment of the change in BMI status over 10 years could be made had a mean (standard deviation) age of 48.30 (11.42) years, and there was a higher proportion of men (61,891 [82.40%]) than women (13,216 [17.60%]). The mean (standard deviation) BMI of the participants was 24.92 (3.35) kg/m^2. Most of them had secondary education (63,308 [84.29%]), 30,656 (40.82%) had hypertension, and 5999 (7.99%) had diabetes.

Sociodemographic factors and the BMI status transitions

In multivariate logistic regression analyses, we found that the transition to higher BMI categories was most strongly associated with age (Fig. 2). Young participants aged 18–24 years were at the highest risk of transitioning to the higher BMI categories. Over the 10-year follow-up period, the adjusted OR for the transition from the underweight or normal weight to the overweight or obesity in the youngest group (18–24 years) was 2.42 (95% CI, 2.12–2.77) in comparison with individuals aged 65–74 years. The absolute risk of the transition from the underweight or normal weight BMI category to the overweight or obesity BMI category increased from 21.16% for the 65–74 years age group to 40.62% for the 18–24 years age group. In addition, we observed the weak obesity-depressing

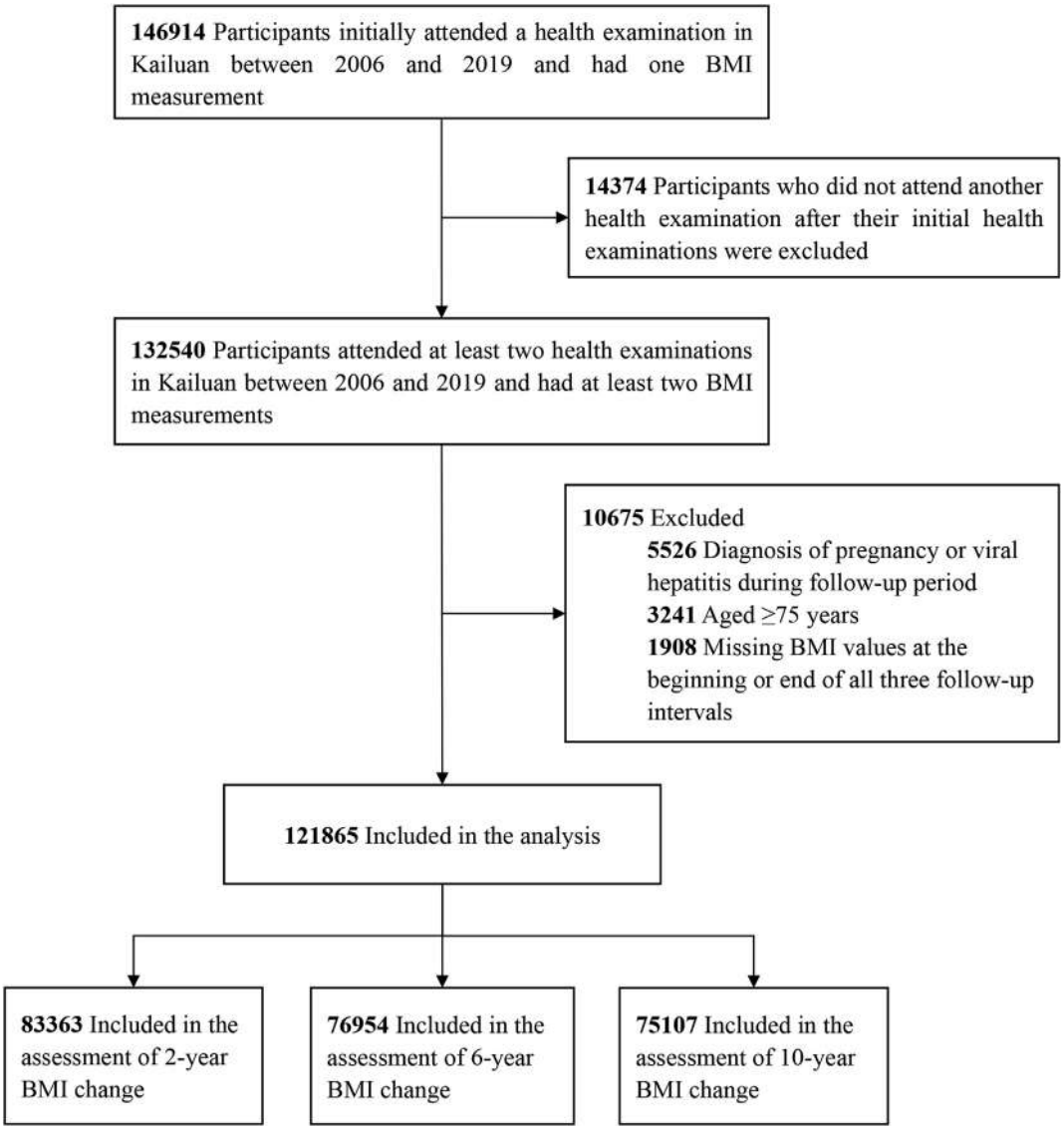

Fig. 1. Flowchart of enrollment of participants in this study. We regarded the time at which each participant first attended for a medical examination as the baseline and respectively included individuals with follow-up intervals of 2, 6, and 10 years since their initial medical examinations.

Table 1
Characteristics of the participants at baseline.

Characteristics	2-year BMI change (n = 83,363)	6-year BMI change (n = 76,954)	10-year BMI change (n = 75,107)
Age (years)	46.73 (12.12)	47.25 (11.95)	48.30 (11.42)
18–24	3882 (4.66)	3299 (4.29)	2612 (3.48)
25–34	11,462 (13.75)	9739 (12.66)	7764 (10.34)
35–44	20,034 (24.03)	18,431 (23.95)	16,617 (22.12)
45–54	27,441 (32.92)	24,713 (32.11)	26,425 (35.18)
55–64	14,718 (17.66)	15,677 (20.37)	16,808 (22.38)
65–74	5826 (6.99)	5095 (6.62)	4881 (6.50)
Sex			
Female	12,642 (15.17)	12,581 (16.35)	13,216 (17.60)
Male	70,721 (84.83)	64,373 (83.65)	61,891 (82.40)
BMI (kg/m^2)	24.85 (3.36)	24.91 (3.36)	24.92 (3.35)
<18.5	2019.0 (2.42)	1785.0 (2.32)	1688.0 (2.25)
18.5–24.9	42,222 (50.65)	38,550 (50.09)	37,517 (49.95)
25.0–29.9	33,452 (40.13)	31,186 (40.53)	30,639 (40.79)
≥30.0	5670.0 (6.80)	5433.0 (7.06)	5263.0 (7.01)
Education level			
Primary or below	5690 (6.83)	5856 (7.61)	5925 (7.89)
Secondary	69,364 (83.21)	64,606 (83.95)	63,308 (84.29)
Tertiary or above	8309 (9.97)	6492 (8.44)	5874 (7.82)
Family monthly income, ¥			
<1000	21,204 (25.44)	18,738 (24.35)	19,013 (25.31)
1000–3000	40,226 (48.25)	37,908 (49.26)	36,398 (48.46)
>3000	21,933 (26.31)	20,308 (26.39)	19,696 (26.22)
Lifestyle			
Smoke	33,239 (39.87)	29,568 (38.42)	28,311 (37.69)
Drink	34,859 (41.82)	31,707 (41.20)	30,764 (40.96)
Physical activity	12,225 (14.66)	11,659 (15.15)	11,515 (15.33)
Prevalence of chronic diseases			
Myocardial infarction	655 (0.79)	684 (0.89)	683 (0.91)
Stroke	997 (1.20)	936 (1.22)	875 (1.17)
Hypertension	32,415 (38.88)	30,874 (40.12)	30,656 (40.82)
Diabetes	6734 (8.08)	6069 (7.89)	5999 (7.99)
Chronic kidney disease	83,444 (10.13)	8977 (11.67)	8952 (11.92)
Cancer	227 (0.27)	199 (0.26)	213 (0.28)
Antidiabetic drugs	1607 (1.93)	1546 (2.01)	1509 (2.01)
Diuretics	676 (0.81)	659 (0.86)	721 (0.96)
TC (mmol/L)	4.89 (1.11)	4.91 (1.12)	4.93 (1.12)
TG (mmol/L)	1.27 (0.87–1.94)	1.27 (0.89–1.94)	1.28 (0.90–1.95)

BMI, body mass index; TC, total cholesterol; TG, triglyceride.
Data are presented as mean (standard deviation), median (interquartile range), or n (%).

effect of education. Education level (most educated vs least educated OR, 0.75; 95% CI, 0.66–0.84) was less associated with this transition. However, sex (men vs women OR, 1.05; 95% CI, 0.98–1.12) and income (most affluent vs least affluent OR, 0.99; 95% CI, 0.93–1.05) were not significantly associated with this change.

In terms of the progression from overweight to obesity, the adjusted OR for the transition from the overweight to the obesity in the youngest group (18–24 years) was 2.85 (95% CI, 2.17–3.75) compared with the 65–74 years age group. The absolute risk of the transition from the overweight to the obesity category increased from 6.22% for the 65–74 years age group to 21.34% for the 18–24 years age group. As expected, the age-related patterns to the transition to higher BMI categories over two and six years were broadly similar to that identified over 10 years, except for the transition from the underweight or normal weight to the overweight or obesity category over two years (Supplementary Table S1 and Table S2). Furthermore, the restricted cubic spline model showed a reverse J-shaped or U-shaped dose–response relationship between age and the risk of the transition to higher BMI categories across the three time intervals (all P-non-linearity <0.001; Fig. 3, Supplementary Figure S1 and Figure S2).

Subgroup and sensitivity analysis

The subgroup analyses performed according to smoking status, drinking status, and physical activity generated similar results to the main analysis (Supplementary Table S3–Table S5). Sensitivity analyses showed no substantial changes in the findings. Compared with our main model, similar results were obtained when BMI was classified according to the Chinese criteria (Supplementary Table S6). In addition, the estimated associations did not alter dramatically when individuals with several chronic diseases were excluded separately (Supplementary Table S7–Table S10). The results were generally consistent with the main analysis when the missing data were imputed using multiple imputation by chained equations (Supplementary Table S11). The inclusion of participants aged ≥75 years did not significantly alter the results (Supplementary Table S12).

Discussion

In the longitudinal cohort study of Chinese adults, we found age-dependent changes in the risk of weight gain and the youngest adults (aged 18–24 years) had the highest relative and absolute risk of shifting to higher BMI categories. Compared with age, education level was less related to these transitions, whereas sex and income were not significantly associated with these changes. Therefore, community and healthcare strategies for the prevention and management of overweight and obesity should target young adults who are at the highest risk of weight gain.

The association between demographic factors and weight change has been extensively researched in several cohort studies. Consistent with our findings, other previous studies have also

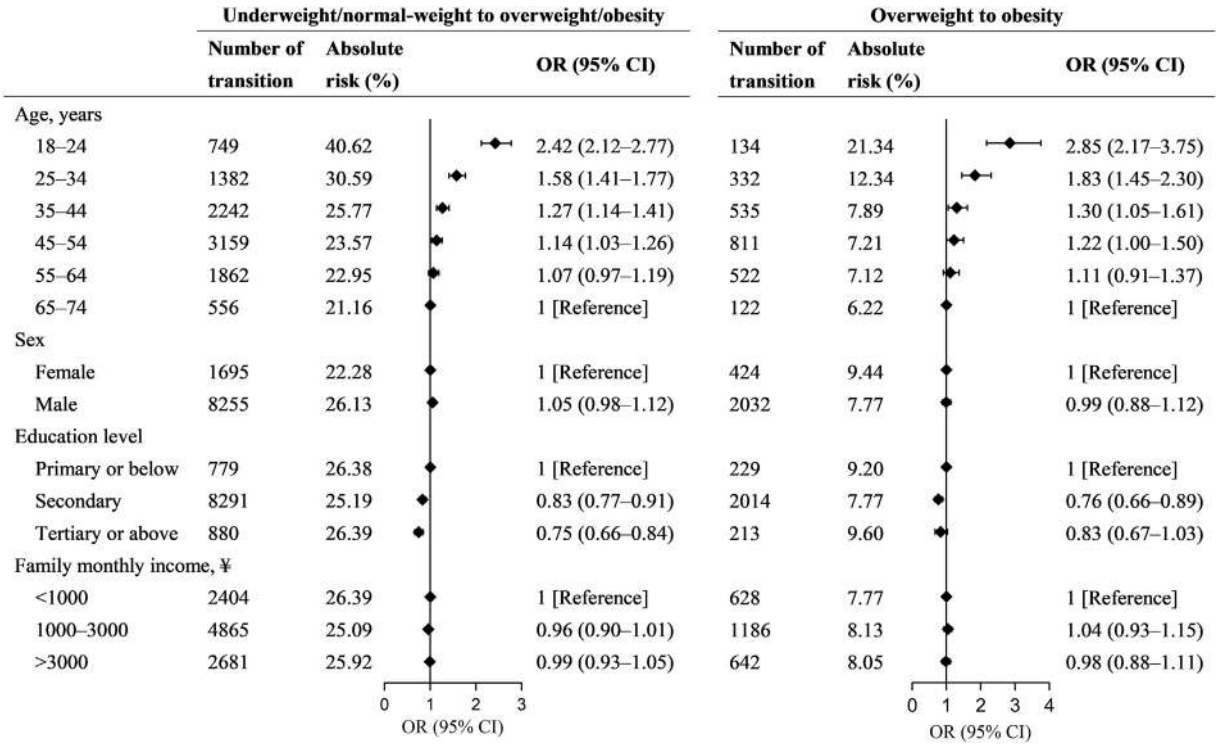

Fig. 2. Absolute risks and odds ratios of shifting to higher BMI categories over 10 years. Odds ratios were additionally adjusted for baseline BMI, smoking status, drinking status, physical activity, myocardial infarction, stroke, hypertension, diabetes, chronic kidney disease, cancer, the use of diuretics and antidiabetic drugs, total cholesterol, and triglycerides. BMI, body mass index.

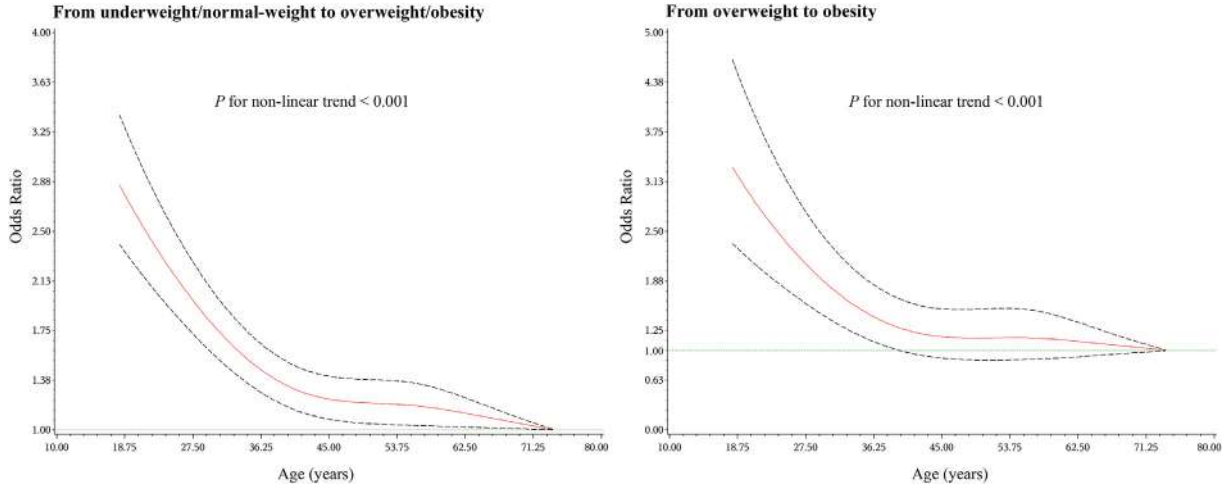

Fig. 3. Restricted cubic spline of the association between age and BMI status transition over 10 years. Solid lines indicate odds ratios, and dashed lines indicate 95% CIs from restricted cubic spline regression. The association was adjusted for gender, educational level, income, baseline BMI, smoking status, drinking status, physical activity, myocardial infarction, stroke, hypertension, diabetes, chronic kidney disease, cancer, the use of diuretics and antidiabetic drugs, total cholesterol, and triglycerides. The maximum age (74 years) was chosen as a reference. CI, confidence interval.

shown that young people are at a higher risk of weight gain than older people. An epidemiological study of the US CARDIA cohort revealed that weight gain is greatest among people in their 20s.[22] Caman et al.[23] showed in a Swedish cohort that the increase in BMI with increasing age is higher in younger individuals than in older individuals. A longitudinal study of an Austrian cohort by Peter et al.[24] showed that body weight increases between 20 and 70 years of age, with the largest increase occurring in men aged 20–25 years. However, most of these previous studies that focused on only one or a limited number of sociodemographic factors did not involve the collection of information necessary to assess several risk factors or use self-reported weight which is associated with the risks of reporting or recall bias. The present study, conducted in a large Chinese population–based cohort and involving long-term follow-up, has the strength that numerous accurate and reliable BMI measurements were made, and this has extended previous findings by evaluating the joint effect of four significant socio-demographic factors (age, sex, educational level, and income) on the change in BMI category.

The population-based longitudinal study conducted in the United Kingdom, similar in design to the present study, has reported similar findings.[16] However, we did not identify evident

associations between age and the transition from underweight or normal weight to the overweight or obesity category over the two year follow-up period. This may be attributed to the short-term changes in weight being more susceptible to multiple factors.[13] Additional studies are warranted to better elucidate the short-term effects of age on weight gain in Chinese population. Although the magnitude of the decrease in OR associated with weight gain with increasing age appears to differ according to discrepancies in geographical region and demographic characteristics of study population, both the present study and the UK study have demonstrated that young adults are at the highest risk of weight gain, which emphasizes that future prevention strategies for overweight and obesity should focus on young adults.

The mechanisms underlying the higher risk of weight gain in young adults remain unclear, but there are several possible explanations. First, at the population level, obesity is primarily driven by environmental effects that diminish the ability of people to make decisions regarding their own behavior.[25] Young adults confront unique challenges in their living environment, and numerous beverage and fast-food companies target young people, increasing their access to high-calorie foods.[26] In contrast, older people may follow more traditional lifestyles and have higher dietary fiber consumption. In addition to the physical environment, interpersonal relationships have an impact on the weight status of young adults and their willingness to lose weight.[27] Young adults with overweight or obesity tend to have more overweight friends, relatives, and romantic partners than their peers who are not overweight.[28] When living in these obesogenic environments, it may be challenging to maintain a healthy weight. Furthermore, at the individual level, a poor lifestyle with respect to diet and physical activity contributes to weight gain in an increasing number of individuals. Most young people have unhealthy dietary habits, including substantial consumption of fast food and sugary drinks and more frequent binge eating.[29–31] In addition, physical inactivity by young people because of a lack of time, motivation, and social support would further increase this weight gain.[32–34]

The findings of the present study have important clinical and public health implications. Data obtained during the Global Burden of Overweight and Obesity Study show that the prevalence of overweight and obesity is lower in young people than in older adults, but that weight gain is most rapid in those aged 20–40 years.[35] Our findings also show that the risk of weight gain is higher in young people than in older people. Thus, most adults are at high risk for overweight and obesity in early adulthood (18–44 years) rather than in late adulthood. Clinical studies have shown that the use of various weight loss interventions, including lifestyle interventions, medication, and bariatric surgery, are associated with huge challenges to the maintenance of this weight loss over time, despite good short-term outcomes.[36–38] Therefore, the prevention of obesity is particularly important in early adulthood before the onset of obesity. Moreover, weight gain between early and mid-adulthood is associated with higher risks of morbidity and mortality related to several chronic diseases in later life, including type 2 diabetes, cardiovascular disease, cancer, and non-traumatic death.[39,40] Our findings advocate for efforts to prevent overweight and obesity to extend to younger people to reduce the lifetime risk for developing major non-communicable diseases.

This study has several limitations. First, although many potential confounders were adjusted for in our analysis, we were unable to directly adjust for psychological disorders because those important covariates were not available in the Kailuan study. These and other unmeasured factors may cause residual confounding. Second, an additional limitation was the lack of consideration of dietary patterns. However, many obesogenic drivers could have distal effects on obesity.[41] For example, income inequality and chronic diseases might convert to higher obesity prevalence through a number of pathways, such as through changes in dietary patterns and psychosocial effects. Hence, dietary patterns might be mediators rather than confounders of age-dependent changes in BMI increase, which merit further study. Finally, the participants were all employees and retirees of the Kailuan Group and were mostly male. The homogeneity of geographical region and ethnicity may help minimize confounding and enhance the internal validity, but this would limit the generalizability of the findings.

Conclusions

The risk of weight gain in Chinese adults is age dependent. Young adults were found to be at significantly higher risk of weight gain than older age groups. Early adulthood may be the optimal timing for overweight and obesity prevention interventions. These findings underscore the importance of providing young adults with clear public health information because they may underestimate their risk of weight gain and imply that young adults should adhere to obesity prevention strategies and individual weight management interventions.

Author statements

Acknowledgments

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Ethical approval

The Ethics Committee of Kailuan Hospital approved this cohort study, and written informed consent was provided by all the participants. This study was conducted in accordance with Helsinki Principles. Data obtained from all participants were kept confidential.

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Competing interests

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.03.004.

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Themed Paper — Short Communication

An intra-action review conducted by the CDC Foundation during COVID-19 to evaluate emergency response procedures

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ABSTRACT

Objectives: During times of emergency response, the CDC Foundation leverages partnerships and relationships to better understand the situation and respond rapidly to save lives. As the COVID-19 pandemic began to unfold, an opportunity became clear to improve our work in emergency response through documentation of lessons learned and incorporating them into best practices.
Study design: This was a mixed methods study.
Methods: The CDC Foundation Response, Crisis and Preparedness Unit conducted an internal evaluation via an intra-action review to evaluate and rapidly improve emergency response activities to provide effective and efficient response-related program management.
Results: The processes developed during the COVID-19 response to conduct timely and actionable reviews of the CDC Foundation's operations led to the identification of gaps in the work and management processes and to creation of subsequent actions to address these issues. Such solutions include surge hiring, establishing standard operating procedures for processes not yet documented, and creating tools and templates to streamline emergency response operations.
Conclusions: The creation of manuals and handbooks, intra-action reviews, and impact sharing for emergency response projects led to actionable items meant to improve processes and procedures and the ability of the Response, Crisis and Preparedness Unit to quickly mobilize resources directed toward saving lives. These products are now open-source resources that can be used by other organizations to improve their own emergency response management systems.

Introduction

The CDC Foundation activated its Emergency Response Fund in January 2020 for the COVID-19 response. The magnitude of the response strained existing processes, revealing gaps in emergency response operations. This led to an intra-action review involving members of the CDC Foundation's Response Crisis and Preparedness Unit (RCPU). The review included internal evaluation of response activities to address identified barriers and gaps. Through this process, actionable items were documented, and improvements were made in emergency response operations. Sharing response-focused guidance and intra-action review results can help the CDC Foundation and other organizations improve their future engagement in emergency responses.

Background

The CDC Foundation is the sole entity authorized by Congress to mobilize resources to leverage the work of the Centers for Disease Control and Prevention (CDC). During an emergency response, the CDC may request that the CDC Foundation activate the Emergency Response Fund. Once activated, the CDC Foundation uses the Emergency Response Fund to support requests for assistance received from CDC and other implementing partners. During an emergency response, the CDC Foundation works with CDC's Emergency Operations Center leadership to understand priority response needs, gaps to filling needs and how partners can support these efforts. CDC Foundation receives resources from philanthropic, private donors, and grants from CDC to provide CDC and implementing partners with resources to fill immediate needs during public health emergencies.

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CDC Foundation's implementing partners include public and private organizations, such as non-profits, community-based organizations, and public health and academic entities. Following emergency activation, The CDC Foundation receives requests for support from key public health partners to address emergency response issues. CDC Foundation then deploys resources to address these identified priorities. As an independent non-profit, the CDC Foundation can also distribute resources to other entities (e.g. health departments, research partners) as part of the organization's own strategic initiatives.

There are multiple CDC Foundation teams that work together to mobilize resources and implement programmatic responses. The RCPU has primary responsibility for emergency response activities by establishing and overseeing partner projects through grants and contracts. As the response continued beyond activation into January 2020, the RCPU began to implement hundreds of projects with a wide range of partners, including mass hiring of public health workers to build the public health infrastructure, providing laboratory and personal protective equipment, supporting health departments and community-based organizations through grant funding, and filling additional gaps in the pandemic response. The enormity of the COVID-19 response revealed that the RCPU's effectiveness could benefit from an internal review, so an intra-action review was conducted to evaluate emergency response activities, and based on those results, RCPU rapidly adjusted activities to provide a more effective response-related program management.

Methods

An intra-action review is a method of identifying current challenges and understanding successes. The purpose of an intra-action review is to quickly address questions about current activities, emerging issues, lessons learned from gaps and challenges, and proposed changes to ensure continued success.[1] During this process, a root-cause analysis was conducted to propose practical ways to remediate identified challenges.

To conduct the intra-action review, a survey was distributed to all employees within the RCPU. The survey was conducted in September 2020, eight months into the COVID-19 response, which resulted in nine respondents from RCPU staff (response rate of 100%). This survey was distributed for the second time 15 months into the response in June of 2021, which resulted in 17 responses from RCPU staff (response rate of 27.9%). The shift in response rates is reflected by the growth of the RCPU to meet the needs of the emergency response. Note that response rates are low for the second survey, as the RCPU was actively engaging in emergency response activities, and this is an exclusively internal evaluation among a small, exclusive team. The timing of survey distribution was determined by staff capacity and status of emergency response activities, as at the time the CDC Foundation was activated for the COVID-19 response. A qualitative analysis of survey results was conducted with the lens of evaluating strengths, weaknesses, opportunities, and threats to the unit's operational capacity. The results describe the culmination of these two reports.

Results

Each response was categorized into the following themes: staffing, processes, data systems, communications, and next steps (Table 1). During the COVID-19 response, hiring surge staff—including program managers and field employees—assisted core staff in remaining focused on their primary responsibilities. New staff were brought onto the unit to increase capacity, which required efforts to refine the onboarding experience for quick resource mobilization. Confusion in onboarding processes led to delays in programmatic implementation, which needed to be addressed for the rapid implementation of projects. In response, standard operating procedures (SOPs) were created to guide the hiring of surge staff, including creation of onboarding handbooks and training videos to streamline introduction to processes in a fast-paced environment. Developing procedure-related documents for onboarding new emergency response staff allowed for faster onboarding and efficient and effective program management during the response. This experiential knowledge has been adapted into an internal surge staffing document for reference in future emergency responses. Internal and external surge staffing expanded the unit's ability to respond during the crisis, so documenting and developing procedure-related documents will be helpful for staffing the RCPU in the future.

Developing processes during an emergency response slowed down operations; the creation of SOPs before emergency response mobilization is recommended. For the RCPU, at the start of the response, there were limited resources to guide program managers through the process. There was a need identified to establish SOPs that considered context and restraints of emergency situations. In response, the RCPU created an emergency response manual that lists procedures to undertake in the event of emergency response activation. As the RCPU expanded its internal capacity during the response, it became evident that implementing partners were experiencing similar limitations in capacity and that guidance documents were needed. In alignment with an organizational strategic goal to help strengthen the public health system, the RCPU modified internal manuals to create external handbooks that partners can reference for fundraising and programmatic activities during emergency response.[2,3]

Another primary issue identified was the inefficiencies created by manual entry of data generated by projects. This initial tracking process was effective but placed a burden on program managers, as it was centered around a non-automated monitoring sheet requiring manual entry of each value, and a lack of resources to guide data collection processes. To address this, the RCPU Impact and Evaluation team created, piloted, and implemented a streamlined data collection process and accompanying templates for emergency response projects, including data trackers, logic models, evaluation frameworks, and automatic data reporting forms. Data systems trainings were also implemented to assist with streamlining and automating RCPU systems further.

Lack of clarity in emergency response roles and responsibilities across all CDC Foundation departments led to confusion in responsibilities and delays in processes needed to support rapid emergency response implementation. The RCPU Emergency Response Manual includes detailed descriptions of response-related roles and responsibilities of each internal department and unit and a primary point of contact for each department. In addition, the RCPU had limited structure for telling the stories of program activities and impacts, which limits what can be presented to funders and philanthropic entities that support emergency response work. To have more opportunities for sharing impact, the RCPU created a manuscript team and identified a process for storytelling of emergency response projects.

Limited evaluation of lessons learned during emergency response may lead to repetitive issues or gaps that become persistent over time. The RCPU now has plans to conduct an intra-action review during future emergency responses to ensure that the emergency response team is continuously learning from limitations and threats in emergency response work. The RCPU

Table 1
CDC Foundation Response, Crisis and Preparedness Unit intra-action review evaluation qualitative themes, subthemes, identified gaps, and actionable items taken to address gaps.

Intra-action review qualitative themes	Intra-action review qualitative subthemes	Identified gaps via intra-action review	Actionable items taken to address gaps identified: to address the identified gaps, the CDC Foundation's RCPU…
Staffing	• Employee roles and responsibilities • Onboarding and offboarding • Work-life balance • Communication with human resources • Shifting to emergency response priorities	Limited proper onboarding training resources in a central place led to delays in onboarding. Slow onboarding processes lead to delays in programmatic implementation. Confusion in onboarding roles and responsibilities leads to delays and duplication of efforts.	1. Documented specific departmental responsibilities for onboarding staff and identification of points of contact for each department 2. Created an internal surge staff plan for internal surge during emergency response 3. Created video training for onboarding processes, primarily regarding the use of platforms and necessary documents to review
Processes	• Proposal review processes • Meeting cadence • Internal organizational tools and platforms • Project metric and impact tracking • Project management and digital organization • In-unit engagement and management • Cross-departmental engagement and management	Contract negotiations with partners can be challenging and take time, and there are limited resources to guide program managers through this process. Manual entry for the project tracker leads to inefficiency and puts burden on program managers.	1. Created internal CDC Foundation Emergency Response Manual 2. Created emergency response manuals for fundraising and programmatic activities that can be referenced by partners to improve their emergency response operations 3. Developed and piloted an automatic survey form for subcontractor progress and final reports on Smartsheet 4. A shorter, letter-format agreement was created for community partners and faster review and execution of agreements to address challenging contract negotiations
Data systems	• Project metric and impact tracking • Daily use of platforms • Data collection and digital platform training needs	Lack of automatic systems to manage projects puts burden on program managers. Requirement of manual entry to data collection trackers puts burden on program managers.	1. Implemented trainings on data systems and platforms used for program management 2. Developed streamlined data collection process and templates for emergency response projects, including data trackers, logic models, evaluation frameworks, reporting forms for partners, donor reporting forms, etc.
Communications	• Email updates • Use of digital platforms and related preferences • External communication with programmatic partners • Program impact stories	Lack of clarity in emergency response roles and responsibilities across all departments leads to confusion in responsibilities and therefore delays in a process that needs to support rapid emergency response implementation.	1. Defined response-related roles and responsibilities of each department and unit within the emergency response manual 2. Designated primary points of contact in each unit for emergency response activities 3. Created a manuscript team and identification of process for storytelling of projects in emergency response
Next steps	• Impact measurements and frameworks • Risks and opportunities found in external partnerships • Staff capacity and emergency response responsibilities	Lack of structure for evaluating and telling the stories of program activities limits what can be presented to funders and philanthropic entities that support emergency response work. Limited evaluation of lessons learned during emergency response may lead to repetitive issues or gaps that become persistent over time.	1. Created program initiation and close-out checklists within personalized program management toolkits to guide program managers 2. Presently conducting an after-action review to understand lessons learned during the COVID-19 response

additionally has plans to conduct after-action reviews to follow up on lessons learned during intra-action reviews and to enforce actions that need to be taken to address gaps in the rapid implementation of projects.

Discussion

The intra-action review provided an opportunity for the CDC Foundation's RCPU to understand gaps in emergency response activities and how the CDC Foundation can better enable and augment the efforts of CDC and other partners. Expanding the process of conducting intra-action reviews and impact surveys to be a routine part of emergency response programmatic work before, during, and after public health emergencies allows for an efficient, impactful, and sustainable response. Creating feedback mechanisms to engage employees allows for the capture of successes and lessons learned to incorporate into current and future emergency response work. In addition, an analytical review of procedures enables the development and improvement of emergency response–related documents and the opportunity to create tools for public health partners that secure positive outcomes during future public health emergencies.

Limitations

The results of the intra-action review and operational improvements are primarily reflected on an internal level. The effectiveness of the external products created for partners should be further evaluated to understand their impact. Similar operations-related evaluations, such as an after-action review[1] should be conducted in the future to further understand how improvements affected the success of the response.

Author statements

Ethical approval

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Competing interests

The authors have no conflicts of interest, and all authors certify that this material has not been published previously and is not under consideration by another journal. The authors further certify that they have had substantive involvement in the preparation of this article and are fully familiar with its content.

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Original Research

Association between ideal cardiovascular health and multiple disabilities among US adults, BRFSS 2017–2019

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ABSTRACT

Objectives: Cardiovascular health is the leading cause of death and disability in the United States. Our objective was to estimate the association between ideal cardiovascular health (ICVH) and multiple disabilities among US adults stratified into the three age groups of young (18–44 years), midlife (45–64 years), and older adults (≥65 years).

Study design: We conducted a cross-sectional analysis using data pooled from the 2017 and 2019 Behavioral Risk Factor Surveillance System (BRFSS).

Methods: Using American Heart Association's seven-component (four ideal behaviors and three ideal health factors) scoring tool, we identified ICVH as a composite score ≥5 and also computed the ideal behavioral (score ≥3) and ideal health factors (score = 3) submetrics. The outcome, single vs multiple disabilities indicator, was defined using US Census's disability domains and analyzed using multinomial regression.

Results: For all three groups, the prevalence of multiple disabilities was significantly lower among those meeting ICVH, ideal behavioral, and ideal health factors compared with those that did not. After controlling for covariates, ICVH score ≥5 was associated with lower relative risk of multiple disabilities in all groups. Although both ideal health and ideal behavioral factors were associated with lower relative risk of multiple disabilities among all groups, the reduction in risk was the highest for multiple disabilities and ideal behavioral factors among midlife (relative risk ratio: 0.30, 95% confidence interval: 0.25, 0.36) and older adults (relative risk ratio: 0.40, 95% confidence interval: 0.33, 0.48).

Conclusion: Adults with less-than-ideal cardiovascular health had a higher relative risk of multiple disabilities. Addressing the risk of multiple disabilities of US adults will require effective promotion of ICVH.

Introduction

Cardiovascular disease (CVD), the leading cause of death and disability in the United States, represents a steep cost to the US health care and the economy, over $300 billion each year.[1–3] While the prevalence of CVD, as well as risk conditions such as obesity and diabetes, remains high among American adults, the prevalence of disability is rising partly due to progressive aging of the United States.[3–5] Concerning parallel trends include increasing deaths from cardiometabolic causes, particularly among the young working-age population, and a stalling of the decline in CVD mortality.[6]

To promote heart health and reduce CVD burden, the American Heart Association (AHA) has used the concept of ideal cardiovascular health (ICVH) since 2010.[2,4] The ICVH metric comprises four ideal health behaviors (non-smoking status, normal body mass index [BMI], physical activity [PA], and healthy diet) and three ideal health factors (normal blood pressure, cholesterol, and blood glucose levels).[2,4] Coexistence of these ideal behavioral and ideal health factors are salient not only for prolonging CVD-free survival but to also maintain a healthy life without disability.[2] However, most prior works examine the association of ICVH with CVD and CVD-related mortality,[7–17] with only a handful of studies focusing on disability.[18–22]

Among the studies investigating the association of ICVH with disability, two[18,19] are US-based analyses that examine adults aged ≥20 years, whereas the rest[20–22] are non-US studies analyzing the relationship among older adults. Consequently, age-related variations in the association between ICVH and disability were overlooked as study samples consisted of either adults or older adults as a single group. While age is an independent predictor of

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cardiovascular functionality and age-based disparities in ICVH profile of US adults are widely highlighted,[2,3,23,24] understanding on how the protective association of ICVH with disability may differ across age groups is not known. This knowledge is essential for strategic promotion of ICVH targeting specific age groups. Therefore, our objective is to estimate the association between ICVH and disability among young, midlife, and older adults. In so doing, our focus rests on multiple disabilities, an intersectional characteristic that often overlaps with other marginalized identities and social disadvantages and has profound implications for social and labor-force participation of adults.[25–28]

Methods

Data

We considered the two most recent years with consistent information on all seven ICVH components and pooled data from the 2017 and 2019 Behavioral Risk Factor Surveillance System (BRFSS).[29] The response rates were 45% and 50%, respectively, resulting in a total of 868,284 participants. The BRFSS is a leading source of nationally representative health data in the United States and is conducted annually in 50 states and US territories using a probability-based multistage cluster sampling methodology. Participants are randomly selected non-institutionalized adults (≥18 years) and self-reported data on chronic conditions, health risk behaviors, access to and use of health services, and sociodemographics are collected. Annual BRFSS data are publicly available for download, and the Institutional Review Board at the Centers for Disease Control and Prevention has approved BRFSS for research.[30]

Study sample

Three BRFSS questions asked respondents about their lifetime diagnosis of (1) 'a heart attack, also called a myocardial infarction'; (2) 'angina or coronary heart disease'; and (3) 'a stroke.' We considered all BRFSS participants (aged ≥18 years) responding 'no' to these three CVD-related questions for our study. Of the 758,976 respondents without a self-reported history of CVD, 69% (unweighted observations, $n = 524{,}088$; weighted observations, $N = 305{,}513{,}625$) had no missing information on the components of the outcome and the explanatory variables and covariates (except income). Covariates most frequently missing information were race/ethnicity ($n = 14{,}891$) and age ($n = 11{,}467$). The age groups were (1) young, 46.0% ($n = 150{,}427$, $N = 140{,}981{,}266$); (2) midlife, 35.0% ($n = 202{,}721$, $N = 106{,}913{,}955$); and older adults, 19.0% ($n = 170{,}940$, $N = 57{,}618{,}403$).

Outcome and explanatory variables

We constructed the outcome, single vs multiple disability indicator, using the six-item disability module in BRFSS. This six-item questionnaire was introduced by the US Census's American Community Survey[31] and has been used since 2008 to ask about and collect data on disability in the United States. These questions ask respondents about:

1 hearing difficulty: *are you deaf or do you have serious difficulty hearing*?
2 vision difficulty: *are you blind or do you have serious difficulty seeing, even when wearing glasses*?
3 cognitive difficulty: *because of a physical, mental, or emotional condition, do you have serious difficulty concentrating, remembering, or making decisions*?
4 ambulatory difficulty: *do you have serious difficulty walking or climbing stairs*?
5 self-care difficulty: *do you have difficulty dressing or bathing*? and
6 independent living difficulty: *because of a physical, mental, or emotional condition, do you have difficulty doing errands alone such as visiting a doctor's office or shopping*?

The previously mentioned questions thus cover six disability types related to functional limitations across the domains of vision, cognition, ambulation, self-care, and independent living and have been used in the prior literature to examine single vs multiple disabilities using a composite score and/or to estimate the protective role of ICVH.[18,20,32–34] Consistently, we identified multiple disabilities as respondents reporting 'two or more types of disability.' We aggregated the binary (no = 0/yes = 1) responses to the six disability questions and computed a composite disability score (range: 0–6). Using this composite score, we created a 3-category indicator identifying single (score = 1) and multiple (score >1) disabilities with no disability (score = 0) as the reference category.

The primary explanatory variable is ICVH defined using AHA's seven-component metric.[2–4] The two submetrics, ideal behavioral and ideal health, served as secondary independent variables in our analysis.[2–4] To compute these metrics, we considered BRFSS questions that have been used in prior studies to create components, calculate scores, and define ICVH.[35–38] We coded the binary responses (yes = 0/no = 1) to three BRFSS questions asking about respondents' lifetime diagnosis of (1) 'high blood pressure,' (2) 'high blood cholesterol,' and (3) 'diabetes' to define the three ideal health factors.

To derive the ideal behavioral components, we considered responses on fruit and vegetable consumption and categorical data on participants' BMI, PA, and smoking status in BRFSS. We used the categorical information to code ideal BMI (underweight or overweight/obese = 0, normal weight: 18.5 < BMI < 25 = 1), ideal PA level (150+ minutes or vigorous equivalent minutes of physical activity = 1, 0 otherwise), and non-smoking status (current/former smoker = 0, never smoked = 1). Fruit and vegetable consumption correlates with health, diet, cardiovascular, health and has been used in prior studies on CVD[39,40] and ICVH.[35–37] We computed daily fruit and vegetable intake of respondents based on questions in the BRFSS 'fruits & vegetables' module (fruit: 100% fruit juice and fruits; vegetable: vegetables, green leafy/lettuce salad, and potatoes/sweet potatoes) using methodology out lined by the Centers for Disease Control and Prevention.[38,41] Respondents indicating intake of both fruits and vegetables five or more times per day were coded with a value of [1] or [0] otherwise.

We combined all seven binary (0/1) components, the three ideal health factors, and the four ideal behavioral factors to respectively compute respondents' composite ICVH score (range: 0–7) and scores on the ideal health (range: 0–3) and ideal behavioral (range: 0–4) submetrics. Finally, we dichotomized each of these scores to identify the presence of (1) ICVH (score ≥5 = [1], 0 otherwise), (2) ideal behavioral health (score ≥3 = [1], 0 otherwise), and (3) ideal health factors (score = 3 = [1], 0 otherwise).

Covariates

Consistent with prior studies, we included respondents' sociodemographic characteristics and chronic health condition as control variables in our analysis.[18,20,36,37,42] Sociodemographic factors included sex (male/female), age (5-year categories), race/ethnicity (non-Hispanic [NH] Whites, NH Blacks, other/multiracial NH, and Hispanics), education (less than high school, high school, some college, and college/technical) and household income levels (<$15,000, $15,000 to <$25,000, $25,000 to <$35,000, $35,000 to <$50,000, and ≥$50,000). We combined binary (0 = no/1 = yes)

responses to BRFSS questions on lifetime diagnosis of chronic conditions that included depressive disorders, arthritis, chronic kidney disease, asthma, chronic obstructive pulmonary disease, and skin or other cancers to get an aggregate chronic health condition score (range: 0–7). This score was then used to indicate the presence (score ≥1 = 1) or absence (score 0 = 0) of one or more of these chronic conditions.

Statistical analysis

For both descriptive and regression analyses, we estimated statistics stratified by the three age categories (young, midlife, and older adults), starting with the prevalence and 95% confidence intervals (CIs) of ICVH, the two submetrics, and single/multiple disabilities. We then computed the prevalence and 95% CI of single and multiple disabilities by sociodemographic, chronic health, and ICVH characteristics of young, midlife, and older adults. Finally, we estimated the unadjusted and adjusted relative risks of single and multiple disabilities associated with the presence of ICVH, ideal behavioral, and ideal health factors using multinomial logistic regression. The adjusted models included all covariates. Using Stata (version 15), we accounted for the complex survey design of BRFSS and report weighted estimates and statistically significant findings at $p \leq 0.05$ (unless specified otherwise).

Results

Descriptive results

In Fig. 1, we provide the summary view on the weighted prevalence of ICVH metrics (Panel A) and disabilities (Panel B) among young, midlife, and older adults. The proportion of individuals meeting ICVH (score ≥5) and ideal health factors (score = 3) was the lowest among the older adults (ICVH: 18.2%, 95% CI: 17.76, 18.73; ideal health factors: 24.8%, 95% CI: 24.27, 25.29). In contrast, the proportion of individuals meeting ideal behavioral factors (score ≥3) was the lowest among the midlife adults (9.8%, 95% CI: 9.48, 10.05). Overall, self-reported prevalence of both single and multiple disabilities increased across the age groups and was highest among the older adults (single: 21.8%, 95% CI: 21.34, 22.33; multiple: 13.7%, 95% CI: 13.33, 14.16).

Age-stratified summary statistics on single vs multiple disabilities by sociodemographics and chronic health are in Table 1 and by ICVH characteristics in Table 2. Across age groups, self-reported prevalence of single disability of males and females was alike, but the prevalence of multiple disabilities was much higher among women compared with men, with the largest difference present among the midlife adults (male: 9.4%, 95% CI: 9.03, 9.79; female: 12.3, 95% CI: 11.9, 12.77). Within broad racial/ethnic disparities characterizing both single and multiple disabilities of each age group, NH Blacks had the highest rate of self-reported multiple disabilities in the young (6.2%, 95% CI: 5.51, 7.01) and midlife (14.6%, 95% CI: 13.63, 15.67) groups, whereas Hispanics had the highest rate of multiple disabilities among older adults (19.8%, 95% CI: 17.84, 21.99). In addition, in each age group, self-reported prevalence of disabilities, both single and multiple, decreased with higher levels of education and household income and was lower among those reporting no chronic health conditions.

Next, as indicated in Table 2, in each age group, self-reported prevalence of both single and multiple disabilities was significantly lower ($p < 0.05$) among those meeting ICVH (score ≥5), ideal behavioral (score ≥3), or ideal health factors (score = 3) compared with those that did not. Among those with ICVH score ≥5, less than

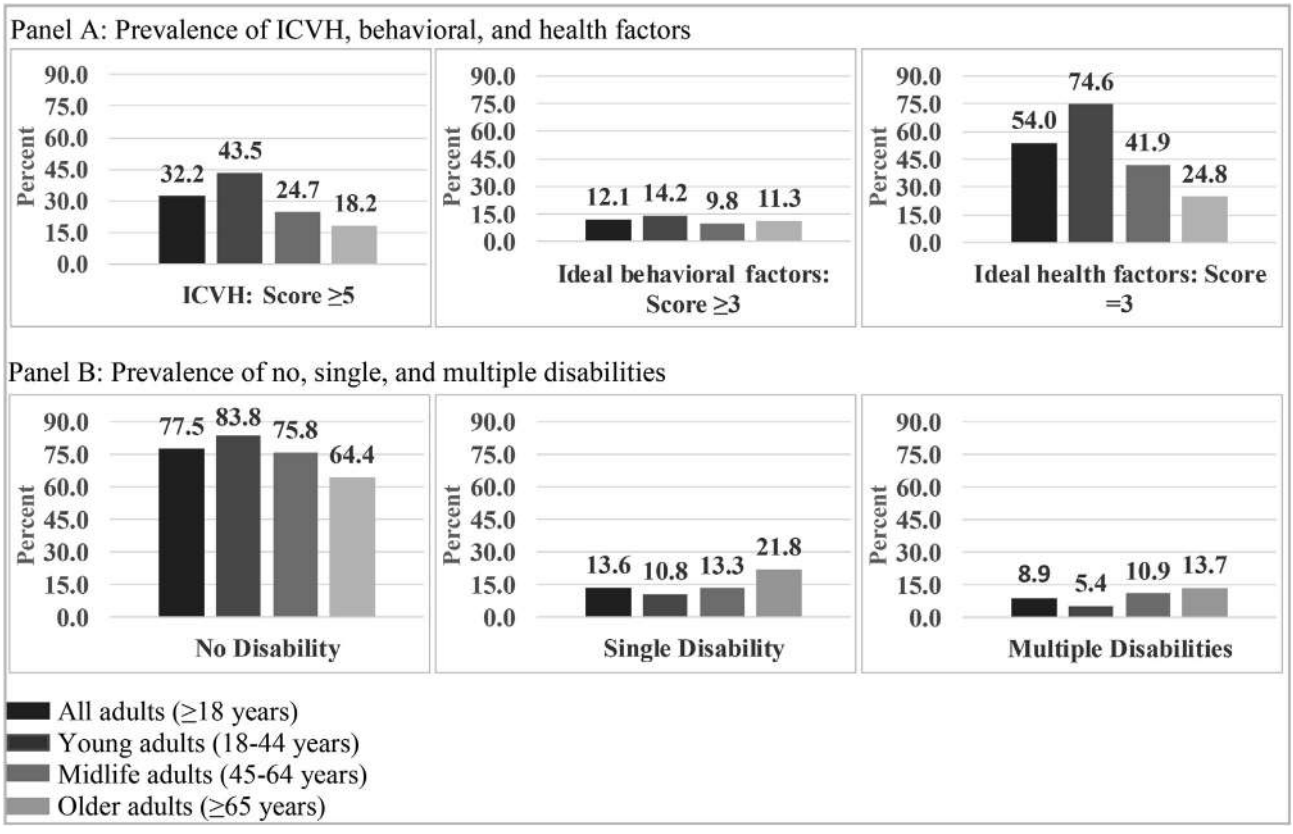

Fig. 1. Weighted prevalence of ideal cardiovascular health (ICVH) metrics and disabilities among young (18–44 years), midlife (45–64 years), and older adults (≥65 years), BRFSS 2017, 2019.

Table 1
Single vs multiple disabilities of young (18–44 years), midlife (45–64 years), and older adults (≥65 years) by sociodemographic and chronic health characteristics, BRFSS 2017, 2019.

Variables	Young adults (18–44)		Midlife adults (45–64)		Older adults (≥65)	
	Single disability	Multiple disabilities	Single disability	Multiple disabilities	Single disability	Multiple disabilities
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
Overall	10.8 (10.45, 11.06)	5.4 (5.23, 5.65)	13.3 (12.95, 13.61)	10.9 (10.61, 11.20)	21.8 (21.34, 22.33)	13.7 (13.33, 14.16)
Sex						
Male	10.1 (9.73, 10.55)	4.4 (4.17, 4.74)	13.2 (12.7, 13.68)	9.4 (9.03, 9.79)	21.7 (20.98, 22.40)	12.3 (11.69, 12.87)
Female	11.4 (10.93, 11.85)	6.5 (6.14, 6.78)	13.4 (12.92, 13.82)	12.3 (11.9, 12.77)	22.0 (21.27, 22.64)	14.9 (14.36, 15.53)
Race/ethnicity						
NH Whites	10.3 (9.93, 10.63)	5.4 (5.19, 5.69)	12.7 (12.38, 13.05)	9.9 (9.57, 10.17)	21.6 (21.09, 22.07)	12.6 (12.21, 12.98)
NH Blacks	10.6 (9.79, 11.56)	6.2 (5.51, 7.01)	14.6 (13.57, 15.79)	14.6 (13.63, 15.67)	22.0 (20.02, 24.2)	17.2 (15.33, 19.33)
Multiracial/other NH	9.1 (8.18, 10.00)	4.5 (3.87, 5.1)	10.9 (9.65, 12.25)	9.1 (8.04, 10.2)	20.1 (17.37, 23.13)	15.2 (12.35, 18.52)
Hispanics	12.9 (12.05, 13.81)	5.5 (4.92, 6.03)	16.2 (14.92, 17.61)	13.9 (12.78, 15.09)	24.9 (22.5, 27.56)	19.8 (17.84, 21.99)
Education						
Less than high school	17.4 (15.92, 19.08)	11.8 (10.66, 13.01)	21.4 (19.72, 23.1)	25.5 (23.97, 27.18)	26.8 (24.7, 28.93)	25.7 (23.77, 27.64)
High school	13.1 (12.42, 13.73)	6.7 (6.22, 7.15)	15.8 (15.16, 16.48)	13.9 (13.28, 14.52)	24.6 (23.63, 25.51)	16.4 (15.57, 17.24)
Some college	11.6 (11.05, 12.18)	6.2 (5.79, 6.58)	14.0 (13.42, 14.64)	11.4 (10.88, 11.92)	21.7 (20.78, 22.61)	13.2 (12.44, 13.95)
College/technical	6.3 (5.95, 6.58)	2.0 (1.82, 2.19)	8.3 (7.98, 8.71)	3.9 (3.67, 4.15)	17.8 (17.19, 18.52)	7.7 (7.28, 8.17)
Income						
<15,000	17.5 (16.25, 18.83)	16.1 (15.02, 17.31)	22.4 (21.00, 23.75)	39.5 (37.97, 41.09)	26.9 (24.81, 29.12)	31.4 (29.17, 33.81)
15,000 to <25,000	16.2 (15.19, 17.16)	10.4 (9.68, 11.21)	22.6 (21.33, 23.84)	24.7 (23.57, 25.88)	26.5 (25.24, 27.71)	21.1 (20.1, 22.2)
25,000 to <35,000	14.1 (12.96, 15.29)	5.9 (5.26, 6.57)	18.1 (16.53, 19.76)	15.4 (14.19, 16.71)	24.8 (23.38, 26.28)	16.5 (15.37, 17.72)
35,000 to <50,000	11.9 (11.05, 12.87)	4.9 (4.33, 5.44)	15.0 (14.03, 16.05)	10.7 (9.81, 11.56)	23.8 (22.49, 25.07)	11.4 (10.61, 12.24)
≥50,000	7.3 (7.00, 7.68)	2.4 (2.22, 2.64)	9.5 (9.14, 9.83)	4.1 (3.83, 4.37)	17.4 (16.79, 18.06)	7.2 (6.74, 7.71)
Chronic conditions						
No	6.6 (6.24, 6.88)	1.5 (1.39, 1.70)	7.7 (7.33, 8.18)	2.7 (2.46, 2.91)	15.1 (14.24, 15.94)	4.9 (4.37, 5.47)
Yes	17.9 (17.28, 18.5)	12.1 (11.57, 12.56)	18.4 (17.86, 18.85)	18.4 (17.95, 18.94)	24.6 (23.95, 25.15)	17.3 (16.77, 17.83)

CI, confidence interval; NH, non-Hispanic.

Table 2
Single vs multiple disabilities of young (18–44 years), midlife (45–64 years), and older adults (≥65 years) by ideal cardiovascular health characteristics, BRFSS 2017–2019.

ICVH: 7 components	Young adults (18–44)		Midlife adults (45–64)		Older adults (65+)	
	Score <5	Score ≥5	Score <5	Score ≥5	Score <5	Score ≥5
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
No disability	79.8 (79.28, 80.31)	89.0 (88.55, 89.50)	71.3 (70.76, 71.76)	89.7 (89.09, 90.32)	61.2 (60.58, 61.87)	78.8 (77.58, 79.91)
Single disability	12.6 (12.13, 13.00)	8.4 (7.98, 8.83)	15.2 (14.80, 15.60)	7.4 (6.89, 8.02)	23.3 (22.77, 23.89)	15.1 (14.15, 16.19)
Multiple disabilities	7.6 (7.32, 7.98)	2.6 (2.35, 2.81)	13.5 (13.18, 13.92)	2.8 (2.59, 3.13)	15.5 (14.97, 15.94)	6.1 (5.46, 6.80)
Chi-squared *P*-value		<0.001		<0.001		<0.001
Ideal behavioral submetric: 4 components	Score<3 % (95% CI)	Score≥3 % (95% CI)	Score<3 % (95% CI)	Score≥3 % (95% CI)	Score<3 % (95% CI)	Score≥3 % (95% CI)
No disability	82.7 (82.26, 83.06)	90.8 (89.99, 91.55)	74.1 (73.63, 74.52)	91.9 (91.18, 92.61)	62.7 (62.06, 63.28)	78.2 (76.46, 79.81)
Single disability	11.3 (11.01, 11.68)	7.2 (6.48, 7.90)	14.1 (13.7, 14.42)	6.1 (5.47, 6.73)	22.6 (22.1, 23.15)	15.7 (14.24, 17.2)
Multiple disabilities	6.0 (5.76, 6.24)	2.0 (1.71, 2.44)	11.9 (11.55, 12.19)	2.0 (1.69, 2.38)	14.7 (14.27, 15.17)	6.1 (5.22, 7.23)
Chi-squared *p*-value		<0.001		<0.001		<0.001
Ideal health submetric: 3 components	Score<3 % (95% CI)	Score = 3 % (95% CI)	Score<3 % (95% CI)	Score = 3 % (95% CI)	Score<3 % (95% CI)	Score = 3 % (95% CI)
No disability	77.2 (76.41, 78.03)	86.1 (85.66, 86.44)	70.3 (69.77, 70.90)	83.4 (82.85, 83.98)	61.5 (60.81, 62.17)	73.3 (72.34, 74.31)
Single disability	13.0 (12.40, 13.71)	10.0 (9.63, 10.32)	15.4 (15.00, 15.89)	10.3 (9.80, 10.78)	23.1 (22.49, 23.67)	18.1 (17.22, 18.95)
Multiple disabilities	9.7 (9.18, 10.31)	4.0 (3.77, 4.19)	14.2 (13.8, 14.66)	6.3 (5.96, 6.65)	15.4 (14.93, 15.96)	8.6 (8.05, 9.18)
Chi-squared *p*-value		<0.001		<0.001		<0.001

CI, confidence interval; ICVH, ideal cardiovascular health. The ICVH metric comprises four ideal health behaviors (non-smoking status, normal body mass index, physical activity, and healthy diet) and three ideal health factors (normal blood pressure, cholesterol, and blood glucose levels).

3% in the young (2.6%, 95% CI: 2.35, 2.81) and in the midlife (2.8%, 95% CI: 2.59, 3.13) adults reported multiple disabilities, compared with more than 8% multiple disabilities among those not meeting ICVH in these age groups. Among the older adults, this gap in the prevalence of multiple disabilities was more prominent, 6.1% (95% CI: 5.46, 6.80) among those meeting ICVH vs 15.5% (95% CI: 14.97, 15.94) among those with score <5 on the ICVH metric.

Multivariable findings

In Table 3, we present results from the multinomial logistic regression models. We first estimated the unadjusted and adjusted relative risk ratios (RRRs) of single/multiple disabilities with ICVH as the explanatory factor (Table 3, Panel A). We then estimated the unadjusted and adjusted RRRs of single/multiple disabilities with the two submetrics, behavioral and health factors, as explanatory variables (Table 3, Panel B).

As indicated in Table 3, Panel A, having a score ≥5 on the composite ICVH metric is associated with lower relative risk ($P < 0.05$) of single and multiple disabilities of all groups after controlling for sociodemographic and chronic health characteristics. Across the three age groups, the reduction in relative risk of multiple disabilities was consistently larger than that in single disability, particularly among the two older groups. Among the

midlife and older adults, relative risk of multiple disability reduced, respectively, by 69% (RRR: 0.31, 95% CI: 0.27, 0.34) and 62% (RRR: 0.38, 95% CI: 0.34, 0.44), whereas the relative risk of single disability reduced by 42%–44% in these two groups. In comparison, among the young adult group, the reductions in the relative risk of both single and multiple disabilities were more modest, respectively, 30% (RRR: 0.70, 95% CI: 0.65, 0.75) and 55% (RRR: 0.45, 95% CI: 0.40, 0.50).

Both submetrics, ideal behavioral (score ≥3) and ideal health (score = 3), were also associated with lower relative risk of single and multiple disabilities of all three age groups ($p < 0.05$) after controlling for covariates (Table 3, Panel B). For the ideal behavioral submetric, the reduction in relative risk across the age groups ranged between 29% and 46% for single disability and between 47% and 70% for multiple disabilities. The decrease in relative risk on the ideal health factors submetric across age groups varied between 23% and 25% for single disability and between 41% and 50% for multiple disabilities. Thus, similar to the composite ICVH metric, each of the two submetrics is also associated with a larger drop in the relative risk of multiple disabilities compared with single disability. The magnitude of this decrease in the relative risk of multiple disabilities of the two older groups was greater than that of the young adult group. In addition, a within-group comparison indicated the salience of meeting ideal behavioral factors over meeting ideal health factors—for both single/multiple disabilities, the RRRs were consistently smaller for the ideal behavioral metric compared with the ideal health factors metric. The only exception was multiple disabilities of the young adult group with ideal behavioral score ≥3 and ideal health factors score = 3 associated respectively, with 47% (RRR: 0.53, 95% CI: 0.44, 0.65) and 50% (RRR: 0.50, 95% CI: 0.46, 0.55) lower relative risk of multiple disabilities.

A visual summary of the previously mentioned findings is shown in Fig. 2. The benefits from meeting ICVH score ≥5, ideal behavioral factor score ≥3, or ideal health factor score = 3 are consistently greater for multiple disabilities (Panel B: RRR between 0.30 and 0.59) when compared with single disability (Panel A: RRR between 0.54 and 0.77) of all three groups. In Fig. 2, Panel B, RRRs also indicate the dominance of ideal behavioral factor score ≥3 over ideal health factor score = 3 for the two older groups. In contrast, ideal scores on both submetrics were associated with comparable RRRs for multiple disabilities of the young adults.

Discussion

A handful of previous findings report a negative correlation between ICVH and disability of adults or older adults.[18–22] We add to this literature by focusing on multiple disabilities of US adults. Disability is a multidimensional concept spanning the domains of hearing, vision, mobility, cognition, self-care, and independent living.[31] Multiple disabilities represent difficulties in more than one of these domains and indicate an increased severity of disability, amplified burden on healthcare needs, and greater restrictions on social and work participation of Americans.[25,26,42] It is also most often prevalent among vulnerable groups experiencing social

Table 3
Age group stratified multinomial logistic regression results: Relative risk ratios (RRRs) for single and multiple disabilities among young (18–44 years), midlife (45–64 years), and older adults (65 years and older).

Panel A: single/multiple disabilities and ideal cardiovascular health (ICVH ≥5)			
	Young adults: 18–44	Midlife adults: 45–64	Older adults: ≥65
	RRR (95% CI)	RRR (95% CI)	RRR (95% CI)
Unadjusted models (base category: no disability)			
Single disability			
ICVH: score ≥5 (Ref: score <5)	0.60*** (0.56, 0.64)	0.39*** (0.38, 0.42)	0.50*** (0.46, 0.55)
Multiple disabilities			
ICVH: score ≥5 (Ref: score <5)	0.30*** (0.27, 0.33)	0.17*** (0.15, 0.19)	0.31*** (0.27, 0.35)
Adjusted models[a] (base category: no disability)			
Single disability			
ICVH: score ≥5 (Ref: score <5)	0.70*** (0.65, 0.75)	0.56*** (0.51, 0.61)	0.58*** (0.53, 0.63)
Multiple disabilities			
ICVH: score ≥5 (Ref: score <5)	0.45*** (0.40, 0.50)	0.31*** (0.27, 0.34)	0.38*** (0.34, 0.44)
Panel B: single/multiple disabilities and ideal behavioral (≥3) vs ideal health (=3) factors			
	Young: 18–44	Midlife: 45–64	Older adults: ≥65
	RRR (95% CI)	RRR (95% CI)	RRR (95% CI)
Unadjusted models (base category: no disability)			
Single disability			
Ideal behavioral: score ≥3 (Ref: score <3)	0.60*** (0.54, 0.68)	0.39*** (0.35, 0.44)	0.58*** (0.52, 0.66)
Ideal health: score = 3 (Ref: score <3)	0.71*** (0.67, 0.77)	0.60*** (0.56, 0.64)	0.68*** (0.64, 0.73)
Multiple disability			
Ideal behavioral: score ≥3 (Ref: score <3)	0.36*** (0.30, 0.44)	0.17*** (0.14, 0.20)	0.36*** (0.31, 0.44)
Ideal health: score = 3 (Ref: score <3)	0.39*** (0.36, 0.43)	0.40*** (0.38, 0.44)	0.49*** (0.45, 0.54)
Adjusted models[b] (base category: no disability)			
Single disability			
Ideal behavioral: score ≥3 (Ref: score <3)	0.71*** (0.63, 0.80)	0.54*** (0.48, 0.61)	0.62*** (0.55, 0.70)
Ideal health: score = 3 (Ref: score <3)	0.77*** (0.72, 0.83)	0.75*** (0.70, 0.80)	0.75*** (0.70, 0.81)
Multiple disability			
Ideal behavioral: score ≥3 (Ref: score <3)	0.53*** (0.44, 0.65)	0.30*** (0.25, 0.36)	0.40*** (0.33, 0.48)
Ideal health: score = 3 (Ref: score <3)	0.50*** (0.46, 0.55)	0.58*** (0.54, 0.63)	0.59*** (0.54, 0.64)

CI, confidence interval; ICVH, ideal cardiovascular health; RRR, relative risk ratio.
The ICVH metric comprises four ideal health behaviors (non-smoking status, normal body mass index, physical activity, and healthy diet) and three ideal health factors (normal blood pressure, cholesterol, and blood glucose levels).
Ref: Reference category; ***$p < 0.05$.
[a] Adjusted models included all covariates (sociodemographics and chronic health) in addition to the explanatory factor: ICVH.
[b] Adjusted models included all covariates (sociodemographics and chronic health) in addition to the two explanatory factors: ideal behavioral and ideal health factors submetrics.

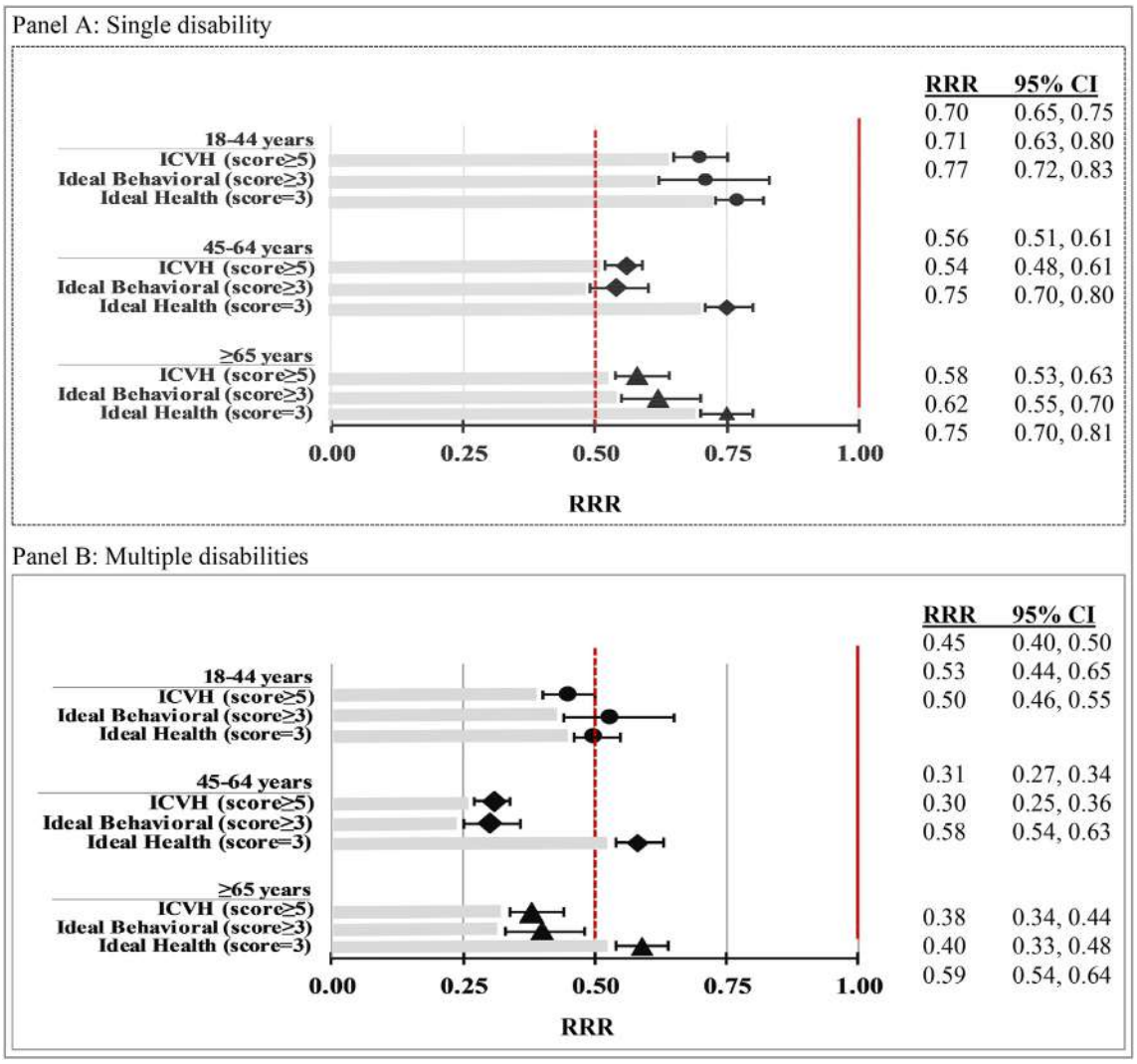

Fig. 2. Age group stratified multinomial logistic regression—Adjusted relative risk ratios (RRRs) for single and multiple disabilities among young (18–44 years), midlife (45–64 years), and older adults (≥65 years), BRFSS 2017, 2019.

disadvantages.[27,28] To the best of our knowledge, our study is the first to examine multiple disabilities and its relation with ICVH separate from single disability and among the three distinct age groups of young (18–44 years), midlife (45–64 years), and older adults (>65 years).

Another contribution of our study was the estimation of age-stratified association between disabilities and the two ICVH submetrics measured using four ideal health behaviors and three ideal health factors. The results revealed within- and between-group differences that indicate distinct cardiovascular health-promoting implications among different age groups. Among the youngest age group (18–44 years), the decrease in relative risk of multiple disabilities associated with ideal health factors slightly outweighed that associated with the ideal behavioral factors. Thus, in addition to promoting healthy behaviors, a specific focus on primordial prevention of cardiovascular risk factors assumes prominence among young adults.[43] Delivery of health education and messaging tailored to include information on CVD risk factors as well as heart healthy behaviors should therefore be prioritized across different setting, including worksites of young adults.[44]

For the two older age groups, although our findings similarly do not indicate a causality in the relation between ICVH and multiple disabilities, the cross-sectional results support evidence of a significant association between the two, suggesting that promotion of ICVH among adults aged ≥45 years is also critical. Having an ICVH score ≥5 was associated with a lower relative risk of multiple disabilities of all age groups, but the magnitude of this decrease was far greater among the two older groups when compared with the young adult group. In addition, among the two older groups, the ideal behavioral factors emerged as the more prominent ICVH submetric that correlated with the lowest relative risk of multiple disabilities. A longstanding barrier toward meeting ideal behavioral factors among adults ≥50 years is low adherence to healthy lifestyles and habits.[43] Together with this trend, our findings showcase the salient need for public health promotion efforts to support healthy behaviors and lifestyle among midlife and older adults. For instance, the US Medicare program could consider expanding access to a broad range of preventative services for behavioral health essential in sustaining healthy and active lifestyle for cardiovascular health of older adults.[45,46] Community care providers could also play an important role in motivating, connecting, and extending the care continuum to include behavioral interventions such as exercise programs for those aged ≥45 years.[45]

Our study has several limitations. In the BRFSS data set, health information are recorded from self-reported responses. Thus, the cardiovascular health metrics in our study are proxy measures that do not represent precise clinical measurements or updates recently forwarded by AHA. Nevertheless, analogous methodological applications using the BRFSS data set are found in previous studies on ICVH.[35–38] In addition, the cross-sectional design of BRFSS did not allow us to test for the longitudinal effect of ICVH on disabilities. Thus, future studies are needed to establish the protective role of ICVH on multiple disabilities over time.

In conclusion, our analysis revealed a statistically significant association between cardiovascular health and multiple disabilities and provided granular information on the inverse relation between ICVH, ICVH submetrics, and multiple disabilities across age groups in the United States. Overall, the findings showed that adults with less-than-ideal cardiovascular health had a higher relative risk of multiple disabilities than those meeting five or more ICVH recommendations. Public health policies targeted toward health promotion and education are thus critical for promoting ICVH of US adults.

Author statements

Ethical approval

This research uses publicly available secondary data; therefore, ethical approval was not required.

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Competing interests

None.

Data availability statement

Data are available from the authors on request.

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Short Communication

Changes in cerebrovascular disease–related deaths and their location during the COVID-19 pandemic in Japan

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ABSTRACT

Objective: The COVID-19 pandemic placed an enormous strain on healthcare systems and raised concerns for delays in the management of patients with acute cerebrovascular events. In this study, we investigated cerebrovascular excess deaths in Japan.
Study design: Vital mortality statistics from January 2012 to May 2022 were obtained from the Japanese Ministry of Health, Labour and Welfare.
Methods: Using quasi-Poisson regression models, we estimated the expected weekly number of cerebrovascular deaths in Japan from January 2020 through May 2022 by place of death. Estimates were calculated for deaths in all locations, as well as for deaths in hospitals, in geriatric health service facilities, and at home. The age subgroups of ≥75 and <75 years were also considered. Weeks with a statistically significant excess of cerebrovascular deaths were determined when the weekly number of observed deaths exceeded the upper bound of 97.5% prediction interval.
Results: Excess deaths were noted in June 2021 and became more pronounced from February 2022 onward. The trend was notable among those aged ≥75 years and for those who died in hospitals. With respect to the location of deaths, the excess was significant in geriatric health services facilities from April 2020 to June 2021, whereas no evidence of excess hospital deaths was observed during the same period.
Conclusions: Beginning in the late 2021, excess cerebrovascular deaths coincided with the spread of the Omicron variant and may be associated with increased healthcare burden. In 2020, COVID-19 altered the geography of cerebrovascular deaths, with fewer people dying in hospitals and more dying in geriatric health service facilities and at home.

Introduction

The COVID-19 pandemic has had significant impacts on access to and quality of healthcare across the globe, and the management of cerebrovascular diseases is no exception. In addition to a purported association between COVID-19 and neurologic conditions such as cerebral infarction,[1] the early stage of the pandemic was characterized by decreased stroke consultations[2] and higher rates

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of mortality among acute ischemic stroke patients.[3] In Japan, significant excess all-cause deaths, the net difference between the number of deaths observed and expected on the basis of past trends, were not observed during 2020[4] but were temporarily recorded in 2021[5] in line with the surge of infection.

However, trends in cerebrovascular deaths during the pandemic era remain unclear, particularly during the recent spread of the Omicron variant. In the present study, we aimed to assess changes in cerebrovascular deaths from before and after the start of the COVID-19 pandemic using vital statistical data. We also aimed to assess the changes in the reported location of death among those who died due to cerebrovascular causes.

Methods

Data source and population

We used national mortality (vital statistical) data obtained from the Ministry of Health, Labour and Welfare between January 2012 and May 2022. Death certificates in Japan are prepared by a physician within one week of an individual's death and contain information regarding the place of death and underlying cause of death (based on the International Classification of Diseases, 10th Revision). All persons with a certificate of residence who died in Japan, regardless of nationality, are captured by the mortality data. Those whose place of residence or date of birth was unknown, those who died abroad, and those who stayed in Japan for a short period (without a residence card) were not included in the present study. Daily data were converted to weekly data.

We analyzed deaths where the underlying cause of deaths was a cerebrovascular disease (International Classification of Diseases, 10th Revision, classification I60–I69), including but not limited to cerebral infarction, subarachnoid hemorrhage, and intracerebral hemorrhage (see Supplementary Table 1). In other words, it should be noted that our analysis did not include deaths of patients with cerebrovascular disease who contracted COVID-19, became severely ill, and subsequently died (in this case, at least during the study period, the underlying cause of death would be recorded as COVID-19). In this study, 'all places' refers to total deaths across all places of death. Place-specific estimations were performed for hospitals, geriatric health service facilities (which are intermediate facilities that link hospitals and homes with the aim of supporting the independence of older people with disabilities and returning them to their homes; and the length of stay is also limited), and homes, where the number of weekly deaths was sufficient to avoid instability in the model. With respect to age, analyses were conducted for all ages in addition to those aged ≥75 and <75 years.

Statistical analysis

The Farrington algorithm, which is a variant of the quasi-Poisson regression model, was used to estimate the expected number of deaths for any given week between January 2018 and May 2022. Briefly, this algorithm uses historical data to construct a baseline from a five year moving window along with parameters to control for seasonality and then estimates the expected number of deaths and the corresponding two-sided 95% prediction intervals for any given week. The method is also described elsewhere.[5]

We estimated the expected number of deaths per week for the study period, adjusting for linear trends and seasonality using the Farrington algorithm.[6] The expected number of deaths for a certain week, t, was calculated using data from weeks $t - w$ and $t + w$ of years $h - b$ and $h + b$, where w and b are specified parameters and h is the year of t, referred to as the reference period. This method is intended to limit the data used for estimation. Thus,

$$log(E(Y_t)) = \alpha + \beta t + f^T(t)\gamma_{f(t)}$$

can be used to define the Farrington algorithm, where Y_t is the number of deaths in a given week, and t is assumed to follow a quasi-Poisson distribution with a dispersion parameter. As shown in the previously mentioned equation, α and β are regression parameters, $f(t)$ is a vector of dummy variables that evenly splits time points outside the reference period, and $\gamma_{f(t)}$ is a regression parameter vector that represents seasonality. To regulate seasonality, the present study separated data for one year period that were not part of the reference period into nine evenly distributed segments, as done in prior studies.[7] We considered data up to five years prior ($b = 5$) to the reference period and data from three weeks ($w = 3$) before and after a certain week in the reference period, in line with previous studies.[7] For all estimates of expected weekly mortality, we calculated 95% two-sided prediction intervals.

The discrepancy between the observed and expected death toll was used to compute the number of excess deaths. We also defined percent excess as a relative measure of the magnitude of the excess, which was calculated as the number of excess deaths divided by the expected number of deaths. Weeks in which the observed number of deaths exceeded the upper bound or fell below the lower bound of the 97.5% prediction interval were considered weeks of statistically significant excess deaths or exiguous deaths, respectively. All analyses and visualization were conducted in *R* version 4.1.0 (R Core Team, Vienna, Austria).

Results

In 2020, no excess cerebrovascular deaths were observed, but in 2021 and 2022, consecutive weeks with excess deaths were noted from May 31 to June 13, 2021, and from February 7 to March 13, 2022 (Fig. 1A). A similar trend was observed among those aged ≥75 years (Fig. 1B) and in-hospital deaths (Fig. 1D). Excess home deaths were reported from the week of January 31 to February 13, 2022 (Fig. 1F). There were no consecutive weeks of excess deaths among those aged <75 years in 2022 (Fig. 1C). Among those who died in geriatric health service facilities, weeks of excess deaths were observed from April 13, 2020, to May 16, 2021 (Fig. 1E). For in-hospital deaths, weeks of exiguous deaths were observed from January 20 to November 29, 2020 (Fig. 1D).

With respect to the percentage of the number of excess deaths divided by the expected number of deaths (percent excess deaths), many weeks showed a negative value in 2020 (mean −2.97%, standard deviation [SD] 3.57%; Supplementary Fig. 1A, Supplementary Table 2). Percent excess deaths began to uptrend in 2021, with positive values predominating in May 2021 (2021: mean 2.96%, SD 3.64%; 2022: mean 5.78%, SD 4.72%). Similar findings were noted among those aged ≥75 years (Supplementary Fig. 1B) and those who died in hospitals (Supplementary Fig. 1D). In contrast, among those who died in geriatric health service facilities (Supplementary Fig. 1E), positive values of percent excess deaths began manifesting around April 2020 to June 2021, then reverted to primarily negative values in late 2021.

Discussion

In Japan, we found evidence of excess cerebrovascular deaths at the beginning of June 2021 and more predominantly from February 2022 onward. Excesses were particularly notable among those aged ≥75 years and those who died in hospitals. Notably, these excesses coincided with the beginning of the spread of the Omicron variant in Japan.

Increased cerebrovascular mortality postpandemic has been noted elsewhere.[3] The excesses in cerebrovascular deaths observed

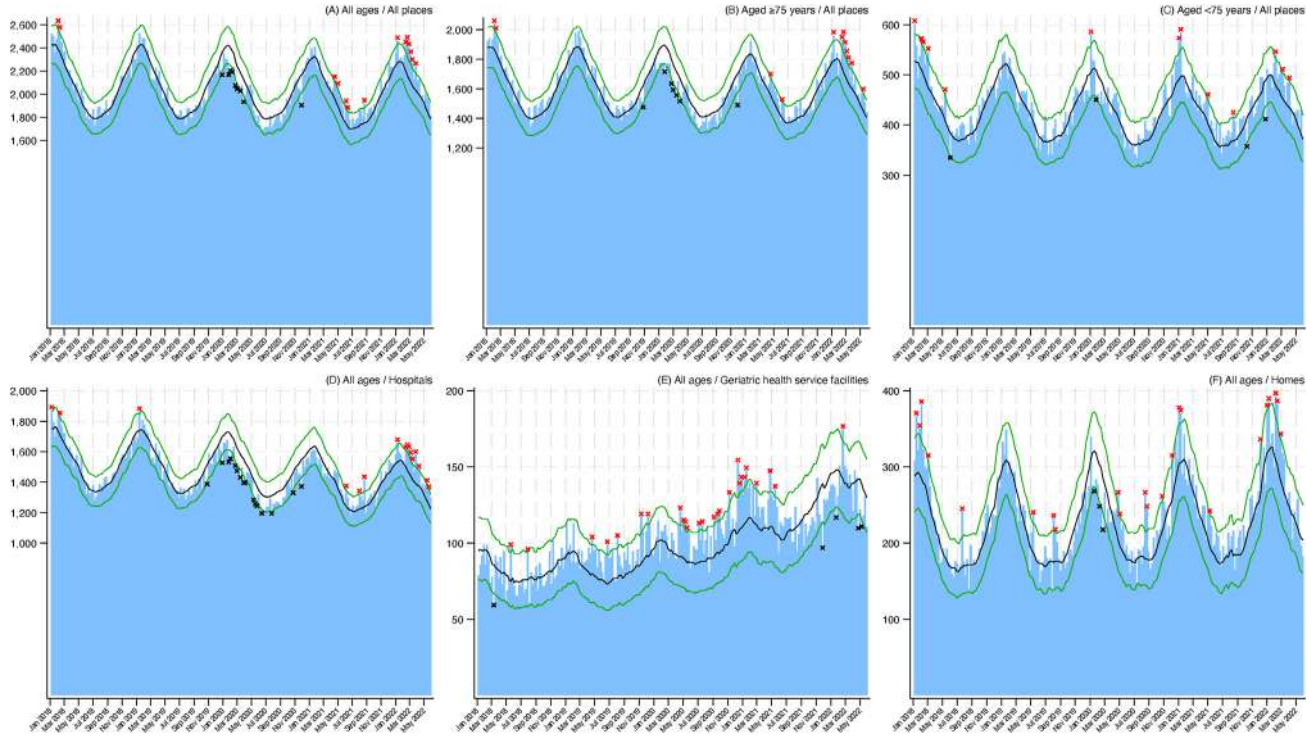

Fig. 1. Weekly observed and expected trends in the number of deaths due to cerebrovascular disease in Japan from January 2018 to May 2022, stratified by age group or place of death. The expected number of deaths and the 97.5% upper and lower bounds of the expected number of deaths are indicated by black and green lines, respectively. Red and black crosses denote weeks in which the observed number of deaths exceeded the 95% upper or lower bounds, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article).

in Japan were noted slightly later than those in Western countries, possibly because of superior control of COVID-19 transmission and relatively low case counts until late 2021. During the spread of the Omicron variant, increased healthcare burden and the resultant effect on the quality of cerebrovascular disease management may have disproportionately affected older patients even more than during the initial COVID surges.[8]

With respect to the location of deaths, our findings also suggest that during 2020, COVID-19 altered the geography of cerebrovascular deaths, with fewer people dying in hospitals and more dying in geriatric health service facilities. These periods largely corresponded with state of emergency declarations implemented throughout Japan, which encouraged Japanese residents to minimize outings and social interaction. A US study suggested that decreased healthcare-seeking behavior or fear of presenting to clinical spaces may have contributed to worse cerebrovascular disease outcomes.[9] Previous research has shown that Japanese residents avoided clinical spaces generally during the early phases of the pandemic,[10] which likely contributed to changes in the geography of cerebrovascular deaths. The reversion of mortality from non-hospital to hospital settings occurred in early 2022, at which point no states of emergency had been declared.

The present study has limitations. First, we specifically assess changes in cerebrovascular deaths; we do not assess changes in the incidence of cerebrovascular disease and cannot determine changes in case fatality rates for such patients. Because the COVID-19 pandemic led to widespread changes in healthcare-seeking behavior, excesses or deficits in cerebrovascular deaths may not exactly mirror changes in the incidence of disease. Second, the Farrington algorithm captures gradual changes in trends with the use of historical data; abrupt and pinpoint changes, such as those caused by new policy implementation, may not be fully absorbed by the model when constructing baselines for mortality prediction.

Author statements

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None.

Ethical approval

Ethics approval was granted by the ethics committee of the National Institute of Infectious Diseases (authorization no. 1174). As this study was conducted under a retrospective observational design that specifically included de-identified national mortality data, informed consent was not required.

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Competing interests

S.K. reports investigator-initiated grant funding from Novartis and personal fees from Bristol-Myers Squibb and Pfizer. The rest of the authors have no conflict of interest to report.

Author contributions

All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. S.N. and A.E. contributed to concept and design. S.N., A.E., Y.T., T.K., D.Y., M.S., and M.H. contributed to acquisition, analysis, or interpretation of data. S.N., A.E., C.G., L.Y., S.K.R., and S.K. drafted the article. All authors contributed to critical revision of the manuscript for important intellectual content. S.N., A.E., Y.T., D.Y., and T.K. contributed to statistical analysis. S.N., M.S., and M.H. contributed to administrative, technical, or material support. S.N. contributed to supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.03.006.

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Original Research

COVID-19 pandemic in prisons in Spain: characteristics of cases and implemented control measures, March 2020–June 2022

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ABSTRACT

Objectives: Our aim was to describe the epidemiological characteristics of COVID-19 cases in prison inmates in Spain and the control measures implemented to response to this public health challenge.
Study design: Retrospective observational study.
Methods: All COVID-19–confirmed cases reported to the Spanish information system in prisons between March 2020 and June 2022 were analyzed. Prevention plans and protocols established by penitentiary and health authorities were reviewed. Likewise, information on vaccines administered to prison inmates was described.
Results: A total of 8500 COVID-19 cases were reported to penitentiary public health surveillance. The overall cumulative incidence (CI) was 2054.18 cases per 10,000 inmate population. By epidemic periods, the average weekly CI was 1.15 per 10,000 inmate population during the first period, 6.91 during the second, 25.18 during the third, 3.53 during the fourth, 23.27 during the fifth, 34.72 during the sixth and 25.68 during the seventh period. The median age of cases was 49.2 years, 69.1% was born in Spain, 64.1% was asymptomatic and 16 cases died. Ninety-four percent were vaccinated. Control measures such as lockdown, suspending visitation rights and confining inmates in their cells were adopted at the beginning of the pandemic. These measures changed in accordance with the COVID-19 situation in the general population with a view to restoring the inmates' rights.
Conclusion: The COVID-19 pandemic has had a moderate incidence in Spanish prisons. Hospitalization and CFR were lower than the general population. The control measures adopted against COVID-19 have contributed to preventing and controlling the number of cases in prisons.

Introduction

More than 10 million people are incarcerated worldwide.[1] Infectious diseases spread easily and quickly in closed institutions such as prisons, and outbreaks can lead to serious consequences. This results in prisoners being at higher risk for infectious diseases than outside communities. Highly infectious prison environments are characterized by overcrowding with unavoidable close contact and poor ventilation.[2] Furthermore, prisons have their own health services, and the prevalence of high-risk behaviors among prison populations is higher than in the general population. The outbreak of COVID-19 in prisons has emphasized the need to implement prison-specific healthcare control measures.[3]

The first response from most European countries to the COVID-19 pandemic was to replicate the community measures, such as placing prisons in lockdown. To reduce overcrowding and cut the prison population, some countries reported that prisoners were released under judicial review between January and April.[4] Furthermore, in April 2020, the European Committee for the Prevention of Torture (CPT) urged the implementation of alternatives to detention wherever possible.[5]

In Spain, around 42,000 people were incarcerated during 2020–2021 in 71 penitentiary centers. Our main objective was to describe the epidemiological characteristics of COVID-19 cases in

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Spanish prisons and the control measures implemented to respond to the public health challenge.

Methods

Study design and population

A retrospective study was performed between March 1, 2020, and June 30, 2022, in Spanish prisons, excluding those in Catalonia (all the study period) and, those in Basque Country (since October 1, 2021), whose competencies were decentralized. All COVID-19–confirmed cases among prisoners in Grades 1 and 2 were included. Most prisoners are placed by default in Grade 2, and they are allowed to share common areas and participate in educational or work activities. Prisoners considered dangerous are placed in Grade 1, which implies restrictions in terms of communication and other privileges. Grade 3 prisoners (semi-freedom) were not included in this analysis because their health care depends on regional healthcare systems, rather than on the prisons' healthcare services.

Source of information and variables

Epidemiological information was gathered by the penitentiary public health surveillance system. Sociodemographic and clinical information was collected by prison physicians as part of the standard surveillance system. The variables collected were the following: demographic variables (sex, age, birth region), clinical presentation (asymptomatic – those who were identified by screening or contact tracing showing no symptoms and who did not develop any throughout the course of infection; mild symptoms – defined as those who presented some symptoms; and severe symptoms – defined as those who needed hospitalization) and infection severity (hospitalization, intensive care unit (ICU) admission, exitus), date and penitentiary center of diagnosis.

We reviewed nationwide and regional prevention plans and protocols established by the authorities of the Ministries of Health and Home Affairs. Measures such as physical distancing (limited outside contacts, restricted access to non-essential staff, activities suspension, prisoners exchange), preventive measures (testing algorithms, access to and use of personal protection equipment, hygiene practices, voluntary isolation in cells, adaptation of schedules), ventilation, cleaning and disinfesting strategies were summarized.

Among the control measures analyzed, information about vaccination schedule (type of vaccine and dose) was also collected and reviewed.

Data analysis

An epidemic curve was plotted with the number of confirmed cases by date of diagnosis as well as drawing a comparison with the epidemic period in the general population in Spain (data published by Institute of Health Carlos III – https://cnecovid.isciii.es/).

A descriptive analysis, overall and by age groups, was carried out using frequency tables for categorical variables and median and interquartile range (IQR) for continuous ones. The χ^2 test for independence was used to compare categorical variables and the non-parametric Mann–Whitney test to compare continuous variables.

Crude case fatality rate (CFR) was calculated as the total number of COVID-19 deaths divided by the total number of diagnosed cases.

The percentages of hospitalized cases and CFR in the inmate population were compared with the general population in Spain (data published by Institute of Health Carlos III - https://cnecovid.isciii.es/covid19). (Note: Since March 28, 2022, the national surveillance and control strategy changed and only cases aged 60 years and older were reported.)

All the statistical analyses were performed using Stata software (version 16.0; Stata Corporation, College Station, TX, USA).

Results

Evolution of COVID-19 pandemic

Between March 12, 2020 (the first COVID-19 case in a Spanish prison), and June 30, 2022, 8500 COVID-19 prison cases were reported to the prison monitoring system. The evolution of the COVID-19 pandemic in the Spanish prison population is shown in Fig. 1.

Based on our data, seven different periods by COVID-19 number of cases per epidemiologic week can be described: *Period 1:* From the pandemic declaration to July 3, 2020, when the end of the state of emergency is announced; *Period 2:* From July 4 to December 31, 2020, when the cumulative incidence (CI) of confirmed cases shows the connection point between the second and third epidemic periods; *Period 3*: From January 1 to March 31, 2021, the CI of confirmed cases shows the connection point between the third and fourth epidemic periods; *Period 4:* From April 1 to June 30, 2021, the CI of confirmed cases shows the connection point between the fourth and fifth epidemic periods; *Period 5:* From July 1 to September 30, 2021, the CI of confirmed cases shows the connection point between the fifth and sixth epidemic periods; *Period 6:* From October 1 to March 28, 2022, when the COVID-19 national surveillance and control strategy changed and *Period 7*: From March 29 to data extraction date (June 30, 2022).

The first period accumulated 1.0% of the total cases; the second period accounted for 8.6%; the third for 13.8%; the fourth for 2.2%; the fifth for 14.7%; the sixth for 43.0% and the seventh period for 16.6%.

Cumulative incidence

The overall CI was 2054.18 cases per 10,000 inmate population in the study period. By epidemic periods, the average weekly CI was 1.15 per 10,000 inmate population during the first period, 6.91 during the second period, 25.18 during the third, 3.53 during the fourth, 23.27 during the fifth, 34.72 during the sixth and 25.68 during the seventh period.

The distribution of CI varied according to autonomous regions and epidemic periods. Globally, Aragón showed the highest CI (3163.00 cases per 10,000 inmate population) followed by La Rioja (2983.87), Valencia (2907.71), Castilla y Leon (2631.91) and Madrid (2591.56). During the first wave, Madrid showed the highest CI (118.25 per 10,000 inmate population), Castilla y León (630.04 per 10,000 inmate population) during the second wave, Aragon (1002.59 per 10,000 inmate population) during the third wave, Canary Islands (164.58 per 10,000 inmate population) during the fourth wave, La Rioja (1859.16 per 10,000 inmate population) during the fifth wave, Murcia (1092.38 per 10,000 inmate population) during the sixth wave and Extremadura (818.18 per 10,000 inmate population) during the seventh wave (Fig. 2).

As opposed to the COVID-19 14-day CI in the general population in Spain, we observed a delay of two weeks in the CI in penitentiaries over the study period, although for the sixth period, the CI in prisons began to increase before that of the general population. The maximum value of 14-day CI in the general population was higher (first, second and sixth periods) than or similar (third and fourth) to

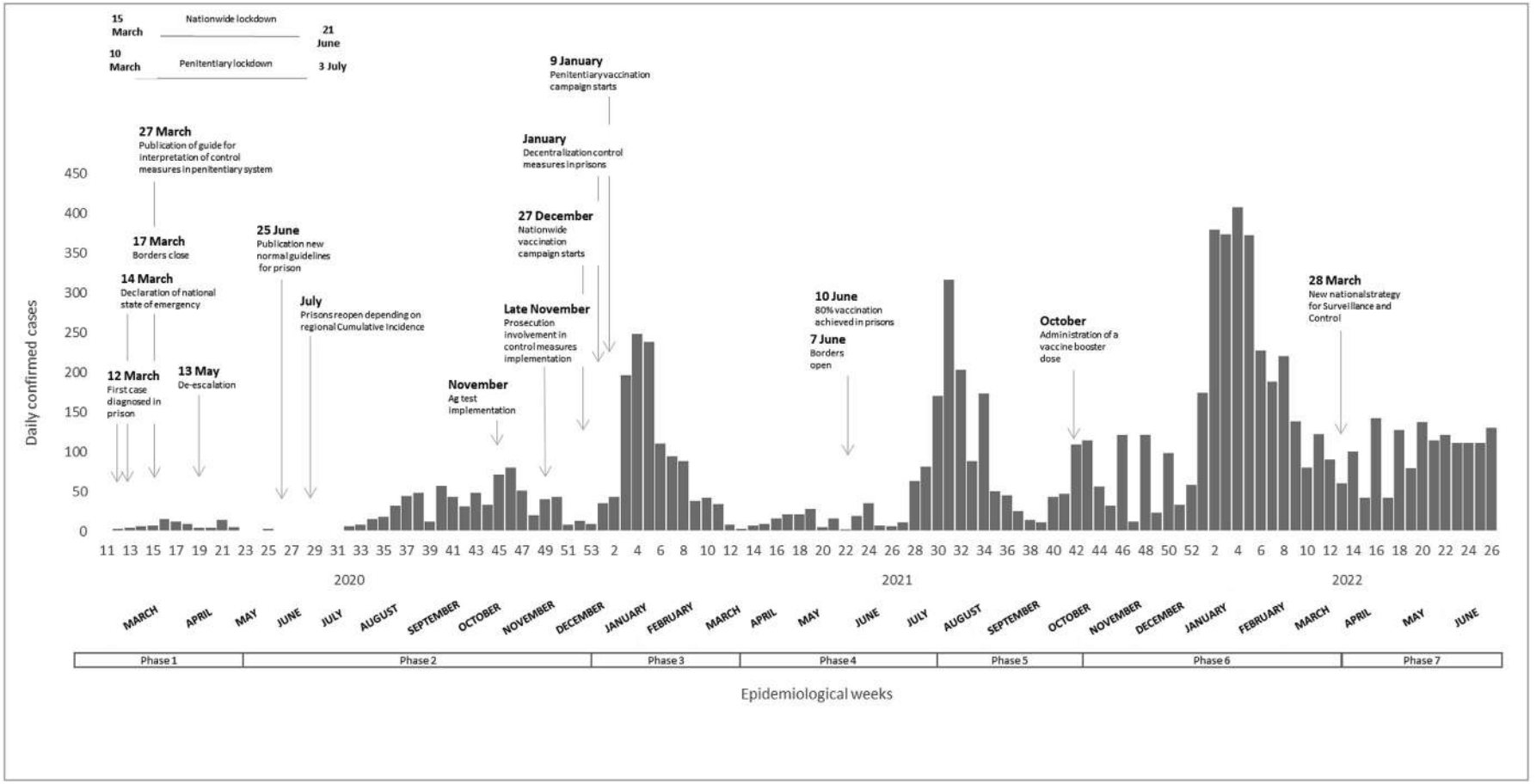

Fig. 1. Number of confirmed COVID-19 cases, national implemented control measures and announcements in prisons.

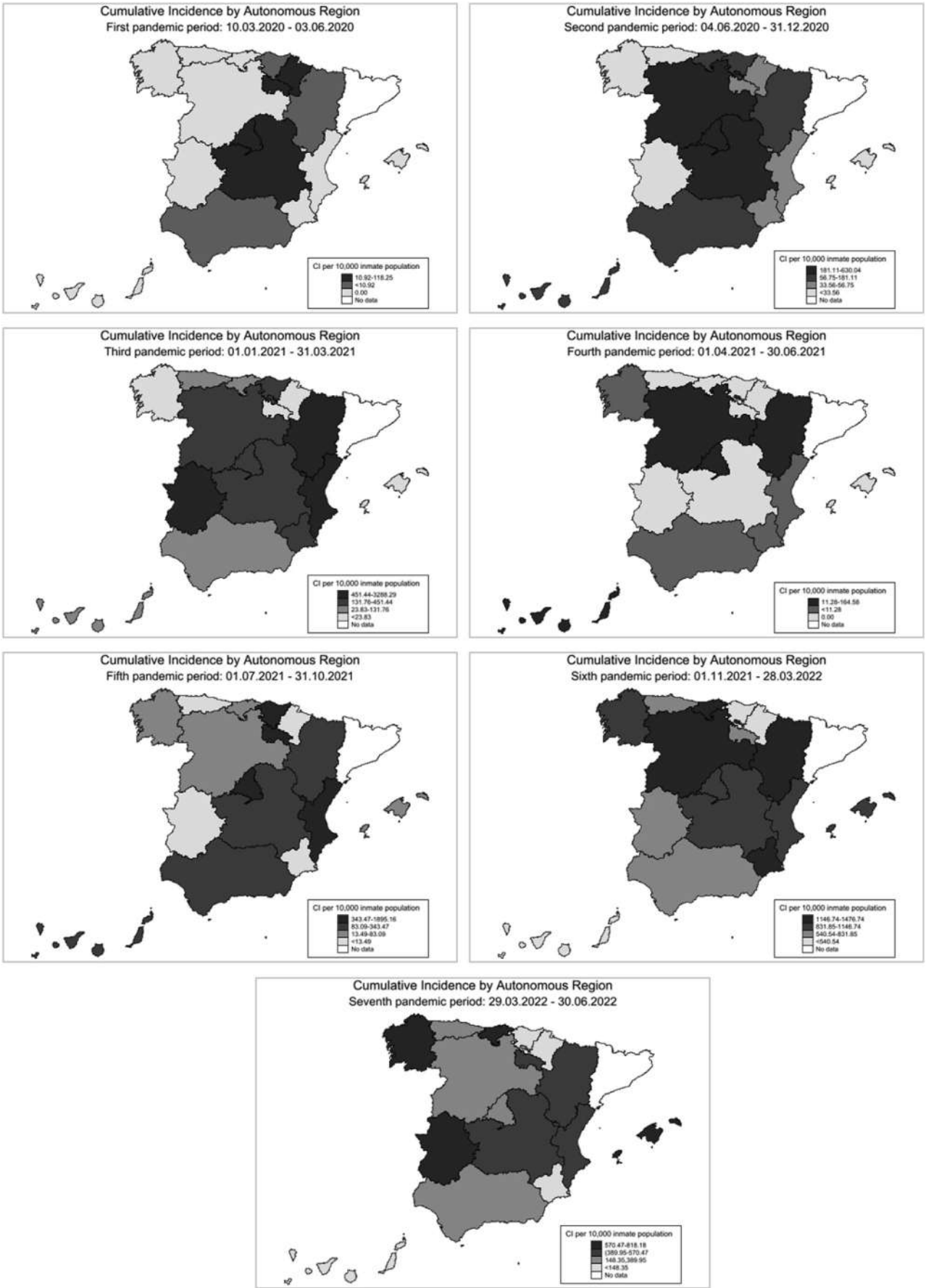

Fig. 2. Cumulative incidence of COVID-19 cases in penitentiary institutions by inmate population and autonomous regions and pandemic periods, Spain, March 2020–June 2022.

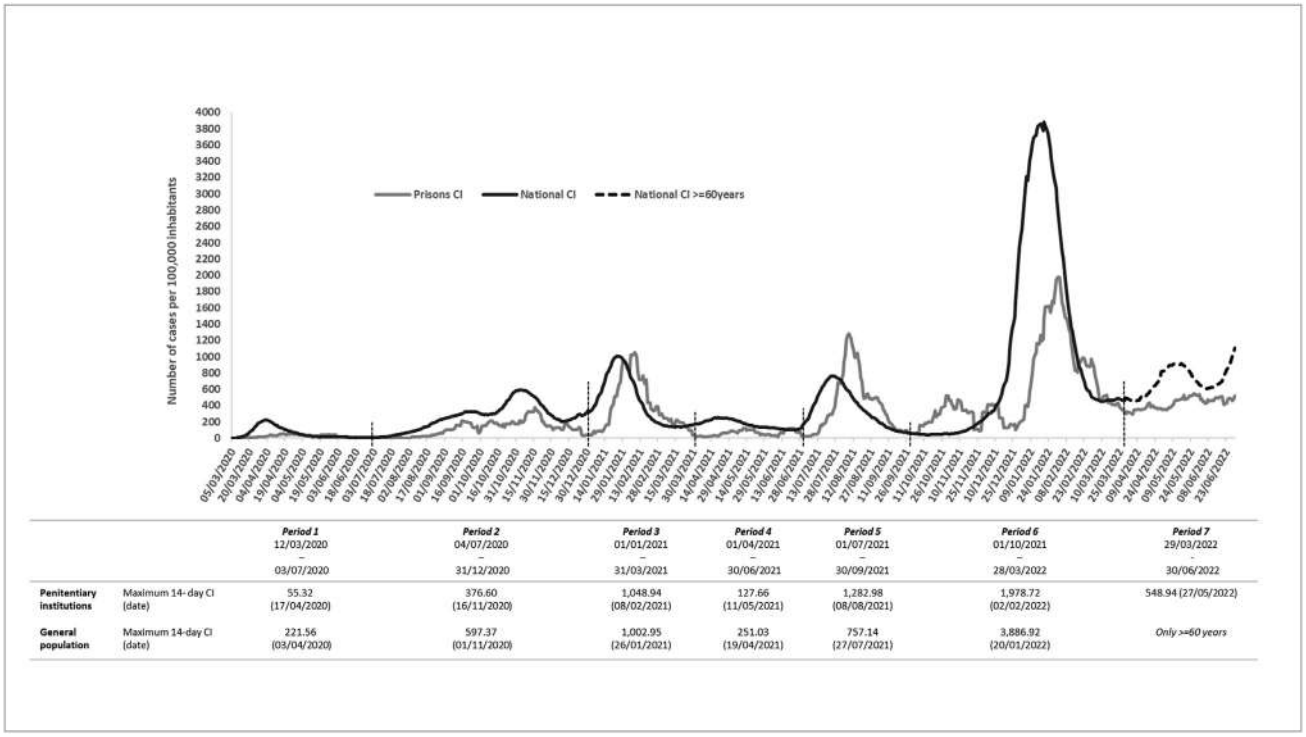

Fig. 3. COVID-19 14-day cumulative incidence in penitentiaries and in the general population.

Table 1
Demographic and clinical characteristics of COVID-19 cases in prisons, Spain, March 2020–June 2022.

	Total		Age group (years)								***P*-value**
			18–29		30–39		40–49		≥50		
	N	%	N	%	N	%	N	%	N	%	
Total	8500	100	1503	17.7	2549	30.0	2392	28.1	2506	24.2	
Sex											0.431
Men	8006	94.2	1414	94.1	2415	94.7	2240	93.6	1937	94.2	
Women	494	5.8	89	5.9	134	5.3	152	6.4	119	5.8	
Region of birth											**<0.001**
Spain	5877	69.1	821	54.6	1667	65.4	1756	73.4	1633	79.4	
Latin America	827	9.7	192	12.8	279	10.9	215	9.0	141	6.9	
Europe	765	9.0	139	9.2	253	9.9	207	8.6	166	8.1	
North Africa & Middle East	747	8.8	295	19.6	253	9.9	125	5.2	74	3.6	
Sub Saharan Africa	210	2.5	42	2.8	77	3.0	65	2.7	26	1.3	
Asia & Pacific	64	0.8	10	0.7	17	0.7	23	1.0	14	0.7	
Unknown	10	0.1	4	0.3	3	0.1	1	0.04	2	0.1	
Clinical presentation											**<0.001**
Asymptomatic	5451	64.1	1049	69.8	1653	64.8	1515	63.3	1234	60.0	
Mild symptoms	2912	34.3	452	30.1	885	34.7	851	35.6	724	35.2	
Severe symptoms	137	1.6	2	0.1	11	0.4	26	1.1	98	4.8	
Hospitalization – Yes	137	1.6	2	0.1	11	0.4	26	1.1	98	4.8	**<0.001**
Death	16	0.2	0	0	0	0	2	0.1	14	0.7	**<0.001**

Table 2
Hospitalization and CFR rate among the COVID-19 cases in penitentiary institutions and the general population[a] according to pandemic period.

	Penitentiary institutions		General population	
	Hospitalization rate	CFR	Hospitalization rate	CFR
Period 1 (12/03/2020–03/07/2020)	20.2%	2.38%	44.1%	11.8%
Period 2 (04/07/2020–31/12/2020)	4.1%	0.14%	7.4%	1.5%
Period 3 (01/01/2021–31/033/2021)	2.6%	0.59%	7.7%	1.8%
Period 4 (01/04/2021–31/03/2021)	3.7%	0%	7.2%	0.8%
Period 5 (01/07/2021–30/09/2021)	2.5%	0.08%	3.8%	0.5%
Period 6[a] (29/03/2022–30/06/2022)	0.5%	0.14%	1.5%[a]	0.2%[a]

[a] Data available for the general population until 28/03/2022.

that of penitentiaries in all epidemic periods, with the exception of the fifth one, where the peak of 14-day CI in penitentiaries was 1282.98 versus 742.70 in the general population. In the sixth period, the 14-day CI in the general population reached a value of 3886.92 in January 21, 2022, while the maximum CI value in the prisoners was 1978.72 in February 2, 2022 (Fig. 3).

Table 1 shows the main characteristics of the 8500 COVID-19 prison cases. The median age of COVID-19 cases was 49.2 years (IQR: 32.2–49.2 years), similar in males and females, and 24.2% of cases were older than 50 years. Women accounted for 5.8% of the total number of cases.

69.2% of cases were born in Spain, followed by 9.7% from Latin-American countries, 9.0% from Europe and 8.8% from North Africa and Middle East. The median age of Spanish cases was 41.9 years (IQR: 33.9–50.5 years), whereas it was 36.4 years for foreign cases (IQR: 29.2–44.9 years) ($P < 0.001$).

Most cases, 64.1% (5451 cases) were asymptomatic, identified by screening or contact tracing, 34.3% (2912 cases) presented mild symptoms, and 1.6% showed severe symptoms that required hospitalization ($P < 0.001$). By sex, 64.6% of men were asymptomatic versus 56.9% of women ($P = 0.001$), 33.8% of men presented mild symptoms compared to 41.7% of women ($P < 0.001$) and 1.6% of men and 1.4% of women presented severe symptoms ($P < 0.723$).

The presence of severe symptoms was more likely among patients older than 50 years (4.8%) than younger (0.1%, 18–29 years; 0.4%, 30–39 years and 1.1%, 40–49 years; $P < 0.001$). Among all cases, 1.6% (137 cases) were hospitalized. The percentage of patients hospitalized increased with age; 71.5% of the hospitalizations occurred among cases aged 50 years and older. The highest percentage of hospitalizations occurred during the first period (20.2%) and the lowest in the sixth (0.5%), as in the general population (Table 2).

Sixteen cases died (CFR: 0.19%), their median age being 61.5 years (IQR: 51.6–76.3 years). Seven deaths (43.7%) (CFR: 0.59%) were during the third period, five deaths (31.2%) (CFR: 0.08%) happened during the sixth period, two deaths (12.5%) (CFR: 2.38%) during the first period, and one death (6.2%) (CFR: 0.14%) during second and (CFR: 0.08%) fifth period, respectively. All deaths were from COVID-19, except four people who died of other causes.

Control measures

The main national events and public health measures are shown in Fig. 1. The initial response was to emulate the community's response to COVID-19: placing prisons in lockdown, suspending visitation rights and confining inmates to very little movement outside their cells. As visitation was suspended, free telephone and videoconferencing with families and attorneys were implemented.

On January 31, 2020, the General Secretariat of Penitentiaries sent an action algorithm for prisons, included as part of the first General Protocol of Action. This algorithm provided contact tracing guidance. First control measures for prisons were issued on March 5, 2020, after the first cases were reported in Spain (February 26). Prisons in four provinces were the first penitentiaries in lockdown due to community transmission being detected. On March 10, 2020, the rest of Spanish prisons were closed. On March 12, the state of emergency was declared.[6] The Ministries of Health and Home Affairs (the General Secretariat of Penitentiaries) published a technical report on March 27, 2020. In this document, the following main measures were established: collection of samples and their transport to the laboratory, isolation and transfer of probable and confirmed cases, contact tracing, judicial proceeding of cases under investigation.

Furthermore, new prison admission was placed in quarantine to prevent transmission from asymptomatic cases. At the end of the quarantine period, a screening test was performed.

First de-escalation measures were announced by the General Secretariat of Penitentiaries to prisons on May 13, including health measures. On June 10, an updated and consolidated version was published by the Ministries of Health and Home Affairs.

For the second COVID-19 period, a dynamic control strategy was implemented in phases according to regional CI: a) Phase I, when CI was lower than 250, open visits (vis a vis) and family visits were cancelled; b) Phase II, (CI > 250), in-person visiting at 50% capacity and suspension of exit permits and c) Phase III (CI > 500), full lockdown of the center.

On June 25, the General Secretariat of Penitentiaries published a 'new normal' measure report related to: resumption of prison activities, inmate transfers, exits, appointments with relatives, resumption of face-to-face visits for inmates who were on probation by a judicial authority, as long as their health and the pandemic situation allowed for it.[7]

To face the third COVID-19 period in prison, the Spanish Prosecutor's Office began to review the restrictions in place to align them with the measures proposed by public health institutions as of late November 2020.[8]

Quarantine of close contacts (residents in the same module as the case) was established in the form of cell isolation for 10 days, if they were not vaccinated or fully vaccinated, and in the form of restricted movement within their module and in 'bubble' groups in the courtyard, if they were vaccinated. For new admissions to prison and furloughs, a cell quarantine was maintained for 7 days for people who were fully vaccinated and for 10 days if they had not been vaccinated. In the context of community transmission, limited contact between prison and the outside world was recommended.

The COVID-19 vaccination campaign started on January 9, 2021, in penitentiaries (vaccination in the general population started on December 27, 2020). The inmate population was considered a vulnerable population, as they are in closed environments with a higher risk of exposure to the disease and infection. At that time, there were four vaccines approved for use in Spain: BioNTech-Pfizer (Cominarty, BNT162b2), Moderna (Spikevax, mRNA-1273), Janssen (Ad26. COV2-s (recombinant)) and Oxford-AstraZeneca (Vaxzevria, ChAdOx1/nCoV-19). In the first months of the prison vaccination campaign, health authorities prioritized the Janssen vaccine over other types/brands because it required only one dose. In the following months, the other brands were used interchangeably.

Since October 2021, a booster dose was administrated in penitentiaries. The vaccination status of prisoners was assessed on admission to prison and they were vaccinated if necessary, according to national recommendations for the general population.

By June 30, 2022, 94.0% inmates were fully vaccinated, 3.1% were still pending to completion of the vaccine series and 2.9% inmates refused vaccination. Regarding the vaccines type/brand, 31.7% of inmates received the Janssen Covid-19 vaccine, 33.7% Pfizer-BioNTech's, 29.5% Moderna's, 2.9% others. Among fully vaccinated inmates, the Janssen Covid-19 vaccine was the more frequently used (65.8%) as a first dose, followed by Pfizer-BioNTech's (18.7%) and Moderna's (10.0%). As a booster dose, 53.5% received the Moderna Covid-19 vaccine and 44.9% Pfizer-BioNtech's.

The median age of inmates vaccinated was 41 years (IQR: 33–49 years), whereas the median age of those refusing vaccination was 36 years (IQR: 28–45 years) ($P < 0.001$). Three percent of men refused vaccination compared to 1.7% of women ($P < 0.001$).

Discussion

To our knowledge, this is the first study that describes the epidemiology of the COVID-19 pandemic in Spanish prisons and the implementation of public health measures. Our results show a moderate incidence of coronavirus disease in prisons.

Hospitalization and CFR were lower than the general population, although they are not fully comparable populations.

Most COVID-19 cases were asymptomatic, only 1.6% of the total were hospitalized and the CFR was 0.19% during the study period. Data published from a COVID-19 outbreak observed in a Catalonian prison also reported that 95% of cases were asymptomatic.[9] The presence of severe symptoms, hospitalization and death were more frequent among older people, as was the case with the general population.[10]

Since the COVID-19 pandemic was declared, 8500 cases have been reported to the public health Central Prison Monitoring System over a period of 28 months, from March 1, 2020, to June 30, 2022. The early nationwide lockdown implemented in penitentiaries on March 10 led to a first flat epidemic curve. The number of cases began to increase as of September 2020, when the second pandemic period started. During this period, there were movement restrictions both in the general population and penitentiaries, which were correlated with a decrease in CI at the end of 2020. The third pandemic period began in prisons at the end of January 2021, approximately two weeks later than in the general population. During that period, the CI in prisons was similar to the CI observed in the general population, unlike what occurred in the previous two. In February 2021, control measures in prison were decentralized. From that moment on, the recommendations and measures adopted were based on the CI of the province where the prison was located, together with the prisons' inspection judges and the bodies responsible for public health in each autonomous region. The fourth pandemic period was milder than the previous ones, probably due to the large number of cases that occurred in the immediately preceding period and the vaccination program that started in prisons at the beginning of January 2021. As in previous periods, in the fifth pandemic period, the increase in prison cases was observed two weeks after the increase in the general population. During this period, the maximum 14-day CI peak observed in prisons exceeded that reached in the general population (1282.98 vs 742.70 per 100,000 inhabitants, respectively). The beginning of the sixth pandemic period came early in the prison compared to the general population, but 14-day CI in the general population was higher than inmate population (3886.92 vs 1978.72 per 100,000 inhabitants, respectively).

The higher number of cases observed in the fifth and sixth pandemic periods in the inmate population could be due to some extent to the vaccination campaign conducted in prisons. Most inmates were vaccinated with Janssen, following the recommendation approved by the Ministry of Health's Interterritorial Board. This vaccine only required one dose, which made it easier to complete vaccination in this fast-changing population (entry-exit in prison) that has a high degree of mobility. However, several subsequent studies have shown that loss of immunity occurs faster in people vaccinated with Janssen, as opposed to those vaccinated with Moderna or Pfizer.[11–13] According to data published by the Spanish Ministry of Health, Janssen's vaccine showed a much lower efficacy against infection and symptomatic infection, while the protection against hospitalization and death was somewhat lower for Janssen's vaccine than others (Pfizer, Moderna and AstraZeneca).[14] Furthermore, the large increase observed in the sixth period was due to the emergence of the new Omicron variant of SARS-CoV2, which had higher transmissibility but lower symptomatology and risk of hospitalization.[15,16]

The moderate incidence of COVID-19 cases shown in our study contrasts with the deficiencies of the prison systems worldwide, e.g., overcrowding in prison settings, lack of resources and health and social support in the prison health-care services,[17–19] which have posed additional challenges to mitigate the effects of this disease in the prison population. In Spanish prisons, as in most European countries,[4,20,21] the control measures implemented against COVID-19 emulated the community's response: prison lockdown, suspending visitation rights and limiting movement outside the cells. In our context, the collaboration between the health care and public health services in the regions where the prisons are located has made it possible to provide a level of care to the prison population comparable to that of the general population in the face of the COVID-19 pandemic. Furthermore, the measures established during the pandemic were well accepted by inmates, despite their rights being restricted in terms of communication, permits and others. In this regard, the intervention of health and management teams and the information on health education provided to inmate by all workers played an essential role. On-demand consultations, group workshops and other types of meeting were organized to inform inmates about the benefits of hygiene measures (handwashing, use of mask, social distancing, …) and restrictive measures (restriction of communication with relatives, open visits, exit permits, quarantine and isolation) in order to control the epidemic.

In conclusion, although prisons are closed settings that could amplify and spread infectious diseases both inside and outside their walls, measures established in Spanish prisons have made it possible to contain the spread of the COVID-19 epidemic.

Author statements

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We would like to thank Laura Reguero and Andrea Rodriguez for their collaboration in the early phases of this work.

Ethics approval

The study was performed in accordance with the requirements of the Spanish legislation on data protection. Ethical approval was not sought since data were collected by routine surveillance systems. No personal identifiers were collected in this study; only aggregated anonymized data were used. Informed consent for epidemiological surveillance is deemed unnecessary according to national regulations (Act 33/2011, of October 4, General Public Health, BOE-A-2011-15623. Section 41 and Constitutional Act 3/2018, of December 5, on the protection of Personal Data and Guarantee of Digital Rights. Additional provision 17).

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Competing interests

The authors declare no competing interests.

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Original Research

COVID-19 vaccines effectiveness against symptomatic disease and severe outcomes, 2021–2022: a test-negative case–control study

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ABSTRACT

Objectives: This study evaluated the effectiveness of COVID-19 vaccines in preventing symptomatic and severe disease.
Study design: This was an observational test-negative case–control study.
Methods: Study participants were adults with at least one symptom included in the World Health Organization COVID-19 definition who sought health care in a public emergency department between 1 November 2021 and 2 March 2022 (corresponding with the fifth pandemic wave in Portugal dominated by the Omicron variant). This study used multivariable logistic regression models to estimate and compare the odds ratio of vaccination between test-positive cases and test-negative controls to calculate the absolute and relative vaccine effectiveness.
Results: The study included 1059 individuals (522 cases and 537 controls) with a median age of 56 years and 58% were women. Compared with the effectiveness of the primary vaccination scheme that had been completed ≥180 days earlier, the relative effectiveness against symptomatic infection of a booster administered between 14 and 132 days earlier was 71% (95% confidence interval [CI]: 57%, 81%; $P < 0.001$). The effectiveness of the primary series against symptomatic infection peaked at 85% (95% CI: 56%, 95%) between 14 and 90 days after the last inoculation and decreased to 34% (95% CI: −43%, 50%) after ≥180 days.
Conclusions: Despite the known immunological evasion characteristics of the Omicron variant, results from this study show that vaccine effectiveness increases after booster administration. COVID-19 vaccine effectiveness decreases to less than 50% between 3 and 6 months after completion of the primary cycle; therefore, this would be an appropriate time to administer a booster to restore immunity.

Introduction

Real-world studies have revealed that COVID-19 vaccines offer excellent short-term protection against human SARS-CoV-2 infection and its severe consequences, including hospitalisation and death.[1,2] In addition, vaccination and non-pharmacological measures have resulted in fewer people requiring hospitalisation, despite the latest high-incidence waves.[3] However, recently, concerns have been raised regarding the reduced effectiveness of the vaccines against new variants of concern.[4] Moreover, there is evidence that protection against symptomatic disease wanes over time.[5,6]

Results regarding booster protection against severe COVID-19 due to the Omicron variant are inconsistent. Some studies have

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suggested robust protection similar to the effectiveness against prior variants,[7,8] while other studies have reported reduced protection against the Omicron variant and further reduction over time after the booster dose.[9–11]

The vaccination campaign in Portugal started on 27 December 2020 with the Comirnaty vaccine developed by Pfizer-BioNTech, Mainz, Germany/New York, USA, followed by Spikevax from Moderna, Cambridge, USA, in the first weeks of January 2021, Vaxzevria from AstraZeneca, Cambridge, UK, on 7 February 2021 and Jcovden from Janssen, Beerse, Belgium, on 14 April 2021. Thus, these were the four vaccines approved for use in the EU/EEA during the data collection period.

This test-negative case–control study aims to evaluate the effectiveness of COVID-19 vaccines in preventing symptomatic and severe disease in Alto Minho, Portugal, during the fifth pandemic wave.[12]

Methods

Participants

Study participants were individuals aged ≥18 years who were residents of Alto Minho, had at least one symptom included in the World Health Organization (WHO) COVID-19 definition,[13] sought health care in a public emergency department in the region between 1 November 2021 and 2 March 2022, and were tested for SARS-CoV-2 using respiratory samples. Alto Minho is a Nomenclature of Territorial Units (NUTS) III region with 231,293 inhabitants according to the 2021 census[12] and is located in the Northern region of Portugal. This region was one of the most affected regions in Portugal and where the first cases of COVID-19 arose. A local approach was used for this study to enable access to more detailed and complete data.

Exclusion criteria included individuals who were not eligible for vaccination against COVID-19, those with unavailable laboratory test results, those without information on vaccination status and those with a symptom onset of more than 10 days before the test date. In addition, all individuals who had previously tested positive for COVID-19 were excluded from the analysis to minimise bias caused by natural immunity.

Study design

In this test-negative case–control study, the effectiveness of COVID-19 vaccines against symptomatic and severe SARS-CoV-2 infection was estimated, as described in detail elsewhere.[14] In brief, study participants were divided into two groups: SARS-CoV-2 test-positive cases and test-negative controls. Vaccination status between participants with symptomatic COVID-19 and those with reported symptoms but with a negative test result were compared. In addition, vaccination status between the patients with moderate-to-severe COVID-19 and those with mild COVID-19 were also compared.

Outcomes

The following were considered as the primary outcomes:

(1) Symptomatic SARS-CoV-2 infection confirmed with rRT-PCR tests, antigen tests or Xpress RT-PCR tests performed on respiratory samples from the nasopharynx or oropharynx; and
(2) Moderate-to-severe disease associated with SARS-CoV-2 infection defined by hospitalisation over 24 h, intermediate or intensive care unit (I/ICU) admission or death with a recent positive test result.

Hypothesis

The hypothesis questions tested were as follows:

(1) Is the effectiveness of COVID-19 vaccines against symptomatic disease due to the Omicron variant higher than 50%?; and
(2) Does the effectiveness of COVID-19 vaccines wane over time?

Sample size

According to the WHO guidelines,[15] the minimum sample size (N_1) in a test-negative case–control study should be calculated using the following formula:

$$N_1 = (z/d)^2[1/A(1-A)+1/CP_2(1-P_2)]$$

where C is the control-to-case ratio; P_2 is the prevalence of vaccine exposure in the control group (i.e. vaccine coverage in the population being studied); $A = P_2(1-VE)/[1-P_2(VE)]$, where VE denotes the anticipated effectiveness of the vaccine; z denotes the (1-α) percentage point of the standardised normal distribution (normally, this is based on an α-value of 0.05 and thus a z-value of 1.96); and d is determined by solving the equation $W(\widehat{\beta},\widehat{d}) = \exp(\widehat{\beta})(\exp(\widehat{d}) - (\exp(-\widehat{d}))$ where $\widehat{d} = z\widehat{\sigma}$ and where and $W(\widehat{\beta},\widehat{d})$ denotes the confidence interval width. The number of controls needed is then calculated as $C*N_1$.[15]

Therefore, assuming a vaccine coverage of 90%, as the vaccine coverage for primary series vaccination was 88% in mainland Portugal in the middle of the study period, this study needed a sample size of at least 580 cases and 580 controls to detect an anticipated vaccine effectiveness (VE) of 70%, with a precision estimate of ±10%, and a type 1 error probability of 0.05.

Data sources

Databases extracted from Clinidata were used to identify all SARS-CoV-2 tests performed in the public emergency departments in Alto Minho during the study period. Participants' vaccination status were obtained from the national vaccination registry, including the type of vaccine, number of doses and date of inoculation. These and other clinical and sociodemographic variables were complemented with data from patients' electronic medical records and from the national platform of contact tracing (Trace COVID-19).

Covariates

Health and demographic data were collected, including age, sex, municipality of residence and comorbidities that confer an extremely vulnerable status,[16] including the following: (1) solid organ transplant receptors under long-term immunosuppression; (2) patients with active cancer under chemotherapy/radiotherapy or radical radiotherapy for lung cancer; (3) individuals under immunotherapy or other continuous antibody treatments for cancer; (4) patients under other directed cancer treatments that affect the immunological system, such as kinase protein or poly (ADP-ribose) polymerase inhibitors; (5) patients with haematologic cancer with leukaemia, lymphoma or myeloma in any treatment stage; (6) patients who have undergone bone marrow transplant or

stem cell treatment in the last 6 months or who are currently under immunosuppressive treatment; (7) patients with severe respiratory disease, including severe asthma and severe chronic obstructive pulmonary disease; (8) individuals with cystic fibrosis or idiopathic pulmonary fibrosis, regardless of disease stage; (9) patients with a rare disease and innate errors in metabolism that substantially increase the risk of infection (e.g. severe combined immunodeficiency and homozygotic sickle cell disease); (10) patients prescribed immunosuppressive therapy in the last 6 months; and (11) pregnant women with significant congenital heart disease.

The study sample included individuals who were (a) either unvaccinated or vaccinated with one dose less than 14 days before the symptom onset; (b) vaccinated with one dose of mRNA vaccine or Vaxzevria at least 14 days before the symptom onset or vaccinated with two doses of mRNA vaccine or Vaxzevria less than 14 days before the symptom onset (partially vaccinated); (c) vaccinated with two doses or one dose of Jcovden at least 14 days before the symptom onset (fully vaccinated) or vaccinated with a booster less than 14 days before the symptom onset; or (d) vaccinated with three doses or with Jcovden and a booster at least 14 days before the symptom onset.

Statistical analyses

In the univariate analysis, the Mann–Whitney test was used for continuous variables (age and time) and the chi-squared test or Fisher's exact test (every time there was a cell with under 10 observations) for categorical variables.

Multivariable logistic regression models were used to estimate and compare the odds ratios (ORs) of vaccination between the test-positive cases and test-negative controls; unvaccinated individuals were considered as a reference group for calculation of the absolute effectiveness and primary scheme completion between 14 and 179 days or ≥180 days earlier as a reference group for calculation of the relative effectiveness of a booster dose. The crude and adjusted ORs were estimated, accounting for all covariates, which were selected based on their known association with SARS-CoV-2 infection or severity and receipt of a COVID-19 vaccine,[16,17] and were assessed as potential confounders. VE was calculated using the following formula:

$$VE = (1-aOR) \times 100\%$$

Covariates were added to the model when they changed the OR by at least 5% or were statistically significant ($P < 0.05$). Thereafter, the main analysis was stratified by the type of vaccine (mRNA vs viral vector) and time from the last dose (14–179 or ≥180 days). This cut-off was selected according to the methodology used by Thompson et al.[11] and because 180 days is the recommended interval for inoculation with a booster after the primary series.[18]

The analysis was repeated for severe outcomes (hospitalisation over 24 h, I/ICU admission and/or death). Data analysis and graphical representation were conducted using the R software, Vienna, Austria (version 4.1.3 for Rstudio Build 461) with additional packages: 'readxl', 'xlsx', 'lubridate', 'dplyr', 'summarytools', 'car', 'splines', 'ggplot2', and 'ggpubr'.

The goodness of fit of the logistic regression models was assessed using the Hosmer–Lemeshow test instead of indicating a pseudo-R^2 as it does not have a clear interpretation.[19]

Possible interactions were evaluated between age and group of municipalities of residence in both models, and between age and extreme vulnerability status in the severe disease model. The likelihood ratio test was used to search for interactions.

This study included 1059 individuals (522 cases and 537 controls) with a median age of 56 years and 58% were women. Participant characteristics and eligibility criteria are shown in Table 1 and Fig. 1, respectively.

Results

Descriptive statistics and characteristics

The majority of study population were vaccinated with at least two doses of COVID-19 vaccine (89%), comparable to the national vaccine coverage during the study period.[15] In addition, most participants completed their primary scheme with mRNA vaccines, mainly Comirnaty (75%); among those administered with a booster, the last dose was an mRNA vaccine. Among the test-positive cases, 81 (16%) were hospitalised for more than 24 h; 12 (2%) were admitted to the I/ICU; and 18 (3%) died.

Effectiveness against symptomatic infection – crude model

The crude effectiveness of the primary vaccination scheme was 38% (95% confidence interval [CI]: 3%, 61%) between 14 and 179 days after the last vaccination, and 29% (95% CI: −17%, 57%) ≥180 days after the last vaccination (see Fig. 2A). The crude effectiveness of the primary scheme followed by a booster was 78% (95% CI: 65%, 86%).

Effectiveness against symptomatic infection – adjusted model

The absolute effectiveness of the primary vaccination series against symptomatic infection was lower ≥180 days after the last dose (34%; 95% CI: −12%, 61%) than between 14 and 179 days after the last dose (50%; 95% CI: 18%, 69%). Meanwhile, the absolute effectiveness of booster vaccination was higher (81%; 95% CI: 68%, 89%) than that of complete vaccination, as represented in Fig. 2A. The model was adjusted for age (as a continuous variable) using a cubic spline, for the group of municipalities of residence and the calendar month of testing, as shown in Table 2. Sex was not a confounder in any model in this study and extreme vulnerability status did not prove to be a confounder in this specific model.

Compared with the effectiveness of the primary vaccination scheme at 14–179 days after the last dose, the relative effectiveness of the booster vaccination was 63% (95% CI: 42%, 76%; $P < 0.001$). The relative effectiveness of booster vaccination was higher (71%; 95% CI: 57%, 81%; $P < 0.001$) than the effectiveness of the primary vaccination scheme ≥180 days after the last dose.

Type of vaccine

The effectiveness of the primary series against symptomatic infection was 56% (95% CI: 24%, 74%) and 41% (95% CI: −13%, 70%) between 14 and 179 days after the last dose of mRNA and viral vector vaccines, respectively. At ≥180 days after the last dose, the effectiveness of mRNA and viral vector vaccines was 40% (95% CI: −6%, 66%) and 33% (95% CI: −60%, 74%), respectively. The vaccine effectiveness stratified by the type of vaccine is presented in Fig. 2B.

The effectiveness of three doses of mRNA and viral vector vaccines and a booster dose with mRNA vaccine was 84% (95% CI: 70%, 92%) and 74% (95% CI: 30%, 90%), respectively. This model was adjusted for age (as a continuous variable) using a cubic spline, for the group of municipalities of residence and the calendar month of testing.

Table 1
Clinical and demographic characteristics of the study participants during the fifth pandemic wave dominated by the Omicron variant (1 November 2021 to 2 March 2022).

Characteristics	Total ($N = 1059$)	Cases ($n = 522$)	Controls ($n = 537$)	*P*-value
Age group in years [(n (%)]				
<65	622 (58.7%)	363 (69.5%)	259 (48.2%)	<0.001[a]
≥65	437 (41.3%)	159 (30.5%)	278 (51.8%)	
Age in years [median year (IQR)]	56 (37–78)	47 (33–71)	66 (44–81)	<0.001[a]
Sex [(n (%)]				
Male	441 (41.6%)	216 (41.4%)	225 (41.9%)	0.913
Female	618 (58.4%)	306 (58.6%)	312 (58.1%)	
Vaccination status [(n (%)]				
Unvaccinated	107 (10.1%)	72 (13.8%)	32 (6.5%)	<0.001[a]
Partially vaccinated	22 (2.1%)	14 (2.7%)	8 (1.5%)	
Fully vaccinated	563 (53.2%)	322 (61.7%)	241 (44.9%)	
Booster	367 (34.7%)	114 (45.4%)	253 (47.1%)	
Extremely vulnerable status [(n (%)]				
Yes	125 (11.8%)	54 (10.3%)	71 (13.2%)	0.175
No	934 (88.3%)	468 (89.7%)	466 (86.8%)	
Hospitalisation for >24 h [(n (%)]				
Yes	199 (18.8%)	81 (15.5%)	118 (22.0%)	0.009[a]
No	860 (81.2%)	441 (84.5%)	419 (78.0%)	
Test type [(n (%)]				
rRT-PCR	1042 (98.4%)	511 (97.9%)	531 (98.9%)	0.321
Xpress RT-PCR	4 (0.4%)	2 (0.4%)	2 (0.4%)	
Antigenic	13 (1.2%)	9 (1.7%)	4 (0.7%)	
Type of vaccine, if vaccinated [(n (%)]				
1st dose				
Comirnaty	633 (66.5%)	296 (65.8%)	337 (67.1%)	0.027[a]
Spikevax	129 (13.6%)	52 (11.6%)	77 (15.3%)	
Vaxzevria	106 (11.1%)	45 (10.0%)	61 (12.2%)	
Janssen	66 (6.9%)	41 (9.1%)	25 (5.0%)	
Missing	18 (1.9%)	16 (3.6%)	2 (0.4%)	
2nd dose				
Comirnaty	628 (72.0%)	290 (72.5%)	338 (71.6%)	
Spikevax	122 (14.0%)	49 (12.2%)	73 (15.5%)	
Vaxzevria	105 (12.0%)	45 (11.2%)	60 (12.7%)	0.428
Missing	17 (1.9%)	16 (4.0%)	1 (0.2%)	
3rd dose				
Comirnaty	344 (93.5%)	102 (88.7%)	242 (95.7%)	
Spikevax	21 (5.7%)	10 (8.7%)	11 (4.3%)	
Missing	3 (0.8%)	3 (2.6%)	0 (0%)	0.136
I/ICU admission [(n (%)]				
Yes	17 (1.6%)	12 (2.3%)	5 (0.9%)	0.127
No	1042 (98.4%)	510 (97.7%)	532 (99.1%)	
Residence [(n (%)]				
Vale do Minho	128 (12.1%)	39 (7.5%)	89 (16.6%)	<0.001[a]
Vale do Lima	931 (87.9%)	483 (92.5%)	448 (83.4%)	
Time between the date of the last dose and date of symptoms, if vaccinated [median no. of days (IQR)]				
Primary series	160 (134–195.5)	163.5 (138.3–196.8)	154 (123–193)	0.013[a]
Booster	57 (36.5–83)	62.5 (37.3–80.8)	56 (36–84)	0.576

The Mann–Whitney test was used for the continuous variables (age and time) and the chi-squared or Fisher's exact test for the categorical variables. IQR, interquartile range; I/ICU, intermediate or intensive care unit.
[a] Statistical significance for $\alpha = 0.05$.

Waning of effectiveness

Vaccine effectiveness decreased over time (Fig. 2C). The point estimate of the effectiveness of the primary series against symptomatic infection peaked at 85% (95% CI: 56%, 95%) between 14 and 90 days after the last inoculation and decreased to 66% (95% CI: 22%, 85%) between 91 and 120 days, 43% (95% CI: 2%, 67%) between 121 and 179 days, and 34% (95% CI: −30%, 56%) after ≥180 days (Fig. 2C).

The point estimate of the effectiveness of a booster was 83% (95% CI: 67%, 92%) between 14 and 42 days, remained stable (83%; 95% CI: 65%, 92%) between 43 and 70 days, and decreased after >70 days (69%; 95% CI: 23%, 88%). This model was adjusted for age (as a continuous variable) using a cubic spline, the group of municipalities of residence and the calendar month of testing.

Vaccine effectiveness for severe outcomes

The effectiveness of the primary vaccination series against severe outcomes was 83% (95% CI: 61%, 93%), while that with a booster was 90% (95% CI: 71%, 97%). Stratification showed an effectiveness of 87% (95% CI: 60%, 96%) between 14 and 179 days after the last dose and 81% (95% CI: 51%, 92%) ≥180 days after the last dose. This model was adjusted for age (as a continuous variable), extreme vulnerability status, the group of municipalities of residence and the calendar month of testing (Table 3).

The Hosmer–Lemeshow test yielded *P*-values of 0.195 and 0.633 for the symptomatic and severe disease models, respectively. Therefore, this study could not exclude the hypothesis of the models having a good fit.

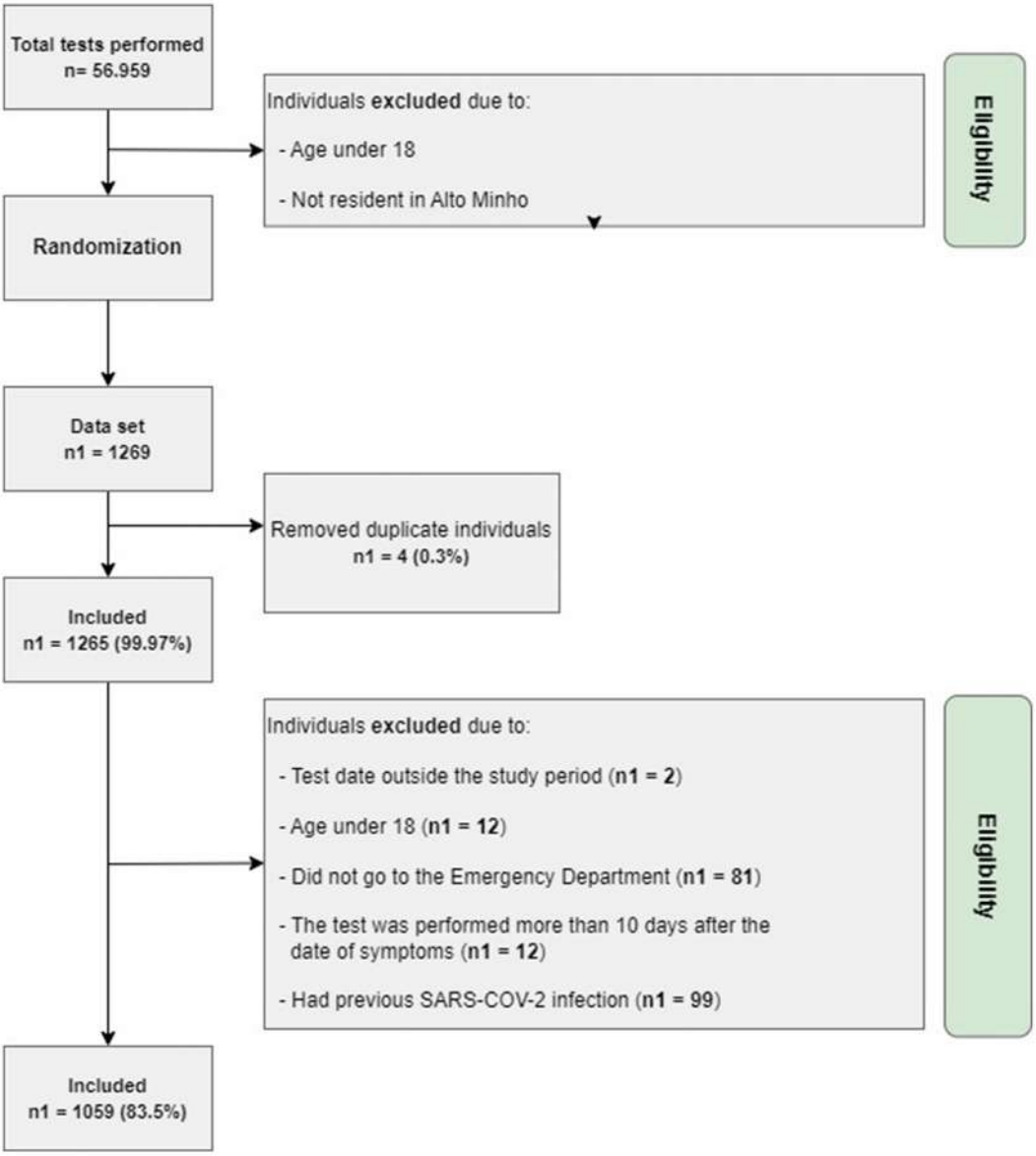

Fig. 1. Flowchart of the included and excluded individuals. A sample was randomly selected from the total tests performed between 1 June 2021 and 2 March 2022 ($N = 56{,}959$).

A statistically significant interaction was found in the severe disease model between age and the group of municipalities of residence (Table 3).

The magnitude of missing data was low (9%). Most missing data were observed on the date of symptom onset (7%); missing observations were completed with the test date. As there were a few missing observations, this was unlikely to impact the results.

Discussion

In this analysis, the absolute effectiveness of a booster was superior to that of the primary series and was even higher when the last inoculation was ≥180 days. In the study population who completed the primary series more than six months earlier, the booster prevented 71 of 100 symptomatic infections that would have occurred in the absence of a booster.

The mRNA vaccines (BNT162b2 and mRNA-1273) provided superior protection against symptomatic disease over the viral vector vaccines, although the result was not statistically significant.

Having an extremely vulnerable status was considered a confounder in the model of severe outcomes. Table 3 shows that being extremely vulnerable (as a result of immunosuppression and/or severe respiratory diseases, among other criteria described elsewhere)[16] is a risk factor for severe disease.

The residents in Vale do Minho showed a reduced risk of infection (adjusted OR = 0.50) but an increased risk of severe disease (adjusted OR = 3.54) compared with the residents in Vale do Lima. Vale do Minho is a more rural part of Alto Minho and is inhabited by older people who are usually less exposed to the virus but who can develop complications and more severe diseases. However, as the model was adjusted for age, an external factor may explain these differences, such as the access to health care, which may be compromised for residents in Vale do Minho, as the two hospitals in Alto Minho are located in Vale do Lima.

Despite the known characteristics of immunological evasion of the Omicron variant, the results of the present study show that vaccine effectiveness increased after booster vaccination, which is consistent with results from other studies.[9,20] Furthermore,

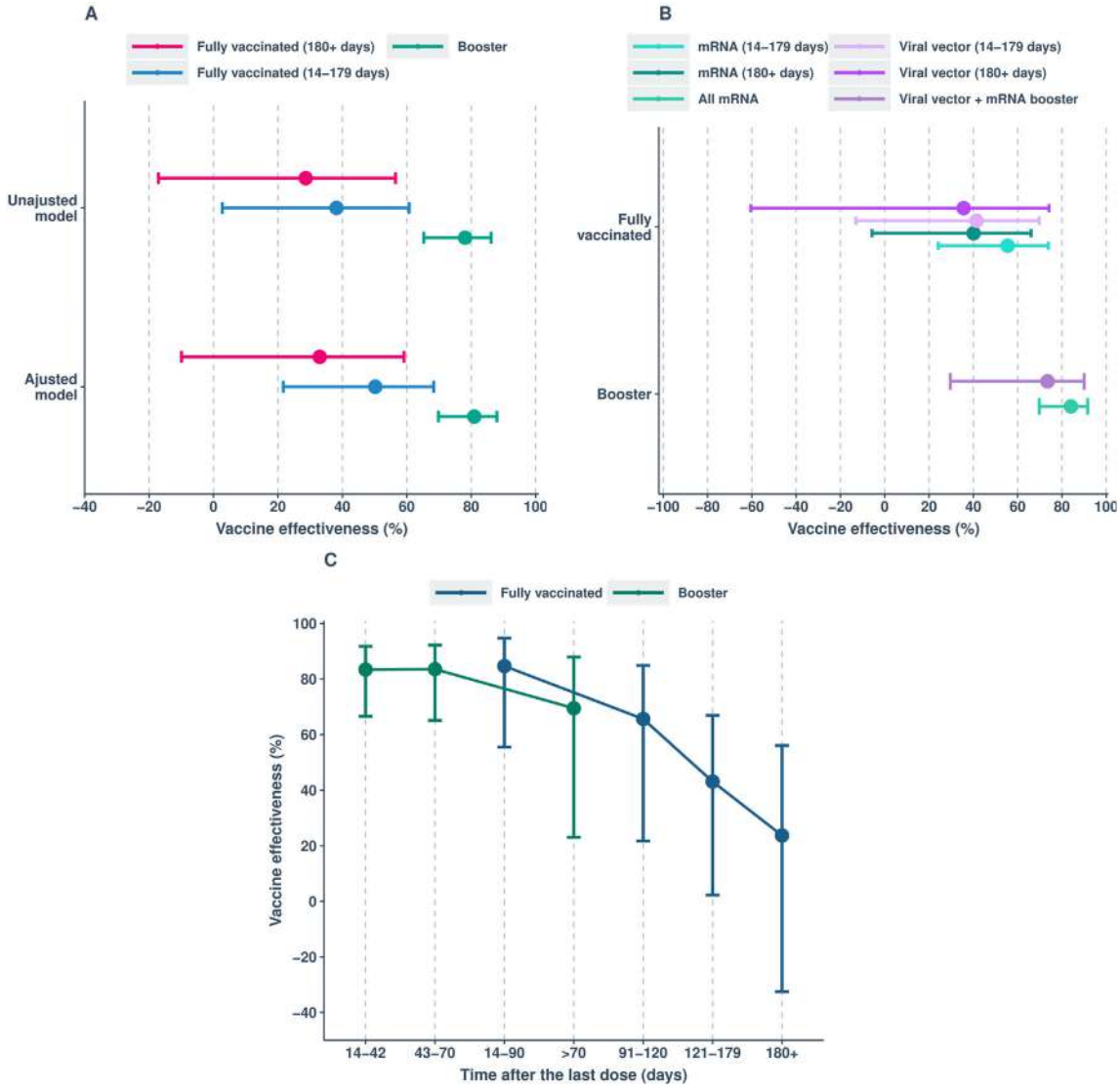

Fig. 2. Scree plot of the vaccine effectiveness for symptomatic infection in the fifth pandemic wave: A – Fully vaccinated (i.e. primary series only) vs. booster, stratified by time since the last vaccine dose. B – Fully vaccinated (i.e. primary series only) vs. primary series + booster, stratified by time since the last dose and type of vaccine (mRNA vs viral vector vaccines). C – Waning of vaccine effectiveness stratified by time after the last dose. Models adjusted for age and the group of municipalities of residence.

immunological studies suggest that there is an increase in immune response after the second dose, including a rise in the concentration and adaptation of the anti-receptor binding domain, specific for memory B cells, which confers biological plausibility for a higher vaccine effectiveness after booster vaccination, even with a highly divergent variant such as Omicron.[21–24]

The present study results also add to the accumulating evidence of the waning of vaccine protection over time for the primary series.[24,25] The effectiveness decreased to less than 50% between the third and sixth months after the last dose, so this may be the most appropriate time for booster administration.

The present study suggests that COVID-19 is less likely to result in hospitalisation, I/ICU admission and/or death in patients inoculated with a booster than in those who received only the primary scheme.

Strengths and limitations

The present study design has the following substantial strengths: (1) the cases and controls were recruited from the same healthcare unit and resided in the same geographical area, reducing bias due to risk variation according to locality;[15] (2) the cases and controls all sought care for a defined set of symptoms, which lowers the probability of health-seeking bias, an advantage of the study compared with traditional case–control and cohort studies;[15,26,27] (3) the vaccination status is usually recorded before knowing the test result, avoiding a potential differential misclassification bias;[15] and (4) the Local Health Unit of Alto Minho provided resident-level demographic and clinical data, allowing the study to analyse more detailed and complete data.

Some weaknesses of the study must also be considered, mainly due to its observational nature. There may be confounding when the vaccination status is associated with the risk of SARS-CoV-2 exposure. If, for instance, individuals who choose not to be vaccinated are also those who do not adhere to individual protective measures, this may lead to an overestimation of the vaccine effectiveness. Meanwhile, vaccinated individuals may exhibit more risky behaviours by believing they are protected, resulting in an underestimation of the vaccine effectiveness.[15] The sensitivity of PCR tests is not 100%, which may have led to the misclassification of

Table 2
Multivariable logistic regression model for symptomatic infection.

Variables	Symptomatic infection model		
	OR	95% confidence interval	*P*-value
Vaccination status			
Unvaccinated	Ref.	Ref.	Ref.
Fully vaccinated (14–179 days)	0.50	(0.31–0.82)	0.006[a]
Fully vaccinated (≥180 days)	0.66	(0.39–1.12)	0.123
Booster	0.19	(0.11–0.32)	<0.001[a]
Age (cubic spline with 3 DF)			
Component 1	0.63	(0.33–1.22)	0.169
Component 2	0.51	(0.15–1.74)	0.281
Component 3	0.28	(0.14–0.55)	<0.001[a]
Residence			
Vale do Lima	Ref.	Ref.	Ref.
Vale do Minho	0.52	(0.33–0.81)	0.003[a]
Month			
November	Ref.	Ref.	Ref.
December	1.25	(0.81–1.94)	0.317
January	3.51	(2.15–5.71)	<0.001
February	3.00	(1.79–5.05)	<0.001
March[b]	<0.001	(0–inf)	0.973

OR: odds ratio. Ref: reference.
[a] Statistical significance for $\alpha = 0.05$.
[b] Data were only analysed until March 2; therefore, we only had few observations in March, all of which were controls, rendering the confidence interval for this month to be wide.

Table 3
Multivariable logistic regression model for severe disease.

Variables	Severe disease model		
	OR	95% confidence interval	*P*-value
Vaccination status			
Unvaccinated	Ref.	Ref.	Ref.
Fully vaccinated (14–179 days)	0.13	(0.05–0.40)	<0.001[a]
Fully vaccinated (≥180 days)	0.19	(0.08–0.49)	<0.001[a]
Booster	0.10	(0.04–0.30)	<0.001[a]
Age	1.08	(1.06–1.10)	<0.001[a]
Group of municipalities of residence			
Vale do Lima	Ref.	Ref.	Ref.
Vale do Minho	<0.001	(0.001–25)	0.140
Group of municipalities of residence by age			
Vale do Lima	Ref.	Ref.	Ref.
Vale do Minho	1.18	(1.03–1.51)	0.008[a]
Extremely vulnerable status			
No	Ref.	Ref.	Ref.
Yes	4.49	(2.00–10.13)	<0.001[a]
Month			
November	Ref.	Ref.	Ref.
December	0.25	(0.09–0.70)	0.008[a]
January	0.37	(0.13–1.08)	0.069
February	0.34	(0.11–1.03)	0.056

OR: odds ratio; Ref: reference.
[a] Statistical significance for $\alpha = 0.05$.

cases in either of the controls and consequently may have attenuated the vaccine effectiveness estimates. In addition, the sample size precluded distinguishing the vaccine effectiveness among the more severe outcomes of COVID-19 – ICU admission and death. It was also difficult to directly measure the vaccine effectiveness against specific virus variants owing to the low proportion of genotyped cases. Nevertheless, this study analysed periods when different variants were dominant; thus, the study had an approximated vaccine effectiveness against these variants indirectly.

The present study was conducted primarily in the context of the Omicron sublineage BA.1. The sublineage BA.2 became dominant in the last week of the study period, and its prevalence increased in many areas of the world, indicating a likely competing advantage compared with BA.1. Nevertheless, recent evidence suggests that this advantage is related mainly to increasing transmissibility rather than to a higher immunity evasion.[28–30] Therefore, theoretically, the present study results would have been the same in the context of BA.2.[31]

The present results may not be representative of the wider general population, including people who are less prone to seek medical care in case of symptoms (e.g. ethnic minorities or people living in deprived areas). Although many relevant confounders were controlled in the models of vaccine effectiveness, residual or unmeasured confounding may have occurred.

The present study was restricted to the analysis of the first booster, as the second booster was approved in Portugal only after the study period. Future studies on the second booster are necessary.

Conclusions

This study has shown that vaccine effectiveness increases after booster administration. The optimal time for booster administration is between 3 and 6 months after completion of the primary cycle as this is the time when vaccine effectiveness decreases to less than 50%.

Author statements

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Ethical approval

The Ethics Committee of the Local Health Unit of Alto Minho (ULSAM) approved the protocol of this study with the reference number 05/2022. We followed STROBE guidelines, as can be seen in the supplementary material. The ethical principles of human medical research contained in the Declaration of Helsinki and national legislation were respected. The data collected were anonymised, guaranteeing the necessary confidentiality of the information collected. In addition, the principal investigator and her supervisors are subjected to medical confidentiality according to the Code of Ethics of the Portuguese Medical Association.

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Competing interests

None declared.

Author contributions

Conceptualisation, C.B., A.A. and R.D.; methodology, C.B., A.A., M.P. and F.A.; writing – original draft preparation, C.B.; writing – review and editing, all authors; supervision, R.D., M.P., A.A. and L.S. All authors have read and agreed to the published version of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.015.

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Original Research

Did the UK's public health shielding policy protect the clinically extremely vulnerable during the COVID-19 pandemic in Wales? Results of EVITE Immunity, a linked data retrospective study

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ABSTRACT

Introduction: The UK shielding policy intended to protect people at the highest risk of harm from COVID-19 infection. We aimed to describe intervention effects in Wales at 1 year.

Methods: Retrospective comparison of linked demographic and clinical data for cohorts comprising people identified for shielding from 23 March to 21 May 2020; and the rest of the population. Health records were extracted with event dates between 23 March 2020 and 22 March 2021 for the comparator cohort and from the date of inclusion until 1 year later for the shielded cohort.

Results: The shielded cohort included 117,415 people, with 3,086,385 in the comparator cohort. The largest clinical categories in the shielded cohort were severe respiratory condition (35.5%), immunosuppressive therapy (25.9%) and cancer (18.6%). People in the shielded cohort were more likely to be female, aged ≥50 years, living in relatively deprived areas, care home residents and frail. The proportion of people tested for COVID-19 was higher in the shielded cohort (odds ratio [OR] 1.616; 95% confidence interval [CI] 1.597−1.637), with lower positivity rate incident rate ratios 0.716 (95% CI 0.697−0.736). The known infection rate was higher in the shielded cohort (5.9% vs 5.7%). People in the shielded cohort were more likely to die (OR 3.683; 95% CI: 3.583−3.786), have a critical care admission (OR 3.339; 95% CI: 3.111−3.583), hospital emergency admission (OR 2.883; 95% CI: 2.837−2.930), emergency department attendance (OR 1.893; 95% CI: 1.867−1.919) and common mental disorder (OR 1.762; 95% CI: 1.735−1.789).

Conclusion: Deaths and healthcare utilisation were higher amongst shielded people than the general population, as would be expected in the sicker population. Differences in testing rates, deprivation and pre-existing health are potential confounders; however, lack of clear impact on infection rates raises questions about the success of shielding and indicates that further research is required to fully evaluate this national policy intervention.

Summary

What is already known on this topic

Some people, particularly those with pre-existing conditions, are more vulnerable to serious harms resulting from COVID-19 infection than others.

What this study adds.

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The three largest clinical categories in the shielded cohort were people with a severe respiratory condition (35.5%), people on immunosuppressive therapy (25.9%), and people with cancer (18.6%).

People in the shielded cohort were more likely to be female, aged >50 years, living in more deprived areas, resident in care homes and frail.

Deaths and healthcare resource utilisation were higher in the shielded population than in those not included in this policy initiative but impact on infection rates was not clear.

How this study might affect research, practice or policy.

These findings indicate that caution should be exercised before applying this policy in a future pandemic until further evidence is available about costs, benefits and harms of shielding.

Background

During the COVID-19 pandemic, it became apparent at an early stage that the virus was seriously affecting some parts of the general population. However, there was a lack of definitive evidence about who was at greatest risk. Evidence emerged during the early months of 2020 that older age was strongly associated with risk of death,[1] whereas analyses from China[2] and the United Kingdom[3] identified a higher risk of death among patients with pre-existing conditions, such as cardiovascular disease, respiratory disease, immunodeficiency and cancer. A cohort study of over 17 million primary care records in England[4] confirmed the association between diagnoses, such as diabetes and asthma, and the risk of death from COVID-19 and also highlighted the risks associated with deprivation, old age and being male and Black or South Asian.

International responses to the COVID-19 pandemic included national lockdowns that restricted population movement to slow disease transmission.[5] Non-pharmaceutical interventions included physical distancing, handwashing and stay at home advice.[6] The World Health Organisation recognised that some people are at higher risk than others from COVID-19 and advocated care plans be inclusive of monitoring and support if some groups, such as older people, were urged to stay at home for an extended period of self-isolation.[7]

In response to increasing transmission and deaths from COVID-19, uniquely, the UK government introduced a new intervention called 'shielding'. Although there were minor variations in implementation, this policy intervention in Wales was similar to the rest of the United Kingdom. Individuals identified as being at the highest risk of serious illness or death following COVID-19 infection were sent personal communications by letter, text or email strongly advising them to stay at home and to self-isolate, including from anyone – even family members – sharing the same premises for at least 12 weeks. Governments across the United Kingdom developed methods, including predictive algorithms[8] and clinical screening, to identify people thought to be most vulnerable to COVID-19–related hospital and intensive care unit (ICU) admissions or death for shielding. People with diagnoses, including cancer, transplants, immunodeficiency, serious heart conditions, respiratory problems, and under certain treatments, such as immunosuppressant medications, were identified for shielding from routine national and local NHS data sources.[9–12] People resident in care homes were excluded from shielding.[11,13] In England, this shielded population was estimated at 1.5 million, and in Wales 130,000.[14]

The shielding policy intended to protect those at the highest risk of serious harm, including death from COVID-19,[15] with the mechanism for protection being avoidance of infection. The shielding policy was a new public health intervention, introduced in the 2020 pandemic without prior evidence of effects on health outcomes, costs or behaviour.

Aim

This study aimed to describe the shielded cohort and compare routine health outcomes between this high-risk population and the rest of the unshielded general population in Wales at 1 year after the introduction of the shielding intervention.

Objectives

The objectives were to describe the shielded population in terms of demographic and clinical characteristics and to compare with the non-shielded population.

- Demographic characteristics
- COVID-19 test, infection and mortality
- All-cause mortality, ICU and hospital admissions and emergency department (ED) attendances.
- Mental health outcomes

Methods

In this article, we follow the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement guidelines.[16]

Study design

We undertook a retrospective comparative analysis of demographic and clinical characteristics, COVID-19 tests and results, deaths and healthcare resource utilisation between people identified for inclusion in the shielding policy and everyone else in Wales.

Data were accessed and analysed via the Secure Anonymised Information Linkage (SAIL) Databank (www.saildatabank.com), a remotely accessible, privacy-protecting Trusted Research Environment, accredited under the Digital Economy Act.[17,18]

Data sources

The C20 Cohort was created in response to the outbreak of COVID-19 to provide a population-level electronic data resource to facilitate research assessing the impact of the COVID-19 pandemic in Wales.[19] The C20 Cohort comprises more than 3.2 million people who were alive and living in Wales on 1 January 2020 or who moved into or were born in Wales after that date.

People identified for shielding are tagged within the C20 Cohort with a date of inclusion. Health outcomes were derived from routinely collected electronic health record data sources held within SAIL, including the Annual District Death Daily; Annual District Death Extract; the Consolidated Death Data Source; the COVID-19 Pathology Data; the Patient Episode Database for Wales; the Critical Care Data Set; and the Welsh Longitudinal General Practice data sources.

Participants

C20 Cohort members alive and living in Wales on 23 March 2020 were included, with those identified for shielding between 23 March 2020 and 21 May 2020 allocated to the shielded cohort and others allocated to the non-shielded comparator cohort (Fig. 1). Age (in years) was calculated as at 23 March 2020 and grouped in 5-year age bands up to 85 years, with all older ages grouped together. Anonymised address fields where individuals were registered as living at

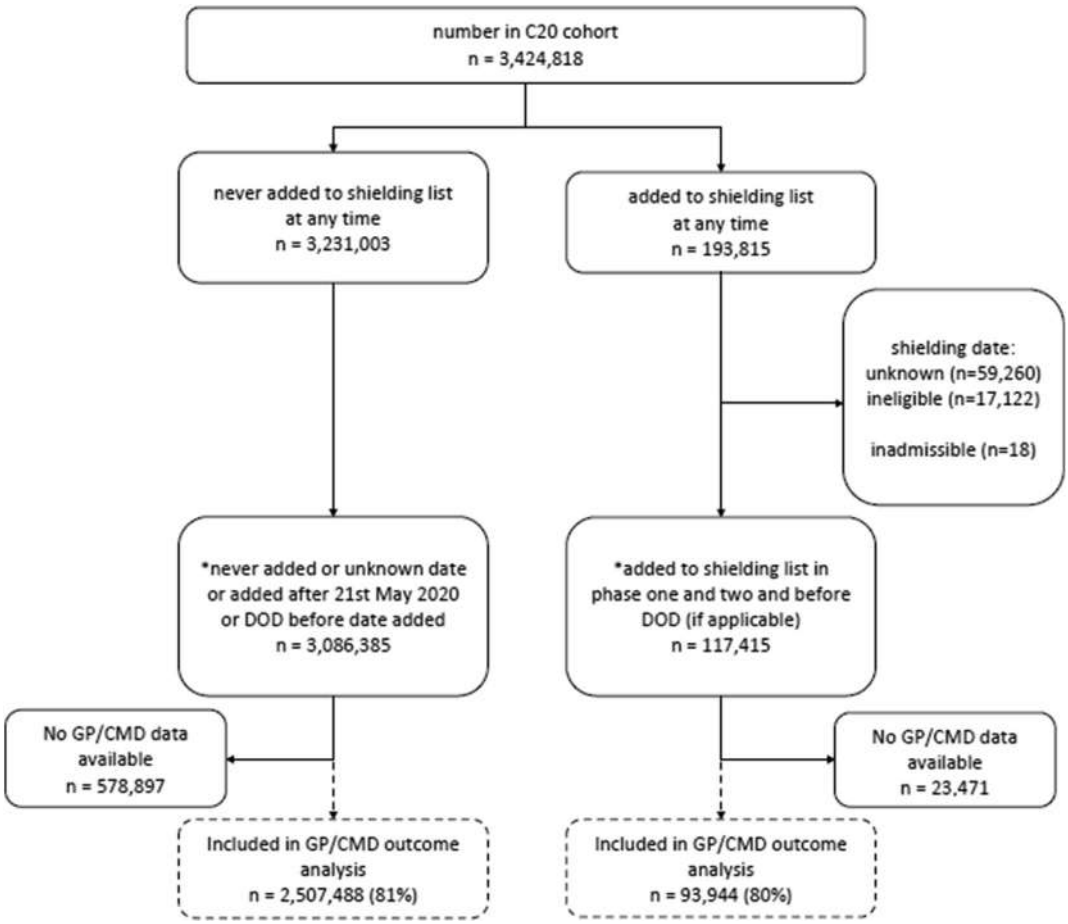

Fig. 1. Cohort recruitment flowchart.

the time of cohort entry were used to identify those living in Care Homes by linking to a list of residential care homes within Wales, as well as the corresponding statistical geography codes, which were used to categorise deprivation based on the 2019 Welsh Index of Multiple Deprivation. Frailty Categories were based on an Electronic Frailty Index score,[20,21] calculated as at 23 March 2020.

Outcomes

We used routine health data to assess the following outcomes.

1. COVID-19 infection tests
2. Positive COVID-19 infection tests
3. Deaths from COVID-19 and all-cause
4. ED attendances
5. Emergency hospital admissions and days in hospital
6. ICU admissions and days in ICU
7. Indicators of common mental disorder (CMD)

Table 1
Shielded cohort clinical categories.

CEV category	$n = 117,415$	%
Severe respiratory conditions	41,711	35.5
Immunosuppression therapy	30,464	25.9
Cancer	21,895	18.6
Rare diseases	13,207	11.2
Severe organ disease	6529	5.6
Organ transplant recipients	2014	1.7
Other	822	0.7
Renal dialysis	635	0.5
Pregnancy with congenital heart disease	138	0.1

CEV, clinically extremely vulnerable.

Health records were extracted with event dates between 23 March 2020 and 22 March 2021 for the non-shielded (comparator) cohort and from the date of inclusion until 1 year later for the shielding cohort, except for data relating to mental health outcomes. CMD General practitioner (GP) events (diagnoses, symptoms and treatments for CMD) were assessed monthly during the study period, using an established method,[22] based on a search of primary care records in 13-month windows centred on each month. Given the almost complete coverage of the population of Wales, we have identified no significant source of bias in participants included in the analysis or in the completeness of information available on these participants.

Analysis

Profiles for both the shielded and non-shielded cohorts describe the number and percentage of people by age, sex, deprivation category, care home residential status and frailty score. Counts and percentages of clinical vulnerability categories were produced for the shielded cohort.

Frequencies for each health outcome were generated for the shielded and non-shielded cohorts, as well as clinical subgroups within the shielded cohort. Event, count and measurement

Table 2
Shielded and non-shielded cohort demographic characteristics.

Cohort	Shielded (n = 117,415)	Non-shielded (n = 3,086,385)
Sex, *n* (%)		
Male	54,473 (46.4)	1,545,471 (50.1)
Female	62,942 (53.6)	1,540,914 (49.9)
Age (years), median (LQ, UQ)	66 (53, 75)	41 (22, 59)
Age group (years), *n* (%)		
0–19	4768 (4.1)	689,915 (22.4)
20–39	9865 (8.4)	811,478 (26.3)
40–59	28,723 (24.5)	813,797 (26.4)
60–79	58,099 (49.5)	617,367 (20.0)
80+	15,960 (13.6)	153,828 (5.0)
WIMD[2]: *n (%)*		
Missing	5797 (4.9)	208,852 (6.8)
Recorded	111,618 (95.1)	2,877,533 (93.2)
WIMD quintile: *n (% recorded)*		
1. Most deprived	24,832 (22.2)	591,184 (20.5)
2	23,553 (21.1)	575,100 (20.0)
3	22,019 (19.7)	571,523 (19.9)
4	20,956 (18.8)	566,235 (19.7)
5. Least deprived	20,258 (18.1)	573,491 (19.9)
Care home status: *n (%)*		
Care home resident	1113 (0.9)	14,072 (0.5)
Other	116,302 (99.1)	3,072,313 (99.5)
Frailty category: *n (%)*		
Missing GP data	19,904 (17.0)	540,662 (17.5)
Recorded	97,511 (83.0)	2,545,723 (82.5)
Frailty category: *n (% recorded)*		
Fit	40,654 (41.7)	2,178,021 (85.6)
Mild	37,711 (38.7)	287,362 (11.3)
Moderate	15,111 (15.5)	66,045 (2.6)
Severe	4035 (4.1)	14,295 (0.6)

WIMD, Welsh Index of Multiple Deprivation.

outcomes were analysed using generalised linear models, with an appropriate link function (negative binomial for counts) and logarithmically transformed dependent variables for heavily skewed measurement outcomes; sex (factor) and age (covariate; linear and quadratic) were included as independent variables, with interaction between age and sex.

Generalised linear models were fitted using SPSS (version 26); models retained all independent variables; no adjustment was made for multiple testing.

Comparisons between shielded and non-shielded cohorts were based on estimated odds ratios (ORs) for binary outcomes, estimated incident rate ratios (IRRs) for count outcomes and estimated differences (Δ) for measurement outcomes, with 95% confidence intervals (CIs) for these estimates.

Research management and public involvement

The EVITE Immunity research team includes clinical, policy, academic, methodological and public contributors who have equal responsibility in all decisions to develop, manage and deliver this study. Two public contributors (L.B. and L.D.) are co-applicants and members of the Research Management Group and work with six more public contributors via a Patient Advisory Panel. An independent Study Steering Committee includes two further public contributors. Our public contributors were directly or indirectly affected by the implementation of the shielding policy.[23,24]

Results

Cohort profiles

Through the use of algorithms and screening of routine NHS data, a total of 193,815 individuals were identified as eligible for the shielding intervention. With inclusion restricted to those identified between 23 March and 21 May (the first and second phases of the shielding policy implementation) and linked to the C20 Cohort, we included 117,415 people in the shielded cohort for analysis (Fig. 1), with the remaining 3,086,385 allocated to the non-shielded comparator cohort.

The three largest categories within those identified for shielding comprised people with a severe respiratory condition (35.5%), with immunosuppressive therapy (25.9%), and cancer (18.6%; Table 1).

Women made up a slightly higher proportion of the shielded cohort (53.6% vs 49.9%); people aged ≥50 years made up a much higher proportion of the shielded cohort (79.6% vs 39%); people living in areas of relatively high deprivation made up a slightly higher proportion of the shielded cohort (highest two quintiles: 43.3 vs 40.5%); people resident in care homes made up a higher proportion of the shielded cohort (0.9 vs 0.5%); and people categorised as mildly, moderately or severely frail made up a much higher proportion of the shielded cohort (58.3% vs 14.5%; Table 2).

Health outcomes

Testing

A total of 130,039 COVID-19 tests were recorded during 1-year follow-up for 44,523 individuals in the shielded cohort, an average of 1.11 tests per person, with 37.9% of the cohort tested at least once. This compares with an average of 0.83 tests per person and 30.8% tested at least once in the non-shielded cohort (Table 3). After adjusting for age and sex, the OR for persons tested was 1.616 (95% CI: 1.597–1.637) for the shielded cohort relative to the non-shielded cohort. All clinical sub-cohorts had an OR >1 relative to the non-shielded cohort, with the highest OR for the cancer sub-cohort (Table 4).

Within persons tested, 15.6% (6939/44,523) of the shielded cohort recorded a positive test; compared with 18.5% (176,120/950,818) in the non-shielded cohort. After adjusting for age and sex, the OR for persons with a positive test was 0.716 (95% CI: 0.697–0.736) for persons tested in the shielded cohort relative to those tested in the non-shielded cohort. For clinical sub-cohorts, the corresponding ORs were all <1, with the lowest OR for the cancer sub-cohort.

The known infection rate in the shielded cohort was 5.9% and in the non-shielded cohort was 5.7%. We extrapolated from tested sub-cohorts to entire cohorts based on demographic characteristics alone and assumed similar infection rates between tested and untested. Using these assumptions, 15.5%–15.9% (95% confidence) of the entire shielded cohort would have tested positive, compared with 18.6%–18.7% of the entire non-shielded cohort.

Mortality

After adjusting for age and sex, the OR for mortality in the shielded cohort was 3.683 (95% CI: 3.583–3.786) relative to the non-shielded cohort. COVID-19 was less likely to have been recorded as a cause (15.3% vs 21.4%). There was variation among the shielded clinical sub-cohorts, with cancer patients showing the highest mortality (1.3%).

Healthcare utilisation

Critical care admissions, emergency admissions, and ED attendances were all more likely amongst people in the shielded cohort: ORs 3.339 (95% CI: 3.111–3.583), 2.883 (95% CI: 2.837–2.930) and 1.893 (95% CI: 1.867–1.919), each with some variation across the four clinical sub-cohorts in the shielded cohort. The IRRs for the number of attendances and admissions in the shielded cohort were all significantly >1 relative to the non-shielded cohort, both for entire cohorts and within those attending or admitted.

Mental health outcomes

After adjusting for age and sex, the OR for an indicated CMD in the shielded cohort was 1.762 (95% CI: 1.735–1.789) relative to the non-shielded cohort, with ORs >1 in all clinical sub-cohorts.

Discussion

Key findings

People were more likely to have been identified for inclusion in the shielding intervention with increasing age, frailty and residence in deprived areas. Although people living in care homes were intended to be excluded from shielding, we found more than 1000 people included in the shielded cohort who were care home residents, almost double the proportion of care home residents in the general population.

Reported infection rate was higher in the shielded cohort than the non-shielded general population; however, testing rates were higher, and infection rates amongst those not tested in each cohort are unknown.

Limitations

Our analyses were adjusted for differences in distributions by age and sex to facilitate general descriptive comparisons in observed rates of events. However, comparisons made in this article do not take into account of deprivation status or clinical vulnerability. In phase 2 of the EVITE Immunity study, we will carry out more complex analyses, with a matched control cohort of non-shielded people within the general population, as well as inclusion of self-reported outcomes in samples. We will also adjust for other differences, for example, deprivation, ethnicity and frailty.

We found a higher rate of testing for COVID-19 in the shielded population, potentially causing an overstated infection rate in this cohort compared with the general population. It is possible that a higher number of people within the shielded cohort were tested without symptoms of COVID-19, for example, as a requirement before attending hospital for routine treatment or due to anxiety, or that people in the shielded population were more likely to experience symptoms, for example, those with chronic obstructive pulmonary disease (COPD), which triggered higher testing rates. Testing availability varied considerably across the period of study and also geographically. Systematic differences in the way testing processes were implemented give rise to challenges in interpreting differences in recorded infection rates. It is neither credible to assume that all those untested would have tested negative nor that the rate of positive tests would have been similar in the untested to those tested. But we have no data on which to estimate where the true rate of infection should lie – we therefore present a range of 5.9–15.9% in the shielded cohort and 5.7–18.7% in the non-shielded cohort, as the likely outer limits. We will explore this further in phase 2 of this study, using a matched cohort design.

Implications

We took an 'intention to treat' analysis approach,[25] with no attempt to account for variation in adherence to the shielding guidance because this is not possible to determine from administrative data. This generates a real-life evaluation of policy. Subsequent research will include analysis of linked data from questionnaires, which include self-reported adherence to shielding advice, and qualitative interviews, which will seek to understand people's experiences of the shielding policy. It is likely the autonomy and agency for some people on the shielding list to control their level of adherence would have been dependent on a number of factors, such as mobility, household composition, access to services (supermarkets, for example), geographical location or hospitalisation. These factors have not been considered in this analysis.

Shielding was an untested public health policy that was introduced in the United Kingdom early in the pandemic, in contrast to other countries where there was more focus on closing borders, lockdown, test and trace systems. The shielding policy was based on assumptions rather than evidence of effectiveness. There were uncertainties about (1) risk factors, (2) the performance of predictive risk stratification models in this context, (3) the ability and willingness of clinically vulnerable people to carry out the strict self-isolation advised and (4) primary transmission routes.

The United Kingdom, in common with other countries, experienced high levels of nosocomial infection and infection in care homes and healthcare settings, with transmission presumed to be through contact with other patients, health professionals and care givers.[26,27] We found a very high rate of contact with health services throughout this period for people in the shielded cohort. It is likely that despite efforts to support shielding for those at highest risk, clinically vulnerable people were exposed to other people with COVID-19 at home, in care homes, or in hospital or other healthcare settings, for example, people requiring dialysis, and then been vulnerable to infection and serious harm despite all intentions to avoid these outcomes.

We found a higher rate of all-cause mortality in the shielded population, as well as higher rates of health service utilisation. This is likely to be due to a higher level of sickness in the shielded population, and we do not attribute these differences to the introduction of shielding.

Table 3
Frequency counts of Health outcomes in the Shielded cohort and sub-cohorts: comparison with non-shielded general population.

Health outcomes	Shielded cohort and sub-cohorts					Non-shielded cohort (n = 3,086,385)
	All (n = 117,415)	Severe respiratory condition (n = 41,711)	Immunosuppression therapy (n = 30,464)	Cancer (n = 21,895)	All others (n = 23,345)	
Testing						
Persons tested: n (proportion of cohort or sub-cohort)	44,523 (0.379)	15,890 (0.381)	10,367 (0.340)	8933 (0.408)	9333 (0.400)	950,818 (0.308)
Persons tested positive: n (proportion of persons tested)	6939 (0.156)	2517 (0.158)	1721 (0.166)	1232 (0.138)	1469 (0.157)	176,120 (0.185)
Tests recorded: n (average per person)	130,039 (1.11)	46,292 (1.11)	27,286 (0.90)	26,699 (1.22)	29,762 (1.27)	2,551,739 (0.83)
Positive tests recorded: n (average per person tested)	9132 (0.205)	3408 (0.214)	2126 (0.205)	1626 (0.182)	1972 (0.211)	192,353 (0.202)
Mortality						
All causes: n (proportion of cohort or sub-cohort)	7950 (0.068)	3101 (0.074)	774 (0.025)	2776 (0.127)	1299 (0.056)	27,934 (0.009)
COVID-19 related: n (proportion of all deaths)	1220 (0.153)	608 (0.196)	172 (0.222)	238 (0.086)	202 (0.156)	5987 (0.214)
Healthcare utilisation						
Persons with an ED attendance: n (proportion of cohort or sub-cohort)	29,142 (0.248)	11,781 (0.282)	5893 (0.193)	5495 (0.251)	5973 (0.256)	424,032 (0.137)
Total ED attendances (average per person in cohort/sub-cohort)	51,461 (0.438)	21,995 (0.527)	9552 (0.314)	9097 (0.415)	10,817 (0.463)	630,767 (0.204)
Persons with a critical care admission: n (proportion of cohort or sub-cohort)	989 (0.008)	334 (0.008)	199 (0.007)	211 (0.010)	245 (0.010)	4701 (0.002)
Total critical care admissions (average per person in cohort/sub-cohort)	1120 (0.010)	383 (0.009)	225 (0.007)	235 (0.011)	277 (0.012)	5140 (0.002)
Total bed days − ICU (average bed days per admission) (average bed days per person with an ICU admission)	6162.0 (5.50) (6.23)	1989.0 (5.19) (5.96)	1332.5 (5.92) (6.70)	1210.5 (5.15) (5.74)	1630.0 (5.88) (6.65)	37,275.5 (7.25) (7.93)
Persons with an emergency admission: n (proportion of cohort or sub-cohort)	22,212 (0.189)	8829 (0.212)	3926 (0.129)	5010 (0.229)	4447 (0.190)	161,307 (0.052)
Total emergency admissions (average per person in cohort/sub-cohort)	39,267 (0.334)	15,392 (0.369)	6507 (0.214)	9156 (0.418)	8212 (0.352)	229,084 (0.074)
Total bed days − emergency admissions (average bed days per admission) (average bed days per person with an emergency admission)	385,384.0 (9.81) (17.35)	155,026.5 (10.07) (17.56)	65,825.0 (10.12) (16.77)	78,881.5 (8.62) (15.74)	85,651.0 (10.43) (19.26)	1,998,733.5 (8.72) (12.39)
Common mental disorder						
Persons with CMD flag data (proportion of cohort or sub-cohort)	93,944 (0.800)	33,982 (0.815)	24,424 (0.802)	16,818 (0.768)	18,720 (0.802)	2,507,448 (0.812)
Persons flagged with CMD (proportion of persons with CMD flag data)	26,400 (0.281)	11,655 (0.343)	6230 (0.255)	3857 (0.229)	4658 (0.249)	422,750 (0.169)

CMD, common mental disorder; ED, emergency department; ICU, intensive care unit.

Table 4
Comparisons, adjusted for age and gender, of health outcomes in the shielded cohort and sub-cohorts, relative to the non-shielded general population.

Health outcomes		Shielded cohort	Shielded sub-cohorts			
		All (n = 117,415)	Severe respiratory condition (n = 41,711)	Immunosuppression therapy (n = 30,464)	Cancer (n = 21,895)	All others (n = 23,345)
Testing						
Persons tested: OR (95% CI)	Within cohort/sub-cohort	1.616 (1.597, 1.637)	1.759 (1.724, 1.795)	1.253 (1.223, 1.283)	1.916 (1.864, 1.969)	1.687 (1.643, 1.732)
Persons tested positive: OR (95% CI)	Within persons tested	0.716 (0.697, 0.736)	0.725 (0.694, 0.757)	0.769 (0.730, 0.810)	0.608 (0.572, 0.646)	0.760 (0.718, 0.804)
Tests recorded, per person: IRR (95% CI)	Within cohort/sub-cohort	1.298 (1.287, 1.309)	1.324 (1.306, 1.343)	0.983 (0.967, 0.999)	1.448 (1.422, 1.475)	1.565 (1.538, 1.593)
Positive tests recorded: IRR (95% CI)	Within persons tested	0.852 (0.832, 0.872)	0.862 (0.830, 0.895)	0.877 (0.837, 0.920)	0.735 (0.697, 0.776)	0.930 (0.885, 0.977)
Mortality						
All causes: OR (95% CI)	Within cohort/sub-cohort	3.683 (3.583, 3.786)	3.059 (2.936, 3.187)	1.903 (1.765, 2.053)	7.265 (6.944, 7.601)	3.671 (3.450, 3.907)
COVID-19–related deaths: OR (95% CI)	Within all deaths	0.667 (0.623, 0.715)	0.852 (0.775, 0.936)	1.059 (0.890, 1.259)	0.351 (0.306, 0.403)	0.701 (0.600, 0.818)
Healthcare utilisation						
Persons with an ED attendance: OR (95% CI)	Within cohort/sub-cohort	1.893 (1.867, 1.919)	2.147 (2.100, 2.195)	1.471 (1.429, 1.514)	1.882 (1.825, 1.942)	2.025 (1.966, 2.087)
ED attendances, per person: IRR (95% CI)	Within cohort/sub-cohort	1.960 (1.939, 1.982)	2.263 (2.225, 2.302)	1.483 (1.449, 1.518)	1.820 (1.776, 1.866)	2.133 (2.085, 2.183)
ED attendances, per person: IRR (95% CI) [a]	Within persons with $\geq$ 1 ED attendances	1.494 (1.466, 1.522)	1.678 (1.632, 1.724)	1.220 (1.170, 1.272)	1.258 (1.206, 1.313)	1.603 (1.542, 1.665)
Persons with an ICU admission: OR (95% CI)	Within cohort/sub-cohort	3.339 (3.111, 3.583)	2.801 (2.501, 3.137)	2.835 (2.458, 3.271)	3.333 (2.898, 3.833)	4.752 (4.173, 5.411)
ICU admissions, per person: IRR (95% CI)	Within cohort/sub-cohort	3.485 (3.261, 3.726)	2.974 (2.674, 3.307)	2.930 (2.561, 3.351)	3.404 (2.980, 3.887)	4.915 (4.349, 5.554)
ICU admissions, per person: IRR (95% CI) [b]	Within persons with $\geq$1 CC admission	1.453 (1.179, 1.789)	1.612 (1.172, 2.217)	1.372 (0.899, 2.092)	1.290 (0.833, 1.997)	1.376 (0.938, 2.017)
ICU bed days, per person: Δ (95% CI) [c]	Within cohort/sub-cohort	0.009 (0.008, 0.009)	0.008 (0.007, 0.008)	0.007 (0.006, 0.007)	0.010 (0.009, 0.011)	0.013 (0.012, 0.014)
ICU bed days, per person: Δ (95% CI) [d]	Within persons with $\geq$ 1 CC admission	−0.149 (−0.210, −0.088)	−0.177 (−0.277, −0.078)	−0.130 (−0.256, −0.004)	−0.149 (−0.272, −0.026)	−0.131 (−0.246, −0.016)
Persons with an emergency admission: OR (95% CI)	Within cohort/sub-cohort	2.883 (2.837, 2.930)	2.833 (2.763, 2.905)	2.173 (2.099, 2.250)	3.401 (3.290, 3.515)	3.304 (3.193, 3.420)
Emergency admissions, per person: IRR (95% CI)	Within cohort/sub-cohort	3.107 (3.068, 3.147)	2.913 (2.856, 2.972)	2.330 (2.266, 2.396)	3.681 (3.588, 3.777)	3.741 (3.643, 3.842)
Emergency admissions, per person: IRR (95% CI) [b]	Within persons with $\geq$ 1 emergency admission	1.717 (1.679, 1.756)	1.583 (1.530, 1.637)	1.516 (1.441, 1.595)	1.835 (1.759, 1.915)	1.978 (1.892, 2.068)
Emergency admission bed days, per person: Δ (95% CI) [c]	Within cohort/sub-cohort	0.221 (0.218, 0.224)	0.248 (0.243, 0.252)	0.119 (0.114, 0.124)	0.288 (0.282, 0.294)	0.251 (0.245, 0.256)
Emergency admission bed days, per person: Δ (95% CI) [d]	Within persons with $\geq$1 emergency admission	0.247 (0.231, 0.262)	0.102 (0.169, 0.215)	0.231 (0.197, 0.264)	0.234 (0.204, 0.265)	0.365 (0.333, 0.397)
Common mental disorder						
Persons with CMD flag data: OR (95% CI)	Within cohort/sub-cohort	0.982 (0.967, 0.996)	1.100 (1.073, 1.128)	0.967 (0.940, 0.995)	0.822 (0.796, 0.848)	0.972 (0.942, 1.004)
Persons flagged with CMD: OR (95% CI)	Within person with CMD flag data	1.762 (1.735, 1.789)	2.597 (2.535, 2.660)	1.313 (1.274, 1.353)	1.336 (1.287, 1.387)	1.594 (1.539, 1.650)

ED, emergency department; ICU, intensive care unit.
[a] modelling uses further attendances as the dependent variable, to improve model fit.
[b] modelling uses further admissions as the dependent variable, to improve model fit.
[c] modelling uses a log-transformed dependent variable to improve model fit, but this transformation does not remove the spike at 0.
[d] modelling uses a log-transformed dependent variable, to improve model fit.

We do not believe that there is any reason that results from the entire population of Wales would be any different from other areas of the United Kingdom – although of course there may be differences in sub-populations, for example, those with high levels of deprivation, older residents or people from ethnic minorities.

A study comparing COVID-19 outcomes between shielded and non-shielded populations in the West of Scotland describes a similar trend in infection rates, with the shielded population having an infection rate eight times higher than those considered 'low risk' as well as having higher rates of mortality.[28] Our findings are similar to those reported in a Scottish study, which found that the shielding population had a higher risk of mortality from COVID-19.[29] Interestingly, a study of the English population during the first 12 weeks of the shielding policy found that during the first 21 days of the policy, mortality in the shielded cohort was half that of the non-shielded matched cohort. However, during the following 9 weeks, mortality in the shielded group rose significantly to 1.5 times higher than in the matched cohort, which although shows a similar trend; it is a much smaller difference than reported in our study.[30]

Evidence is now emerging regarding the effects of shielding on infections, deaths and general health and well-being, but this is still very limited.[28,31] Shielded people and their families made great efforts to isolate and protect themselves from COVID-19 infection and subsequent harms, including death. This isolation and restrictions on going out may have affected the mental and physical health of people included in this public health policy intervention, without evidence so far of substantive protective effects.[32,33]

Conclusions

Further research using a matched comparator group, self-reported outcomes and costs are needed to fully evaluate the effects of this policy intervention. Initial findings from the EVITE Immunity study show that there is some uncertainty about the success of the policy in terms of reducing COVID-19 infections in the shielded cohort. Higher rates of mortality and health service utilisation were to be expected in a clinically vulnerable population – but a clinically effective shielding policy may have been expected to reduce COVID-19 infection rates to a higher degree than we found in this study.

Author statements

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Ethical approval

This study was undertaken with the approval of the SAIL IGRP (project number 0911). No NHS research ethics application was required.

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Competing interests

The authors declare that they have no competing interests.

Data availability statement

The data used in this study are available in the SAIL Databank at Swansea University, Swansea, UK. All proposals to use SAIL data are subject to review by an independent Information Governance Review Panel (IGRP).

Author contributions

The study was conceived and led by H.S. The study was designed by H.S. in collaboration with R.A.L., A.W., J.L., A.A., R.B., L.B., A.C.S., A.E., H.E., B.A.E., S.J., A.J., M.K., A.P., B.S. and V.W. J.L. and A.A. undertook the data preparation, with analysis led by H.S. and A.W. H.S. and A.W. drafted the initial article with contributions from all authors. All authors read the first draft of the article and approved the final document for submission.

Transparency statement

The lead author (the manuscript's guarantor) affirms that this article is an honest, accurate and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

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Original Research

E-cigarette, cigarette, dual e-cigarette with cigarette use, and disability status among reproductive-aged women

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ABSTRACT

Objective: E-cigarettes have increased steadily among reproductive-aged women, despite our limited understanding of their effect on reproductive health. This study examined the associations of e-cigarette, cigarette, and dual use with disability in reproductive-aged women.
Study design: This was a cross-sectional study.
Methods: Data for this study were obtained from reproductive-aged women (18–44 years; $n = 24{,}904$) from the 2020 Behavioral Risk Factor Surveillance System. Descriptive statistics and logistic regression analyses were conducted to assess the associations of tobacco use patterns (dependent variable, i.e. non-use, current e-cigarette use, current cigarette use, and current dual use of e-cigarettes and cigarettes) with overall disability and the type of disability (independent variables).
Results: Among women who reported any disability, 70.6%, 8.7%, 11.4% and 9.3% reported non-use, e-cigarette, cigarette, and dual use, respectively. In adjusted analysis, relative to non-use, women who reported any disability had higher odds of e-cigarette (adjusted odds ratio [aOR]: 1.88; 95% confidence interval [CI]: 1.15–3.07), cigarette (aOR: 1.58; 95% CI: 1.12–2.25), and dual use (aOR: 2.37; 95% CI: 1.55–3.62) compared with women without disabilities.
Conclusions: This cross-sectional study found higher odds of current e-cigarette use, cigarette use, and dual use of e-cigarettes and cigarettes among women of reproductive age with ≥1 disability. Improved screening for the use of nicotine products among women of reproductive age with disabilities may be necessary to lessen the use of nicotine products in this vulnerable population.

Introduction

The tobacco use landscape in the United States has diversified in the last two decades.[1] Cigarette use is declining, whereas the use of alternative products such as electronic nicotine delivery systems (e-cigarettes) is increasing, mainly among young adults.[1,2] These two products, cigarettes and e-cigarettes, constitute the most used combustible and non-combustible tobacco products in the United States, respectively.[2] Despite these changes in the last decade, smoking prevalence remains high among women of reproductive age[3] and higher than the national prevalence average.[3–6]

Cigarette and non-cigarette tobacco product use among women of reproductive age is a public health concern. This concern is based on evidence indicating women who smoke have a higher likelihood of developing cervical cancer, osteoporosis, and early menopause.[7] Also, women who smoke during pregnancy are at risk of adverse outcomes such as stillbirth, as well as experiencing neonatal and perinatal death.[8] Aside from the well-known health effects of cigarettes on women of reproductive age, e-cigarettes, although of lower risk, also present some health risks related to pulmonary functioning and the harmful effect of nicotine on fetal development during pregnancy.[7,9–11]

Furthermore, epidemiological studies have demonstrated that cigarettes are the most common tobacco products used among women of reproductive age in the United States. For example, Do et al.[7] detailed the past 30-day estimates of 16.9% for cigarette only, 1.5% for self-reported e-cigarette only, and 6.1% for dual use. These rates are comparable to national estimates of tobacco product use in the general population and among women.[3,6,12] In addition,

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factors associated with increased odds of tobacco use among reproductive-aged women have also been documented, including poverty, lower educational attainment, non-Hispanic White race/ethnicity, alcohol and drug use, and internalizing symptoms.[3,7,13,14]

Recently, there has been an interest in monitoring the rapidly changing market of tobacco product use, especially among higher risk populations such as people with disabilities.[3,4,6–8] Prior studies have demonstrated that adults with disabilities are more likely to smoke cigarettes than those without disabilities.[2,15–18] In the United States, approximately 18% of women of reproductive age report at least one disability related to cognition, hearing, independent living, mobility, self-care, or vision.[19] Women of reproductive age with disabilities are uniquely vulnerable to tobacco use, particularly for combustible cigarettes and e-cigarettes (i.e. dual use). Despite the risk presented by these tobacco products, there is limited knowledge on the association of dual use with disability status among reproductive-aged women in the United States.

Women of reproductive age (18–44 years) represent an essential segment of the general population because tobacco product use in this group has the potential for a multigenerational impact, which can advance or mitigate tobacco control gains in the general population.[3] Hence, investigating the relationship of tobacco use with disability among reproductive-aged women underscores an attempt to provide evidence for policies to reduce tobacco use in some of the most vulnerable populations. The present cross-sectional study examines the associations of e-cigarette only, cigarette only, and dual use of e-cigarettes and cigarettes with disability in reproductive-aged women in the United States.

Methods

Study population

The study population was drawn from the 2020 Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a national, repeated, cross-sectional telephone-based survey of a random sample of non-institutionalized US residents aged ≥18 years. The survey collects information on health-related risk behaviors, chronic health conditions, and use of preventive health services. Respondents are drawn from all 50 US states, the District of Columbia and three US territories. The data set is de-identified and publicly available at http://www.cdc.gov/brfss. The present study was restricted to 24,904 women of reproductive age (18–44 years) from the 2020 BRFSS data set (Fig. 1). The details of sampling and weighting measures are described on the BRFSS webpage: https://www.cdc.gov/brfss/annual_data/annual_2020.html.

Study measures

Tobacco use patterns

The dependent variable, tobacco use patterns, that is, non-use, current e-cigarette use, current cigarette use, and current dual use of e-cigarettes and cigarettes, was assessed from questions related to cigarette and e-cigarette use. Current e-cigarette use was evaluated from the question: 'Do you now use e-cigarettes or other electronic "Vaping" product, every day or some days?' Participants who responded 'Yes' were classified as current e-cigarette users. Those who responded 'No' to the question, 'Have you ever used an e-cigarette or electronic vaping product even just one time in your entire lifetime?' were classified as non-users. Current cigarette use was assessed from the question, 'Have you smoked at least 100 cigarettes your entire lifetime?' and if participants were smoking every day or some days when the survey was conducted. Current dual use was assessed from those who responded 'Yes" to both current e-cigarette and cigarette use. Non-users were those who responded 'No' to having smoked at least 100 cigarettes in their entire lifetime and 'No' to the ever use of e-cigarette.

Disability status

Disability status was defined from questions about difficulty hearing; difficulty seeing; difficulty concentrating, remembering, or making decisions; difficulty walking or climbing stairs; difficulty bathing or dressing; and difficulty doing errands alone due to physical, mental, or emotional conditions.[19,20] Participants who responded 'No' to all six questions were grouped as having no disability. Participants could report more than one disability type. Difficulty hearing and seeing were further grouped as sensory disabilities; difficulty concentrating, remembering, or making decisions was considered a cognitive disability, whereas the remaining three were considered disabilities of daily living.

Covariates

The sociodemographic information of participants was included in this study. These included age in years (18–24, 25–34, 35–44), race/ethnicity (non-Hispanic White, non-Hispanic Black, non-Hispanic Other, non-Hispanic Multiracial, and Hispanic), marital status (single, divorced/widowed/separated, and married/partnered), educational attainment (high school or below, attended college/technical school, graduated college/technical school), and income (<$25,000, $25,000 to <$50,000, ≥$50,000). Other measures collected were pregnancy status (pregnant/not pregnant), depression ('Ever told you had a depressive disorder'—Yes/No), self-rated general health (optimal: excellent, very good, good and suboptimal: fair, poor), self-reported current smokeless tobacco use (every day/some days, not at all), past-month marijuana use, and heavy alcohol consumption (Yes/No).

Statistical analysis

All analyses were performed using STATA version 16.1 (StataCorp LP, College Station, TX) and were conducted between December 2021 and December 2022. The characteristics of the study population were analyzed, and the weighted prevalence of the tobacco use patterns was estimated for the covariates and any disability. The Chi-squared test was used to compare the equality of proportions between tobacco use patterns for disability and other covariates. Unadjusted and adjusted multinomial logistic regression models (generalized logit) were used to assess the associations of tobacco use patterns (dependent variable, that is, non-use [reference], current e-cigarette use, current cigarette use, and current dual use of e-cigarette and cigarette) with any disability and type of disability (independent variables). No disability was the reference group for any disability and for type of disability. We adjusted the models for demographic factors (age, race/ethnicity, education, income, marital status), pregnancy status, self-rated health, depression, current smokeless tobacco, past-month marijuana use, and heavy alcohol consumption. We also conducted additional analysis for the associations of current smokeless tobacco use, past-month marijuana use and heavy alcohol consumption with disability status in separate models. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported for the associations of disability with tobacco use patterns. Sampling weights were used in all analyses to account for the complex features of the survey design, and the level of significance was set at an alpha level of 0.05 in consideration of other evidence, such as the magnitude of the association and variability. Because BRFSS is publicly available de-identified data, it is deemed exempt by Florida International University Institutional Review Board.

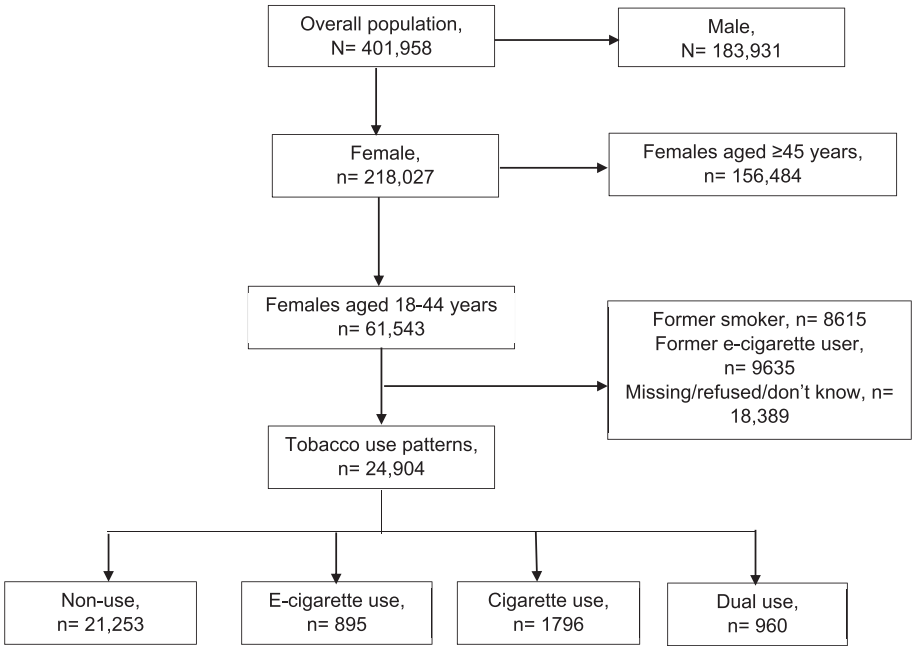

Fig. 1. Flow diagram of study participants.

Results

In the 2020 BRFSS data, the 24,904 women of reproductive age (18–44 years) who had complete data were analyzed in our study. Overall demographic characteristics of the women are presented in Table 1. An estimated 49.5% were non-Hispanic White, 17.1% were non-Hispanic Black, 8.2% were non-Hispanic Other, 1.5% were non-Hispanic multiracial, and 23.7% were Hispanic women (Table 1). Furthermore, 85.8% reported non-use of e-cigarettes and cigarettes, 3.9% reported e-cigarette use, 6.4% reported cigarette use, and 3.8% reported dual use. Among these reproductive-aged women, 18.2% reported any disability. Women with disabilities had a higher prevalence of e-cigarette (8.7% vs 2.9%), cigarette (11.4% vs 5.3%), and dual (9.3% vs 2.6%) use compared with women without disabilities (Table 1).

Women with any disability had higher odds of e-cigarette (OR: 3.82; 95% CI: 2.69–5.43), cigarette (OR: 2.71, 95% CI: 2.17–3.39), and dual use (OR: 4.52; 95% CI: 3.54–5.77) compared with women with no disabilities (Table 2). Associations were similar for women who had cognitive disabilities and disabilities of daily activities. However, we did not observe a significant association between sensory disabilities and e-cigarette use (OR: 1.48; 95% CI: 0.93–2.36). In the adjusted analysis, relative to non-use, women who reported any disability (≥1) had higher odds of e-cigarette (adjusted OR [aOR]: 1.88; 95% CI: 1.15–3.07), cigarette (aOR: 1.58; 95% CI: 1.12–2.25), and dual use (aOR: 2.37; 95% CI: 1.55–3.62) compared with women without disabilities (Table 2). Furthermore, women who reported cognitive disabilities had higher odds of cigarette (aOR: 1.76; 95% CI: 1.17–2.64) and dual use (aOR: 2.16; 95% CI: 1.39–3.37) compared with women without disabilities. Likewise, women with disabilities in daily activities had higher odds of e-cigarette (aOR: 2.99; 95% CI: 1.61–5.55) and dual use (aOR: 2.03; 95% CI: 1.21–3.40) compared with women without disabilities. Stronger associations were found for the associations of sensory disabilities with cigarette (aOR: 1.72; 95% CI: 1.03–2.87) and dual use (aOR: 3.58; 95% CI: 1.84–6.96). We found no significant associations of cognitive (aOR: 1.63; 95% CI: 0.93–2.85) and sensory (aOR: 1.14; 95% CI: 0.37–3.56) disabilities with the use of e-cigarettes. We also found no significant association between disabilities of daily activities with cigarette use (aOR: 1.46; 95% CI: 0.89–2.39). In the additional analyses, we found no significant associations of any disability and disability type with current smokeless tobacco use, past-month marijuana use, and heavy alcohol consumption in the adjusted models (Supplemental Table 1).

Discussion

The associations of e-cigarette only, cigarette only, and dual use with disabilities were assessed in reproductive-aged women. Our findings suggest that women with disabilities have a higher likelihood of cigarette, cigarette, and dual use compared with women without disabilities. Specifically, reproductive-aged women with cognitive disabilities had significantly higher odds of e-cigarette, cigarette, and dual use compared with women without disabilities. Women who reported disabilities in daily activities had higher odds of e-cigarettes and dual use. However, there were no significant differences in e-cigarette use with cognitive and sensory disabilities among reproductive-aged women compared with those without disabilities and those who reported disabilities of daily activities with cigarette use. Our findings provide data about a relatively understudied group who are especially vulnerable to the harms of tobacco use.

Consistent with prior studies[7,21], cigarettes were the most used tobacco product among reproductive-aged women with disabilities. Furthermore, dual use was the next highest proportion among these women. The American College of Obstetricians and Gynecologists recommends that clinicians inquire about all tobacco and nicotine use during prepregnancy, pregnancy, and postpartum periods.[21] This recommendation is because most women of reproductive age may not intuitively equate alternative forms of nicotine (i.e. e-cigarettes) with tobacco use.[21] In addition, cigarettes present significant perinatal risks, such as orofacial clefts, fetal growth restriction, increased perinatal mortality, ectopic pregnancy, and decreased maternal thyroid function.[21] Similarly, e-cigarettes, although less harmful than cigarettes, also contain nicotine, and studies suggest that if used during pregnancy, they can be detrimental to the fetal lung.[21,22] These findings indicate

Table 1
Participant characteristics by current tobacco use among US women of reproductive age (18–44 years), BRFSS 2020 ($N = 24,904$).[a]

Characteristics	Total, *n* (%)	Current tobacco use, *n* (%)			
		Non-use[b]	E-cigarette use	Cigarette use	Dual use
Total	24,904	21,253 (85.8)	895 (3.9)	1796 (6.4)	960 (3.8)
Age (years)[c]					
18–24	4628 (26.0)	3743 (83.4)	593 (10.3)	75 (1.9)	217 (4.5)
25–34	8644 (35.9)	7489 (87.1)	212 (2.7)	568 (6.2)	375 (4.0)
35–44	11,632 (38.1)	10,021 (86.3)	90 (0.7)	1153 (9.8)	368 (3.2)
Education					
High school or below	7317 (38.8)	5580 (80.0)	366 (4.4)	877 (9.9)	494 (5.7)
Attended college/technical school	6935 (30.9)	5645 (84.4)	355 (5.3)	603 (6.3)	332 (4.0)
Graduated college/technical school	10,591 (30.4)	9971 (94.6)	174 (1.9)	313 (2.2)	133 (1.2)
Race/ethnicity					
Non-Hispanic White	14,958 (49.5)	12,500 (81.6)	600 (5.2)	1139 (7.2)	719 (6.1)
Non-Hispanic Black	2823 (17.1)	2477 (86.6)	68 (3.5)	245 (8.6)	33 (1.3)
Non-Hispanic other	2094 (8.2)	1796 (91.1)	72 (3.4)	174 (3.4)	52 (2.0)
Non-Hispanic multiracial	711 (1.5)	542 (78.0)	43 (5.3)	77 (10.8)	49 (6.1)
Hispanic	3967 (23.7)	3622 (92.4)	107 (1.8)	148 (4.3)	90 (1.5)
Income					
<$25,000	5116 (29.3)	3840 (78.4)	228 (3.9)	671 (10.7)	377 (7.1)
$25,000 to <$50,000	4628 (21.2)	3783 (82.8)	176 (4.1)	437 (8.2)	232 (5.0)
≥$50,000	11,034 (49.6)	10,075 (90.7)	280 (3.6)	475 (3.8)	204 (1.8)
Marital status					
Single	8534 (40.5)	6900 (82.8)	597 (6.8)	638 (6.1)	399 (4.3)
Divorced/widowed/separated	2613 (9.2)	1942 (77.0)	62 (1.8)	381 (13.5)	228 (7.7)
Married/partnered	13,585 (50.2)	12,260 (89.8)	228 (2.0)	769 (5.5)	328 (2.8)
Pregnancy status					
Yes	888 (3.7)	827 (93.3)	12 (1.5)	36 (4.3)	13 (0.9)
No	23,781 (96.3)	20,219 (85.5)	875 (4.0)	1748 (6.5)	939 (4.0)
Depression					
Yes	5963 (22.9)	4280 (69.8)	407 (9.0)	688 (10.8)	588 (10.4)
No	18,797 (77.1)	16,856 (90.6)	478 (2.4)	1098 (5.1)	365 (1.9)
Self-rated health					
Suboptimal	2176 (9.3)	1574 (72.7)	99 (5.8)	312 (13.2)	191 (8.3)
Optimal	22,699 (90.7)	19,654 (87.2)	795 (3.7)	1483 (5.7)	767 (3.4)
Current smokeless tobacco					
Yes	291 (1.1)	150 (44.7)	28 (15.4)	60 (20.5)	53 (19.5)
No	24,591 (98.9)	21,084 (86.3)	867 (3.8)	1733 (6.3)	907 (3.7)
Past-month marijuana					
Yes	968 (8.1)	436 (39.4)	170 (18.5)	161 (16.0)	201 (26.1)
No	11,086 (91.9)	9860 (88.6)	253 (2.6)	707 (6.5)	266 (2.4)
Heavy alcohol consumption					
Yes	1284 (4.5)	783 (60.2)	115 (10.6)	236 (16.8)	150 (12.5)
No	23,032 (95.5)	20,006 (87.0)	740 (3.6)	1509 (5.9)	777 (3.5)
Any disability					
Yes	4087 (18.2)	2809 (70.6)	305 (8.7)	529 (11.4)	444 (9.3)
No	20,817 (81.8)	18,444 (89.2)	590 (2.9)	1267 (5.3)	516 (2.6)

BRFSS, Behavioral Risk Factor Surveillance System.
[a] Percentages may not total 100% in each category due to rounding. *Ns* are unweighted. The difference between the tobacco use patterns was significant for all included covariates at $P < .001$, determined by the Chi-squared test. Analytic *ns* do not always add to total in columns due to missing data.
[b] Non-use: no use of e-cigarettes or cigarettes; e-cigarette use: individuals reporting current use of e-cigarettes only; cigarette use: individuals who report current use traditional cigarette use only; dual use: individuals who report both current e-cigarette and cigarette use.
[c] Distribution across tobacco use patterns are row percentages.

that more work needs to be done, especially in at-risk groups, such as women of reproductive age with disabilities, to reduce the prevalence of use. The high rates of nicotine use in this group of women remain a source of regulatory concern and point at gaps that need to be bridged in the concerted attempt by tobacco control advocates to reduce the burden of tobacco-induced diseases in the United States.

Prior research in the United States has indicated that people with disabilities are generally more prone to substance use than those without disabilities.[23–25] In the present study, participants with cognitive disabilities and disabilities of daily activities were more likely to use all tobacco products studied compared with those without these disabilities. The higher likelihood of smoking among persons with disabilities may be ascribed to a sense of entitlement.[24] However, this association might also be explained by the cumulative mental and social stressors associated with a disability, which could increase the susceptibility to smoking, as well as other substance use. Furthermore, stigma related to these disabilities and internalizing of negative stereotypes by this group might encourage sensation-seeking or an entitled status to engage in substance use and smoking.[24] Although tobacco products are inherently harmful to this population, perceived short-term benefits of these products can also encourage use. For example, they may help reduce anxiety and improve mood.[25] Therefore, women of reproductive age with disabilities will benefit from policies and programs that proactively educate them about the risks of tobacco product use to enable them make healthy and informed decisions. Based on these findings, women of reproductive age with disabilities might benefit from counseling about the personal and fetal risks of tobacco product use. The American College of Obstetricians and Gynecologists recommends that clinicians advise cessation of tobacco products in any form.[21] Future studies can explore the

Table 2
Associations between current tobacco use and disability status among reproductive-aged women (18–44 years), BRFSS 2020.

Disabilities	Current tobacco use[a]		
	E-cigarette use	Cigarette use	Dual use
	Crude OR (95% CI)		
Any disability[b]			
Yes	3.82 (2.69–5.43)	2.71 (2.17–3.39)	4.52 (3.54–5.77)
No	ref	ref	ref
Sensory disabilities			
Yes	1.48 (0.93–2.36)	2.85 (2.02–4.04)	4.37 (2.80–6.83)
No	ref	ref	ref
Cognitive disabilities			
Yes	5.27 (3.51–7.91)	2.95 (2.26–3.84)	5.70 (4.40–7.39)
No	ref	ref	ref
Disabilities of daily activities			
Yes	4.44 (2.78–7.09)	3.76 (2.90–4.88)	5.79 (4.39–7.63)
No	ref	ref	ref
	Adjusted ORs (95% CIs)[c]		
Any disability			
Yes	1.88 (1.15–3.07)	1.58 (1.12–2.25)	2.37 (1.55–3.62)
No	ref	ref	ref
Sensory disabilities			
Yes	1.14 (0.37–3.56)	1.72 (1.03–2.87)	3.58 (1.84–6.96)
No	ref	ref	ref
Cognitive disabilities			
Yes	1.63 (0.93–2.85)	1.76 (1.17–2.64)	2.16 (1.39–3.37)
No	ref	ref	ref
Disabilities of daily activities			
Yes	2.99 (1.61–5.55)	1.46 (0.89–2.39)	2.03 (1.21–3.40)
No	ref	ref	ref

BRFSS, Behavioral Risk Factor Surveillance System; CI, confidence interval; OR, odds ratio.
[a] Non-use (reference): no use of e-cigarettes or cigarettes; e-cigarette use: individuals reporting current use of e-cigarettes only; cigarette use: individuals who report current use traditional cigarette use only; dual use: individuals who report both current e-cigarette and cigarette use.
[b] Any disability: includes sensory, cognitive, and daily activities; sensory disability includes difficulty hearing or seeing; cognitive disability includes difficulty concentrating, remembering, or making decisions; daily activity includes difficulty dressing/bathing, difficulty with errands or difficulty in walking. No disabilities was the reference group for all disabilities.
[c] Model adjusted for age, education, race/ethnicity, income, marital status, pregnancy status, depression, self-rated health, smokeless tobacco use, past-month marijuana use, and heavy alcohol consumption.

reasons for the use of tobacco products among reproductive-aged women living with disabilities to strengthen individualized psychosocial and behavioral cessation interventions.

Our findings should be interpreted with caution for several reasons. First, we used the BRFSS measures of cognitive, daily, and sensory disability, which are self-reported and may not reflect experienced disability. Also, the estimates of disability might be inaccurate or under-reported, as the survey may be inaccessible to people with cognitive or sensory disabilities based on limitations of the BRFSS survey mode. Second, the overall median response rate to the BRFSS survey in 2020 was 47.9%. If the relationship between tobacco use and disability status among reproductive-aged women differed for people who did not respond to the survey, there could be the possibility of selection bias in the study. Similarly, the survey sampled non-institutionalized US adults, excluding those that are institutionalized who tend to have high proportions of individuals with disabilities; thus, our results may not be representative of all reproductive-aged women with disabilities. Finally, an alternative explanation for the association reported in this study might be that tobacco use, especially cigarettes, can directly or indirectly increase the risk of cognitive disabilities. For example, several studies have demonstrated that tobacco use can impair physical health over time and exacerbate underlying cognitive dysfunction.[26,27] Nonetheless, we used a nationally representative sample in a relatively understudied population. Furthermore, because tobacco use is generally decreasing in the United States, targeted efforts are warranted to protect the health of vulnerable groups, such as reproductive-aged women with disabilities.

Conclusion

In conclusion, we found significantly higher rates of current cigarette use, e-cigarette use, and dual use of e-cigarettes and cigarettes among women of reproductive age with one or more disabilities than those without disabilities. However, these cross-sectional data are descriptive, and our analysis represents associations rather than causal relationships. Our findings provide important preliminary evidence for e-cigarette and dual e-cigarette and cigarette use among reproductive-aged women with disabilities. Given the results reported herein, the harmful health effects of tobacco and nicotine on maternal, pregnancy, and fetal development, and direct health care costs associated with cigarette smoking,[21,25] examination of effective differential messaging and appropriate smoking cessation programs is crucial for reproductive-aged women with disabilities. Qualitative and longitudinal research are needed to explore motivations for tobacco use among reproductive-aged women with disabilities. Furthermore, improved screening for the use of nicotine products among women of reproductive age with disabilities may be necessary to lessen the use of nicotine products in this vulnerable population.

Author statements

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Ethical approval

Florida International University institutional review board deemed study exempt due to publicly available de-identified data.

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Competing interests

None declared.

Prior presentations

The abstract of this work was presented at the 2022 annual meeting of the Society for Nicotine & Tobacco Research, March 15–18, Baltimore, MD.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.012.

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Original Research

Effectiveness of a preschool emotional education programme administered over 3 grades: a cluster randomised controlled trial

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ABSTRACT

Introduction: Emotional education programmes are universal preventive strategies for health promotion, especially mental health. The aim of this study is to evaluate the effectiveness and implementation of '1,2,3, emoció!': a preschool-based programme designed to improve emotional competence and targeted to 3–5-year-old children in Barcelona during three academic years.
Study design: Cluster randomised trial, using schools as clusters.
Methods: The study's population included preschoolers 3-5 years old from Barcelona. Teachers offered the programme during one or three academic years in the intervention groups. We evaluated the emotional competence of each child at the beginning and the end of the academic year with the Emotional Competence Assessment Questionnaire (30–180 scale). We studied the implementation process and analysed the outcomes with nested linear regression models. Considering sociodemographic variables and implementation outcomes, we obtained the individual differences in emotional competence at the end of the school year—segregated by sex—for intervention and comparison groups.
Results: 1586 children participated in the study. The emotional competence level increased significantly after one year (4.1 in boys; 5.6 in girls; $P < 0.05$) and after three years of intervention (5.5 in boys; 8.0 in girls; $P < 0.01$), compared to comparison group. The level of emotional competence was the highest for the 3-year intervention group: we obtained an average ECAQ score of 131.1 (95% CI 126.9–135.2) for boys and 141 (95% CI 137.2–144.9) for girls. We observed that an accurate implementation improved its results.
Conclusions: The programme '1,2,3, emoció!' effectively increases preschool children's emotional competence, especially when the programme is rigorously implemented for three years.

Introduction

In recent years, the awareness of mental health issues in childhood and adolescence has increased at the European level.[1,2] In Barcelona, 2021's adolescent health survey found that four out of 10 girls and two out of 10 boys, aged 13 to 19, suffered emotional distress.[3] Various programmes and actions have been developed, implemented, and evaluated to promote emotional competence or Socio-Emotional Learning (SEL). These actions improve the emotional well-being of children and young adults and prevent mental health issues and high-risk behaviours.[4–9] To further understand these programmes, different systematic reviews and meta-analyses have studied their effectiveness.[10–21] Overall, these studies have found positive effects when socio-emotional skills and attitudes are further developed: emotional well-being increased,[11,12,16] academic skills[10,12,17] and social relationships

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improved[10,11,16,17]; and emotional stress,[11–13,16] substance use,[14–17] police arrests,[14] risky sexual behaviour,[11,16] and presence of psychiatric symptomatology decreased.[13,16,17,20] They have also analysed the influence of different socio-demographic variables on the effectiveness of SEL programmes. The variables included were gender, socioeconomic status,[5,11,22] and special educational needs,[10] which did not interfere with a programme's effectiveness. Some contributions highlight that social determinants, like the level of tension and conflict in the neighbourhood, affect young people's emotional distress.[5,23] However, this effect has not been analysed in the outcomes of SEL interventions. Therefore, it is necessary to monitor how the social environment[12] affects emotional health.[24–26]

Emotional competence should be developed throughout the life cycle,[27,28] and preschool age from 3 to 5 years is postulated as an ideal time to initiate it.[10,18] There are several reasons for this. First, early life is a period of great opportunity to promote health behaviours because of the impact on adult life.[29,30] Moreover, between 3 and 5 years of age, infants develop significant social and emotional competencies.[30] Finally, children's behaviours tend to stabilise around the age of 8 years,[30] so it is necessary to intervene before to avoid that maladaptive behaviours are consolidated.

The emotional education programme '1,2,3, emoció!'[31] was developed by the Barcelona Public Health Agency and targeted children in preschool education: P3 (3-years-olds), P4 (4-year-olds), and P5 (5-year-olds). It aims to promote mental health and prevent high-risk behaviour by developing emotional competence. '1,2,3 emoció!' is an adaptation of the Social and Emotional Aspects of Learning (SEAL) programme.[32] It follows the theoretical bases proposed by Bisquerra,[33,34] which establish a model of emotional competence considering five main skills: emotional awareness, emotional regulation, emotional autonomy, social competence, and life skills and well-being. The programme includes 20 h of online training for the teachers involved and has a didactic guide (for each grade) that includes 48 activities to carry out in the classroom and six activities to propose to families. It also has a complementary guide including 12 activities for outside the classroom, but within the school environment (e.g., in the school canteen). The programme has six thematic units: 1) belonging, 2) self-esteem, 3) friendship, 4) challenges, 5) justice and harassment, and 6) change, loss, and death. A detailed description of '1,2,3 emoció!' can be found in other works.[35,36] In the 2017–18 academic year we conducted a pilot test of the provisional version of the programme, which allowed our research team to improve it and create the final version. The latter was implemented the following academic year (2018–19). In the 2020–21 academic year, some students had completed the programme for three academic years and others had completed it for a single academic year.

Any public health intervention, such as school-based emotional education programmes that aim to promote emotional competence, must be evaluated before mass dissemination and implementation to observe whether the results are as expected.[37] This evaluation to assess the effectiveness of the programme requires both an evaluation of results and an evaluation process for the implementation.[38–40] To ensure that the SEL programme's objectives were met and to facilitate its replication, we evaluated its effectiveness[37] and analysed the implementation process: coverage, exhaustivity, and fidelity.[39,41,42]

The objectives of this study were the following: 1) to evaluate the effectiveness of the emotional education programme '1,2,3, emoció!' in 3- to 5-year-old children from preschools in the city of Barcelona and 2) to compare the results obtained between the comparison group, the 1-academic-year intervention group, and the 3-academic-year intervention group.

Methods

Study design and population

We conducted a cluster randomised controlled trial, with schools being the randomization unit. The study population consisted of 3- to 5-year-old preschoolers from Barcelona. In the second quarter of 2017, all preschools in the city of Barcelona were invited to participate in the programme for the next school year 2018–19. We used a convenience sample: schools that accepted and signed the informed consent form were randomly distributed between the intervention and the comparison groups. To ensure comparability between groups, the schools were randomised by stratifying by socioeconomic level, according to the average income of the school neighbourhood (high/low), and the type of school, according to its ownership (public or private/semi-private). Additionally, the number of classes for each preschool year was weighted to ensure a similar number of children in each group. The OxMaR - Oxford Minimization and Randomization system was used.

Through this randomisation, three groups were formed according to whether: 1) they participated in '1,2,3, emoció!' during the three years of preschool (P3, P4, and P5, Complete Programme - CP); 2) they participated in the programme for only one year (P5, Partial Programme - PP); and 3) they did not participate in the programme (Comparison - C). Teachers assessed the level of emotional competence of all children of the three groups at the beginning and the end of the final year of preschool (P5). The implementation and evaluation of the programme took place for the academic years: 2018–19, 2019–20, and 2020–21. Our research protocol was approved by the Research Ethics Committee of Parc Salut Mar under number 2019/850/I.

Study variables and data collection

To evaluate the implementation of the programme, we analysed different variables: coverage of the programme in the city of Barcelona, exhaustivity, and fidelity. We extracted this information from the activity records completed by teachers. Exhaustivity or "intervention dose' was classified as "'high' —when children completed four or more classroom activities for each of the six thematic units—or "low'—when children received less than four classroom activities in one or more units. Fidelity was defined as "high'—when the intervention was 'high' in exhaustivity and included at least three family activities—or 'low'—when the intervention was 'low' in exhaustivity and/or did not include at least three family activities.

To evaluate the outcome, the dependent variable was the level of emotional competence measured with the Emotional Competence Assessment Questionnaire (ECAQ). ECAQ is a 30-item questionnaire with a Likert-type response scale with six options (from 1 = Never to 6 = Always), so its total score can range from 30 to 180 points. The ECAQ measures emotional competence in 3- to 5-year-olds and it is answered by teachers. This instrument shows good evidence of validity and reliability.[43]

The main independent variable was the type of participation in the programme (CP, PP, or C). We also analysed other independent variables, which were provided by the teacher: gender ("'boy' or "'girl') and the presence of special educational needs ("yes' or "'no'). Finally, we considered the following socio-demographic variables: 1) year of the assessment (2018–19, 2019–20, or 2020–21); 2) type of school ("'public' or "private or semi-private'), extracted from the databases of the Barcelona Education Consortium; 3) socioeconomic level ("'high' or "'low'); and 4) perception of insecurity in the neighbourhood ("'high' or "'low'). The socio-economic status

of the school's neighbourhood was determined with the 2018 Territorial Socio-economic Index (TSI) from the Statistical Institute of Catalonia.[44] The TSI gathers information on the employment status, educational level, immigration rate, and income of all residents within a given territory. The reference value for Catalonia (equal to 100) was used to dichotomise the variable ('"high' or '"low'). The perception of neighbourhood insecurity was collected from the 2018's Barcelona victimisation survey, which shows the percentage of the population > 16 years old that consider their neighbourhood unsafe.[45,46] This variable was dichotomised ('"high' or '"low') according to the average value for Barcelona (equal to 17.1).

Data analysis

We analysed the sample considering the type of participation in the programme (CP, PP, or C) and we identified differences between the various individual and contextual variables with the Chi-square test. We examined the relationship between the level of emotional competence at the beginning and the end of the final year of preschool (P5) (pre- and postintervention scores, respectively) and the type of participation with BoxPlot graphs (see Fig. 1). For each type of participation, these differences were verified by comparing the mean levels of emotional competence in pre- and postintervention. To evaluate the effectiveness of the programme, we designed a multiple linear regression model with paired measures. The postintervention score was the dependent variable and the type of participation in the programme was the main independent variable. In addition, the model was adjusted with the pre-intervention score, the year of the assessment and individual and/or contextual variables (special educational needs, school type, socio-economic status of the neighbourhood, and perception of insecurity in the neighbourhood). Finally, we analysed the association between the exhaustivity and fidelity in the programme's implementation and the increase in the postintervention score for participants in the CP group by comparing means. All analyses were stratified by gender. Data were analysed with STATA v.15 with a 95% confidence interval (CI) and a *P*-value < 0.05 for significance.

Results

Thirty-five out of the 201 (17.4%) schools in the city of Barcelona and 70 teachers (97.1% women) participated in the study. This included 1586 children (48.0 boys and 52.0% girls) of whom 360 were in the CP group (22.7%), 449 in the PP group (28.3%), and 777 in the C group (49%) (see Table 1). We observed no statistically significant differences concerning gender or special educational needs among the participants in different groups. There was a higher representation of public schools in the CP group than in the PP and C groups (CP: 76.9%, PP: 61.3%, C: 61.3%; P = < 0.001). Similarly, in the CP group there was a higher percentage of schools located in low socio-economic neighbourhoods (CP: 46.7%, PP: 34.5%, C: 40.9%; *P* = 0.002). In the C group, there was a higher representation of schools located in neighbourhoods where the perception of insecurity was low (CP: 53.1%, PP: 54.3%, C: 66.5%; P = < 0.001).

As shown in Fig. 1, at the end of P5, the level of emotional competence had increased in all three groups for both boys and girls. However, this increase was greater in the two groups that carried out the intervention (CP and PP). Furthermore, pre-intervention and postintervention scores were higher in the CP group in comparison to the other two. We corroborated these differences by the comparison of means (see Table 2). We observed significant differences between the mean pre-intervention scores of all children in the C and PP groups and those in the CP group, both in boys [CP 121.3 (95% CI 117.6–125); PP: 110 (95% CI 106.8–113.1); C: 112.5 (95% CI 110.1–114.8)], and in girls [CP: 130.9 (95% CI 127.3–134.6); PP: 119 (95% CI 116.2–121.8); C: 123.5 (95% CI

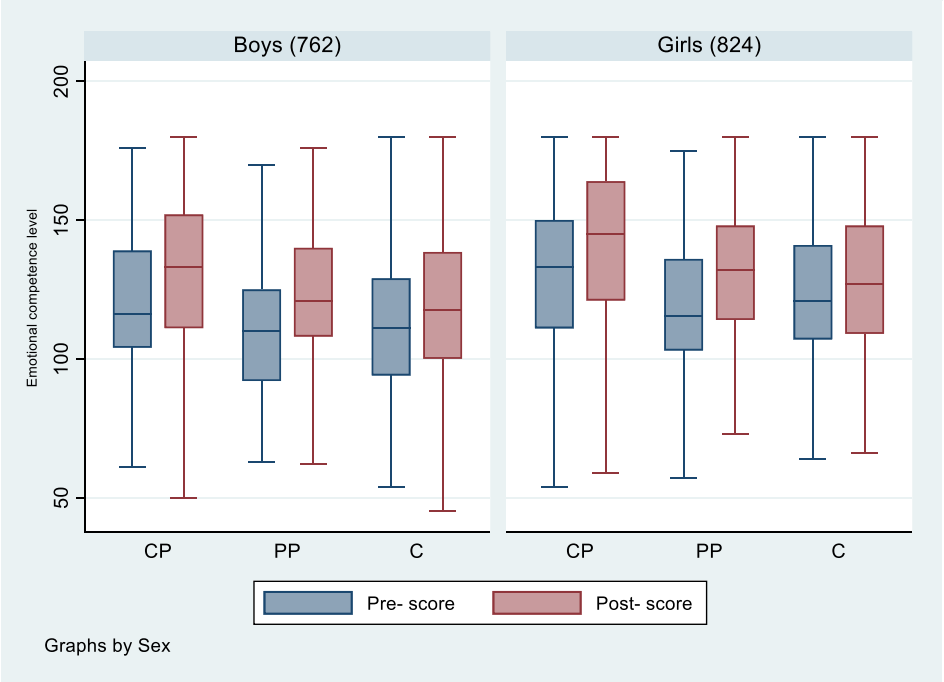

Fig. 1. Pre- and postintervention emotional competence level of boys and girls participating in the study, organised by type of participation. Barcelona, 2020–21 (*N* = 1586). Emotional competence level measured with the Emotional Competence Assessment Questionnaire (ECAQ); score range: 30–180 points. CP: Complete Programme; PP; Partial Programme; C: Comparison.

Table 1
Characteristics of the sample organised by intervention group. Barcelona, 2020–21 ($N = 1586$).

Variables	Complete Programme (360)		Partial Programme (449)		Comparison (777)		*P*-value[a]
	N	%	*N*	%	*N*	%	
Gender							
Boy	171	47.5	203	45.2	388	49.9	0.273
Girl	189	52.5	246	54.8	389	50.1	
Special educational needs							
Yes	5	1.4	18	4.0	20	2.6	0.070
No	355	98.6	431	95.6	757	97.4	
Type of school							
Public	277	76.9	275	61.2	476	61.3	< 0.001*
Private or semi-private	83	23.1	174	38.8	301	38.7	
Socioeconomic level of the neighbourhood							
High	192	53.3	294	65.5	459	59.1	0.002*
Low	168	46.7	155	34.5	318	40.9	
Insecurity perception in the neighbourhood							
High	169	46.9	205	45.7	260	33.5	< 0.001*
Low	191	53.1	244	54.3	517	66.5	

[a] Chi-square test, statistical significance: <0.050 (* significant).

Table 2
Mean comparison of emotional competence levels at the beginning and the end of the year (pre- and postintervention scores and score differences), organised by intervention type and stratified by gender. Barcelona, 2020–21 ($N = 1586$).

Intervention type	Boys (762)					
	Prescore		Postscore		Score differences	
	Mean (SD)	*95% CI*	*Mean (SD)*	*95% CI*	*Mean (SD)*	*95% CI*
Complete Programme	121.3 *(1.9)*	117.6–125.0	131.1 *(2.1)*	126.9–135.2	12.1 *(1.3)*	9.5–14.7
Partial Programme	110.0 *(1.6)*	106.8–113.1	122.1 *(1.8)*	118.6–125.6	9.8 *(1.4)*	7.0–12.5
Comparison	112.5 *(1.2)*	110.1–114.8	119.5 *(1.4)*	116.8–122.2	7.0 *(0.9)*	5.3–8.8
	Girls (824)					
	Prescore		Postscore		Score differences	
	Mean (SD)	*95% CI*	*Mean (SD)*	*95% CI*	*Mean (SD)*	*95% CI*
Complete Programme	130.9 *(1.9)*	127.3–134.6	141.0 *(1.9)*	137.2–144.9	12.5 *(1.2)*	10.0–14.9
Partial Programme	119.0 *(1.4)*	116.2–121.8	131.5 *(1.5)*	128.6–134.4	10.1 *(1.4)*	7.4–12.8
Comparison	123.5 *(1.2)*	121.2–125.8	129.2 *(1.3)*	126.6–131.8	5.6 *(0.8)*	4.0–7.3

Emotional competence level measured with the Emotional Competence Assessment Questionnaire (ECAQ); score range: 30–180 points.
SD: Standard Deviation; 95% CI: 95% Confidence Interval.

121.2–125.8)]. The postintervention mean scores were also higher in the CP group than in the PP and C groups, with significant differences in both boys [CP: 131.1 (95% CI 126.9–135.2); PP: 122.1 (95% CI 118.6–125.6); C: 119.5 (95% CI 116.8–122.2)], and girls [CP: 141 (95% CI 137.2–144.9); PP: 131.5 (95% CI 128.6–134.4); C: 129.2 (95% CI 126.6–131.8)].

Table 3 describes the results of the multiple linear regression model on the postintervention score. The data were adjusted considering the pre-intervention score, the year of the assessment, and the individual and contextual variables (special educational needs, school type, socioeconomic status, and perception of insecurity in the school's neighbourhood). We stratified results by gender. Participation in either the CP or PP group positively contributed to the final emotional competence score for both boys and girls. For boys, the postintervention emotional competence level score was 4.1 points higher (95% CI: 0.8–7.4) in the PP group and 5.5 points higher (95% CI: 1.7–9.3) in the CP group, in comparison to the C group. In the case of girls, we obtained a similar result: an increase in the postintervention score of 5.6 points (95% CI: 2.5–8.7) in the PP group and of eight points (95% CI: 4.2–11.7) in the CP group, in comparison to the C group. In conclusion, children who participated in '1,2,3, emoció!' showed an increased level of emotional competence at the end of P5. This increase was greater for those children who participated in the programme throughout the whole preschool education stage.

Table 3
Multiple linear regression models[a] of the emotional competence level (post-intervention score) stratified by gender. Barcelona, 2020–21 ($N = 1586$).

Intervention type	Boys (762)			Girls (824)		
	Coef.	*SE*	*95% CI*	*Coef.*	*SE*	*95% CI*
Complete Programme	5.5*	1.9	(1.7–9.3)	8.0**	1.9	(4.2–11.7)
Partial Programme	4.1*	1.7	(0.8–7.4)	5.6**	1.6	(2.5–8.7)
Comparison	-	-	-	-	-	-

Emotional competence level measured with the Emotional Competence Assessment Questionnaire (ECAQ); score range: 30–180 points.
- Reference value; Coef.: coefficient; SE: Standard Error; * Statically significant (*P*-value < 0.05); ** Statically significant (*P*-value < 0.01).
[a] Data is adjusted by emotional competence pre-intervention, year of evaluation, and individual and contextual socio-demographic variables (type of school, special educational needs, socio-economic level of the neighbourhood, and insecurity perception in the neighbourhood).

Finally, Table 4 shows the relationship between the exhaustivity and fidelity in the programme's implementation and the level of emotional competence of participants in the CP group through a comparison of means. We observed that high exhaustivity and fidelity relate to higher scores at the end of the school year. Boys who completed the programme exhaustively increased an average of 13.5 points (95%CI: 10.5–16.6), while those who did not do all the activities only increased an average of 2.4 points (95% CI: −2.6–7.4).

Table 4
Emotional competence level (pre- and post-intervention scores and score differences). Results are organised by the level of exhaustivity and fidelity on programme implementation at Complete Intervention group schools and stratified by gender. Barcelona, 2020–21 ($N = 360$).

Implementation variables	Boys (171)					
	Prescore		Postscore		Score differences	
	Mean (SD)	*95% CI*	*Mean (SD)*	*95% CI*	*Mean (SD)*	*95% CI*
Exhaustivity						
High	121.0 *(2.1)*	117.0–125.1	134.5 *(2.4)*	129.7–139.3	13.5 *(1.6)*	10.5–16.6
Low	121.7 *(3.9)*	113.8–129.6	124.1 *(3.9)*	116.2–132.0	2.4 *(2.5)*	- 2.6–7.41
Fidelity						
High	120.1 *(2.5)*	115.8–125.1	140.6 *(3.0)*	134.5–146.6	20.5 *(2.3)*	15.9–25.0
Low	121.8 *(2.5)*	116.8–126.9	126.4 *(2.7)*	121.2–131.7	4.6 *(1.5)*	1.5–7.7
	Girls (189)					
	Prescore		Postscore		Score differences	
	Mean (SD)	*95% CI*	*Mean (SD)*	*95% CI*	*Mean (SD)*	*95% CI*
Exhaustivity						
High	127.4 *(2.2)*	123.0–131.8	141.6 *(2.5)*	136.6–146.7	14.2 *(1.6)*	11–17.5
Low	136.0 *(3.2)*	129.7–142.3	140.1 *(3.1)*	134.0–146.3	4.1 *(2.2)*	- 0.4–8.51
Fidelity						
High	126.4 *(3.3)*	119.8–133.0	150.7 *(3.3)*	144.0–157.5	24.3 *(2.8)*	18.7–29.9
Low	132.3 *(2.2)*	127.8–136.6	138.2 *(2.3)*	133.6–142.7	5.9 *(1.4)*	3.1–8.7

Emotional competence level measured with the Emotional Competence Assessment Questionnaire (ECAQ); score range: 30–180 points.
SD: Standard Deviation; 95% CI: 95% Confidence Interval.

For girls, this increase was 14.2 (95% CI: 11–17.5) and 4.1 (95% CI: −0.4–8.5) points, respectively. Similarly, completing the programme with high fidelity increased the level of emotional competence at the end of the school year by 20.5 points (95%CI: 15.9–25) for boys and 24.3 points (95%CI: 18.7–29.9) for girls, in comparison to 4.6 (95% CI: 1.5–7.7) and 5.9 (95% CI: 3.1–8.7) points for boys and girls, respectively, who receive the programme with low fidelity.

Discussion

The results of our study indicate that participation in the emotional education programme '1,2,3, emoció!' significantly improved children's emotional competence. This was especially true for children—both boys and girls—who participated in the programme during the three years of the preschool education. We also observed that a high exhaustivity and fidelity in the programme's implementation led to a higher postintervention score.

Boys and girls, who participated in the programme, both for one and three years, significantly increased their emotional competence, in comparison to those who did not participate. Our work confirms the result obtained in a previous study, which showed that children who participated in the programme for one school year increased their level of emotional competence more than those who did not.[47] Although the increase in emotional competence was similar between the CP and the PP groups, children from the CP group began the final year of preschool with a higher level of emotional competence, probably because they participated in the programme also during the previous two years. This further corroborates that an early implementation and completion of an emotional education programme leads to a higher emotional competence.[10,29,48]

Another aspect that has most likely influenced the effectiveness of the programme is the previous training of the implementers as previously reported in other studies.[49] It is known that when the teacher believes in the program's results and shares experiences with the students, the effectiveness of the programme is higher.[50] On the contrary, when teachers have negative attitudes towards the programme, the results obtained are lower.[51,52]

Our study also proves that '1,2,3, emoció!' improves emotional competence independently of individual and contextual characteristics. This finding is in line with other published works that show the universal benefits of these types of programmes.[5,12,22] However, its effectiveness is related to an exhaustive and accurate implementation. The association between an optimum implementation and the results obtained appears in the analyses of various authors.[39,41,42] All these contributions urge schools to report and follow up on these variables to maintain the results after the evaluation phase.

Nevertheless, our work has some limitations. First, individualised socio-economic data were unavailable. However, since '1,2,3, emoció!' is a school-based programme, we prioritised identifying whether a certain type of school profile could benefit from this intervention, resulting in aggregated data for each school. Second, teachers in the CP group may have generated some bias in their responses to the ECAQ because of their familiarity with the questionnaire. However, the existence of different groups for comparison (PP and C) should have compensated for these possible biases. Moreover, the fact that the questionnaire was not self-administered, could also have made the collected scores more prone to bias. However, teachers spend a substantial number of hours every day with children, so the scoring is likely to be accurate. This contrasts with other school programmes in which the children are evaluated by the researchers or not at all. Also, we do not have data on the relationships in the classroom. However, this aspect was explored in a previous study that included qualitative methodology and detected an improvement in relationships between classmates, an increase in empathy, an improvement in conflict resolution, and a decrease in violence after the programme. Finally, the SARS-CoV-2 pandemic and its different preventive measures may have affected students' emotional competence. In any case, the comparison groups that were equally affected compensated this possible bias. We included the pandemic's effect by adjusting the models for the year of the assessment.

This study has three key strengths: 1) its randomized design with the comparison group, that allowed us to assume a similar distribution of possible confounders and to minimise diffusion among participants and non-participants;[53] 2) the evaluation of the implementation process, that enabled us to correctly interpret the results of the intervention;[39,40,42] and 3) the breadth of the sample and the longitudinal follow-up (i.e., three years).[11]

The results shown here are consistent with available evidence on the effectiveness of SEL programmes. As a SEL programme,

'1,2,3, emoció!' promotes emotional education by promoting emotional competence, reducing risk factors and reinforcing protective mechanisms for positive adaptation.[12] The content of '1,2,3, emoció!' focuses on emotional awareness and regulation, self-esteem, problem solving, and establishment of positive relationships with others through various structured sessions that are developed over several academic years as in the Positive Attitude programmes in Portugal[54] or the PATHS (Promoting Alternative Thinking Strategies) programme in the United States,[55] or Be You in Australia.[56] The results also provide further knowledge on the programme's implementation thanks to a rigorous evaluation, as suggested by several reviews.[20,39,41] The '1,2,3, emoció!' programme has demonstrated its effectiveness in increasing the emotional competence of three- to 5-year-old children. For this reason, we highly recommend implementing this programme in preschools throughout the three years of this stage of education in a comprehensive manner to ensure its success.

Author statements

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None declared.

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Original Research

Evaluation of the allocation efficiency of medical and health resources in China's rural three-tier healthcare system

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ABSTRACT

Objectives: Evaluating the efficiency of health resource allocations is critical to improving China's rural three-level health service network.
Study design: This was a prospective panel data study.
Methods: Based on panel data of the medical and health resources of 31 provinces within rural China, collected from 2003 to 2020, this study uses a three-stage Data Envelopment Analysis–Malmquist index to analyze the evolution of efficiency and productivity.
Results: The efficiency and productivity of county and county-level medical and health institutions rank highest, followed by township hospitals, whereas village clinics are shown to be in great need of improvement. A decline in technical advancement appears as a crucial factor exacerbating loss of factor productivity.
Conclusions: Policy makers should further optimize the efficiency of medical resource allocation and promote the coordinated development of rural health in China.

Introduction

People's health is tied to national prosperity. Historically, compared with China's urban counterparts, rural residents are more prone to health concerns, such as cardiovascular, cerebrovascular, and metabolic chronic diseases. This is attributed to a 'backward culture', lack of knowledge, and poor awareness regarding disease prevention and control. At the same time, the COVID-19 outbreak has pushed healthcare concerns into the public spotlight. Efficient and judicious allocation of medical resources stands out as essential to any effort at modernization of the health governance system.[1]

'Strategic Plan for Rural Revitalization in China (2018–2022)' asserted that the development of national social undertakings should prioritize directing medical and health resources to rural areas.[2] China's rural three-tier health service network consists of, leading at the top, county-level municipal health institutions (CMHIs), township hospitals (THs) acting as hubs and, at the bottom, village clinics (VCs).[3] As China aims to implement medical reform, lingering deep-seated contradictions in the institutional and structural health system, however, have seen developments stall.[4]

In recent years, researchers have attempted to define, quantify, evaluate, and promote efficiency. Cheng[5] conducted a study of health systems in 171 countries around the world and found that maternal and under-five mortality most impacted national health systems. Ethiopia, for example, has improved maternal, newborn, and child health indices by rapidly expanding medical services to rural areas and, in so doing, leveraged international attention and funding.[6] Similarly, a large number of scholars have analyzed the efficiency of China's medical institutions. Zhao used the four-stage Data Envelopment Analysis (DEA) method to measure the service efficiency of China's rural medical institutions and found significant differences between county and township levels.[7] Tang[8] also found that in Jiangsu Province, the relative input-output efficiency of THs was weak, whereas VCs were non-DEA efficient. Yet, no studies have comprehensively evaluated the efficiency of health resource allocation in China's rural three-tier medical and health system. China's current health care delivery standard has reached that of moderately developed countries. This is despite the burden of chronic diseases and health resource shortages. Therefore, the achievements of China in health are expected to be instructive to

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countries similarly poorly endowed in terms of resources but looking to elevate their health outcomes. In this regard, this study provides a benchmark for horizontal comparison across different levels of medical and health institutions, static and dynamic difference analysis, and efficiency maximization of different health resources.

This study aims to systematically evaluate the efficiency characteristics and changes of medical and health resources allocation in China's rural three-tier medical and health system. So as to provide a reference benchmark against which government will be better positioned to optimize input-output and control operation scales optimized to local conditions.

Methods

Variables selection

Referring to previous studies of public health for precedent,[9] we use input and output indicators, supplemented by environmental variables, to measure efficiency. Input indicators primarily comprise capital (the number of institutions and beds) and labor (the number of health personnel). The number of outpatient and inpatients visits were selected as output indicators.[10] The VCs do not have data on inpatient visits because there are no beds available. Environmental variables are factors that have a significant impact on efficiency but are not within the subjective control of decision-making units,[11,12] which consist of per capita Gross Domestic Product (GDP), per capita disposable income of rural residents, urbanization rate, and year-end population number.

Data sources

The data on health resources used in this study were obtained from the China Statistical Yearbook, the China Health Statistical Yearbook, and the China Health Yearbook. The data on environmental variables were obtained from the China Population and Employment Statistical Yearbook. These sources are compiled and edited by authoritative institutions such as the National Bureau of Statistics of China and the National Health Commission, attesting their reliability. Because the data of CMHIs, THs, and VCs were only all first published in the China Health Statistical Yearbook for the first time in 2004, the time span for this study was limited to the period 2003 to 2020. Any missing data of medical visits of VCs over the different regions from 2003 to 2008 were supplemented by a time series linear interpolation method.

The three-stage DEA model

DEA is a flexible and objective non-parametric method that uses multiple input and output indicators for evaluating efficiency.[13] In the three-stage DEA model, the first stage uses DEAP2.1 software to calculate the resource allocation efficiency of each province. Under the factors of medical reform measures, preliminary market competition, government regulation, and financial capital constraints, we choose the input-oriented DEA-BCC model (formula (1–2)).[14] However, traditional DEA is limited by measurement errors of the included variables and omissions of unobserved potential relevant variables.[15,16] In response, Fried introduced environmental factors and random noise into the DEA model. At the second stage, in line with stochastic frontier theory,[17] Frontier 4.1 software was used for regression with the Stochastic Frontier Analysis (SFA) method. In the third stage, the adjusted input index of the medical and health service system replaces the original value, and we recalculate the efficiency of the medical and health service system in each province and city.

$$\min\left[\theta-\varepsilon\left(\sum_{i=1}^{m}S_i^- + \sum_{r=1}^{s}S_r^+\right)\right] \tag{1}$$

$$s.t.\begin{cases}\sum_{j=1}^{n}\lambda_j X_j + S_i^- = \theta X_0\\ \sum_{j=1}^{n}\lambda_j Y_j - S_r^+ = Y_0\\ \sum_{j=1}^{n}\lambda_j = 1\\ \theta, \lambda_j, S_r^+, S_i^- \geq 0\end{cases} \tag{2}$$

where j = 1,2 …, n, n is the number of decision-making units, θ is the efficiency value of the decision-making unit, and ε can effectively judge the effectiveness of the relative efficiency. S_r^+ and S_i^- are the slack and residual variables, respectively; X_j and Y_j are the input and output variables of decision-making unit.[18]

Malmquist index model

Productivity measures efficiency changes when converting inputs to outputs in terms of production units.[19] MPI (Malmquist; also known as total factor productivity change [TFP]) was proposed to analyze productivity changes. MPI can be deconstructed into technical efficiency change (TE) and technical change (TC).[20] If MPI is greater than 1, the change in TFP is positive and vice versa.[21] The calculation for TFP is shown in Eqs. (3)–(6).

$$TFP = TE \times TC = (PTE \times SE) \times TC \tag{3}$$

$$PE = \frac{D_v^t(X_{t+1,}Y_{t+1})}{D_v^t(X_{t,}Y_t)} \tag{4}$$

$$SE = \frac{D_v^t(X_{t,}Y_t)}{D_c^t(X_{t,}Y_t)} \times \frac{D_c^{t+1}(X_{t+1,}Y_{t+1})}{D_v^{t+1}(X_{t+1,}Y_{t+1})} \tag{5}$$

$$TC = \sqrt{\frac{D^t(X_{t+1,}Y_{t+1})}{D^{t+1}(X_{t+1,}Y_{t+1})} \times \frac{D^t(X_{t,}Y_t)}{D^{t+1}(X_{t,}Y_t)}} \tag{6}$$

where $D^t(X_{t,}Y_t)$ and $D^t(X_{t+1,}Y_{t+1})$ are the input distance functions of the decision-making unit at time t and t + 1, respectively; $D^t(X_{t+1,}Y_{t+1})$ and $D^{t+1}(X_{t,}Y_t)$ are input distance functions of decision-making units at different times; D_c and D_v are the distance functions based on fixed-scale returns and variable-scale returns, respectively.[22]

Results

Status of health resource allocation in three-level health service network in rural China

Significant changes have occurred in rural health care in China over the period 2003–2020. As shown in Table 1, in the input variables, the number of institutions, beds, and personnel manning CMHIs has steadily risen. THs responded positively to the requirements of withdrawing from the township and merging with the town. While the number of institutions decreased, the more

Table 1
Descriptive statistics of the input-output of the three-level health service network in rural China.

Year	Input variables								Output variables				
	CMHIs			THs			VCs		CMHIs		THs		VCs
	Institution	Beds	Personnel	Institution	Beds	Personnel	Institution	Personnel	Medical visits	Hospitalization person-times	Medical visits	Hospitalization person-times	Medical visits
2003	1.1	95.9	134.6	4.4	67.3	105.7	51.5	86.8	47,239.7	2058.6	69,134.0	1607.6	120,332.4
2004	1.1	98.4	135.7	4.2	66.9	102.6	55.2	88.3	49,770.6	2284.3	68,057.4	1599.5	123,400.4
2005	1.1	101.0	136.6	4.1	67.8	101.2	58.3	91.7	52,077.9	2475.9	67,923.3	1621.9	123,411.6
2006	1.2	105.5	141.0	4.0	69.6	100.0	60.9	95.7	55,442.1	3119.5	70,088.3	1836.1	134,838.9
2007	1.2	108.4	144.5	4.0	74.7	103.3	61.4	93.2	60,240.6	3155.2	75,855.9	2662.2	138,676.7
2008	1.2	118.0	151.3	3.9	84.7	107.5	61.3	93.8	65,550.2	3644.1	82,680.1	3312.7	136,891.2
2009	1.2	129.4	160.9	3.8	93.3	113.1	63.3	105.1	71,766.3	4243.7	87,660.8	3807.7	155,170.1
2010	1.2	141.8	171.5	3.8	99.4	115.1	64.8	109.2	76,289.5	4746.9	87,420.1	3630.4	165,702.3
2011	1.3	158.0	185.5	3.7	102.6	116.6	66.3	112.6	84,516.8	5382.8	86,649.8	3448.8	179,206.5
2012	1.4	181.3	202.7	3.7	109.9	120.5	65.3	112.6	96,412.8	6431.8	96,757.8	3907.5	192,707.6
2013	1.5	201.8	220.7	3.7	113.6	123.4	64.9	108.1	10,3320.5	7007.1	100,712.7	3937.2	201,218.4
2014	1.5	218.7	235.1	3.7	116.7	124.7	64.5	105.8	111,940.6	7591.7	102,865.9	3732.6	198,628.7
2015	1.6	232.6	246.6	3.7	119.6	127.8	64.1	103.2	114,001.4	7736.6	105,464.3	3676.1	189,406.9
2016	1.6	245.9	261.0	3.7	122.4	132.1	63.9	100.0	120,358.2	8323.7	108,233.0	3799.9	185,263.6
2017	1.7	264.5	276.9	3.7	129.2	136.0	63.2	96.9	126,739.0	8852.1	111,075.6	4047.2	178,932.5
2018	1.8	282.3	292.4	3.6	133.4	139.1	62.2	90.7	132,531.7	9214.5	111,595.8	3985.1	167,207.0
2019	1.9	300.0	311.7	3.6	137.0	144.5	61.6	84.2	142,588.8	9619.7	117,453.6	3909.4	160,461.7
2020	1.9	311.7	324.8	3.6	139.0	148.1	60.9	79.2	128,552.5	8482.2	109,516.3	3383.3	142,753.8

CMHI, county-level medical and health institution; TH, township hospital; VC, village clinic.

important indicator of number of beds and personnel has trended upward. The number of institutions and personnel of VCs, however, showed an upward rise before 2011, followed by a downward slump after 2012. In the output variable, the number of visits and inpatients of CMHIs and THs continued to increase and then decreased with the onset of COVID-19. VCs continued increased over the period 2003–2013, then declined 2014–2020. Over the same period, the rate of inpatients growth outpaced that of medical treatment, whereas the growth rate of inpatients in the eastern region remained lowest throughout.

Efficiency of health resource allocation in three-level health service network

The first stage of DEA

This article calculated the allocation efficiency of medical and health resources across 31 provinces and cities in China, with the average change trend of SE, TE, and PTE over the years shown in Fig. 1. SE is the largest in the time series, followed by PTE, with TE the smallest. The overall trend is an inverted 'U' shape, indicating that a decrease of PTE limits the improvement of TE. In addition, the mean values of TE and PTE have the maximum value of CMHIs, followed by THs and the minimum value of VCs. The results of CMHIs and THs in SE are similar and with efficiency high. The efficiency of CMHIs, THs, and VCs in the eastern regions are generally better than that of the central and western regions. And the provinces of VCs have the least number of DEAs. The probability of fully using health resource input and achieving the best output in technology and scale is the lowest.

The second stage of SFA

The results of the SFA regression are presented in Table 2. The Likelihood Ratio (LR) unilateral test as well as most environmental factors pass the 1% significance test. The γ values are close to 1, indicating the outcome is suited to a regression analysis using an SFA model. In the external environment, the per capita GDP that reflects the economic development has a negative impact on the number of institutions and beds of CMHIs and THs. At the same time, however, it has a positive impact on personnel and a negative impact on the institutions and personnel of VCs. Population agglomeration has a negative impact on the institutions of CMHIs and THs but a positive effect on beds and personnel for VCs the opposite is true. The growing urbanization rate has a negative impact on institutions and the personnel of CMHIs and VCs but a positive impact on beds. For THs, the opposite is true. High per capita disposable income of rural residents has a negative impact on CMHIs and THs personnel yet has a positive impact on institutions and beds as well as institutions and personnel of VCs.

Table 2
SFA regression results of input indicator slack variables and environmental factors.

Input relaxation variable	CMHIs			THs			VCs	
	Institution	Beds	Personnel	Institution	Beds	Personnel	Institution	Personnel
Constant term	−47.90	−4330.83	−2926.38	−29.93	−3251.73	−1427.00	−1172.58	−1841.29
Per capita GDP	−15.18	−1743.33	1486.62	−0.01	−1428.57	358.63	−246.19	−210.77
Year-end population	−0.44	2300.73	1179.50	−0.02	293.15	686.10	205.00	−151.78
Urbanization rate	−11.83	146.64	−321.74	0.00	−22.84	657.96	−28.04	−816.47
Per capita disposable income of rural residents	9.90	1107.85	−1196.37	0.02	1136.24	−725.92	215.04	510.20
σ^2	17,059.74	85,326,503.00	21,027,354.00	26,279.33	36,358,950.00	5,213,796.60	3,154,671.70	13,745,836.00
γ	0.99	1.00	0.99	1.00	0.99	0.99	1.00	0.99
LR test of the one-sided error	2028.32	2529.83	2117.39	9611.06	2365.49	1927.15	3004.99	2301.28

TH, township hospital; VC, village clinic; GDD, Gross Domestic Product; LR, Likelihood Ratio.
A positive coefficient indicates that increasing the environmental variable will increase input redundancy and cause inefficiency.

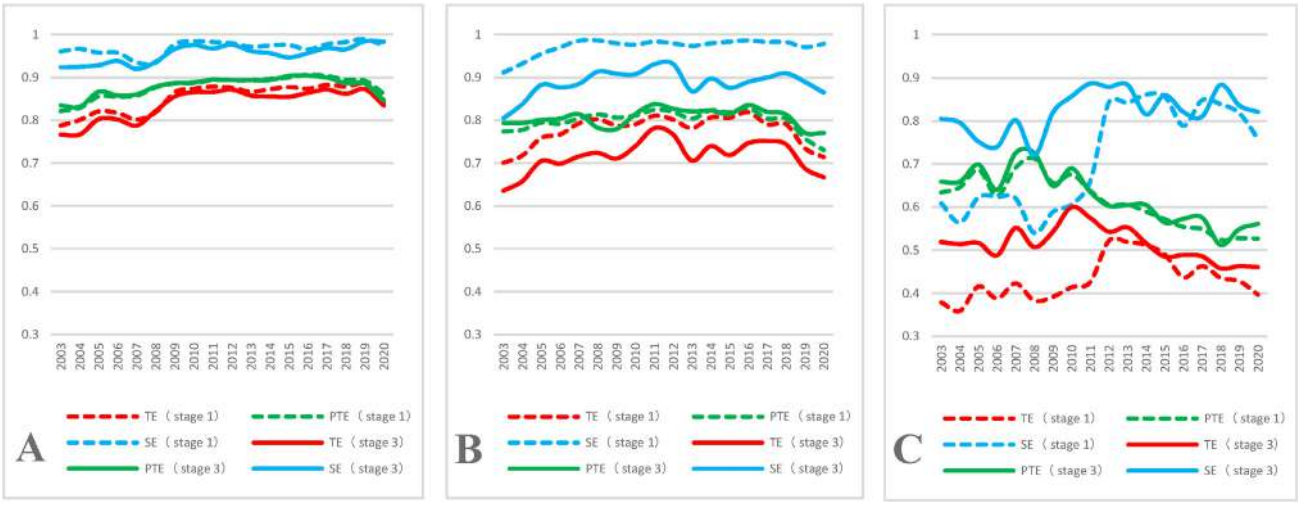

Fig. 1. TE, PTE, and SE of health resource allocation by year (A, B, and C represent CMHIs, THs, and VCs, respectively.)

The third stage of DEA

The solid line in Fig. 1 shows the efficiency change over the years across the third. The study found that the ranking order and change trend of SE, PTE, and TE in the first and third stages were generally consistent but that the TE and SE calculated in the third stage of CMHIs and THs declined somewhat, compared with the first stage, whereas the TE and SE of VCs actually increased. Over the same period, the PTE of CMHIs in the third stage first increased but then decreased. PTE of THs and VCs generally increased, indicating that compared with the first stage, the decrease of SE of CMHIs and THs in the third stage became the key factor inhibiting the increase of TE, and the joint progress of PTE and SE of VCs promoted the rise of TE. From the perspective of ranking, because of the decrease of SE of THs, the CMHIs values of TE, PTE, and SE are the largest, followed by THs, with VCs being the smallest. Nevertheless, TE scores are still low, and the potential for improvement is enormous.

Productivity of medical and health resources allocation in rural China

Because the three-stage DEA can only reflect the static efficiency of decision-making units and cannot be used for time series comparative analysis. The results are shown in Table 3. From the average TFP, the TFP of CMHIs, THs, and VCs from 2003 to 2020 are 1.025, 1.006, and 0.992, respectively. The TFP of CMHIs, THs, and VCs decreased in an irregular manner, with the lowest values of 0.85, 0.845, and 0.873 in the years 2019–2020. After decomposing TFP, we found that the trend of TFP is highly similar to that of TC. Further analysis shows that the decline of TC is the most crucial factor, leading to the deterioration of TFP. The values of TE, PTE, and SE are relatively similar. The decomposition of TE shows that the changing trend of TE is consistent with that of SE. Decreasing PTE values hinders the improvement of TE.

Discussion

This study takes CMHIs, THs, and VCs across 31 of China's provinces, from 2003 to 2020, as the primary research units. The three-stage DEA and Malmquist index model are used to analyze the changes in efficiency and productivity. The study found that the economic development of economically underdeveloped areas is slow, and there is a lack of a plausible mechanism for introducing health personnel. The total allocation of human health resources

Table 3
MPI summary of annual means by year.

year	CMHIs					THs					VCs				
	TE	TC	PTE	SE	TFPC	TE	TC	PTE	SE	TFPC	TE	TC	PTE	SE	TFPC
2003–2004	1.018	1.068	1.009	1.008	1.086	1.028	0.968	1.007	1.021	0.995	0.942	1.055	1.029	0.915	0.994
2004–2005	1.027	1.04	1.036	0.991	1.067	1.065	0.964	1.033	1.031	1.027	1.21	0.756	1.1	1.1	0.915
2005–2006	0.995	1.065	0.995	0.999	1.059	1.009	1.068	0.992	1.017	1.077	0.897	1.15	0.908	0.987	1.032
2006–2007	0.98	1.135	1.004	0.976	1.111	1.037	1.154	1.02	1.017	1.197	1.109	0.959	1.106	1.003	1.064
2007–2008	1.022	1.067	1.022	1.001	1.091	1.035	1.052	1.029	1.006	1.089	0.893	1.083	1.03	0.867	0.968
2008–2009	1.058	1.023	1.01	1.048	1.083	0.965	1.082	0.977	0.987	1.044	0.994	1.047	0.903	1.1	1.04
2009–2010	1.008	1.029	1.001	1.007	1.037	1.004	0.959	1.007	0.997	0.962	1.053	0.971	1.027	1.026	1.023
2010–2011	1.007	1.038	1.009	0.998	1.046	1.02	0.936	1.012	1.008	0.955	1.015	1.016	0.925	1.098	1.032
2011–2012	0.996	1.088	0.999	0.997	1.084	0.989	1.093	0.993	0.996	1.08	1.225	0.861	0.949	1.29	1.054
2012–2013	0.993	1.009	1.002	0.991	1.002	0.975	1.027	0.981	0.994	1.001	0.991	1.072	0.996	0.994	1.062
2013–2014	1.009	1.004	1.005	1.004	1.013	1.033	0.929	1.026	1.007	0.959	0.984	1.003	0.961	1.024	0.987
2014–2015	1.006	0.962	1.005	1	0.967	0.999	0.973	0.995	1.004	0.972	0.952	1.008	0.96	0.992	0.96
2015–2016	0.999	1.012	1.009	0.99	1.011	1.021	0.993	1.018	1.003	1.014	0.876	1.128	0.961	0.912	0.988
2016–2017	1.011	0.989	0.998	1.013	1	0.997	1.021	1	0.996	1.018	1.073	0.915	0.988	1.086	0.981
2017–2018	0.994	0.98	0.989	1.005	0.974	0.97	0.98	0.97	1	0.95	0.93	1.016	0.942	0.988	0.945
2018–2019	1.004	0.974	0.997	1.007	0.978	0.914	1.051	0.926	0.987	0.96	0.98	0.991	1.007	0.973	0.971
2019–2020	0.944	0.901	0.959	0.985	0.85	0.954	0.886	0.946	1.008	0.845	0.907	0.963	0.992	0.915	0.873
Mean	1.004	1.021	1.003	1.001	1.025	1	1.006	0.996	1.005	1.006	0.997	0.995	0.986	1.012	0.992

PTE, pure technical efficiency changes; SEs, scale efficiency changes; TC, technological changes; TE, technical efficiency changes; TFPs, total factor productivity changes. A score >1 indicates growth; a score of 1 signifies stagnation; and a score <1 indicates decline or deterioration.

remains insufficient, with the service radius ineffectively small, and the radiation capacity of medical and health institutions weak. People characteristically persist in commuting long distances to obtain hospital services, doing so until they are inevitably hospitalized.[23]

The reduction in PTE limited the improvement in TE. Government should further improve the internal management level and institutional innovation. Tao[24] also found that the average score of SE, in Shanxi Province, was the highest for 84 county-level maternal and child health institutions. China's eastern region enjoys better medical teams and equipment, and the total amount of resources is greater than that of other regions.[25] The central and western regions suffer lower efficiency due to poorer economies, less capable medical staff and insufficient supporting infrastructure, which is consistent with the conclusion of Liu.[26] Input redundancy combined with a shortage of health resources coexist across various regions. The government should thus further develop a flexible hierarchical diagnosis and treatment system through the creation of a general practitioner ecological area and health management network. In this way, high-quality resources may expect to be allocated more efficiently.

Different environmental variables have different effects on health resource input variables. The number of cross-provincial medical treatments in economically developed areas is relatively high, but provinces with a high per capita GDP exhibit a strong siphoning effect and are prone to lack proper planning and guidance. This increases the challenge of fully using CMHIs and THs health personnel, resulting in a reduction of their efficiency. The higher the population is at the end of the year, the stronger the radiation capacity of CMHIs and THs. However, this also results in a shortage of beds and personnel, leading to overcrowding. Areas experiencing a high level of urbanization enjoy more health resources, and in such areas, residents are prone to pay more attention to personal health care and health maintenance. As people's income grows, medical institutions have responded with increased investment, the purchase of new equipment, and more beds, yet fail to correspondingly increase the number of health personnel. At the same time, due to the adjustment of consumption structure, the demand structure of medical and health expenditure has also changed. Where the medical and health service system cannot meet service demand, efficiency is negatively affected, as reported by Ming.[27]

The decrease of SE of CMHIs and THs in the third stage emerge as the critical factor influencing TE. The joint advancements of PTE and SE of VCs is linked to the rise of TE, indicating that a consideration of environmental factors is important in determining the actual allocation of resources. Supervisors should further strengthen and coordinate the overall planning of medical and health resources across all regions and levels so as to optimize allocation of existing resources while at the same time augmenting those resources with additional needed supplemental supports. The “Internet + medical” model should be standardized to support the accelerated development of telemedicine. Policymakers should increase investment in health resources to improve health delivery in vulnerable areas while also enhancing the driving role of health big data.

CMHIs show the best production efficiency in transforming input into output, while VCs experience a growth bottleneck. This means the productivity of rural health resource allocation is experiencing decreasing utility,[28] and this needs to be attended to. A plausible explanation is that the ‘revenue and expenditure separation’ policy cuts off the interest chain between third-hand enterprises, medical personnel and pharmaceutical companies. Inadequate facilities, backward technology, lack of skilled personnel, and reduced income have exacerbated the loss of high-quality medical professionals in health institutions, resulting in a decline in PTE and TC, which is consistent with the research conclusions of Xu[29] and Li.[30] The supervision bureau should implement a mandatory information disclosure system across all medical institutions, improve social supervision, and establish systems to ensure the efficient and timely allocation of available medical resources.

However, further problems remain to be studied. On the one hand, while the three-stage DEA model addresses the influence of environmental variables, it cannot be used to analyze all the influencing factors. This is due to a lack of sufficient information regarding hospitals’ case mixes and patient outcomes[31,32] Moreover, it cannot combine the expected and unexpected output measures and analyze the heterogeneity characteristics of efficiency.[27,33] It is also impossible to integrate equity and efficiency into a unified analysis framework for static difference and dynamic solidification analysis and propose feasible implementation paths for dynamic coordination.[34] Therefore, the focus of the follow-up research work can be based on the actual health status and medical service needs of various communities across different regions. At the same time, additional relevant variables can be collected to further improve the accuracy of the research results.

In summary, CMHIs exhibit the best performance in terms of both efficiency and productivity, followed by THs, with VCs coming in last. The decline of PTE hinders the improvement of TE, and the decrease of TC is the most significant factor leading to the decline of TFP.

Author statements

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Ethical approval

The study design was approved by the appropriate ethics review board.

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Competing interests

The authors declared that they have no conflicts of interest in this work.

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Themed Paper – Original Research

Evaluation of the national governmental efforts between 1997 and 2010 in reducing health inequalities in England

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ABSTRACT

Objectives: The pandemic has compounded existing inequalities. In the UK, there have been calls for a new cross-government health inequalities strategy. This study aims to evaluate the effectiveness of national governmental efforts between 1997 and 2010, referred to as the National Health Inequalities Strategy (NHIS).

Study design: population-based observational study.

Methods: Using Global Burden of Disease data, age-standardised years of life lost due to premature mortality (YLL) rates per 10,000 were extracted for 150 Upper Tier Local Authority (UTLA) regions in England for every year between 1990 and 2019. The slope index of inequality was calculated using YLL rates for all causes, individual conditions, and risk factors. Joinpoint regression was used to assess the trends of any changes which arose before, during or after the NHIS.

Results: Absolute inequalities in YLL rates for all causes remained stable between 1990 and 2000, before decreasing over the following 10 years. After 2010, improvements slowed. A similar trend can be observed amongst inequalities in YLLs for individual causes, including ischaemic heart disease, stroke, breast cancer and lung cancer amongst females, and ischaemic heart disease stroke, diabetes and self-harm amongst males. This trend was also observed amongst certain risk factors, notably blood pressure, cholesterol, tobacco and dietary risks. Inequalities were generally greater in males than in females; however, trends were similar across both sexes. The NHIS coincided with significant reductions in inequalities in YLLs due to ischaemic heart disease and lung cancer.

Conclusions: The findings suggest that the NHIS coincided with a reduction in health inequalities in England. Policy makers should consider a new cross-government strategy to tackle health inequalities drawing from the success of the previous NHIS.

Introduction

During 2017 to 2019, the gap in life expectancy between the most and least deprived regions in England was 11.3 years for males and 8.7 years for females.[1] Between 2003 and 2018, approximately one third of deaths in England were attributable to socio-economic inequality.[2] Annually, health inequalities account for productivity losses of approximately £31–33 billion, whilst costs incurred to the NHS amount to more than £5.5 billion.[3] The COVID-19 pandemic has both revealed and exacerbated the stark health inequalities which persist across society.[4]

There is a significant lack of evidence surrounding both the type of policies and methods of implementation most likely to decrease health inequalities.[5] To develop a successful strategy, there is an urgent requirement to better understand past successes and failures. The creation of the NHS in 1948 is often considered the first serious effort to address health inequalities.[6] However, the 13-year systematic attempt to reduce health inequalities in England, between 1997 and 2010, is generally considered the county's most comprehensive attempt to do so.[7,8] The total budget exceeded £20 billion.[7,9]

Overall, consensus as to the effectiveness of the strategy remains unclear.[10] A formal review – Tackling Health Inequalities: 10 Years

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On[11] – by the Department of Health in 2009 acknowledged significant improvements in the health of the population and that the majority of departmental commitments set out in the Programme for Action had been met. Average life expectancy for all groups increased significantly across the whole population, but improvements were lower in the target areas. Early reports[12,13] concluded that whilst the strategy could be considered partially successful, in that reductions in health inequalities were observed between 1997 and 2010, the specific targets outlined in the strategy were not met. Later findings were more encouraging. Time-trend analysis found that geographical health inequalities in life expectancy decreased marginally during the strategy period, temporarily reversing the previously increasing trend, but inequalities since 2010 have widened.[14] A recent study[15] found that geographical inequalities in infant mortality rate increased before the strategy and decreased throughout the strategy, with no evidence that this decrease in inequality continued after the strategy. The increase in proportion of NHS resources allocated to deprived areas between 2001 and 2011 was associated with a reduction in absolute health inequalities from causes amenable to healthcare.[16]

We evaluate the effectiveness of efforts to reduce health inequalities between 1997 and 2010, referred to broadly as the National Health Inequalities Strategy (NHIS). We investigate changes in socio-economic health inequalities before, during and after the implementation of the strategy measured by premature mortality.

In doing so, we address two gaps within the current literature. Whilst analysis to date has highlighted wider condition groups which may have seen improvements in health inequality indicator, tracking trends in health inequalities over time for individual causes before, during and after the strategy has yet to be explored. Second, analysis to date has employed a range of methods of health inequality measurement yet neglected to utilise well-established indices of inequality such as the slope index of inequality (SII).

Methods

Led by the Institute for Health Metrics and Evaluation (IHME), the Global Burden of Disease (GBD) study is a comprehensive worldwide observational epidemiological study enabling the systematic assessment of local, regional, national and international trends in health. Detailed methods have been described elsewhere.[17,18] In brief, the GBD study adopts a standardised analytical approach for estimating life expectancy, years of life lost due to premature mortality (YLLs) and risk factors. It captures data for more than 350 diseases and injuries, by age and sex, from 1990 to present.[19] In England, the GBD study reports data for 150 Upper Tier Local Authority (UTLA) regions, reflecting a total population of approximately 56 million people, including county councils, London boroughs, unitary authorities and metropolitan districts.[17,19]

Age-standardised YLL rates per 10,000 were extracted for 150 UTLA regions in England for every year between and inclusive of 1990–2019, for all causes, individual conditions and risk factors. YLLs are mapped to cause, age and sex groups in the GBD study based on a based upon a four-level hierarchy.[19] YLLs were compared at level 3 to ensure a meaningful and insightful level of analysis. Conditions that would be included in the analysis were determined a priori, informed by the wider research advisory panel consisting of clinicians, public health professionals, and health policy makers. Broadly, conditions were chosen to align with the areas which the strategy aimed to have a specific impact on.

The SII was used to measure inequalities in YLLs. The SII reflects differences in health status between two hypothetical individuals, one at the top and bottom of the socio-economic distribution, respectively.[20] The SII accounts for the social gradient in health[21–24] and is sensitive to the mean health status of a population and distribution of population across different socio-economic groups.[22]

The Index of Multiple Deprivation (IMD) is the official measure of relative deprivation in England, broadly defining deprivation by accounting for a range of factors which relate to an individual's living conditions.[25] IMD ranks were assigned to all 150 UTLA regions for each year between 1990 and 2019. We applied the 2004 IMD Rank for each UTLA region across all years to assess changes from this baseline. Linear regression analysis of all-cause and individual conditions, risk factors, and age-standardised YLL rates per 10,000 individuals by IMD decile was conducted. In each case, the coefficient of the regression was the SII, which reflected the absolute change in YLL rates that occur with every single unit increase in IMD decile. The primary outcome measures were absolute inequalities, measured by the SII, in age-standardised YLL and rates for all causes, individual conditions and risk factors, by sex for each year from 1990 to 2019. All analyses were conducted in STATA 16.1. Joinpoint regression analysis[26] detected the time at which a statistically significant change in the trend of the data was observed, using a series of permutation tests. The analysis was performed for all-cause YLL rates, for both males and females, allowing up to two join points utilising a Monte Carlo permutation method. The analysis was conducted using the Join point regression program from the Surveillance Research Program of the National Cancer Institute Version 4.2.0.2 (Statistical Research and Applications Branch, National Cancer Institute, US).[26]

Results

All causes

Table 1 and Fig. 1 display the change in the SII for all cause YLLs. In general, inequalities in YLLs were higher amongst males than in females. For both females and males, health inequalities increased initially before decreasing from approximately 1996 onwards. After

Table 1
SII for Age-standardised YLLs (rate per 10,000) in 150 UTLA regions in England, Male and Female, 1990–2019.

Year	**Total**				
	SII	*SE*	*P-value*	*(Lower CI)*	*(Upper CI)*
1990	−596	26	<0.00	−648	−544
1995	−626	25	<0.00	−675	−578
2000	−593	23	<0.00	−638	−548
2005	−526	24	<0.00	−574	−478
2010	−434	24	<0.00	−481	−386
2015	−394	26	<0.00	−446	−342
2019	−370	29	<0.00	−427	−314
	Female				
Year	*SII*	*SE*	*P-value*	*(Lower CI)*	*(Upper CI)*
1990	−411	20	<0.00	−450	−371
1995	−411	18	<0.00	−446	−375
2000	−420	18	<0.00	−456	−385
2005	−364	21	<0.00	−405	−323
2010	−312	20	<0.00	−352	−273
2015	−290	23	<0.00	−335	−244
2019	−263	22	<0.00	−307	−219
	Male				
Year	*SII*	*SE*	*P-value*	*(Lower CI)*	*(Upper CI)*
1990	−825	38	<0.00	−900	−750
1995	−884	38	<0.00	−958	−809
2000	−793	31	<0.00	−854	−731
2005	−708	31	<0.00	−769	−647
2010	−566	30	<0.00	−626	−506
2015	−504	32	<0.00	−567	−441
2019	−483	37	<0.00	−557	−410

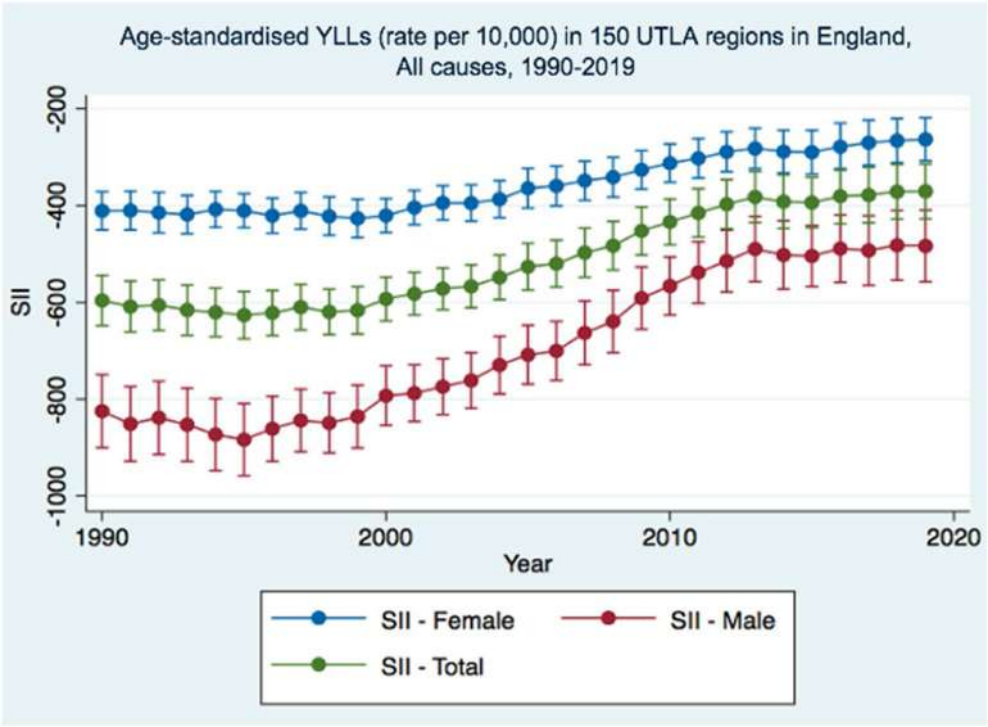

Fig. 1. SII for Age-standardised YLLs (rate per 10,000 with 95%CI) in 150 UTLA regions in England, All causes, 1990–2019.

2010, improvements in health inequalities continued at a slower rate. Joinpoint regression analysis showed that inequalities narrowed, particularly between 1996 and 2013, supporting the findings in linear regression analysis. Amongst males, females and both sexes combined, there was a statistically significant change in trend in SII between 2012 and 2013 for YLLs. This is reflective of a general trend in the years following 2010, whereby improvements in health inequalities began to plateau (see Table 2).

Individual conditions and risk factors

In general, the most substantial inequalities in YLL rates amongst females were observed in ischaemic heart disease, stroke, neonatal preterm birth, lower respiratory infections and COPD, as shown in Fig. 2. Age-standardised YLL rates for ischaemic heart disease were significantly greater than all other conditions and are presented separately in Fig. 3. Inequalities in YLL rates improved over time for stroke, neonatal preterm birth, lower respiratory infections, diabetes and self-harm. Inequalities in YLLs due to COPD, drug use disorders and cirrhosis and other chronic liver diseases showed little improvement and even deteriorated between some years. Amongst males, ischaemic heart disease, COPD, stroke and lower respiratory infections had the most significant inequalities in YLLs. Inequalities in YLL rates for ischaemic heart disease, COPD, stroke and lower respiratory infections reduced significantly between 1990 and 2019. Inequalities in YLL rates for drug use disorders, self-harm and neonatal preterm birth showed comparatively minimal improvements in reductions between 1990 and 2019.

Amongst females, inequalities in YLLs were comparatively low in colorectal and pancreatic cancer, with little fluctuation in SII observed between 1990 and 2019. Inequalities in YLL rates per 10,000 for both breast and lung cancer increased between 1990 and 2000, before steadily decreasing between 2000 and 2019. Amongst males, absolute inequalities for colorectal, prostate and pancreatic cancer were minimal and showed little variation over time. Inequalities in YLL rates due to lung cancer were more significant yet improved steadily over time and had almost halved by 2019, as shown in Fig. 4.

In general, the SII increased steadily over time for cholesterol, tobacco, dietary risks and blood pressure, with reductions in inequalities in YLL rates broadly coinciding with the strategy period, shown in Fig. 5. This increase in SII was most dramatic amongst males, particularly for tobacco, suggestive of a significant reduction in inequalities in YLLs between the most and least deprived regions throughout the strategy period. The SII remained relatively constant amongst alcohol use, child and maternal malnutrition, physical activity and drug use, with little variation between sexes and minimal absolute inequalities observed more generally since 1990.

Table 2
Joinpoint regression analysis, Age-standardised YLLs (rate per 10,000), All causes

Total				
Joinpoint	*Estimate*	*Lower CI*	*Upper CI*	*Slope change*
1	1999	1997	2001	−0.76
2	2013	2009	2015	0.45
Female				
Joinpoint	*Estimate*	*Lower CI*	*Upper CI*	*Slope change*
1	2000	1998	2001	−11.85
2	2012	2010	2014	6.49
Male				
Joinpoint	*Estimate*	*Lower CI*	*Upper CI*	*Slope change*
1	1998	1995	2000	−27.41
2	2013	2011	2015	21.02

Discussion

Statement of principal findings

Findings suggest that the NHIS coincided with a reduction in inequalities in YLL rates. Broadly, total inequalities in YLLs remained

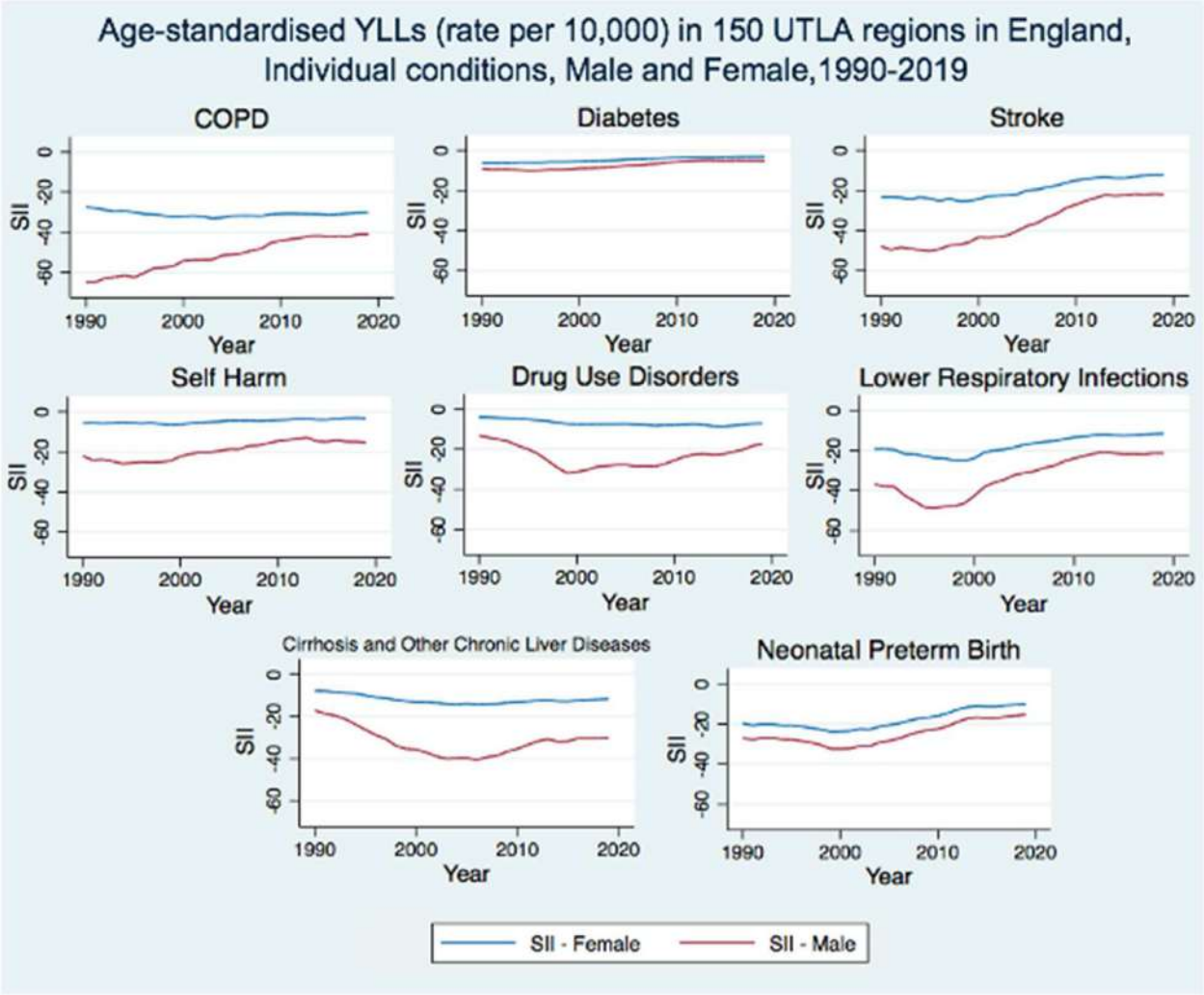

Fig. 2. Age-standardised YLLs (rate per 10,000 with 95%CI) in 150 UTLA regions in England, Individual conditions, Male and Female, 1990–2019.

relatively stable between 1990 and 2000, significantly improved over the following 10 years, and began to plateau in the years following the end of the strategy. This pattern is observed across both males and females although it is particularly evident in males. A similar trend can be observed amongst inequalities in YLLs for individual causes, including ischaemic heart disease, stroke, breast cancer and lung cancer amongst females, and ischaemic heart disease stroke, diabetes and self-harm amongst males. This trend was also observed amongst certain risk factors, notably blood pressure, cholesterol, tobacco and dietary risks.

The years following the strategy saw reduced improvements in inequalities. It is possible that the tendency for inequalities in YLL and mortality rates to plateau in 2010 was due in part to the 2008 financial crisis. Reduced improvements in life expectancy were observed in England from 2011 onwards,[27] which may have simultaneously resulted in the observed levelling off of improvements in health inequalities. There is also evidence to suggest that the substantial increase in public expenditure on the health system which coincided with the NHIS was a major factor driving reductions in health inequalities between 2001 and 2010 (16). Levelling off in subsequent years may have been a result of subsequently implemented financial constraint measures.

Whilst we found that the NHIS was associated with a reduction in health inequalities, there are other potential factors, especially when potential lag effects are considered. Before 2008, there was a period of sustained economic growth with a rise in living standards and there continued to be an expansion of healthcare interventions which may have contributed to overall improved health, with a greater improvement in lower socio-economic groups. Alternatively, the improvements may have been related to other government action not related to the NHIS. However, changes in these factors are not consistent with the start and end of the change in trend, and the NHIS was a cross-government effort and it is difficult to argue that it did not influence every aspect of government.

Strengths and limitations

By measuring absolute health inequalities, we provide useful, interpretable data and insights regarding how inequalities in health have changed over time. The use of GBD data allowed the identification of trends for individual conditions and risk factors. These findings may suggest which direct healthcare or public health interventions may have been the most successful aspects of the strategy. Less clear conclusions can be drawn concerning which actions on the wider determinants of health were more instrumental, given their interacting, complex and indirect effects on both a public health intervention's effectiveness and on a population's health. The comprehensive GBD dataset allowed analysis

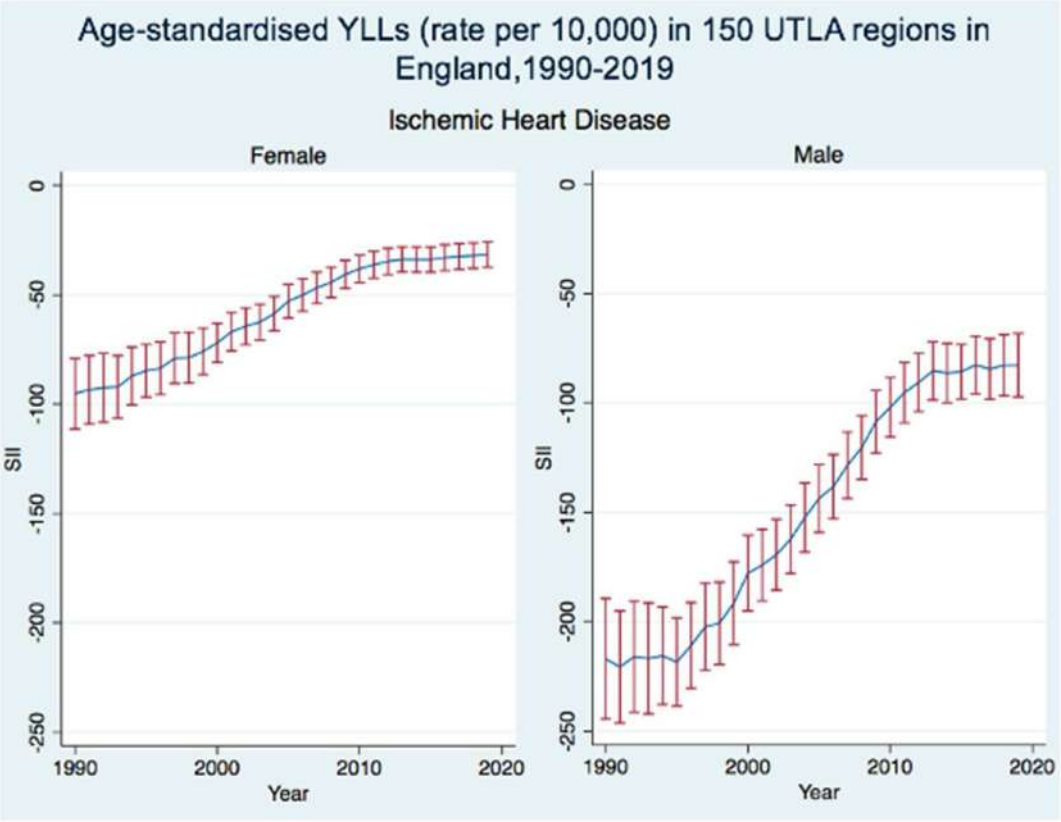

Fig. 3. SII, age-standardised YLLs (rate per 10,000 with 95%CI), ischaemic heart disease, female and male, 1990–2019.

using data over a 30-year period from 1990 to 2019, and present the most comprehensive longitudinal analysis to date. The use of the SII as a measure of health inequality assesses inequalities across the whole population rather than just groups at the most extreme ends. Moreover, which every healthcare system and wider health policy agenda is naturally unique, the methods used in this analysis could be used to assess other nation's progress in reducing health inequalities over time.

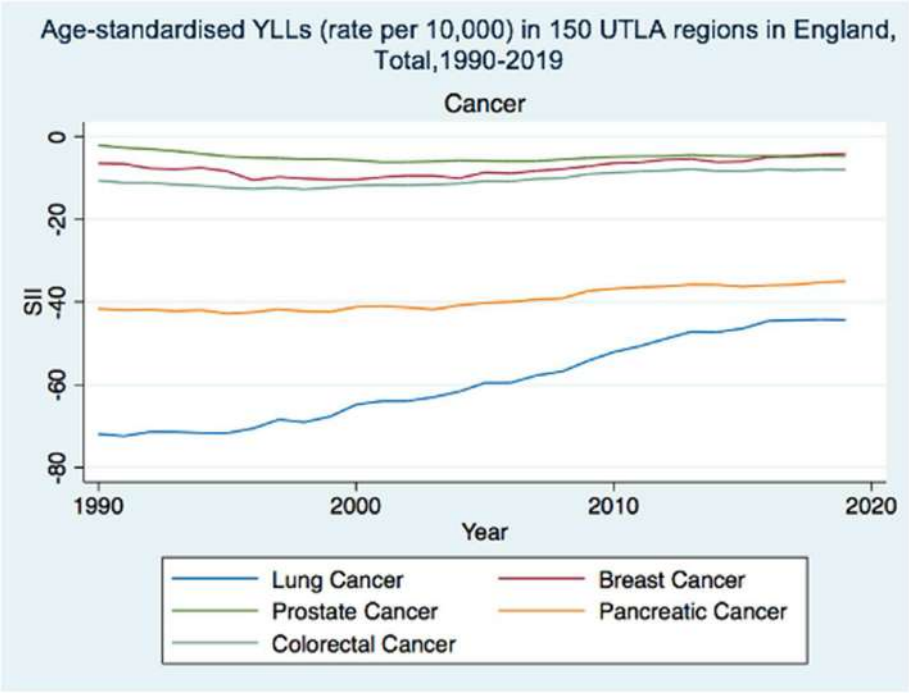

Fig. 4. SII, age-standardised YLLs (rate per 10,000 with 95%CI), cancer, total, 1990–2019.

This study is also subject to several limitations. As the IMD is a composite measure comprised of seven indicators, one of which includes health, it is possible that the strong statistically significant negative correlation between YLLs and deprivation, may be an overestimation of the true association. However, as removing the health component of the IMD has little to no effect on the overall association between two health variables,[28] this is unlikely to influence findings. The level of geographical granularity of our analysis was also limited to the level provided within the GBD study and associated IMD rank. The use of large area estimates has several implications, including ecological fallacy whereby all individuals who live in the same area are assigned to the same level of deprivation, which is unlikely to be the case given the large populations within UTLA regions. The primary limitation of the use of GBD data in the UK is the potential biases arising from the statistical modelling process, including the impact of numerous decisions made at this stage which generally remains unclear. GBD also relies on data from a variety of sources, including vital registration systems, household surveys and hospital records. Whilst data availability in the UK remain comprehensive, it is likely this varied across the 30 years of data used in this study.isk factor data in particular are subject to several biases and are dependent on the underlying quality of data.[29] The GBD uses statistical modelling techniques to estimate health outcomes in countries where data are scarce or missing. Whilst these methods are generally robust, they are subject to uncertainty, and estimates may not always be precise. Whilst the data availability in the UK means that this is not necessarily a significant limitation, UK data are still modelled to ensure international comparability which may lead to biases. ause-specific YLL data in particular are subject to the reallocation of ill-defined death codes. Moreover, whilst the GBD covers a wide range of diseases, injuries, and risk factors, it does not include all health outcomes and it is likely that some conditions such as rare diseases or mental health disorders, may be misrepresented. Whilst the aim of this analysis was to investigate changes in absolute health inequalities using the SII, we do not know the impact of the NHIS on relative inequalities.[30] It is conceivable that changes in absolute inequalities throughout this period may not have reflected the same trend as relative inequalities. The generalisability of the findings is limited in that trends in health inequalities were analysed within the context of the wider society and situational factors present in England between 1990 and 2019. Given the contextual

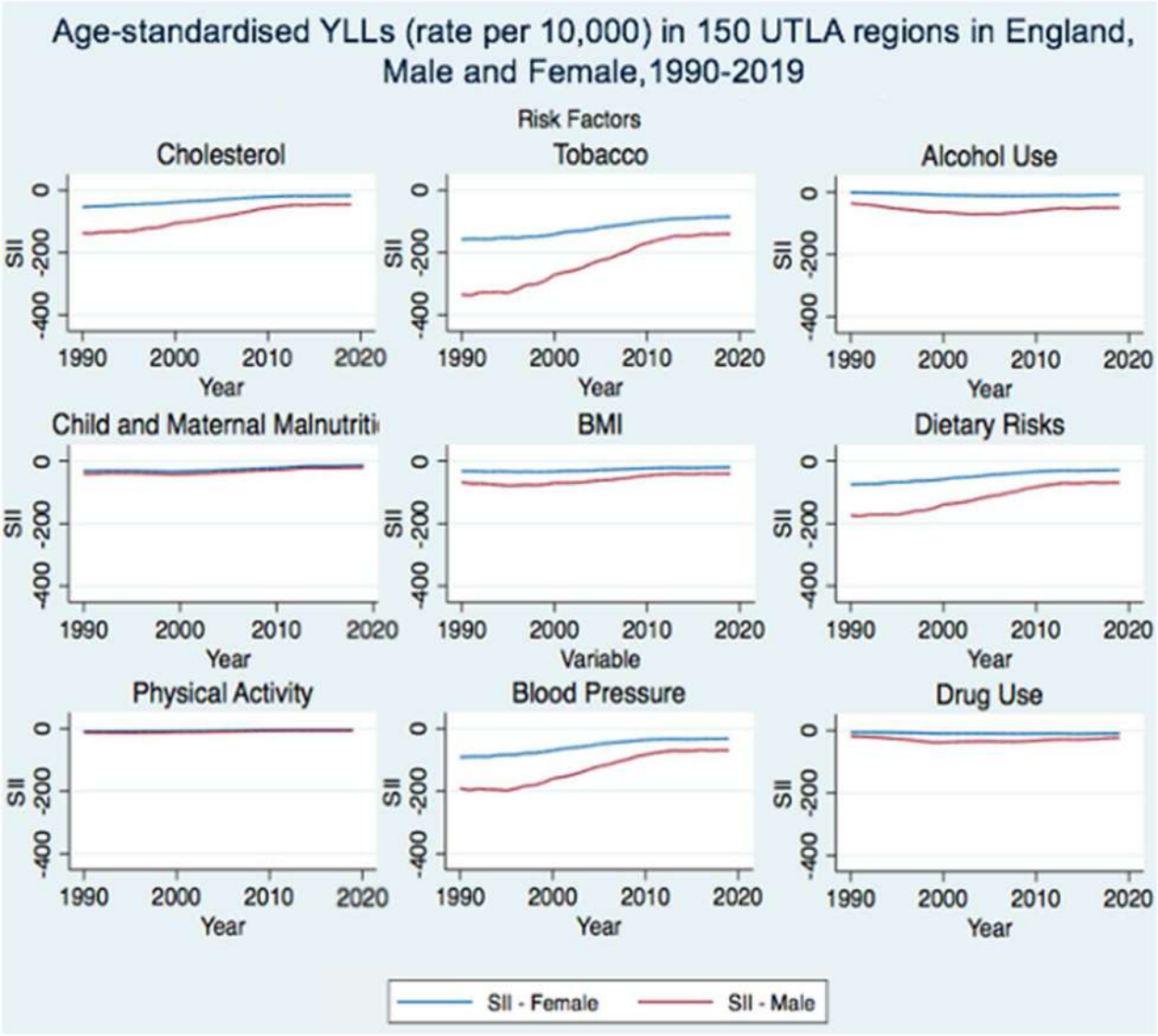

Fig. 5. SII, age-standardised YLLs (rate per 10,000 with 95%CI) in 150 UTLA regions in England, male and female, 1990–2019.

factors in relation to time and place, care must be taken when generalising the findings to different countries.

Comparison to existing literature

The all-cause findings support early studies[12,13] suggesting that the strategy was partially successful in reducing health inequalities, with reductions in health inequalities observed between 1997 and 2010. The findings, particularly those from the Join point regression analysis, align more generally with previous studies[3,14] that suggest that inequalities amongst certain health indicators decreased marginally during the strategy period, temporarily reversing the previously increasing trend, but plateaued or widened from 2010 onwards. Here, we add to the existing literature by undertaking a condition-specific analysis. Moreover, the use of the SII represents a novel methodological contribution, with analysis to date having employed a range of methods of health inequality measurement yet neglected to utilise well-established indices of inequality such as the SII.

Public health and policy implications

This research provides strong evidence that the implementation of a new cross-government strategy to tackle health inequalities has the potential to significantly reduce health inequalities in England. The analysis highlights the importance of accounting for the mechanism through which an individual policy is expected to infer or create an impact. Naturally, we would expect conditions such as drug use disorders to have a longer 'gestation' period between time from policy implementation to impact. When developing target and monitoring dates for a national health inequalities strategy, consider the time through which we would reasonably expect to see an impact, which will differ across individual conditions and risk factors.It remains an unfortunate reality that health policy is often driven by the electoral cycle, whereby interventions that are likely to have a short-term impact are more likely to be commissioned. A greater acceptance of long-term vision is required to ensure inequalities amongst conditions and risk factors with a longer "time to impact" are not neglected. The findings highlight that despite some success in reducing absolute inequalities in YLLs and mortality for conditions including lung cancer and ischaemic heart disease, significant disparities between the most and least deprived regions in England continue to persist.

Further research

The impact of the NHIS was not observable until years after implementation; therefore, it is imperative that future policy evaluations look over the long term. More research is need to explore whether the implementation of the NHIS reduced inequalities to a greater or lesser extent across certain geographical areas, including coastal communities and in north of the country would be useful in order to determine areas which may require a greater investment of resources in the future. In addition, further investigation could assess the NHIS's impact in London given differing health inequality trends in London compared to the rest of the country.[31]

Conclusion

The trends in inequalities in YLL rates reflected through the SII for all causes, individual conditions and risk factors collectively suggest that the NHIS coincided with a reduction in health inequalities between 1997 and 2010. The analysis sheds light on what specific reductions in inequalities across individual conditions and risk factors could be attributed to this observed trend, and highlights similarities and differences in changes in inequalities amongst males and females. This study provides strong evidence to suggest that the development of a new cross-government strategy to tackle health inequalities has the potential to significantly reduce health inequalities in England.

Author statements

Ethical approval

None sought

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Competing interests

None declared.

Data availability

No data available.

Individual author contribution

JF conceptualised the study. AV and JF drafted the protocol and CB, LM, BB and EM provided comments. AV conducted the data analysis and wrote the first draft of the manuscript. All co-authors provided comments. AV, IH and JF redrafted. All authors approved the final version.

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Review Paper

Impact of COVID-19 lockdown on smoking and vaping: systematic review and meta-analysis

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ABSTRACT

Objectives: COVID-19 and the implementation of lockdowns have impacted daily lives worldwide. This systematic review and meta-analysis aimed to investigate the impact of lockdowns on the smoking and vaping behaviours of adults during the pandemic.
Study design: This was a systematic review and meta-analysis.
Methods: A systematic literature search was conducted up to 28 April 2022 in the following databases: PubMed, Embase and Web of Science.
Results: In total, 77 studies met the inclusion criteria for this review. In 34 studies, an increase in smoking behaviour was reported for the majority of participants; however, in 21 and 18 studies, 'no change' and 'decrease' in smoking were the predominant responses, respectively. The results from the meta-analysis, which examined the change in the number of cigarettes smoked per day, showed no difference between the pre- and post-lockdown periods: 0.81 weighted mean difference (95% confidence interval, −0.59 to 2.21). Regarding vaping, three of seven studies reported an increase in smoking for the majority of participants, whereas 'no change' and 'decrease' were the predominant answers in the other four studies.
Conclusions: The results show that lockdowns led most participants to increase smoking/vaping, whereas a decrease or cessation of smoking/vaping was only reported in the minority of participants. Attention should be given to the non-communicable diseases that could arise as a result of the increase in smoking/vaping during lockdowns, and further research in this area is needed.

Introduction

The novel COVID-19 was initially detected in Wuhan, China, near the end of 2019. On 11 March 2020, a pandemic was declared by the World Health Organization.[1] COVID-19 spread quickly because of its extended incubation period and highly infectious characteristics, as well as significant worldwide networking and significant global travel activities.[2] By April 2022, COVID-19 had infected over 300 million individuals and resulted in over 6.2 million deaths.[3] Although the global response to COVID-19 has been far from uniform, most countries have implemented self-isolation, homestay (or lockdown) requirements, social distancing or quarantine measures to reduce COVID-19 transmission and ease the burden on healthcare services until the vaccine became available; however, lockdowns also led to unexpectedly serious health repercussions.[4] Even after the approval and distribution of the vaccines, several countries continued to impose lockdowns when they deemed it essential; these lockdowns have impacted the everyday lives of many people and constituted a severe threat to individuals with addictive behaviours.[5] Evidence on the risk of contracting COVID-19 based on smoking status remains inadequate and conflicting, underlining the need to increase quantitative research with more rigorous study designs.[6–8] Smoking appears to be connected to higher COVID-19 hospitalisation and mortality, even if the linkage for current smokers is still ambiguous.[6,9,10]

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0033-3506/

COVID-19 preventive approaches, such as social distancing and stay-at-home mandates, had a significant impact on interpersonal dynamics.[11,12] Many people were confined to their homes during lockdown periods, either alone, with family members or with other housemates, in addition to participating in fewer social and physical activities.[13–15] These modifications might be especially important for those who smoke in public places or who live with children or other vulnerable people.[16] Pandemic-related issues might also induce increased stress, which is known to lead to increased smoking on an individual basis.[17,18] Notably, after disasters or traumatic events in the United States, such as the September 11th terrorist attacks and Hurricane Katrina, smoking behaviours increased.[19] On the other hand, for some people, a respiratory illness epidemic (such as COVID-19) could be regarded as an ideal moment to decrease or quit smoking because of health concerns.[20] As a result, smoking behaviours could differ from pre-COVID-19 routines in terms of where, when and with whom people smoke; however, the results of current quantitative studies investigating the COVID-19 effects on smoking have shown conflicting results.[21–25]

It is therefore essential that data from existing quantitative research on the influence of COVID-19 on smoking and/or vaping behaviours are collected and analysed to get a more accurate conclusion of the impact of the pandemic on smoking and vaping habits. This study attempted to present an overview of the current data regarding the impact of COVID-19 lockdowns on smoking and vaping behaviours.

Methods

Search strategy and study selection

A systematic literature search was conducted in PubMed, Web of Science and Embase databases up to 28 April 2022. A combination of the key terms ((smoking) OR (tobacco) OR (vaping) OR (cigarette) OR (lifestyle)) AND ((Covid-19) OR (Covid) OR (Covid-19) OR (Sars-cov-2) OR (lockdown)) was used as a search string for PubMed and was modified accordingly for the other databases. The search strategy of this study can be found in Supplementary File S1. The studies identified through the literature search were added into reference manager software (Endnote X9; Thomson Reuters, for Windows) and were screened independently for eligibility by two reviewers (D.B. and K.E.). Any disagreement was solved by consensus. Reference lists of the eligible studies were also screened for additional relevant studies.

The present study was conducted according to the registered protocol in the OSF platform (https://osf.io/vj586/). Eligible studies were observational studies (prospective, retrospective cohort studies and cross-sectional studies) that examined the change in smoking and/or vaping behaviour of adults during the COVID-19 lockdowns. Retrospective studies that were started before the COVID-19 lockdowns were excluded to avoid any other confounding factors. Moreover, studies in which there was a statement that the results referred to combined smoking and vaping change were excluded. Studies that included children (aged <18 years) as a population of interest were also excluded. Editorials, letters to the editor, reviews and studies in languages other than English, French or Spanish were not included in this review.

Data extraction

Information from eligible studies was extracted independently by two authors (D.B. and K.E.) using a standardised data extraction form. Any discrepancies were resolved by consultation with a third author (M.C.) who was not involved in the initial procedure. Study identity (first author, year of publication), country of origin, sex, age and subgroups of participants (if applicable), period when the survey was conducted and information regarding smoking and/or vaping habit before and during/after the COVID-19 lockdown periods were recorded. Specifically, increase, decrease, no change, as well as initiation and cessation of smoking and/or vaping behaviour as a result of COVID-19 restriction measures were examined. Corresponding authors of articles with missing data were contacted and given a 2-week period to respond.

Quality assessment of the studies was conducted independently by two authors (D.B. and K.E.), and any disagreement was solved by consensus. The Joanna Briggs Institute Critical Appraisal tools for cross-sectional studies[26] was used as an instrument for quality assessment.

This systematic review and meta-analysis was completed in adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines 2020[27] (Supplementary Table S1), and its registered protocol was submitted to the OSF platform (https://osf.io/vj586/).

Statistical analyses

A meta-analysis was conducted for studies in which the number of cigarettes before and during/after the COVID-19 lockdown was reported. Random effects in the meta-analytic model were used to estimate the differences of assessment effects in studies because of the high heterogeneity observed between studies. Furthermore, the weight of each study was calculated using the inverse variance method. Weighted mean difference was used because the outcome (number of cigarettes) was calculated using the same measurement scale (mean number of cigarettes and standard deviation). Assessment of the statistical heterogeneity between studies was calculated by the tau-squared and I^2 test. I^2 <25% indicated a low degree of heterogeneity, 25%–50% indicated moderate heterogeneity, and >50% to 70% showed significant heterogeneity. Percentages represented absolute changes in individuals' behaviours before and during/after lockdown. All statistical analyses were performed using the Review Manager (Version 5.4.1).

Results

Search results

A total of 14,848 studies were identified in the literature search up to 28 April 2022. After duplicate removal (n = 6905), 7943 studies were screened for eligibility. Subsequently, the application of inclusion and exclusion criteria led to 77 studies being included in this systematic review.[28–104] A flowchart of this process is presented in Fig. 1.

The characteristics of the included studies can be found in Tables 1 and 2. In total 207,841 adults from a significant geographical section of the globe (Albania, Australia, Bangladesh, Belgium, Brazil, Canada, China, Croatia, Cyprus, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, India, Italy, Israel, Jordan, Kuwait, Libya, Norway, Poland, Portugal, Romania, Russia, Slovenia, South Africa, Spain, Sweden, the Netherlands, Turkey, United Arab Emirates (UAE), The United Kingdom , Ukraine, The United States and Vietnam) were examined about their smoking and/or vaping behaviour. All the included studies had a cross-sectional design, except for one, which was a prospective cohort study.[77] The included studies assessed smoking/vaping behaviour using self-assessment questionnaires (online or not),[28–39,41–43,45,46,48–55,57–59,61–72,75–77,79,81,82,84,86–105] telephone interviews[40,44,47,56,73,78,80] or in-person interviews.[53,83,85,106]

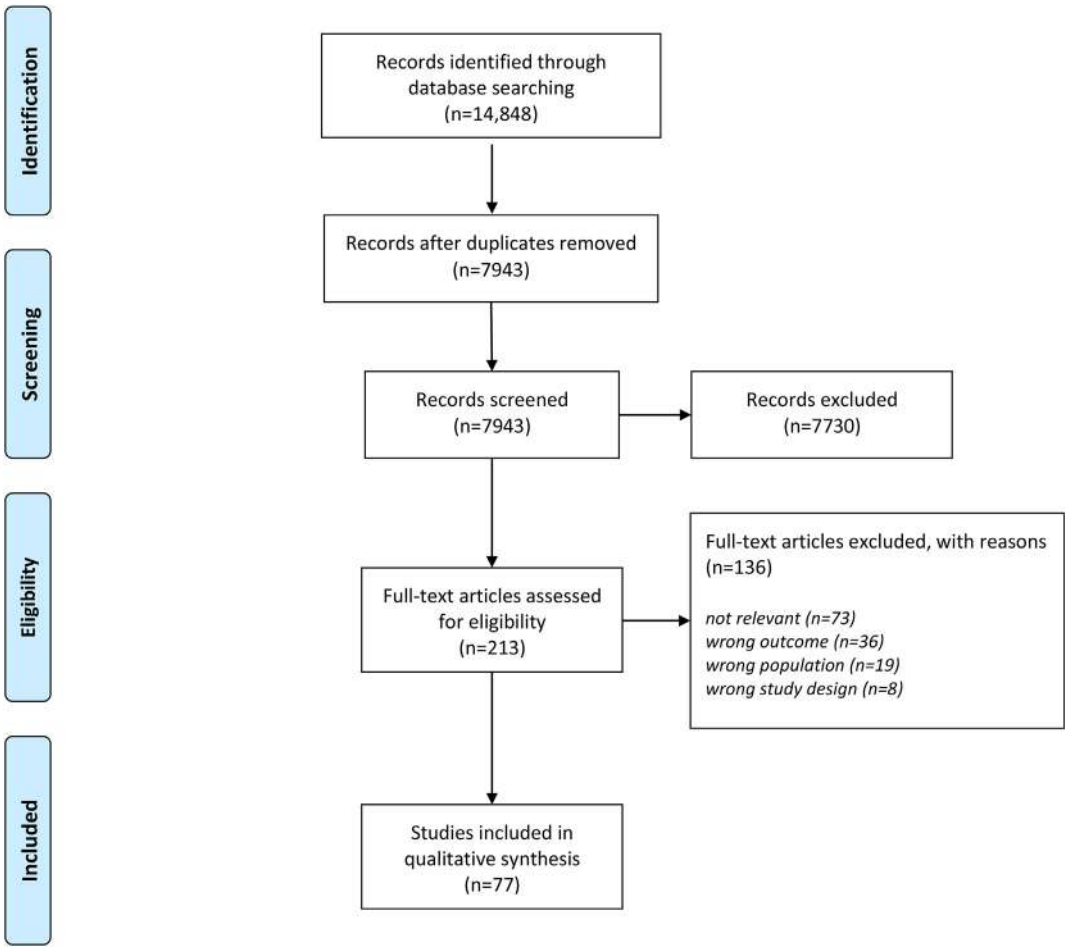

Fig. 1. Flow diagram of the study selection process.

Quality assessment

According to the Joanna Briggs Institute checklist for cross-sectional studies,[26] five of the 77 studies were characterised as 'best' in terms of quality, achieving high ratings in all domains.[64,73,82,87,99] All studies had appropriately defined inclusion criteria, and only two studies did not describe the subjects and settings in detail.[80,97] In most studies, biases and/or unclear statements were detected with reference to validation of exposure measures, criteria for measurement, identification of confounding factors and strategies to deal with the confounding factors.[28–63,65–72,75–81,83–86,88–98,100–105] With regard to outcome measurement, unclear information was provided in three studies,[45,78,101] and unclear statistical analyses were used in four[56,70,79,80] of 77 studies. Supplementary Table S2 provides full-quality assessment results.

Smoking behaviour

In 75 of 77 studies, information about smoking behaviour were reported[28-36,38-62,64-73,75-105] and can be found in Table 1. An increase in smoking habit was stated for most participants in 34 studies.[28,30–33,36,38,40,43,44,47–49,52,53,55,58,62,65,66,71,72,77,78,80,84,86,89,92,93,96,98,99,104,105] The change in smoking behaviour ranged from an increase of 0.4% in France[61] to 79.8% in Libya.[62] Countries that showed a clear increase in smoking habit were Belgium,[28,98] Cyprus,[65] Croatia,[48] Israel,[32] Jordan,[30] Libya,[62] Romania[105] and Turkey.[31,53,96] Moreover, in the study by Manthey et al. that included a population from 21 European countries, an increase in smoking habit was reported in 43.3% of participants.[71]

A decrease in smoking behaviour was reported for the majority of participants in 18 studies.[29,39,42,45,46,54,57,59,60,67,76,79,83,85,87,90,100–102] Countries that showed a clear decrease or cessation of smoking were Poland,[54] UAE[87] and Vietnam.[83] Data about the percentages of participants who quit smoking were available from Belgium,[28,98] Brazil,[45] France,[61,86] Germany,[66] India,[60,76] Italy,[38] Japan,[69,94] Romania,[105] Spain[39] and Turkey[96,101] and ranged from 1% to 73% of participants.

For 21 studies, the majority of participants reported no change in smoking behaviour.[34,35,41,50,51,56,61,64,68–70,73,75,81,82,89,91,94,95,97,103] Countries where smoking behaviour remained stable included Albania,[50] Canada,[95,103] Japan,[69,94] Kuwait[88] and the Netherlands.[51,97]

Within-country variations in the change of smoking behaviours were reported in Australia,[55,91,92] Bangladesh,[29,73] Brazil,[45,70,84] China,[99,100] France,[36,40,44,59,61,75,86] Germany,[66,81] India,[42,60,67,76,90,93] Italy,[38,43,46,47,52,78] Spain,[33,34,39,82] Sweden,[35,49] the United Kingdom[58,77,79,80] and the United States.[41,56,57,64,68,72,85,89,102,104]

Data regarding the change in the number of cigarettes smoked per day varied between countries. In India, 10% of participants stated that they smoked 4-6 cigarettes per day before the COVID-19 lockdown, whereas during/after the lockdown the percentage was 0.5%.[42] On the contrary, in one study from Brazil, despite the fact

Table 1
Baseline characteristics and smoking behaviour before and after/during COVID-19 lockdowns.

First author, year (country)	Subjects (F/M/O) type	Age (years)	Time of survey conduction	Smoking: increase	Smoking: decrease	Smoking: No change	Smoking: quit	No smokers	Initiation of smoking	Efforts to reduce smoking	Smoking before the COVID-19 lockdowns	Smoking after/during the COVID-19 lockdowns
Adriaens 2021 (Belgium)[28]	202 (50/150/2)	≥18/39 (9.89)[a]	25 May to 8 June 2020	42.4%	16.9%	10.2%	30.5%					
Ahmed 2021 (Bangladesh)[29]	1222 (466/750)	18–82/ 30.8 (12.1)[a]	27 June to 20 July 2020	6.4%	48.6%	45%						
Al Domi 2021 (Jordan)[30]	4388 (3086/1302)	NA	March to April 2020	13.3%				71.4%				
Ayran 2021 (Turkey)[31]	503 (234/269)	21.6 (2.5)[a]	May to June 2020	32.4%						Yes: 41.9% No: 58.1%		
Bar-Zeev 2021 (Israel)[32]	660 (397/263)	40.2 (14.55)[a]	6–28 April 2020	44.3%	21.2%	34.5%				Yes: 16%		
Biviá-Roig 2021 (Spain)[33]	124 (124/0)	18–38/ 33.5 (3.7)[a]	28 October 2020	27.5%				72.5%				
Blithikioti 2021 (Spain)[34]	303 (186/113) Subjects with substance use disorders	49.3 (15.6)[a]	June to July 2020	5.4%	9.5%	85.1%					Never: 42.9% 1–2 times/year: 3.1% Monthly: 1% Weekly: 3.4% Daily: 49.7%	Never: 47.5% 1–2 times/year: 4% Monthly: 1.3% Weekly: 2.6% Daily: 44.6%
Blom 2021 (Sweden)[35]	5599 (2800/2800)	46.3 (11.0)[a]	21 April to 2 December 2020	1st wave (April to June): 0.8% 2nd wave (September to December): 0.5%	1st wave (April to June): 3.8% 2nd wave (September to December): 2.5%	1st wave (April to June): 95.4% 2nd wave (September to December): 97%						
Bourion-Bedes 2021 (France)[36]	3928 (2771/1154)	21.7 (4)[a]	7–17 May 2020	7.2%	6.3%	3%		83.5%				
Carreras 2021 (Italy)[38]	1400 (677/724) Current smokers	18–74	27 April to 3 May 2020	36.3%	15%		8.6%					
Celorio-Sardà 2021 (Spain)[39]	321 (256/65)	≥18	22 May to 3 July	22%	30%		15%	87.5%				
Chagué 2020 (France)[40]	124 (49/75) Subjects with congestive heart failure	71.0 (14.0)	17–24 March 2020	44.4%				92.7%				
Chertok 2020 (USA)[41]	180	≥18	Initiation on 7 April 2020	18.3%	21.3%	43.3%						
Chopra 2020 (India)[42]	995	18-85/ 33.3 (14.5)[a]	15–30 August 2020								No: 94.4% Yes, 1-3 cigarettes/day: 3.7% Yes, 4-6 cigarettes/day: 10% Yes, 7-9 cigarettes/day: 0.7% Yes, >10 cigarettes/day: 0.2%	No: 95.3% Yes, 1-3 cigarettes/day: 3.9% Yes, 4-6 cigarettes/day: 0.5% Yes, 7-9 cigarettes/day: 0.0% Yes, >10 cigarettes/day: 0.3%
Cirilo 2021 (Italy)[43]	140 Infertile women	18–49/ 39.4 (5)[a]	20 April to May 2020	27.3% *(of smokers)*								

(*continued on next page*)

Table 1 (*continued*)

First author, year (country)	Subjects (F/M/O) type	Age (years)	Time of survey conduction	Smoking: increase	Smoking: decrease	Smoking: No change	Smoking: quit	No smokers	Initiation of smoking	Efforts to reduce smoking	Smoking before the COVID-19 lockdowns	Smoking after/during the COVID-19 lockdowns
Cransac-Miet 2020 (France)[44]	195 Patients with chronic coronary syndromes	65.5 (11.1)[a]	April 2018 to April 2019	Smoking increase (>25%): 24.1%								
da Silva Leonel 2021 (Brazil)[45]	1515 (1120/395)	18–80/ 31.8 (11.5)[a]	June to July 2020				29.8%	90.5%	0.7% *of non-smokers*		>10 cigarettes/day: 11.9% 1–10 cigarettes/day: 51.5% No: 74.9% <5 cigarettes/day: 8.9% 5–10 cigarettes/day: 8.3% >10 cigarettes/day 7.9%	>10 cigarettes/day: 29.7% 1–10 cigarettes/day: 35.6% *P < 0.001* No: 78.2% <5 cigarettes/day: 8.2% 5–10 cigarettes/day: 6.3% >10 cigarettes/day 7.3%
Di Renzo 2020 (Italy)[46]	3533 (2689/844)	40.03 (13.53)[a]	5–24 April 2020									
Di Santo 2020 (Italy)[47]	126 (102/24) Subjects with mild cognitive impairment or subjective cognitive decline	≥60/ 74.29 (6.51)[a]	21 April to 7 May 2020	33.3%	11.1%			85.71%				
Dogas 2020 (Croatia)[48]	3027 (1989/506)	40 (30-50)[b]	25 April to 5 May 2020								Number of cigarettes: 12.3 (7.8)[a]	Number of cigarettes: 14.3 (10.3)[a]
Ekstrom 2021 (Sweden)[49]	1064 (996/648)	25.3 (0.8)[a]	10 August to 10 November 2020								No: 68.8% Former smokers: 12.3% Occasionally: 12.4% Daily: 6.5%	No: 71.7% Former smokers: 13.6% Occasionally: 11% Daily: 3.7%
Elezi 2020 (Albania)[50]	1678 (1229/449)	26.49 (8.07)	4–29 April 2020	20.8%	39.1%	40.1%		87.7%				
Elling 2020 (The Netherlands)[51]	340 (207/133) Smokers willing to quit smoking	21–80 49 (13)[a]	26 March to 3 April 2020	13.8%	18.5%	67.7%						
Ferrante 2020 (Italy)[52]	7847	48.6 (13.9)[a]	21 April to 7 June 2020	29.5%								
Fidanci 2021 (Turkey)[53]	104 (50/54)	37.4 (10.7)[a]	May to November 2020								Very low dependence: 26.9% Low dependence: 16.3% Moderate dependence: 15.4% High dependence: 18.3% Very high dependence: 23.1%	Very low dependence: 14.4% Low dependence: 20.2% Moderate dependence: 14.4% High dependence: 23.1% Very high dependence: 27.9%
Fila-Witecka 2021 (Poland)[54]	980 (733/247)	22.24 (2.46)[a]	12 May to 30 June 2020	11%	16%							
Gendall 2020 (Australia)[55]	261 (128/133)	≥18	15–18 April 2020								Daily smokers: 11.1% Weekly smokers: 9.1%	Daily smokers: 13% Weekly smokers: 9.5%
Gonzalez 2021 (USA)[57]	2571	≥18	March to May 2020								Number of cigarettes: 13 (8.91)[a]	Number of cigarettes: 11.8 (7.8)[a]
Giovenco 2021 (USA)[56]	44 (24/20) Smokers	≥18	14–24 April 2020	18.2%	13.6%	68.2%						
Grogan 2020 (UK)[58]	132 (73/55/4) Smokers	25 (19-52)[b]	22 May to 22 June 2020	12%								
Guignard 2021 (France)[59]	2003 (1049/954)	≥18	30 March to 1 April 2020	26.7%	38.3%			78.9%				
Gupte 2020 (India)[60]	650 Smokers		14–28 May 2020				34%					
Hansel 2021 (France)[61]	5280 (2677/2587/16)		23–28 April 2020	0.4%	3.3%	90.1%	2.3%					

Jahan 2021 (Libya)[62]	683 (399/284)	≥18	10 October to 10 November 2020	79.8%				85.6%				
Knell 2020 (USA)[64]	1809 (1220/589)	35–49	15 April to 5 May 2020	30.5%	19.2%	50.3%		74.7%				
Kolokotroni 2021 (Cyprus)[65]	745 (550/195)	39 (13)[a]	10 April to 12 May 2020	43.8%	28.1%							
Koopmann 2021 (Germany)[66]	3116	≥18	8 April to 11 May 2020	45.8%	9.0%	31.3%	9.9%	75.7%	4.0%			
Kovil 2020 (India)[67]	343 (110/233) Subjects with T2DM	55 (13.0)[a]	10–16 April 2020								12.2%	8.4%
Kowitt 2020 (USA)[68]	777 (380/389)	39.9 (13.4)[a]	23 April to 7 May 2020	40.9%	17.8%	41.3%				Yes: 46.5%		
Koyama 2021 (Japan)[69]	5120 (2505/2615) Smokers		27 May to 14 June 2020	32.1%	11.3%	44.8%	11.9%					
Malta 2021 (Brazil)[70]	45,161 (26,206/18,955)	≥18	24 April to 24 May 2020	34% (6.4% increase 1-5 cigarettes, 22.5% increase 10 cigarettes, 5.1% increase >20 cigarettes)	12.1%	53.9%		88%				
Manthey et al., 2021 (21 European countries)[71,c]	9816 (4574/5114/128) Smokers	18–98	24 April to 22 July 2020	43.3%	39.6%	17.1%						
Matsungo 2020 (USA)[72]	507 (283/166)	≥18	11–25 May 2020	6.6%	4%	3.7%		85.7%				
Mistry 2021 (Bangladesh)[73]	1032(676/356)	≥60	October 2020	15.9%		84.1%		54.4%				
Mititelu 2021 (Romania)[74]	805 (158/647)	≥20	8–26 July 2020	17.8% (of smokers)			1.8%	70.1%				
Mounir 2021 (France)[75]	702 (564/138)	≥18	18 May to 6 June 2020	24%	4.1%	71.5%						
Naik 2021 (India)[76]	116 (10/106)	>18	December 2020		60.3%	24.1%	27.6%	67.4%				
Naughton 2021 (UK)[77]	1044 (747/279/2)	≥18	8 April to 18 May 2020					63.8%			9.6%	10.8%
Odone 2021 (Italy)[78]	6003	18–74	27 April to 3 May 2020	44%	24%	28%						
O'Donnell 2021 (UK)[79]	25 (12/13)	22–73	September to November 2020								23.3%	21.9%
Osinibi 2021 (UK)[80]	50		January to February 2021	32%	34%	34%						
Palmer 2021 (Germany)[81]	827 (622/205)	18–29	12 March to 3 May 2020	4.9%	5.4%	89.7%						
Pérez-Rodrigo. 2021 (Spain)[82]	1036 (735/301)	≥18	21 April to 8 May 2020	14.1%	14.7%	16.5%						
Pham 2020 (Vietnam)[83]	8291 (4890/3401)	18–85	14 February to 31 May 2020									Never, stopped, or smoke less: 91% Unchanged or smoke more: 9%
Prezotti 2021 (Brazil)[84]	275 (26/249)	30 years (28-31)[b]	11–19 June 2020	53.6% (of smokers)	7.1%			88.6%				
	694 (414/280)	≥18		32%		31%						

(continued on next page)

Table 1 (*continued*)

First author, year (country)	Subjects (F/M/O) type	Age (years)	Time of survey conduction	Smoking: increase	Smoking: decrease	Smoking: No change	Smoking: quit	No smokers	Initiation of smoking	Efforts to reduce smoking	Smoking before the COVID-19 lockdowns	Smoking after/during the COVID-19 lockdowns
Rigotti 2021 (USA)[85]			18 May to 16 July 2020		37% (including 8% quit)							
Rossinot 2020 (France)[86]	1454 (924/523/7)	24–65	23 April to 7 May 2020	11.2%	6.3%	10.2%	72.3%					
Saddik 2021 (UAE)[87]	1469 (1216/253)	≥18	24 March to 15 May 2020	Started/ increased: 13%	Stop/ decreased: 49%							
Salman 2021 (Kuwait)[88]	679 (393/286)	≥21	19 June to 15 July 2020	9.1%	5%	10.3%		75.6%				
Sharma 2020 (USA)[89]	542 (436/106)	18–25/ 22 (2.1)[a]	April to May 2020	8.3%	16.2%			75.5%				
Singh 2021 (India)[90]	10,008	18–81	20 May 2020								I don't smoke: 87%/party smoker: 6.5%/at least 1 cigarette/day: 6.4%	I don't smoke: 94.3%/party smoker: 2.4%/at least 1 cigarette/day: 3.3%
Stanton 2020 (Australia)[91]	4183 (999/484)	50.5 (14.9)[a]	9–19 April 2020	6.9% (negative change)	3.4% (positive change)	89.7%						
Stubbs 2021 (Australia)[92]	317 (227/89/1)	>18	Mid-March 2020 to the end of May 2020	56%	10%	33%		88.9%				
Sujatha 2021 (India)[93]	729 (132/597)	44.1 (14.4)[a]	NA	69%	49%	22%						
Suka 2021[94] (Japan)	8000 (4000/4000)	25–64	November 2020	2.2%	3.8%	81.5%	12.4%					
Tavolacci 2021 (Canada)[95]	3671 (2676/995)	20.9 (2.47)[a]	13–31 May 2020	2% (unfavourable change)	5.8% (favourable change)	92.2%					Regular: 14% Occasional: 4.5%	Regular: 12.4% Occasional: 2.4%
Uysal 2021 (Turkey)[96]	615 (422/193)	18–90	30 June to 30 September 2020	18.2% (initiation) 15.9% increase	14.5%		12.2%					
Van der Werf 2021 (The Netherlands)[97]	1004 (509/495)	≥18	22–27 May 2020	3.7%	8.3%	59.3%		Unknown: 28.8%				
Vanderbruggen. 2020 (Belgium)[98]	3632	42,1 (14.6)[a]	9–29 April 2020	0.9% *(initiation)* 7.4% *(increase)*	2.5%		1%					
Yan 2020 (China)[99]	9016 (5177/3839)	≥18	25 April to 11 May 11 2020	49.2%	28.5%	22.3%						
Yang 2021 (China)[100]	11,500 (5635/5865)	36.79	October 2020	14.9%	18.5%	8.7%		57.9%				
Yenibertiz 2021 (Turkey)[101]	105 (42/63)	39.80 (12.66)[a]	March to June 2020				13.3%					
Yingst 2021 (USA)[102]	291 (216/75)	47.3 (11.6)[a]	23 April 2020								93.1%	90.4%
Zajacova 2020 (Canada)[103]	4319 (2202/2117)	≥25	29 March to 3 April 2020	3%	4%	93%						
Zhang 2021 (USA)[104]	1276 (517/724)	45.0 (17.0)[a]	13 April to 8 June 2020	41%	20.1%	38.9%						

F, female; M, male; NA, not applicable; O, other; T2DM, type 2 diabetes mellitus.
All studies were cross-sectional except for the Naughton 2021, which was a prospective cohort study. Percentages represent absolute changes.
[a] Mean (standard deviation).
[b] Median (interquartile range).
[c] Albania, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Norway, Poland, Portugal, Russia, Slovakia, Slovenia, Spain, Sweden, Ukraine and the United Kingdom.

Table 2
Characteristics of vaping habit before and after/during COVID-19 lockdowns.

Study ID (country)	Subjects (F/M/O) Type	Age (years)	Time of survey conducting	Vaping: increase	Vaping: decrease	Vaping: no change	Vaping: quit	Vaping before COVID-19 lockdown	Vaping after/ during COVID-19 lockdown
Adriaens 2021 (Belgium)[28]	202 (50/150/2)	≥18/39 (9.89)[b]	25 May to 8 June 2020	25.4%	27.1%	40.7%	6.8%[a]		
Caponnetto 2020 (Italy)[37]	1825 (683/1142)	34.7 (14.11)[b]	2–26 April 2020	22.3%	6.5%	34.8%			
Giovenco 2021 (USA)[56]	44 (24/20) Smokers	≥18	14–24 April 2020	2.3%	6.8%	4.5%			
Kale 2021 (UK)[63]	2792 (1452/1340)	NA	30 April to June 2020	42.1%	9.5%				
Odone 2021 (Italy)[78]	6003	18–74	27 April to 3 May 2020					8.1%	9.1%
Yingst 2021 (USA)[102]	291 (216/75)	47.3 (11.6)[b]	23 April 2020					16.2%	13.1%
Zhang 2021 (USA)[104]	1276 (517/724)	45.0 (17.0)[b]	13 April to 8 June 2020	45.9%	18.2%	35.9%			

F, female; M, male; O, other.
All studies were cross-sectional. Percentages represent absolute changes.
[a] All, ran out of e-liquid.
[b] Mean (standard deviation).

that 29.9% of smokers quit smoking, the percentage of subjects who smoked >10 cigarettes per day increased from 11.9% before the COVID-19 lockdown to 29.7% during/after the COVID-19 lockdown ($P < 0.001$).[45]

Meta-analysis results, where data from five cross-sectional studies were analysed,[32,48,57,98,102] showed a tendency towards an increase in the number of cigarettes smoked per day; however, this change was not significant (0.81 weighted mean difference [95% confidence interval, −0.59 to 2.21]), and there was high heterogeneity among studies ($I^2 = 94\%$). The results of the meta-analysis can be seen in the forest plot in Fig. 2.

Vaping behaviour

Vaping behaviour was reported in seven of 77 studies.[28,37,56,63,78,102,104] In two studies, from Belgium[28] and Italy,[37] most of the participants stated that their vaping behaviour was not changed during/after the COVID-19 lockdown. An increase in vaping habit during/after COVID-19 lockdown was observed in three studies, led by Kale,[63] Odone[78] and Zhang.[104] On the other hand, a decrease in vaping habit was recorded in the studies by Giovenco et al.[56] and Yingst et al.[102] Information regarding vaping cessation was only provided by one study from Belgium, where 6.8% of participants quit this habit during/after COVID-19 lockdown.[28]

Discussion

Smoking and vaping behaviours are impacted by the COVID-19 lockdown. To the best of the authors' knowledge, this is the first systematic literature review and meta-analysis that aimed to investigate the impact of the COVID-19 lockdowns on smoking and vaping behaviour.

Regarding smoking behaviour during/after lockdown, an 'increase' was the predominant answer ($N = 35$), followed by the statement of 'no change' ($N = 21$). A decrease in smoking behaviour by the majority of participants was found in 19 studies.

Different results regarding smoking behaviour change during/after lockdown have been observed in France.[36,40,59,61,75,86] An increase in smoking was reported for participants in the studies by Borion-Bédès et al.[36] and Rossinot et al.,[86] which included the general population. Similarly, an increase in smoking behaviour was the predominant answer in the study by Chagué et al. in which participants with congestive heart failure were the target population[40] and in the study by Cransac-Miet et al.[44] that investigated a population of individuals with chronic coronary syndromes. On the other hand, the fact that more than one-third of participants decreased their smoking behaviour in the study by Guignard et al.[59] and that 'no change' was the predominant answer in the studies led by Hansel[61] and Mounir[75] reflects the heterogenous populations that were included in the French studies. It is important to highlight the fact that participants with coronary syndromes increased their smoking behaviour during/after lockdown, thus also increasing their risk of acute coronary events and complications.[107]

With regard to Germany, in one study that was conducted over a 1-month period (April to May 2020), an increase in smoking behaviour was reported for almost half of the participants.[66] However, the study led by Palmer that was conducted for a more representative period of the first lockdown indicated that the 'no change' answer was the predominant response, and this could be more representative for the country.[81]

Most studies from Italy showed an increase in smoking behaviour during/after lockdown.[38,43,47,52,78] The populations in these studies varied significantly, including the general population,[78] current smokers,[38] infertile women[43] and elderly individuals with

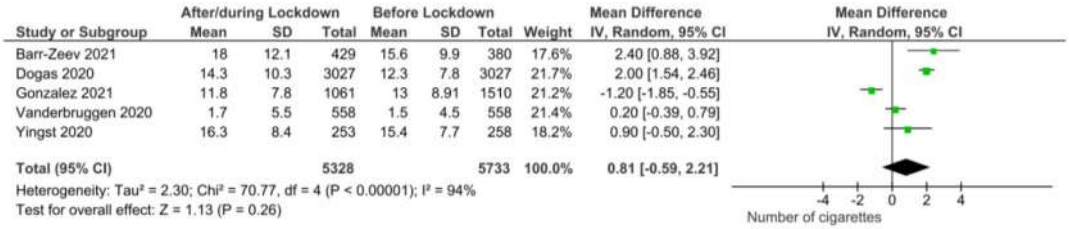

Fig. 2. Forest plot of the number of cigarettes smoked per day before and after/during the COVID-19 lockdown.

cognitive impairment.[47] Of special interest is the fact that infertile women increased their smoking behaviour, whereas it is already known that smoking has a negative impact in female fertility.[108] Only one study from Italy reported a decrease in smoking behaviour. This study included the general adult population, but further information regarding the sample was missing.[46]

Information regarding change in smoking behaviour during/after lockdown in Spain came from four studies.[33,34,39,82] An increase in smoking was reported for almost one-third of participants in the study by Biviá-Roig. This study took place during the second lockdown (October 2020) with a small sample (n = 124 women);[33] therefore, the results might not be representative for the whole country. A decrease in smoking was stated in the cross-sectional study led by Celorio-Sardà,[39] where 30% of smokers reduced their smoking habit and 15% reported having quit smoking. In the study by Perez-Rodrigo, information regarding more than half of the participants' smoking habits was missing, and the interpretation of the results of this study cannot be accurate.[82] In addition, in the study by Blithikioti et al., where a subgroup of participants with substance use disorder from Spain were examined, approximately 85% of participants stated that they did not change their smoking behaviour and almost 10% reduced this habit.[34] These results are in accordance with a study from England that examined drinking and smoking changes during the COVID-19 lockdown, where an increase in smoking cessation attempts was found.[25] A possible explanation could be that this vulnerable population group could be more motivated and focussed to overcome addictions during the lockdown.

The results from Sweden showed that when it came to both the first and second wave of lockdowns, smoking habit was not changed for the majority of participants. In contrast, in a study that was conducted between August and November 2020, a decrease in smoking was observed.[49] However, Sweden was not under restriction measures during this whole period; therefore, lockdown might not be the only factor that had an impact on the decrease in smoking behaviour.

In the United Kingdom, three of four studies showed an increase in smoking behaviour for the majority of participants,[58,77,80] whereas smoking prevalence was found to decrease in the study led by O'Donnell.[79] The difference in these results could be explained by the fact that the study by O'Donnell et al. was conducted between September and November 2020 when there were periods with and without lockdown;[79] therefore, the results from this study might not be representative for the lockdown period.

In the United States, most participants stated that they did not change their smoking behaviour during the lockdown.[41,56,64,68] An increase in smoking behaviour was observed for most of the smokers in the studies by Matsungo et al.,[72] Sharma et al.[89] and Zhang et al.[104] On the contrary, 'decrease' was the predominant answer in the studies led by Rigotti[85] and Yingst.[102] All the US studies included general adult populations.[41,56,64,68,72,85,89,102] The heterogeneity between the results could be explained by the fact that each study included populations that may not be representative for the whole country; however, the results provide some initial evidence about smoking behaviour in the United States.

In Brazil, heterogeneity in the results between studies was observed.[45,70,84] The period that the surveys were conducted was not the same among these three studies and could explain the difference in the results. Most of the participants stated that they did not change their smoking behaviour early in lockdown (April to May 2020).[70] However, 1 month later (June 2020), an increase was observed for more than half of the smokers, showing June as the period of the greatest impact of lockdown.[84] Between June and July 2020, when lockdowns were reduced and daily life seemed to get back to normal, cessation of smoking was seen in almost one-third of smokers, and smoking initiation was observed for <1% of the participants.[45] Nevertheless, the number of cigarettes smoked per day was found to increase, and this could mean that subjects who increased smoking either continued their harmful habit or quitted smoking with a view to limit factors that could worsen any potential COVID-19 infection.[45]

Heterogenicity in results was also observed in studies from Bangladesh.[29,73] The study by Ahmed et al.,[29] which was conducted during the period of the first lockdown (27 June to 20 July 2020) showed that smoking habit decreased for most participants, whereas in the study by Mistry et al.,[73] which was conducted during the second lockdown (October 2020), 'no change' was the predominant response. This could be because people tried to decrease their smoking habits at the start of the pandemic, possibly due to the fear of this respiratory disease, whereas the second lockdown did not have the same impact on the lifestyles of participants.

Moreover, in China, during April and May 2020, almost half of the participants increased their smoking behaviour,[99] whereas a decrease was observed for most participants during October 2020, which reflected the beginning of the second COVID-19 lockdown.[100] The difference between the two lockdowns showed that the first lockdown negatively influenced the daily life of people, possibly due to the fear and stress of the COVID-19.[109]

All studies from India[42,60,67,76,90] reported a decrease and/or cessation of smoking for most participants, except one showed, which showed an increase.[93] According to Gupte et al.,[60] the reasons that participants decreased their smoking behaviour included the increased price, the unavailability of tobacco and the concerns about COVID-19. From another point of view, the high rate of increase in smoking reported in Sujatha et al.[93] was explained by the fact that smokers bought more smoking products due to the fear that stores would run out of stock and the lockdown would be extended. However, the period when the survey was conducted in this study was not reported, and therefore, it was difficult understand the disagreement of the results compared with the other studies from India.[93]

In the studies from Australia, an increase in smoking habit was stated in two of three studies,[55,92] and the 'no change' answer was the most predominant in the study by Stanton et al.[91] Studies led by Gendal and Stanton were both conducted during April 2020;

however, in the Gendal et al. study, data from almost 80% of participants were missing, meaning that the impact of lockdown during April 2020 in Australia was not clear in the results.[55,91] Taking into account the fact that the study led by Stubbs was conducted from mid-March until the end of May 2020, which was a more representative period of lockdown, the increase in smoking behaviour for most smokers may be the most accurate results for change in smoking behaviour in Australia.[92]

In general, lockdowns changed smoking behaviour. Smoking, which in most cases was found to increase during/after lockdown, has been associated with more severe COVID-19 infection and worse outcomes according to recent systematic reviews.[110,111] In addition to the risk of a more severe COVID-19 infection, the increase of smoking can lead to smoking-related illnesses, such as cancer,[112] heart diseases,[113,114] lung impairments[115] and diabetes mellitus type 2.[116] Smoking can also increase the risk eye diseases[117] and immune system disorders, such as rheumatoid arthritis.[118]

Meta-analysis results of the number of cigarettes smoked per day showed a tendency towards an increase, but this was not statistically significant (Fig. 2). Interpretation of these results could be that there is a trend towards increase. However, the high heterogeneity among the studies included in the meta-analysis cannot lead to firm conclusions.

The results on vaping behaviour showed a tendency towards an increase during/after lockdown in most studies.[63,78,104] Information regarding vaping behaviour reflected only the first COVID-19 lockdown (April to June 2020).[28,37,56,63,78,102,104] Studies from the United States showed different results for vaping behaviour.[102,104] The study of Yingst et al.[102] showed a decrease in vaping prevalence, although it should be noted that this was a 1-day survey with a small sample ($N = 291$). The results from the study by Zhang et al.,[104] which took place over almost 3 months and included a larger sample ($N = 1276$), could be more representative of the United States. An increase in vaping behaviour, which is promoted as a safer alternative to smoking, could also lead to detrimental health effects due to the fact that electronic cigarette use has been associated with severe acute and chronic lung injuries.[119,120]

The present study has several strengths. First, to the best of the authors' knowledge, this is the first systematic review and meta-analysis to examine the impact of the COVID-19 lockdown on smoking and vaping. The 77 studies included are from a large geographical section of the globe, results reflect both COVID-19 lockdowns, and provide a representative impact of the pandemic on smoking and vaping behaviour, as more than 207,000 adults were included. Moreover, the quality of included studies was sufficient, which strengthens the present study results.

Among the limitations of the present study is the missing information about the representativeness of each study sample. In addition, the level of statistical significance and the level of change in smoking behaviour were not reported in most of the studies included in the systematic review. Moreover, this study did not investigate the impact of lockdowns on heated tobacco, and it is not known whether the term 'smoking' in some studies included heated tobacco or not. In addition, the fact that different measures were used to assess smoking/vaping behaviour may influence the accuracy of the existing data. Furthermore, only studies in English, French and Spanish languages were included in this analysis; thus, relevant studies in other languages were missing.

Conclusions

According to most included studies, smoking and vaping habits increased during the lockdowns.

However, for a minority of participants, the fear of COVID-19 was a motivation to quit smoking/vaping. The increase in smoking and vaping behaviours could have a detrimental health impact in both the short and long term. If such changes remain for a long time or become permanent, the prevalence of non-communicable diseases is expected to increase. Therefore, in addition to strategies advocating for healthier lifestyles overall, further research is needed in this field. Awareness of the benefits of smoking/vaping cessation may be important for the reversal of this unhealthy habit.

Author statements

Ethical approval

Ethics approval was not required for this study. This study is a review, and data were freely available in the literature.

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Competing interests

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Authors' contributions

D.B., K.E and A.S. searched the databases. D.B, K.E, A.S. and M.C. wrote the article. D.B., J.B., and M.C. made the necessary recommendations. and D.B., J.B., and M.C. revised the article. All authors have read and approved the final version of article.

Appendix A. Supplementary data

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Original Research

Impact of the COVID-19 lockdown on routine childhood vaccination coverage rates in Catalonia (Spain): a public health register–based study

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ABSTRACT

Objective: The aim of this study was to determine the impact of the lockdown measures adopted during the COVID-19 pandemic on routine childhood vaccination coverage rates in Catalonia (Spain) and to estimate its recovery once the progressive return to 'normalcy' had begun.
Study design: We conducted a public health register–based study.
Methods: Routine childhood vaccination coverage rates were analysed in three periods: a first pre-lockdown period (from January 2019 to February 2020), a second lockdown period with full restrictions (from March 2020 to June 2020), and, finally, a third post-lockdown period with partial restrictions (from July 2020 to December 2021).
Results: During the lockdown period, most of the coverage rates remained stable, concerning the pre-lockdown period; however, when comparing the vaccination coverage rates in the post-lockdown period to the pre-lockdown period, we observed decreases in all types of vaccines and doses analysed, except for coverage with the PCV13 vaccine in 2-year-olds, which experienced an increase. The most relevant reductions were observed in measles-mumps-rubella and diphtheria-tetanus-acellular pertussis vaccination coverage rates.
Conclusions: Since the beginning of the COVID-19 pandemic, there has been an overall decline in routine childhood vaccine coverage rates, and the pre-pandemic rates have not yet been recovered. Immediate and long-term support strategies must be maintained and strengthened to restore and sustain routine childhood vaccination.

Introduction

On 11 March 2020, in response to the increase in SARS-CoV-2 infections globally, the World Health Organization (WHO) declared that the situation could be considered a pandemic.[1] Since then, countries have adopted different prevention and control measures depending on their resources and epidemiological situation.[2] In Spain, as in other countries, between March 2020 and May 2021, among other measures, two periods of lockdown were established, of approximately 3 and 6 months, respectively, with severe restrictions on mobility and access to different services, including health services. Moreover, the COVID-19 pandemic challenged healthcare services in most European countries to transform and adapt their activities to maintain essential (non-COVID) health care while contributing to the emergency response to the pandemic.[3,4]

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In public and community health, vaccines are one of the most effective tools for disease prevention. However, the benefits of vaccination are significantly reduced if vaccination schedules are delayed or not completed. Therefore, WHO and United Nations Children's Fund established that routine vaccination must remain a priority during the COVID-19 response to limit preventable communicable diseases.[5] Accordingly, most countries carried out and maintained efforts at routine vaccination during the pandemic, especially for pregnant women and children.[6] However, despite these efforts, more countries worldwide have been forced to interrupt, delay, re-organise or completely suspend routine childhood vaccinations during lockdown.[6,7]

In Catalonia, Spain's second most populated autonomous community with more than 7.7 million inhabitants, and as in the rest of Spain, vaccination services were high on the list of priorities for primary health care (PHC).[8] During the initial period of full lockdown (March to June 2020), the Public Health Agency of Catalonia prioritized the immediate vaccination of children aged up to 15 months, pregnant women and persons with high-risk conditions. Furthermore, during the various de-escalation phases,[9] active recruitment of unvaccinated children and adults was recommended to gradually return to 'normalcy'. Measures for safe vaccination in primary care centres (PCCs) were also implemented.[8] In addition, the Catalan government published the plan to strengthen and transform PHC in September 2020, securing additional funding until 2022 to support this essential healthcare service beyond the impact of COVID-19.[10]

Nevertheless, despite these strategies, in 2020, vaccination coverage rates decreased in all Spanish autonomous communities depending on age and type of vaccine.[8,11] The COVID-19 pandemic is a reminder of the importance of vaccination as a critical public health strategy for preventing and controlling communicable diseases. Recovery of vaccination coverage rates in children should be carried out in the shortest possible time. Therefore, this study aimed to determine, based on the analysis of data available in a public health registry, the impact of the lockdown measures adopted during the COVID-19 pandemic on routine childhood vaccination coverage rates in Catalonia (Spain) and to estimate its recovery once the progressive return to 'normalcy' had begun.

Methods

Study design and setting

We carried out a public health register–based study in February 2022. The study is reported in accordance with the STrengthening the Reporting of OBservational studies in Epidemiology guidelines.[12]

The Catalan Health System has universal coverage with free access to health care for the entire population, public financing, integration of different health service networks and an entry point system based on PHC, which includes health care, prevention, health education, health promotion and community care. Therefore, PHC is structured in PCCs or organisational units with human, physical and financial resources that can be dedicated to the general population (including children or not) or exclusively to the child population. Each of these PCCs is assigned a geographically delimited population.[13] Furthermore, around 35% of the population contracts an additional private insurance company or health maintenance organization, especially maternal and child healthcare services.[14]

The Catalan Department of Health purchases and distributes vaccines to public and private centres to ensure full accessibility. Vaccines included in the routine childhood vaccination schedule are primarily administered by PHC services. Therefore, PHC professionals also go to schools to vaccinate children and adolescents. This strategy aims to maintain the highest possible vaccination coverage and to guarantee the continuity of care and the follow-up of Catalonia's systematic vaccination schedule. The vaccines administered are recorded in the shared public electronic health record if PHC services administer them or if the families contact PHC services for any reason and show their vaccination card with the vaccines administered in private centres.

Participants

In Catalonia, there are currently 393 PCCs, of which data from 375 (95.4%) of them were included in the study, which are those using the same server-based electronic health record system. We analysed the recorded vaccination coverage rates of the attended child population, the assigned population with at least one face-to-face or remote contact during the last year with the PCC. The percentage of the assigned child population attended is estimated to be around 89%.

Variables and data sources

Data were obtained from the Catalan Primary Care Services Information System (SISAP).[15] SISAP is a stable public structure created in 2006 to provide information for the different health services and professionals of the Catalan Health System. The main source of data used by SISAP is the PHC electronic health records. In accordance with the recommendations of the routine vaccination schedule (see Supplementary File 1), the recorded vaccination coverage rates grouped by month and year for the following vaccines: diphtheria-tetanus-acellular pertussis (DTaP/Tdap) vaccine, measles-mumps-rubella (MMR), meningococcal C conjugate (MenC) and pneumococcal conjugate vaccine (PCV13). The vaccination coverage rates in three periods were analysed: a first pre-lockdown period (from January 2019 to February 2020), a second lockdown period with full restrictions (from March 2020 to June 2020) and a third post-lockdown period with partial restrictions (from July 2020 to December 2021).

Vaccination coverage rates were estimated according to the following criteria: (1) DTaP or Tdap vaccination, coverage with two doses in 1-year-old children, three doses in 2-year-old children and a booster dose in 7-year-old children; (2) MMR vaccination, coverage with one dose in 2-year-old children and two doses in 4- and 8-year-old children; (3) MenC vaccination, one dose in 1-year-old children or one dose in 2-year-old children; and, finally, (4) PCV13 vaccination, two doses in 1-year-old children and three doses in 2-year-old children. Vaccine coverage for each period and vaccine evaluated was calculated using as the numerator the attended child population who met the age and doses criteria described earlier divided by the denominator of the attended child population who met the age criteria. Hence, both numerators and denominators were dynamic, as they referred to the number of children who had reached that age within the study's time interval (month or quarter).

Statistical methods

We used the Chi-squared tests for trend test to compare the recorded vaccination coverage rates between different quarters of the same year and between the same quarters of each year. We determined the mean rate of recorded vaccination coverage rates in the pre-lockdown (T1), the lockdown (T2) and the post-lockdown (T3) periods and calculated the differences in percentages between T2 and T1 and between T3 and T1. A P value ≤ 0.05 was interpreted as being statistically significant. Data were analysed

using SPSS version 27 (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp).

Results

Table 1 presents the number of children vaccinated and the recorded vaccination coverage rates by year, quarter, age, type of vaccine and dose.

In 2019, a statistically significant, decreasing trend in vaccination coverage rate was only observed with the Tdap booster dose after 6 years old; in contrast, vaccination coverage (for 2-year-olds) with three doses of DTaP vaccine, with one dose of MenC vaccine and with three doses of PCV13 vaccine showed a statistically significant, increasing trend. Vaccination coverage rates remained stable for all other vaccine types and doses analysed. In 2020, all vaccination rates analysed showed a statistically significant, decreasing trend. Finally, in 2021, only the vaccination rate with

Table 1
Recorded vaccination coverage rates in the attended child population by quarter and year.

Vaccines/doses/age group	Number of children (%)				*P*-value[b]
	First quarter	Second quarter	Third quarter	Fourth quarter	
DTaP/Tdap vaccine					
Two doses (1-year-old)					
2019	44,124 (95.5)	43,632 (95.5)	43,166 (95.4)	42,859 (95.7)	0.175
2020	42,854 (95.9)	42,327 (96.0)	41,644 (95.5)	40,901 (95.1)	<0.001
2021	40,010 (95.0)	39,275 (95.2)	38,201 (94.5)	37,138 (94.0)	<0.001
P-value[a]	0.001	0.106	<0.001	<0.001	
Three doses (2-years-old)					
2019	44,719 (94.5)	44,585 (94.6)	44,225 (94.7)	44,129 (94.9)	0.035
2020	43,495 (94.9)	42,851 (94.8)	42,123 (94.1)	41,323 (94.0)	<0.001
2021	40,786 (93.8)	40,699 (93.8)	40,183 (93.8)	39,800 (93.1)	<0.001
P-value[a]	<0.001	<0.001	<0.001	<0.001	
One booster dose after 6 years (7-years-old)					
2019	39,957 (80.8)	39,523 (80.4)	39,468 (80.3)	39,707 (80.2)	0.019
2020	38,367 (80.1)	36,184 (79.6)	35,515 (78.3)	35,186 (76.3)	<0.001
2021	35,244 (75.9)	37,678 (76.8)	37,793 (77.0)	38,142 (76.8)	0.001
P-value[a]	<0.001	<0.001	<0.001	<0.001	
MMR vaccine					
One dose (2-years-old)					
2019	44,522 (94.1)	44,382 (94.2)	44,020 (94.3)	43,920 (94.4)	0.071
2020	43,314 (94,5)	42,666 (94.4)	41,912 (93.6)	41,073 (93.4)	<0.001
2021	40,539 (93,3)	40,530 (93.4)	39,941 (93,2)	39,587 (92.6)	<0.001
P-value[a]	<0.001	<0.001	<0.001	<0.001	
Two doses (4-years-old)					
2019	42,097 (88.7)	42,086 (88.9)	42,067 (88.9)	42,639 (88.8)	0.861
2020	42,731 (88.9)	41,574 (88.4)	41,224 (87.4)	40,489 (86.6)	<0.001
2021	40,276 (86.6)	41,109 (87.0)	40,380 (86.8)	40,354 (86.3)	0.121
P-value[a]	<0.001	<0.001	<0.001	<0.001	
Two doses (8-years-old)					
2019	47,745 (94.8)	47,572 (94.9)	47,468 (94.8)	46,629 (94.8)	0.589
2020	46,688 (94.6)	44,689 (94.4)	44,082 (93.7)	44,536 (92.6)	<0.001
2021	43,933 (92.1)	45,164 (92.3)	44,703 (92.3)	45,070 (92.0)	0.738
P-value[a]	<0.001	<0.001	<0.001	<0.001	
MenC vaccine					
One dose (1-year-old)					
2019	44,081 (95.4)	43,603 (95.4)	43,128 (95.4)	42,814 (95.6)	0.212
2020	42,800 (95.7)	42,287 (95.9)	41,619 (95.5)	40,883 (95.0)	<0.001
2021	40,013 (95.0)	39,316 (95.3)	38,211 (94.6)	37,135 (94.0)	<0.001
P-value[a]	0.006	0.631	<0.001	<0.001	
One dose after the first year of life (2-years-old)					
2019	43,154 (91.2)	43,123 (91.5)	42,869 (91.8)	42,830 (92.1)	<0.001
2020	42,264 (92.2)	41,615 (92.1)	40,879 (91.3)	40,060 (91.1)	<0.001
2021	39,492 (90.9)	39,455 (91.0)	39,001 (91.0)	38,684 (90.5)	0.111
P-value[a]	0.061	0.003	<0.001	<0.001	
PCV13 vaccine					
Two doses (1-year-old)					
2019	43,803 (94.8)	43,329 (94.8)	42,869 (94.8)	43,588 (95.1)	0.062
2020	42,590 (95.3)	42,104 (95.5)	41,436 (95.0)	40,736 (94.7)	<0.001
2021	39,827 (94.5)	39,083 (94.7)	37,977 (94.0)	36,891 (93.4)	<0.001
P-value[a]	0.128	0.855	<0.001	<0.001	
Three doses (2-years-old)					
2019	43,280 (91.5)	43,451 (92.2)	43,168 (92.4)	43,104 (92.7)	<0.001
2020	42,534 (92.8)	41,995 (92.9)	41,411 (92.5)	40,664 (92.5)	0.014
2021	40,094 (92.2)	40,053 (92.3)	39,500 (92.2)	39,088 (91.5)	<0.001
P-value[a]	<0.001	0.474	0.157	<0.001	

DTaP, diphtheria-tetanus-acellular pertussis; MMR, measles-mumps-rubella; MenC, meningococcal C conjugate vaccine; PCV13, pneumococcal conjugate vaccine; Tdap, tetanus-diphtheria-acellular pertussis.
[a] Chi-squared test for trend test to compare recorded vaccination coverage rates between quarters within the same year.
[b] Chi-squared test for trend test to compare recorded vaccination coverage rates between quarters within each year.

MMR vaccine for 4- and 8-year-olds and with MenC vaccine for 2-year-olds maintained a stable trend. The rest of the vaccination rates analysed showed a statistically significant, decreasing trend.

Regarding the trends observed between the same quarters of each year, a stable trend was observed in the first quarter for vaccination coverage with MenC vaccine for 2-year-olds with the PCV13 vaccine at 1 year of age, in the second quarter for vaccination coverage with the DTaP vaccine, the MenC vaccine and PCV13 vaccine for 1-year-olds, and with the PCV13 vaccine for 2-year-olds, and in the third quarter for vaccination coverage with the PCV13 vaccine for 2-year-olds. A statistically significant, increasing trend in vaccination coverage with the PCV13 vaccine for 2-year-olds was observed only in the first quarter. For all other vaccine types and doses, vaccination coverage showed a statistically significant decreasing trend in each of the four quarters.

Table 2 and Figs. 1–4 show and compare the percentage of recorded vaccination coverage rates according to pre-lockdown, lockdown and post-lockdown periods. Three (30%) of the vaccination coverage rates analysed in the lockdown period were lower than in the pre-lockdown period, and nine (90%) of those analysed in the post-lockdown period were lower than in the pre-lockdown period. The most substantial declines were observed when comparing post-lockdown and pre-lockdown vaccination coverage rates, namely, with Tdap vaccination for 7-year-olds (see Fig. 1) and with MMR vaccination for 4- and 8-year-olds (see Fig. 2).

Discussion

This study aimed at assessing the impact of the lockdown measures adopted to deal with the COVID-19 pandemic on routine childhood vaccination coverage rates and to estimate its recovery once the gradual return to 'normalcy' had begun. During the lockdown period, most of the coverage rates remained stable concerning the pre-lockdown period; however, when comparing the vaccination coverage rates in the post-lockdown period to the pre-lockdown period, decreases were observed in all types of vaccines and doses analysed, except for coverage with the PCV13 vaccine for 2-year-olds, which experienced an increase.

Consistent with the literature, this research found that there has been an overall decline in routine childhood vaccination coverage rates since the onset of the COVID-19 pandemic.[16–19] The most substantial declines have occurred with MMR vaccination for 4- and 8-year-olds and with the Tdap booster vaccination for 7-year-olds. These results reflect those of a study published with data on vaccine administration in 170 countries collected by the different WHO regions from December 2019 to December 2020.[20] This study shows a decrease of 33% fewer vaccinations for three doses of DTaP, with a variable range among different WHO regions from 9% in Africa to 57% in South-East Asia. In addition, data from a modelling study using data from vaccines administered[21] show a global reduction of 7.7% in coverage with three doses of DTaP and 7.9% for one dose of measles-containing vaccines compared with expected coverage in the absence of a pandemic in 2020. This means that, due to the pandemic, an estimated 8.5 million children would not have received all three doses of DTaP, and 8.9 million children would not have received the first dose of the measles vaccine in 2020. Although the month with the most significant reduction was April 2020, there was a recovery until December 2020, unlike the data obtained in the present study, where the decline in coverage rates has been maintained throughout 2021. However, this continued decline in vaccine coverage rates has also been reported by Rachlin et al.[19] who found that the estimated global coverage with three doses of DTaP vaccine, as well as the first dose of measles vaccine, declined to 81% in 2021, the lowest rate since 2008.

Nevertheless, an increase was found in vaccination coverage rates with the PCV13 vaccine. This finding was also reported in other studies.[22,23] This result may be explained by possible public confusion between COVID-19 pneumonia and pneumococcal vaccination caused by information overload, especially false or misleading information, during the pandemic.[24] This "infodemic" may have contributed to the public perception of a possible protective effect of the PCV13 vaccination against COVID-19.[22]

This study has some limitations. First, vaccination coverage rates were calculated for the different indicators based on age and monthly doses, and only the impact on these could be assessed. No data were available regarding the reasons for non-vaccination or delay. Second, we calculated the vaccination coverage rates in the attended child population, and therefore, the vaccination coverage in the assigned child population not attended is unknown. However, it should be noted that despite the restrictions and transformations due to the pandemic, 94.3% of the population of Catalonia (Spain) has been attended at least once during the year 2021 in the public health service.[25] Third, we have not analysed the full routine childhood vaccination schedule. The study focused on analysing the vaccination coverage with those vaccines that are considered to be indicators of a routine vaccination programme performance and indicators for the Sustainable Development Goals.[19] However, in Catalonia, the DTaP vaccine is part of the

Table 2
Recorded vaccination coverage rates (%) in the attended child population across pre-lockdown, lockdown, and post-lockdown.

Vaccines/doses/age group	Pre-lockdown (T1)	Lockdown (T2)	Post-lockdown (T3)	T2-T1	T3-T1
DTaP/Tdap vaccine					
Two doses (1-year-old)	95.5%	95.9%	95.0%	0.40%	−0.50%
Three doses (2-years-old)	94.7%	94.8%	93.9%	0.10%	−0.80%
One booster dose after 6 years (7-years-old)	80.3%	79.8%	77.0%	−0.50%	−3.30%
MMR vaccine					
One dose (2-years-old)	94.3%	94.4%	93.4%	0.10%	−0.90%
Two doses (4-years-old)	88.9%	88.6%	86.9%	−0.30%	−2.00%
Two doses (8-years-old)	94.8%	94.5%	92.6%	−0.30%	−2.20%
MenC vaccine					
One dose (1-year-old)	95.5%	95.9%	95.0%	0.40%	−0.50%
One dose after the first year of life (2-years-old)	91.7%	92.1%	91.1%	0.40%	−0.60%
PCV13 vaccine					
Two doses (1-year-old)	94.9%	95.4%	94.6%	0.50%	−0.30%
Three doses (2-years-old)	92.0%	92.8%	92.3%	0.80%	0.30%

DTaP, diphtheria-tetanus-acellular pertussis; MMR, measles-mumps-rubella; MenC, meningococcal C conjugate vaccine; PCV13, pneumococcal conjugate vaccine; Tdap, tetanus-diphtheria-acellular pertussis.

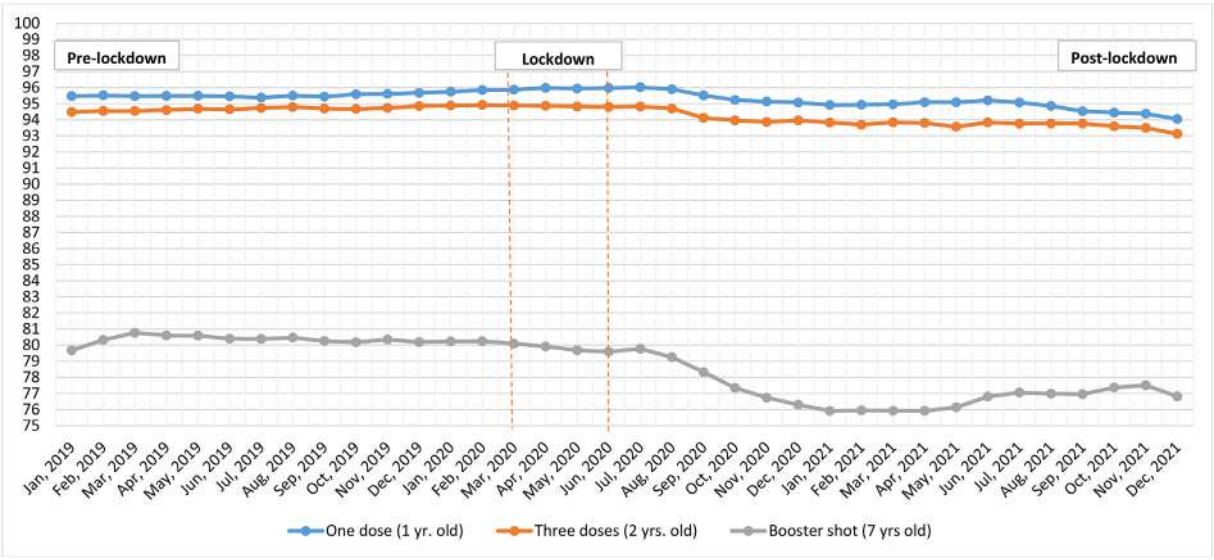

Fig. 1. Recorded vaccination coverage rate (percentage) with DTaP or Tdap vaccines in attended child population. DTaP, diphtheria-tetanus-acellular pertussis; Tdap, tetanus-diphtheria-acellular pertussis.

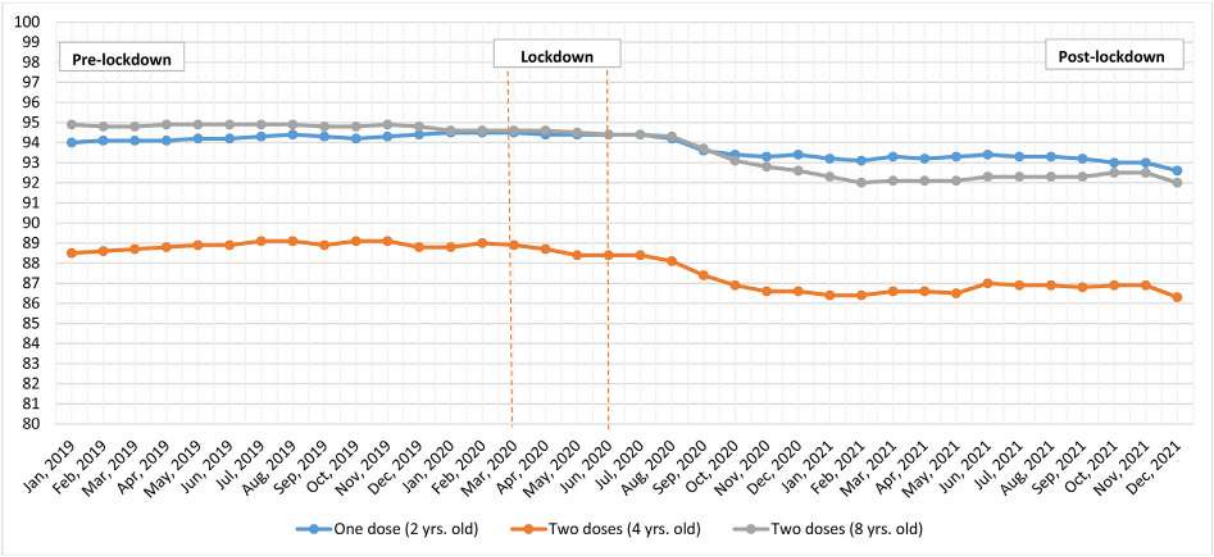

Fig. 2. Recorded vaccination coverage rate (percentage) with MMR vaccine in attended child population. MMR, measles-mumps-rubella.

hexavalent vaccine, which combines six antigens (DTaP-hepatitis B–inactivated poliovirus-*Haemophilus influenzae* type b; see in Supplementary File 1) and is administered to children aged <12 months. Therefore, the findings observed for the DTaP vaccination reflect vaccination against hepatitis B, poliomyelitis and the haemophilus influenzae type B disease. Finally, it was not possible to analyse information from 18 PCCs, representing 4.6% of the total, as they did not yet have access to the public registry system, nor did they have access to information on the population who seek vaccinations in the private healthcare system. In this regard, a tool for registering vaccines administered in private centres was implemented in November 2021. This registry will provide more comprehensive information on vaccination coverage.

Routine childhood vaccination programmes save millions of lives annually and are an essential public health function. The COVID-19 pandemic has highlighted the vulnerability of these programmes worldwide.[20] This study shows that despite strengthening vaccination strategies and ensuring the continuity of vaccination services, gaps in routine childhood vaccination remained after the most severe periods of the pandemic. A return to "normalcy" cannot be achieved without high and sustainable, routine vaccination coverage rates. It is, therefore, necessary to reinforce existing initiatives and establish new ones to return to the vaccination coverage rates of the past and achieve higher rates in the coming years. The current pandemic is a reminder of the ever-present threat of communicable diseases. Failure to restore and increase these vaccination coverage rates may contribute to new outbreaks of communicable diseases and increased morbidity and mortality from vaccine-preventable diseases. There is an acute need to use short- and long-term strategies to restore, maintain and sustain routine childhood vaccination.[26] Sustained catch-up programmes, especially those targeting the most

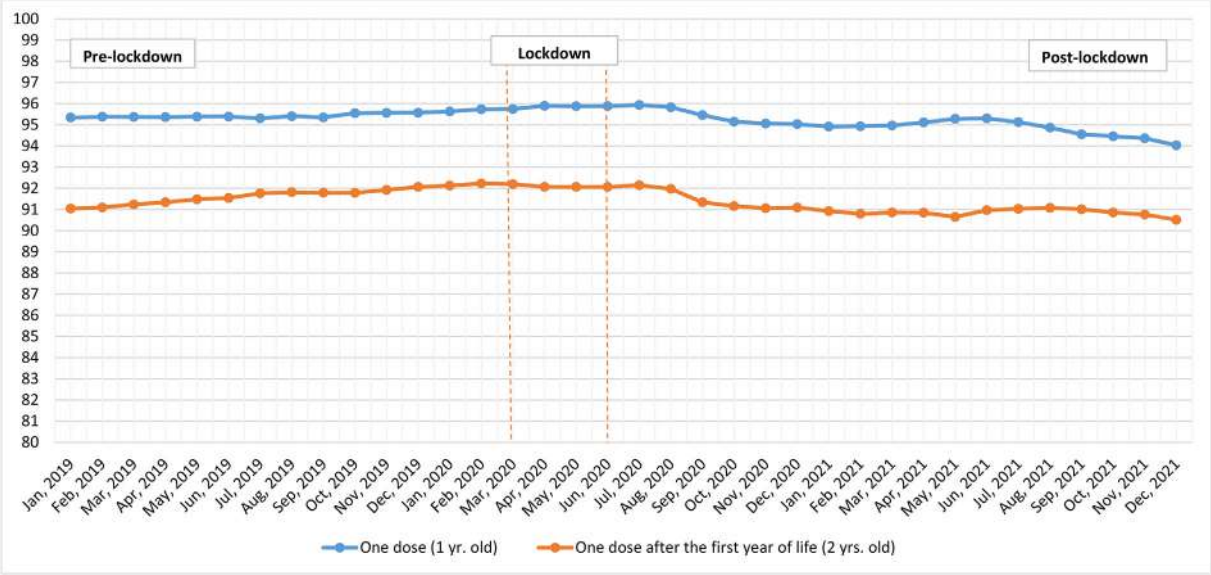

Fig. 3. Recorded vaccination coverage rate (percentage) with meningococcal vaccine in attended child population.

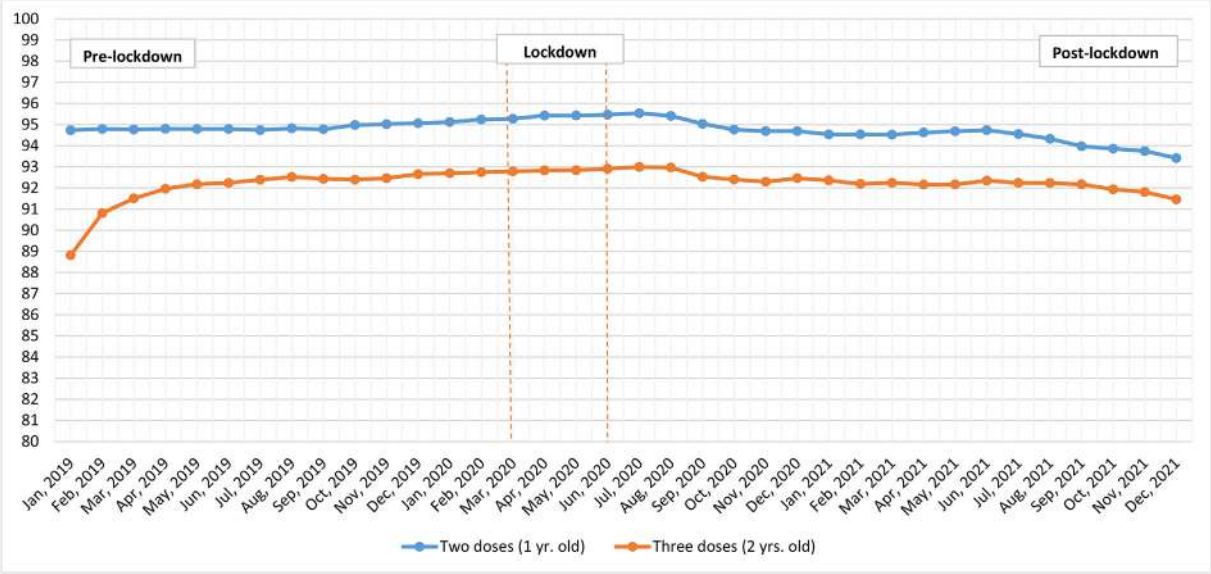

Fig. 4. Recorded vaccination coverage rate (percentage) with pneumococcal vaccine in attended child population.

vulnerable children, need to continue as before. There is also a need to maintain established strategies and develop new ones, if necessary, to make vaccination as easy as possible by ensuring optimal accessibility to vaccination centres, addressing parental concerns and fears and enhancing vaccine availability. Continuous improvement of vaccination information systems is also needed.

The COVID-19 pandemic has highlighted the importance of vaccination as a key public health strategy for preventing and controlling communicable diseases. Despite the significant efforts made by the Catalan Health System, there has been a general decline in the routine childhood vaccination coverage rates since the start of the COVID-19 pandemic, and the pre-pandemic rates have not yet been recovered. Immediate and long-term support strategies must be maintained and strengthened to restore and sustain routine vaccination.

Author statements

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Ethical approval

All data collection and analysis were performed at the autonomous community level. According to the Ethics Committee of the Fundació Institut Universitari per a la recerca a l'Atenció Primària de Salut Jordi Gol i Gurina, there was no ethical approval required for this study.

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Competing interests

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

Authors' contributions

M.M.-M. contributed to conceptualisation, methodology, validation, formal analysis, investigation, data curation, writing the original draft, visualisation, supervision and project administration. E.Z.-d.-O. contributed to methodology, formal analysis, reviewing and editing and visualisation. E.-L.G.-D. contributed to reviewing and editing the article and supervision. A.R.-R. contributed to reviewing and editing the article. C.C.-P. contributed to conceptualisation, methodology, reviewing and editing the article and supervision.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Code availability (software application or custom code)

Not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.017.

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Short Communication

Increases in 'deaths of despair' during the COVID-19 pandemic in the United States and the United Kingdom

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ABSTRACT

Objectives: The COVID-19 pandemic significantly impacted mental health, health-related behaviours such as drinking and illicit drug use and the accessibility of health and social care services. How these pandemic shocks affected 'despair'-related mortality in different countries is less clear. This study uses public data to compare deaths from alcohol, drugs and suicide in the United States and the United Kingdom to identify similarities or differences in the impact of the pandemic on important non-COVID causes of death across countries and to consider the public health implications of these trends.

Study design and methods: Data were taken from publicly available mortality figures for England and Wales, Northern Ireland, Scotland and the United States of America, 2001–2021, and analysed descriptively through age-standardised and age-specific mortality rates from suicide, alcohol and drug use.

Results: Alcohol-specific deaths increased in all countries between 2019 and 2021, most notably in the United States and, to a lesser extent, England and Wales. Suicide rates did not increase markedly during the pandemic in any of the included nations. Drug-related mortality rates rose dramatically over the same period in the United States but not in other nations.

Conclusions: Mortality from 'deaths of despair' during the pandemic has displayed divergent trends between causes and countries. Concerns about increases in deaths by suicide appear to have been unfounded, whereas deaths due to alcohol have risen across the United Kingdom and in the United States and across almost all age groups. Scotland and the United States had similarly high levels of drug-related deaths pre-pandemic, but the differing trends during the pandemic highlight the different underlying causes of these drug death epidemics and the importance of tailoring policy responses to these specific contexts.

Introduction

The global COVID-19 pandemic dramatically changed daily life for most people in high-income countries. The early months of the pandemic saw the closure of schools, bars and restaurants and severe restrictions on social interactions. The resulting social isolation raised concerns about potential increases in depression and suicide.[1] Similar concerns were voiced about increases in heavy drinking and substance misuse to cope with stress of the pandemic. Subsequent data showed significant deteriorations in mental health during the pandemic, particularly among women, young people and those on low incomes.[2] Before the pandemic, increasing levels of mortality from alcohol, drugs and suicide – so-called 'deaths of despair' – had been well documented in the United States.[3] Some have identified this as a uniquely American phenomenon;[4] however, disaggregating the constituent nations of the United Kingdom highlights some dramatic trends. In recent years, Scotland has seen drug-related deaths and male suicide rates rise on a par with increases seen in the United States, whereas alcohol-related deaths have fallen. At the same time, deaths attributable to alcohol have risen consistently in England and Northern Ireland.[5]

While tax data suggested that there was no notable change in overall alcohol consumption in the United Kingdom during the first 2 years of pandemic,[6] individual-level surveys showed an increase in heavier drinking, suggesting greater polarisation of drinking behaviour in England,[7,8] although not necessarily in Scotland.[9] Survey data in the United States showed more drinking days per month and heavier drinking, particularly for women.[10] The

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pandemic also led to significant changes in accessibility of services, including mental health care and specialist alcohol and drug treatment services, that have benefitted some groups, but restricted access to others.[11,12]

Whether the dire predictions around increased mortality from alcohol, drugs and suicide – so-called 'deaths of despair' played out during the pandemic is not clear. Some studies suggest little impact on suicide rates,[13] but notable increases in alcohol deaths in the United Kingdom[14] in 2020 as well as substantial increases in alcohol and drug-related mortality in the United States.[15,16] We use publicly available mortality data from 2001 to 2021 to compare mortality rates from these three causes across nations to better understand the wider impacts of the pandemic on public health.

Methods

We used mortality data for England and Wales from the '21st Century Mortality File' published by the Office for National Statistics,[17] for Northern Ireland from the Annual Reports of the Registrar General published by the Northern Ireland Statistics and Research Agency,[18] for Scotland from the Vital Events Reference Tables published by National Records of Scotland[19] and for the United States from the Centers for Disease Control and Prevention's WONDER Underlying Cause of Death data (for 2001–2020) and Multiple Cause of Death data (provisional) (for 2021).[20] Data were available by International Classification of Diseases, 10th Revision (ICD-10) code, sex and in 5-year age bands for all countries. Deaths were categorised based on the underlying cause of death as being attributable to alcohol, drugs or suicide in non-overlapping categories on the basis of standard ICD-10 code definitions (see supplementary table S1 for the list of included ICD-10 codes).[5,21] Age-standardised mortality rates per 100,000 population for each cause from 2000 to 2021 were calculated using the European Standard Population[22] and population estimates from the Human Mortality Database.[23]

Results

Age-standardised mortality rates for each cause, by sex and country, are illustrated in Fig. 1 and summarised in Table 1. In all countries, suicide rates did not change much during the pandemic period. In the United States, the rates for both men and women dipped slightly *below* the pre-pandemic trend, while there was a small increase for both men and women in Northern Ireland. Suicide rates in England and Wales and Scotland were essentially stable. Changes in alcohol-specific deaths during the pandemic were more noticeable. Mortality increased for both men and women in England and Wales and the United States. In England and Wales, women saw an increase from 10.4 to 12.9 per 100,000 in alcohol-specific deaths from 2019 to 2021, a relative increase of 24.1%, compared with an increase of 19.6% in men. The United States saw even greater increases in alcohol-specific deaths of 29.1% in women and 26.7% in men, and the rates rose to a lesser extent for both men and women in Northern Ireland. Deaths from alcohol increased among Scottish men (23.7% relative increase) after a consistently declining pre-pandemic trend. The picture for drug-related deaths was more mixed, with a continuation of the gradually rising pre-pandemic trend in England and Wales and Northern Ireland. Both Scotland and the United States had seen sharp rises in drug-related deaths in the years immediately before the pandemic, but this trend levelled off in Scotland while accelerating dramatically in the United States, particularly among men. Drug-related deaths among men in the United States rose from 33.5 to 51.6 per 100,000 from 2019 to 2021, a 54.1% relative increase. For women in the United States, the increase was also substantial, from 14.4 to 21.2 per 100,000 (47.9% increase).

We examined differences in these trends by age in Fig. 2. In England and Wales, alcohol-specific deaths rose for everyone except the youngest age groups, whereas increases in drug-related deaths were largely confined to 45- to 64-year-old age groups that had seen rising pre-pandemic rates of drug-related mortality. There are few clear age patterns for Northern Ireland, although there is some evidence of an increase in alcohol deaths among those aged >65 years. In Scotland, alcohol-specific deaths rose sharply in men aged >45 years, reversing sharp declines for many years before the pandemic. While drug-related mortality in Scotland had risen steeply in recent years, deaths fell for those aged 35–44 years during the pandemic but continued to rise among 45- to 54-year-old men. Finally, age-specific data for the United States paints an alarming picture, with both alcohol and drug deaths rising sharply across almost every age group.

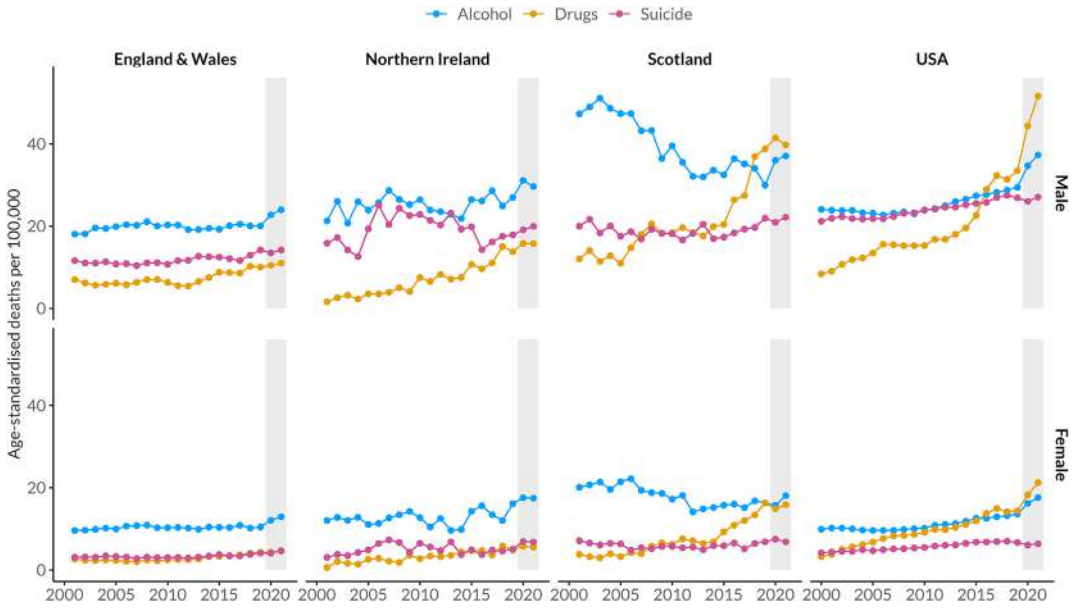

Fig. 1. Age-standardised rates of 'deaths of despair' mortality 2001-2021. Shaded grey areas represent the pandemic period.

Table 1
Changes in age-standardised rates of 'deaths of despair' mortality 2019–2021.

Country	Sex	Cause	Age-standardised deaths per 100,000			Change 2019–2021	
			2019	2020	2021	Absolute	Relative
England and Wales	Male	Alcohol	20.1	22.8	24.0	3.9	19.6%
		Drugs	10.0	10.5	11.0	1.0	9.9%
		Suicide	14.2	13.5	14.2	0.0	0.1%
	Female	Alcohol	10.4	12.1	12.9	2.5	24.1%
		Drugs	4.3	4.3	4.6	0.3	7.8%
		Suicide	4.1	4.0	4.7	0.6	14.0%
Northern Ireland	Male	Alcohol	27.0	31.1	29.6	2.7	9.9%
		Drugs	13.8	15.8	15.8	2.0	14.3%
		Suicide	17.9	19.1	20.0	2.1	11.7%
	Female	Alcohol	16.1	17.5	17.4	1.4	8.4%
		Drugs	4.8	5.8	5.5	0.7	15.0%
		Suicide	5.1	6.9	6.8	1.7	33.8%
Scotland	Male	Alcohol	30.0	36.0	37.1	7.1	23.7%
		Drugs	38.8	41.5	39.8	1.0	2.5%
		Suicide	21.9	20.9	22.2	0.2	1.0%
	Female	Alcohol	16.3	15.7	18.1	1.8	10.9%
		Drugs	16.3	14.9	15.9	−0.4	−2.6%
		Suicide	6.8	7.5	6.8	0.0	−0.1%
USA	Male	Alcohol	29.4	34.7	37.3	7.9	26.7%
		Drugs	33.5	44.4	51.6	18.1	54.1%
		Suicide	26.9	26.0	27.1	0.2	0.7%
	Female	Alcohol	13.6	16.2	17.6	4.0	29.1%
		Drugs	14.4	18.3	21.2	6.9	47.9%
		Suicide	6.7	6.1	6.3	−0.3	−5.2%

Discussion

The COVID-19 pandemic disrupted daily life on an unprecedented scale, closing schools and businesses and restricting social interactions for many months. Concerns about the mental health impacts of social isolation and other disruptions were raised early on, but it is unclear how much this translated into increased non-COVID mortality. We summarised mortality from three 'despair'-related causes (alcohol, drug-related, suicide) in the USA and UK nations over the pandemic and compared them to pre-pandemic trends. Despite these concerns, we found little apparent association between the pandemic on deaths by suicide. The most consistent increase across countries was in alcohol-specific deaths. The United States stood alone in its dramatic increase in drug-related deaths, compounding already very high levels. England and Wales and Northern Ireland saw slight increases in drug-related deaths in line with upward previous trends, while changes in drug deaths in Scotland were flat despite a strong upward trend in recent years. These patterns were largely consistent across age groups, with no evidence that younger age groups suffered more.

The COVID-19 pandemic was expected to impact substance use for many reasons. COVID disrupted most aspects of daily life and increased social isolation, potentially increasing the demand for alcohol and drugs to cope with stress. Supply was also impacted by the closures of typical venues for social drinking, such as pubs and restaurants. A priori, the closing of spaces for social drinking could reduce overall drinking if drinking happens less often at home. On the other hand, the pandemic was a shock to people's routines, and working from home could have made it easier to drink at home. Evidence from England and Wales does suggest shifts towards more heavy drinking during the pandemic,[7,8,24] but this is less clear in Scotland.[9] In the United States and the United Kingdom, sales of alcohol spiked in March 2020 in anticipation of stay-at-home orders,[10,25] and surveys suggested more drinking and heavy drinking days in the months that followed. People may have substituted alcohol for legal or illegal drugs that were harder to obtain during the pandemic.[26] The consistent increase in alcohol-specific deaths across countries suggests that levels of heavy drinking did increase during the pandemic. Most alcohol-specific deaths are due to alcohol-related liver disease,[27] which typically develops over many years,[28] in contrast to poisoning, which is more acute but makes up a small percentage of alcohol-specific deaths. Given the sharp increase in alcohol deaths since the pandemic, this suggests that the pandemic induced extra drinking among already heavy drinkers who were near the threshold of succumbing to liver disease.

It is also likely that access to treatment and harm reduction services was reduced during the time of pandemic restrictions, increasing the potential lethality of these behaviours.[29] Drug supply shortages can also drive consumption of riskier substances and behaviours such as sharing injecting equipment.[30] People may also purchase larger quantities of drugs at one time when they have the opportunity, increasing the risk of overdose. The extent and nature of these issues will vary substantially depending on the local context and the types of drugs implicated in drug-related deaths. In particular, we might expect them to differ between the United States, where rising drug-related deaths are primarily linked to prescription opioids and, more recently, fentanyl,[31] and Scotland where the rise in drug-related deaths is strongly linked to 'street' benzodiazepines.[32]

There are some limitations to our analyses. ICD-10 code–based definitions are imperfect, and the use of codes may vary between countries. Our definitions of each cause of death are in line with previous, similar, studies,[21] but these do not align completely with existing definitions of 'alcohol-specific/induced' deaths as used in the United Kingdom and the United States. We exclude several, generally rare, causes such as alcoholic polyneuropathy (ICD-10 code G62.1), as these cannot be disaggregated in the public mortality data we have used, whereas we have included hepatitis and cirrhosis of the liver (ICD-10 codes K73-74), of which approximately 70% of deaths are estimated to be due to alcohol.[33] A comparison of these two definitions shows close alignment of trends (see supplementary material). This approach remains likely to significantly underestimate the true burden of alcohol mortality, as we exclude other conditions for which alcohol is a contributing cause, such as cancers and cardiovascular disease.[34] For drug-related and suicide

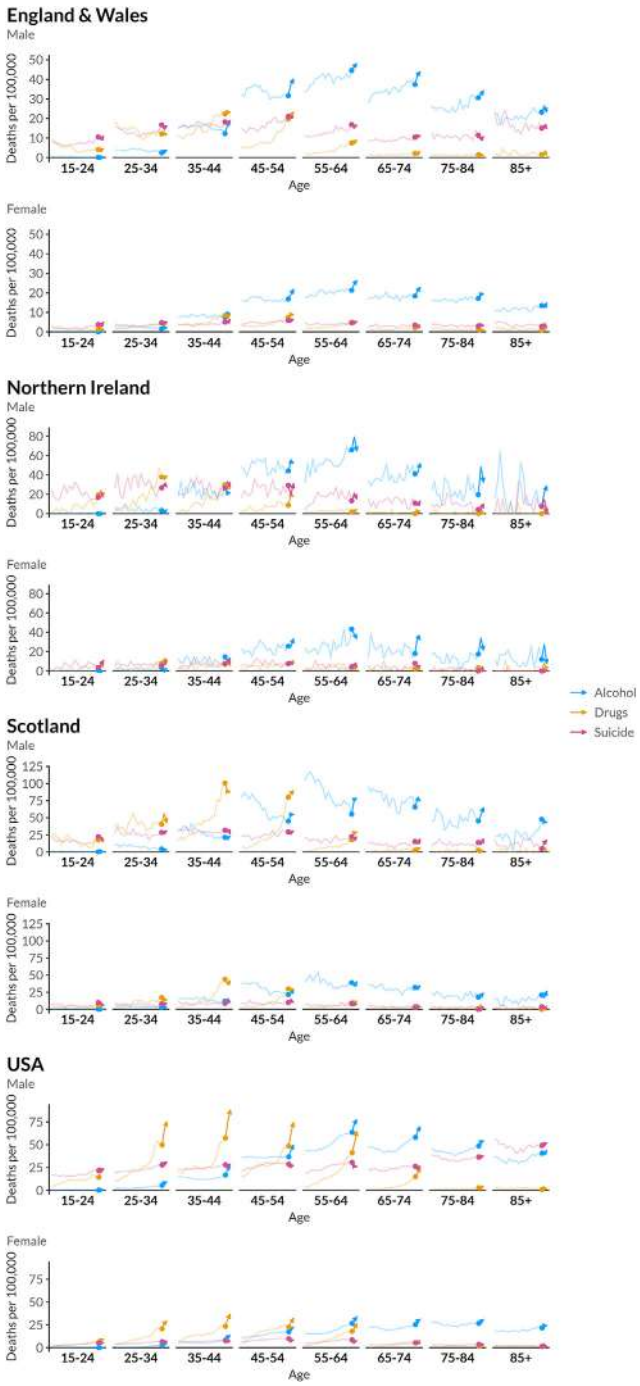

Fig. 2. Age-specific rates of 'deaths of despair' mortality 2001-2021. Bold colours represent the pandemic period. Note the y-axis differs between nations.

mortality, our approach yields similar figures to the official 'drug poisoning'/'drug-induced causes' and suicide figures published within each country (see supplementary material), with differences accounted for largely by the fact that we have defined our causes of death to be non-overlapping, whereas deaths from deliberate overdoses, for example, may be included in published figures for both suicide and drug-related deaths. Our approach does not account for deaths where multiple causes are implicated, for example, combined alcohol and opioid poisonings, which have been shown to account for a substantial minority of all deaths from alcohol and drug poisoning in the United States.[35] Finally, it should be noted that the relatively smaller populations of Northern Ireland and, to a lesser extent Scotland, mean that data for these countries is inherently subject to greater random variation year-on-year and greater caution should therefore be exercised when interpreting annual fluctuations.

Our analysis of age-standardised mortality trends provides straightforward description of changes in these rates during the pandemic. We do not estimate excess mortality by cause, which could more formally incorporate previous trends but is beyond the scope of this analysis. The United States observed substantial differences in drug-related mortality by racial and ethnic group over the pandemic, with overdose mortality particularly accelerating in Black relative to White groups.[36] Although beyond the scope of this study, this would be important to incorporate in future explorations of drug-related mortality. Finally, we did not consider socio-economic differences in 'deaths of despair', although it has been widely documented that these deaths are clustered in those with lower socio-economic status, particularly in the United States,[3] and it is likely that the pandemic widened existing socio-economic gaps in mortality.[37] Further investigation of these socio-economic and ethnic differences in mortality trends during the pandemic, and how these may be linked to aspects of the COVID response and wider government policy may help to understand the full impacts of the pandemic on health inequalities.

The data presented here paint a mixed picture of the impact of the pandemic on 'deaths of despair' in the USA and UK nations. There is little evidence of an increase in deaths by suicide, a marked increase in deaths due to alcohol and notably different trends in drug-related deaths between countries. The increases in alcohol and drug misuse deaths in the United States are particularly stark and suggest that policy action is urgently required. However, the many-faceted interactions between pre-pandemic trends, the existing policy landscape, the direct impact of the pandemic and pandemic response measures, and the broader societal consequences of these mean that it is vital any public health policy response is tailored to the specific circumstances of both the country and affected populations.

The fact that we have seen further increases in mortality rates in 2021 on top of sharp increases in 2020 for alcohol and, in some cases, drug misuse deaths may suggest that these trends are linked more strongly to wider societal impacts of the pandemic, rather than the short-term policy responses to the initial COVID wave in March 2020. Whether these increases in mortality will return to pre-pandemic levels in the coming years represents a major public health concern, and understanding their underlying drivers is an important challenge that may inform short-term policy responses and guide planning for future pandemics.

Author statements

Ethical approval

All analyses use public available data and ethical approval was not required.

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Competing interests

None declared.

Data availability and sharing

All data analysed in this study are publicly available. Code to process these data and reproduce the analysis presented here can be found at https://github.com/VictimOfMaths/DeathsOfDespair/blob/master/DataInsight/DodPandemicPaperFinal.r

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.019.

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Review Paper

Indirect positive health outcomes of COVID-19: a systematic review

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ABSTRACT

Objectives: The aim of this study was to assess the frequency of indirect positive health outcomes as a result of the COVID-19 pandemic.
Study design: This was a systematic review.
Methods: Articles were identified from four online databases (Web of Science, Scopus, PubMed and Google Scholar) using predetermined search terms. After studies were systematically identified, the results were summarised narratively. The indirect positive health outcomes associated with the emergence of COVID-19 and measures taken for its prevention were categorised into four health dimensions (physical, mental, social and digital).
Results: After initial screening, 44 articles were assessed for eligibility, and 33 were included in the final sample. Of the included studies, 72.73% noted a benefit from COVID-19 prevention measures in the physical health dimension. In addition, 12.12%, 9.09%, 3.03% and 3.03% of articles reported a positive impact in the digital, mental, social and combined digital and mental health dimensions, respectively.
Conclusions: Despite the catastrophic health, socio-economic and political crises associated with the COVID-19 emergency, it has also resulted in some positive health outcomes. Reduced air pollutants, improved disease prevention practices, increased digital health delivery and improved mental and social health dimensions were reported during the pandemic. Integrated and collaborative activities for the persistence of these health benefits are recommended.

Introduction

Since its emergence at the end of 2019, COVID-19 infection, caused by SARS-CoV-2, has significantly affected individuals, sectors and countries, regardless of their geographic location or economic status.[1–3] Multidimensional catastrophes have been caused either directly by COVID-19, indirectly by measures adopted for its prevention or both.[4–7]

Notwithstanding the direct and indirect negative impact of COVID-19, the emergence of this pandemic saw indirect outcomes that resulted in short-term, and potentially long-term, positive impacts.[8] Haski-Leventhal[8] argued that there were seven positive outcomes (reduced environmental pollution, increased level of peace and security, increased social connectedness, increased innovations, increased corporate social responsibilities, transformed educational sector, and increased sense of appreciation and gratitude among people) observed following the emergence of COVID-19.

Furthermore, as noted by Nelson,[9] the COVID-19 pandemic has resulted in unexpected positive effects arising from behaviour change and a reduction in infectious disease presentations at hospitals. Other examples include a reduction in traffic accidents, crimes rates and environmental pollution.[9–11]

Recommended COVID-19 prevention practices (e.g. physical and social distancing, quarantining, good ventilation, covering coughs and sneezes, hand washing/sanitising, vaccinations and proper usage of personal preventive equipment) are also suggested infection prevention and control (IPC) strategies for other infectious diseases.[12] Globally, the application of IPC practices during COVID-19 was much higher than in previous years[13]; however, there was still considerable variation reported in compliance rates. For example,

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countries with good COVID-19 transmission prevention compliance included Spain[14] and China,[15] but poor compliance was reported in Uganda[16] and Ethiopia.[17–19] However, there were contradictory data, with a different study in Ethiopia suggesting high compliance with recommended COVID-19 prevention protocols.[20] Nonetheless, the application of IPC for the purpose of COVID-19 prevention appears to have had a positive impact on preventing other infectious diseases, such as *influenza*, *pneumonia* and *Mycobacterium tuberculosis*,[21] with respiratory infections being dramatically reduced in countries such as Vietnam[22] and Pakistan.[23] Similarly, after the easing of COVID-19 restrictions in Israel, respiratory diseases were found to become highly prevalent.[24]

Reports and evidence regarding the context and types of positive health outcomes of COVID-19 are available, but these are currently in a fragmented state with no compiled and informative summary document on this issue. In addition, analysis of which the health dimensions (i.e. physical, mental, social or digital) benefited most from the emergence of COVID-19, and/or from the measures implemented for the prevention of COVID-19, has not been performed. A preliminary search of Cochrane and PROSPERO databases and the Joanna Briggs Institute (JBI) register was conducted, and no current or proposed systematic reviews, metanalyses or scoping reviews on this topic were identified.

Objective, research question and hypothesis

The overarching objective of this systematic review was to assess the frequency of indirect positive health outcomes as a result of the COVID-19 pandemic. This objective was achieved by answering the following research question: *What is the frequency of positive health outcomes arising from COVID-19?* This study hypothesised that the restrictions and measures (e.g. lockdown, IPC and social distancing) taken for the prevention and control of COVID-19 had indirect positive health outcomes (e.g. reduction in air pollution, improvement in telehealth, decline in infectious diseases prevalence, reduction of anxiety and improvement in social health).

Methodology

This systematic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses[25] and the JBI systematic review guidelines. The systematic review was preregistered in PROSPERO (registration number CRD42022352438).

Eligibility criteria

This systematic review focused on indirect positive health outcomes achieved due to measures and restrictions implemented for the prevention of COVID-19. Changes in any of the four health dimensions (physical, mental, social and/or digital) were taken as an outcome. A definition for these indirect positive health outcomes (health dimensions) was adopted from the description in the study by Parrish[26] in which 'positive health outcomes include being alive, functioning well mentally, physically, and socially, and having a sense of well-being.' In addition to these components of positive health outcomes, digital health (a term referring to a variety of technologies that are essential for the treatment of patients, and collect and share their health information) was added by the current review authors. The literature inclusion criteria were primary research articles and written in the English language. No restriction was placed in terms of the study design of articles, and all qualitative, quantitative and mixed method studies were considered. Studies were only considered relevant if they were published after the nominal emergence date of COVID-19 of 31 December 2019.

Information sources and search strategy

The online databases Medline/PubMed, Scopus, Web of Science and Google Scholar (records from the first 20 pages) were the information sources for this systematic review. The first search was conducted on 25 July 2022, and the search was repeated a month later (25 August 2022). The combination of keywords of this systematic review was taken as search terms for the online databases. These search terms were 'indirect health outcomes' OR 'positive health outcomes' OR 'positive health impact' OR 'health benefit' OR 'health merit' AND 'COVID-19' OR 'pandemic' OR 'Coronavirus disease.'

The literature search was conducted in two phases. Studies were first searched for in PubMed, Scopus and Web of Science. Following database searches, publications were explored using the Google Scholar advanced searching tool using the keywords of the systematic review ('indirect health outcomes,' 'positive health outcomes,' 'health benefit,' 'COVID-19 pandemic'). All authors independently searched the literature and no disagreements were noted.

Selection process

Identified publications were imported to EndNote version 20.3 and deduplicated using the unique identifier function. Duplicates missed by the EndNote identifier were then manually removed. After deduplication, the first author screened the literature using title and abstract assessment, followed by whole text reading. The same process was repeated by the other three authors, and any disagreements were solved by discussion. The consecutive repetition of the selection process was to ensure the relevance of the selected studies and avoid missing important literature.

Data collection process and data items

The first author extracted the required data from the included publications, and the other authors reviewed this extraction process to enhance the reliability and validity of the data. The extracted variables include the selected studies (author and publication year), country, subjects/participants, objectives, relevant findings (i.e. positive health outcomes of COVID-19) and factors/reasons for the positive health outcome (see Table 1). Proportions of the health dimensions (mental, social, physical and digital health) that had a positive impact were expressed as percentages. The data collection process was performed using the JBI System for the Unified Management, Assessment and Review of Information guideline.[27]

As the purpose of this review was to identify the frequency of positive health outcomes arising from COVID-19, all primary research articles that reported positive health outcomes in at least one of the four health dimension categories of physical, mental, social and digital health were considered. The primary research articles were considered, both quantitative statistical analysis (descriptive or inferential) and qualitative studies. Studies were considered regardless of the study areas (local, national, regional or global) and study participants (individuals, specific communities, households or general population).

Table 1
General characteristics and main findings of included studies.

Studies	Countries	Participants	Objective of the studies	Findings	Health outcomes	Reason for the health outcomes
Aamir et al.[10]	China	Air pollutants	'To assess the relationships between the concentrations of the six named pollutants and the AQI before, during and after Hubei's COVID-19 lockdown'	'26% PM_{10} and 23% $PM_{2.5}$ reduction observed during COVID-19'	Reduced deaths and increased health quality	Air pollution reduction due to lockdown
Allison et al.[29]	Wales	Hospital patients	'To compare acute medical admissions during COVID-19 with a comparison cohort from 2017'	'Hospital admission in 2020 was reduced by 43% compared with 2017'	Reduced non—COVID-19 cases	IPC practice for COVID-19 helps preventing other diseases
Alves et al.[30]	USA	Children	To investigate how emotional responses (positive/ negative affect), physical activity (PA) and sedentary behaviours related to anxiety during the pandemic'	'Child anxiety scores were over five standard deviations greater than prepandemic normative values'	Anxiety level of children is reduced during COVID-19	Engaging in physical activity during lockdown
Amar et al.[24]	Israel	Clinics	'To examine incidence rates (IRs) of frequently occurring infectious diseases after a successful SARS-CoV-2 vaccination campaign in Israel and cessation of social restrictions'	'Incidence of non—SARS-CoV-2 infections were significantly increased'	Respiratory and gastrointestinal infection incident rate increased	Easing of COVID-19 prevention restriction
Bacon et al.[31]	Australia	Stakeholders	'To explore the perceived benefits, challenges and impacts of telehealth placements for key stakeholders in allied health courses'	'Telehealth placements support competency development, person-centred care, and enabled innovation'	Telehealth usage increased and brought multiple health outcomes	Alternative measure for COVID-19 restrictions
Bai et al.[32]	China	$PM_{2.5}$ pollutants	'To evaluate the potential health impacts of air quality changes during the lockdown, especially for PM 2.5 with adverse health effects'	'The national average $PM_{2.5}$ declined by 18 $\mu g/m^3$ during 2020 compared with 2015—2019'	'Premature death reduced by 35%'	$PM_{2.5}$ reductions due to lockdown measure
Barreda-Angeles & Hartmann[33]	The Netherlands	Social VR platform users	'To examine the associations between feelings of presence and the activities performed by users and the psychological benefits obtained in the context of the COVID-19 pandemic'	'Socialisation activities such as meeting friends in VR are associated with relatedness and enjoyment'	Aloneness reduced and feeling presence increased	Using social VR platforms increased due to physical distancing
Bowe et al.[34]	England	Adult residents	'To explore the relationships between help-giving, community relationships and unity during the pandemic in relation to mental health and well-being'	'Coordinated community helping predicted the psychological bonding of community members during COVID-19'	Depression and anxiety were reduced	Cooperation and helping were increased among fellow residents
Chacon-Quesada et al.[35]	Not indicated	Patients	'To analyse the extent of the intensification of hygiene measures affects the rate of surgical site infections (SSI) after neurosurgical procedures'	'Surgical site infection prevalence dropped from 2.9% to 1.4%'	Non—COVID-19 infectious diseases prevalence reduced	COVID-19 IPC strategies reduced other related infections
Chen et al.[11]	China	Air pollutants	'To describe air pollution during and after the lockdown periods in 2020 compared with 2018—2019 and estimated the mortality burden indicated by the number of deaths and years of life lost (YLL) related to the air pollution changes'	'The mean air quality index, PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO declined by 21.2%, 28.9%, 18.3%, 44.2%, 38.8% and 27.3%, respectively'	Air pollution—related premature death is reduced by 1.1 million YLLs	COVID-19—related lockdown reduces the emission of air pollutants
Dragic et al.[36]	Serbia	Air pollutants	'To determine the change in outdoor air quality during the COVID-19—related state of emergency resulting in a lockdown and the potential health benefits for the urban population'	'The average daily concentrations of $PM_{2.5}$, NO_2, PM_{10} and SO_2 were reduced by 35%, 34%, 23% and 18%, respectively'	The air pollution —related premature deaths were reduced by 8 YLLs	The COVID-19 lockdown indirectly used as air pollution mitigation measure
Elliott et al.[37]	Australia	Isolation beds	'Analysing pre-, during and post-COVID-19 restrictions to evaluate the effectiveness of heightened prevention measures on MRO infections'	MRO transmission reduced during COVID-19	Infectious disease prevalence declined	COVID-19 restrictions (wearing masks, restricting visitors …) reduced MRO
Giani et al.[38]	China and Europe	$PM_{2·5}$ pollutants	'To assess the implications of different lockdown measures on air pollution levels in Europe and China, as well as the short-term and long-term health impact'	'The $PM_{2·5}$ were reduced by 14·5 $\mu g/m^3$ across China and 2·2 $\mu g/m^3$ across Europe'	24,390 short-term and 316,500 long-term $PM_{2·5}$-related YLLs avoided	The lockdown interventions led to a reduction in pollution weighted $PM_{2·5}$
Goel et al.[39]	India	$PM_{2·5}$ pollutants	'To quantify the health benefits due to this lockdown'	$PM_{2.5}$ concentrations during 2020 were 46.6%—58.5% lower than the concentration during 2019	29.85 $PM_{2·5}$ pollution-related deaths per 100,000 persons were avoided	$PM_{2·5}$ emission reduced due to COVID-19 lockdown

(*continued on next page*)

Table 1 (*continued*)

Studies	Countries	Participants	Objective of the studies	Findings	Health outcomes	Reason for the health outcomes
Han & Hong[40]	South Korea	$PM_{2·5}$ pollutants	'To estimate the acute health benefits of $PM_{2.5}$ reduction and changes in public behaviour during the COVID-19 crisis'	'The average $PM_{2.5}$ concentration during 2020 (25.6 μg/m^3) was the lowest compared with 5 years before pandemic'	49.3 $PM_{2·5}$-related non-accidental, cardiovascular and respiratory deaths avoided	$PM_{2·5}$ reduced due to COVID-19 lockdown and wearing filtering masks
Hao et al.[41]	China	$PM_{2·5}$ pollutants	'To predict the monthly $PM_{2.5}$ concentrations in urban cities under permanent lockdown in 2020'	'National mean $PM_{2·5}$ concentration was reduced by 32.2%'	140,200 $PM_{2·5}$ long-term exposure-related deaths were avoided	COVID-19 lockdown reduced $PM_{2.5}$ concentration
Hernandez-Paniagua et al.[42]	Mexico	Air pollutants	'To minimise the impact of the air pollutant long-term trends, pollutant anomalies were calculated using as baseline truncated Fourier series, fitted with data from 2016 to 2019, and then compared with those from the lockdown'	'2–10 folds of air pollutants' concentration were reduced and O_3 concentration increased'	588 deaths related to air pollution exposure were averted	COVID-19 lockdown measure reduced air pollutant's emission
Huang et al.[43]	China	$PM_{2·5}$ pollutants	'To estimate the short-term health impacts associated with $PM_{2.5}$ changes over the Yangtze River Delta (YRD) region due to COVID-19 lockdown'	'$PM_{2·5}$ reduced by 22.9%–54.0% during COVID-19 compared with prepandemic concentrations'	42, 400 $PM_{2·5}$-related premature mortalities were avoided	Strict COVID-19 lockdown reduces air pollutants
Hussain et al.[44]	England	Patients	To compare the prevalence of sternal wound infections during and before pandemic	'The incidence of sternal wound infection was dropped from 3% to 0.8%'	Infectious diseases prevalence reduced	Strict IPC practice of COVID-19 reduced iatrogenic sternal wound infection
Khomsi et al.[45]	Morocco	Air pollutants	'To compare the air quality status, before the pandemic and during the confinement'	'The concentration of NO_2, $PM_{2·5}$, and CO were dropped by 12 μg/m^3, 18 μg/m^3 and 0.04 μg/m^3, respectively'	$PM_{2·5}$-, NO_2- and CO-induced cardiovascular diseases reduced	The COVID-19 lockdown reduced $PM_{2·5}$, NO_2 and CO emissions
Kodros et al.[46]	USA	Face masks and respirators	'To quantify the potential health benefits of wearing a face covering or respirator to mitigate exposure to particulate air pollution'	'N95 respirators, surgical and synthetic-fibre masks reduced smoke-attributable hospitalisations by 22%–39%, 9%–24% and 7%–18%, respectively'	Smoke-attributable hospitalisations reduced during the pandemic	Enforcement of wearing masks during COVID-19 reduced air pollutant inhalation
Lam et al.[47]	Global	$PM_{2·5}$ pollutants	'To establish the relationship between cities' baseline concentration and level of premature deaths during the lockdown'	'$PM_{2.5}$ deduced by 12%–49% in different cities of the world'	$PM_{2·5}$-related premature deaths reduced (example 14,700 YLLs reduction in India)	Due to the COVID-19 lockdown, the $PM_{2·5}$ level is reduced in 15 cities around the globe
Liu et al.[48]	Global	Air pollutants	'To quantify the causal impacts of eight types of lockdown measures on changes of a range of individual pollutants'	'NO_2, PM_{10}, SO_2, $PM_{2.5}$ and CO air quality index value falls by 23%–37%, 14%–20%, 2%–20%, 7%–16% and 7%–11%, respectively'	99,270–146,649 premature deaths were reduced in 76 countries	Intra/intercity travel restrictions during COVID-19 are curbing air pollution
Metzger et al.[49]	USA	Surgeons	'To assess the perspectives of surgical providers towards using telemedicine, defined for this study as either synchronous video encounters or synchronous audio only encounters, to evaluate and care for patients'	'Less than 25% of surgeons use telemedicine before COVID-19; but following COVID-19 restrictions 95% of them use it'	Telemedicine has expanded within paediatric surgery during COVID-19	Lockdown, social and physical distancing forced to use alternative health service
Mollaioli et al.[50]	Italy	Male and female adults	'To evaluate the impact of the community-wide containment and consequent social distancing on the intrapsychic, relational and sexual health'	'Lack of sexual activity during lockdown was associated with a significantly higher risk of developing anxiety and depression'	Anxiety and mood disorders were reduced in sexual partners	COVID-19 lockdown was an opportunity for sexual partners to pass the time together
Pennington et al.[51]	USA	Patients	'To analyse the impact of telemedicine on workflow and care delivery in a neurosurgical department at a quaternary care centre'	'Telemedicine appointment was increased from 0.3% prepandemic to 19.1% postpandemic and customers satisfaction increased from 85.9% to 88.5%'	Telemedicine use significantly increased following the pandemic onset	Social and physical distance restrictions enable the patients to choose alternatives

Perera et al.[52]	USA	$PM_{2·5}$ pollutants	'To estimate the potential public health benefits of fine particulate matter ($PM_{2.5}$) to children and adults and their associated economic benefits'	'23% $PM_{2.5}$ reduction was estimated during the COVID-19 shutdown compared with the average level for in 2015–2018'	$31.8-$77 billion estimated illness and death costs will be avoided from 2021 to 2025	Reduction of $PM_{2·5}$ during COVID-19 lockdown increased health quality and length
Sahi et al.[53]	USA	Virtual partners	'To shed light specifically on associations between virtual interactions and overall mental health at two time points during the COVID-19 pandemic'	'Having a greater number of virtual interaction partners was associated with better mental health'	Mental health of virtually communicated partners was improved	When in-person interactions were restricted, partners were virtually interconnected
Seo et al.[54]	South Korea	Air pollutants	'To analyse the impacts of social distancing and transboundary pollutants on air quality changes examined the corresponding health benefits where the spread of coronavirus was severe'	'During COVID-19, $PM_{2.5}$, PM_{10}, and NO_2 concentrations decreased by 31%, 61% and 33%, respectively, compared with the previous 3 years'	328 air pollution –related premature deaths and $1162 million health costs were avoided	Due to lockdown, air pollutants emission was reduced
Shah et al.[55]	Pakistan	Adults	'To investigate the COVID-19 prevention behaviours within the framework of the Health Belief Model'	'Public health interventions attempting to control the spread of COVID-19 affects a change in people's perceived benefits of preventative actions'	Complying with the IPC measures was improved during COVID-19 than before	COVID-19 prevention restrictions improved the IPC practice of people
Toccafondi et al.[13]	Italy	Patients	'To illustrate how adopting a human factors and ergonomics perspective can provide insights into how clinical work systems have been adapted and reconfigured'	'Clinical work systems have been adapted and reconfigured to keep patients and staff safe from infection'	IPC behaviours of people and healthcare workers are improved	The emergence of COVID-19 leveraged the IPC behaviour of healthcare actors
Wamsley et al.[56]	USA	Patients	'To discuss current trends and the experience with telehealth at our large academic institution, with a focused analysis of plastic surgery'	'COVID-19 prevention restrictions change the way health care is delivered via telehealth for generations to come'	Telehealth visits, appointments and services were increased during the pandemic	Stay at home order and distance restrictions forced to use telehealth service delivery
Ye et al.[57]	China	Air pollutants	'To estimate how COVID-19 restrictions impacted ambient air pollution and the subsequent consequences on health and the health-related economy'	'1239, 2777, 1587 and 4711; $PM_{2.5}$-, PM_{10}-, CO- and NO_2-related deaths were avoided, respectively'	Air pollutant–related deaths were avoided during COVID-19	COVID-19–induced lockdown reduces the air pollutants emission

AQI, Air Quality Index; CO, carbon monoxide; IPC, infection prevention and control; MRO, multidrug-resistant organisms; NO_2, nitrogen dioxide; $PM_{2.5}$, particulate matter with a diameter of 2.5 μm or less; PM_{10}, particulate matter with a diameter of 10 μm or less; VR, virtual reality.

Study risk of bias assessment

The JBI critical appraisal checklist for cross-sectional studies was used to assess the risk of bias (Supplementary file S1). The eight items of the JBI checklist were designed to assess the risk of bias in reviewing cross-sectional primary studies with 'Yes', 'No', 'Unclear' or 'Not Applicable' answers.

Synthesis methods

A narrative synthesis was used to report the results of the included publications. The data extracted from the literature were presented in tables and texts. The indirect positive health outcomes in the context of the emergence of COVID-19 were synthesised, and the proportion of the health dimensions was described. The results of the included literature were qualitatively expressed, with numerical findings included when applicable.

Reporting bias assessment

The Agency for Healthcare Research and Quality tool for evaluating the risk of reporting bias in systematic reviews was used. Using the checklists in the tool, the authors independently assessed the risk of bias as a result of unreported results.[28] Using the checklists as a guide, studies were identified as potentially reporting bias (labelled 'suspected') and or with minimal chance of reporting bias (noted as 'undetected').

Certainty assessment

The certainties of evidence were assessed using the GRADE Pro handbook. The alignment of study findings with the current review objective, the consistency of evidence with each other, the level of suspected publication biases of each reviewed study, the limitations of reviewed studies and the inclusion of indirect health outcomes due to the emergence of COVID-19 were considered as factors for certainty. Based on the criteria (i.e. availability of pre- and post-COVID-19 emergence health outcome information, identification of indirect health benefits of COVID-19 occurrence and the comparison of pre-COVID-19 health situation with the post-COVID-19 emergence health status), the review had set for GRADE domains, the certainty of the evidence was assessed as high, moderate, low or very low. All the authors independently conducted the certainty assessment, and no disagreements were reported.

Results

Selection process and characteristics of studies

Of the initial 1613 potential articles, approximately half (n = 806) were found in the Web of Science database; the

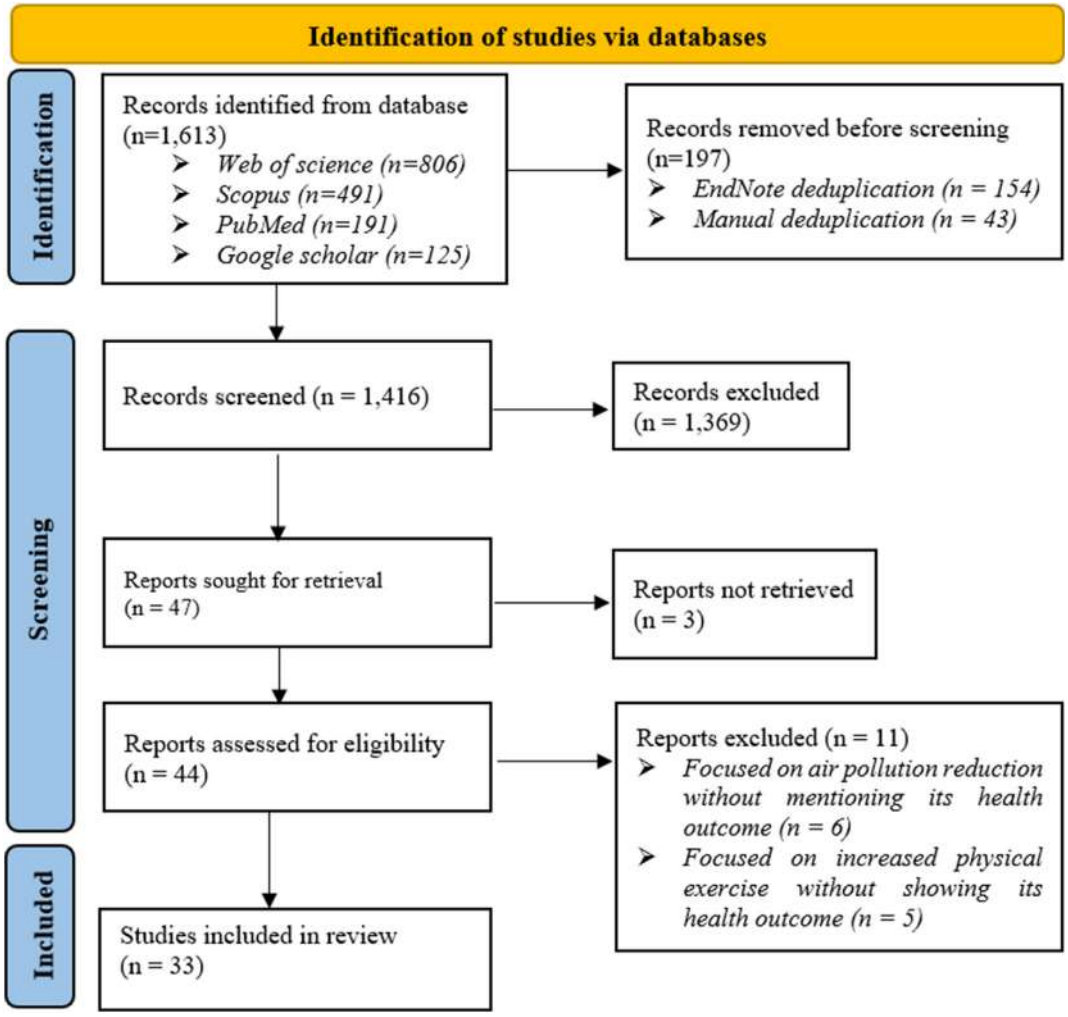

Fig. 1. The literature selection process diagram as recommended by Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020.

remaining 491, 191 and 125 papers were identified in Scopus, PubMed and Google Scholar, respectively (Fig. 1). From the 44 potentially eligible articles arising from the initial search, 11 were removed, as they did not report any health outcomes, leaving a final sample of 33 articles to be included in the review (Fig. 1). The majority (63.63%) of the studies were published in 2021 and the remaining 12.12% and 24.25% were published in 2020 and 2022, respectively (Table 1). All articles included in the review used cross-sectional study designs.

Risk of bias of studies

Based on the JBI critical appraisal checklist for cross-sectional studies, 23 studies were assessed as having a low risk of bias in all eight items of the checklist, whereas nine studies[11,24,31,39,40,42,43,49,51] demonstrated an unclear risk of bias in two items (identification of confounding factors and strategies to deal with confounding factors) of the checklist (Supplementary file S1). The remaining study[37] had a high risk of bias in identifying confounding factors and did not have strategies to mitigate confounding factors.

Health dimension and focus of literature

The majority (72.73%) of the reviewed literature focused on physical health, followed by 12.12% on digital health issues (Table 2, Fig. 2). Three studies reported on mental health[30,34,50] and one study[33] indicated the positive health impact of COVID-19 on social health (Table 2). One study[53] focused on both social and mental health dimensions (multihealth concepts). A high proportion (70.83%) of the studies were conducted on the physical health benefit of COVID-19 and reported the positive impact of lockdown in reducing air pollutants and the indirect contribution to health, with the remaining 29.16%[29,24,36,37,44,55,13] noting the merits of COVID-19 in improving infection prevention practices (Table 2, Fig. 2). Because family members were often spending more time together and helping each other during the pandemic, anxiety and depression were reduced due to increased feelings of togetherness and reduced loneliness.[34,50] In addition, physical exercise within families reduced the anxiety level of children during the pandemic.[30] Barreda-Angeles and Hartmann[33] reported that social reality platform interactions improved the social health of users during COVID-19. The digital health–related studies[31,49,51,56] were focused on the increase of telehealth/telemedicine usage as an alternative to face-to-face health service delivery during the pandemic (Table 2, Fig. 2).

Compared with pre-COVID-19 times, infectious disease prevalence was reduced in the range of 1.4%[35] to 43%[29] during COVID-19. In addition to infectious diseases, the prevalence of antimicrobial resistance was also reduced during COVID-19.[37] Particulate matter with a diameter of 2.5 μm or less ($PM_{2.5}$) air pollutants during COVID-19 was reduced in the range of 12%[47] to 58.5%,[39] compared with the prepandemic PM2.5 status. In the range of 29.85[39] to 340,500[38] years life lost due to premature death, long- and short-term air pollutant–related deaths were reduced during the pandemic compared with prepandemic mortality status. Lockdown measures during COVID-19 reduced air pollutant–related premature mortality by 35%[32] (Table 1). In relation to health costs, $31.8 to $77 billion estimated air pollutant–related illness and death crises will be avoided between 2021 and 2025.[52]

Telemedicine usage increased from 0.3% prepandemic to 19.1% postpandemic.[51] Due to regular physical activity during COVID-19, the anxiety score of children was under five standard deviations from the prepandemic normative value.[30] In addition, reduced work commitments or work-from-home situation during the COVID-19 lockdown increased the sexual activity of couples, which, in turn, improved their anxiety level.[50]

Risk of reporting bias

Using the Agency for Healthcare Research and Quality reporting bias assessment criteria, each reviewed study was assessed for the three types of reporting biases (publication, selective outcome reporting and/or selective analysis bias). The reporting biases were assessed as 'suspected' or 'undetected'.[28] Based on this assessment, eight of the included studies[24,31,33,34,50,53,13,56] were suspected of having a risk of bias, whereas the remaining 25 were judged as having an undetected risk of bias. Except for Amar et al.,[24] seven studies with a suspected risk of bias did not compare the pre-COVID-19 health situation to post-COVID-19 emergence health statuses. The research conducted by Amar et al.[24] reported an analysis of the prevalence of respiratory and gastrointestinal diseases based on hospital/clinic admission; however, patients who

Table 2
The proportion of reviewed literature in terms of the health concepts/dimensions.

Health dimensions	Focus of literature	List of studies		Percentage of studies
Physical health	Air pollution	• Aamir et al.[10] • Bai et al.[32] • Chen et al.[11] • Dragic et al.[36] • Giani et al.[38] • Goel et al.[39] • Han & Hong[40] • Hao et al.[41] • Hernandez-Paniagua et al.[42]	• Huang et al.[43] • Khomsi et al.[45] • Kodros et al.[46] • Lam et al.[47] • Liu et al.[38] • Perera et al.[52] • Seo et al.[54] • Ye et al.[57]	72.73%
	Infection prevention and control	• Allison et al.[29] • Amar et al.[24] • Chacon-Quesada et al.[35]	• Elliott et al.[37] • Shah et al.[55] • Toccafondi et al.[13] • Hussain et al.[44]	
Social health	Virtual reality platform	• Barreda-Angeles & Hartmann[33]		3.03%
Mental health	Anxiety	• Alves et al.[30] • Bowe et al.[34]	• Mollaioli et al.[50]	9.09%
Digital health	Telemedicine/telehealth	• Bacon et al.[31] • Metzger et al.[49]	• Pennington et al.[51]	12.12%
	Multi-electronic health	• Wamsley et al.[56]		
Multihealth	Digital and mental health	• Sahi et al.[53]		3.03%

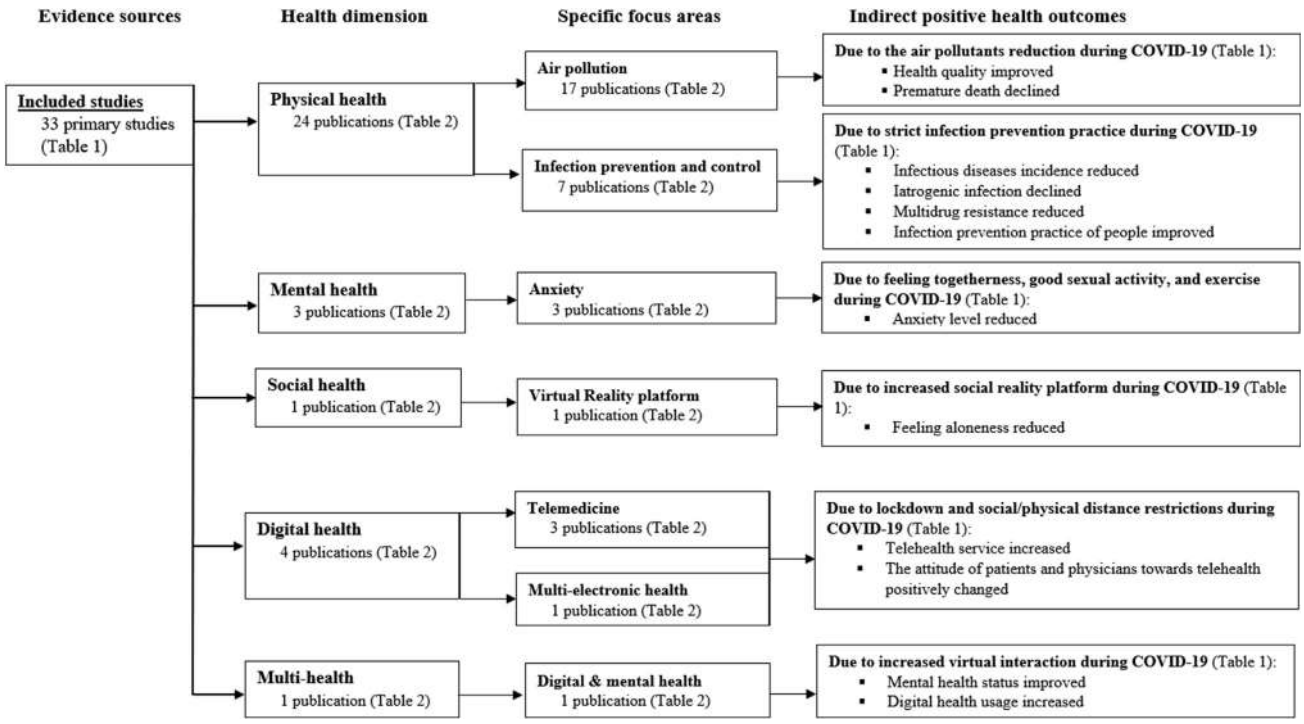

Fig. 2. Evidence map of included publications by health dimension, study focus area and indirect positive health outcomes.

did not attend clinics and recovered by themselves and those who did not attend health facilities due to fear of COVID-19 were not considered. In addition, COVID-19 was the main priority around the world, and some minor health conditions were prohibited from attending health facilities during the pandemic. As these issues were not actively considered, reporting biases were suspected.

Certainty of evidence

Using the GRADE Pro handbook as a guideline, the certainty of results was judged as 'high', 'moderate', 'low' or 'very low'. The majority (75.75%) of the literature had high levels of certainty, whereas 21.21%[31,33,34,50,53,13,56] had low levels of certainty of evidence. The studies judged as having a low level of certainty were due to failure of pre-COVID-19 health situation assessments. Only one study[24] was judged as having a moderate level of certainty. This study only included cases admitted to health facilities and did not consider those who were not admitted due to COVID-19 restrictions or who had mild and home recovery situations.

Discussion

The objectives of this systematic review were to investigate the frequency of positive health outcomes and identify the health dimension(s) that most benefited from the emergence of COVID-19. Although COVID-19 caused substantial multidimensional crises, its preventive measures also, unexpectedly, contributed to positive health outcomes. The positive health outcomes were mostly attained indirectly by measures adopted for its prevention and control. According to the reviewed literature, the emergence of COVID-19 resulted in some improvements in all four health dimensions (physical, mental, social and digital) whilst also acknowledging that this is clearly counter-balanced by the significant negative impact of COVID-19.

Most (72.73%) of the reviewed literature corroborated that COVID-19 contributed to some physical health improvements. This was due to the indirect benefit of lockdown in reducing air pollution[10,32,11,36,45,48,52,54,57] and the critical application of infection prevention protocols.[30,35,37] During COVID-19 lockdown, vehicles, industries and factories were ceased usual activities. As a result, air pollutant emissions, especially $PM_{2.5}$, were reduced, and associated health crises, such as premature deaths due to these air pollutants, declined.[38–41,43,45,47,54] This improvement was not limited to $PM_{2.5}$, the health burden from other air pollutants, such as nitrogen dioxide,[45,54] carbon monoxide[45] and PM_{10},[54] were also reduced during COVID-19 when compared with pre-COVID-19 outcomes.

In addition to the positive health outcomes from air pollution reduction, health benefits from improved IPC practices were reported. The IPC practices implemented to reduce COVID-19 also had a positive impact on reducing other infectious diseases.[35,55,13] COVID-19 IPC practices, such as wearing a facemask, also indirectly minimised inhalation of air pollutants.[46] The contributions of COVID-19 IPC practices in reducing iatrogenic[44] and surgical wound[35] infections were substantial. Infected and recovered persons from COVID-19 appeared to have an improved immune response to other related viral infections.[58] Thus, the causative agent of COVID-19 (SARS-CoV-2) may cross-react with other viruses, and the host immune responses subsequently improve due to immune reactions. This indicates that COVID-19 may have a direct positive health impact in addition to improving health through indirect causation.

In addition to the benefits on physical health, the emergence of COVID-19 positively impacted the delivery of digital health care. Specifically, 12.12% of the reviewed literature confirmed that face-to-face healthcare delivery was replaced by digital health during the pandemic. The reviewed literature[31,49,51] reported that telehealth/telemedicine was often the main health service delivery mechanism during COVID-19 lockdowns. With the need to find alternative health services due to lockdown and physical distancing measures, digital health usage by both health workers and consumers was improved. Electronic media, including social virtual

reality platforms, went beyond existing digital health structures and significantly improved the social health of societies.[33] Communication through virtual platforms was associated with a reduction in feelings of loneliness and contributed to both digital and social health.[56] Owing to feelings of togetherness and cooperation[35] and improved sexual activities,[50] some anxiety levels among individuals were reduced during the COVID-19 pandemic, although it is acknowledged that mental health was also potentially impaired by COVID-19 isolation. An increase in physical exercise during the pandemic positively impacted child mental health compared with the mental health status associated with physical exercise before COVID-19.[30] Virtual communication (digital health) was increased during COVID-19 that in turn benefited patients by reducing anxiety (mental health).[53]

A wide range (1.4%–43%) of infectious disease prevalence reductions were observed during the pandemic[29,35] as a result of the strict application of COVID-19 IPC strategies.[59] In addition to infection reduction, the implementation of COVID-19 infection prevention measures also indirectly reduced antimicrobial resistance development.[37] Furthermore, air pollutants, such as PM2.5, were substantially reduced in a range of 12%–58.5%[39,47] during the pandemic compared with pre-COVID-19 air pollutant levels. Lockdown was the main factor in the reduction of air pollutants emission from vehicles, industries and factories. Owing to air pollutant decline during the pandemic, a significant number (29.85–340,500) of years life lost due to premature deaths associated with air pollutants were avoided.[38,39] As estimated by Perera et al.,[52] $31.8–$77 billion in health costs will be saved due to reduced $PM_{2.5}$-related illnesses and deaths. This indicated that COVID-19–related restrictions (lockdown, distance and movement restrictions) indirectly benefited the health and economy of the society. Owing to lockdown measures and distance restrictions, telehealth was deemed to be an appropriate alternative to face-to-face health services. As a result, prepandemic telehealth usage (0.3%) in the United States increased to 19.1% during COVID-19.[51] Similar to telehealth usage, telehealth customer satisfaction increased from 85.9% to 88.5%.[51] Following the emergence of COVID-19, physical activity of individuals[30] and sexual activity of couples[50] increased, which, in turn, reduced anxiety levels compared with the prepandemic situations. The lockdown and social and physical distancing measures promoted virtual reality platform usage, which, in turn, increased social relatedness and improved the mental[53] and social health of individuals.[33]

Recommendations and implications

COVID-19 resulted in significant behavioural changes around the world that have led to some unexpected positive health benefits. These behavioural changes were as a result of a variety of interventions and personal factors, including government enforcement, the fear of COVID-19, self- induced motivations and self-realisations with time.[60] Using the theory of reasoned action to this phenomenon, the world population has passed the 'pre-contemplation' stage and is currently in the 'action' stage.[60] It is time to invest and support these COVID-19–induced changes to maintain the positive health benefits.

The crises and positive outcomes due to COVID-19 can be taken as a lesson for future pandemic early preparedness. The continuation of COVID-19 prevention and control practices is crucial to limit and/or prevent future pandemics. The persistence of positive COVID-19–induced health outcomes reduces the impact of not only emerging and re-emerging pandemics but also mitigates re/emerging endemics and epidemics.

All the studies included in this review used cross-sectional study designs with short duration (<1 year). As a result, it was not possible to report the annual status of the positive health outcomes for each study. Further studies on the direct and indirect positive health benefits of COVID-19 with measurable impact on health outcomes are suggested. Possible strategies for the persistence of the COVID-19-induced positive health outcomes, the long- and short-term positive health outcomes, the immune cross-reaction of COVID-19 infection, and the multidimensional positive health impact of COVID-19-like impacts on food safety are recommended for future studies.

Limitations of the literature and review

Some articles did not investigate the pre-COVID-19 health situation, and, equally, in some cases, no comparisons were made with the post-COVID-19 emergence health outcomes. As a natural consequence of the time frames, the reviewed studies were not able to show whether the reported positive health impacts are sustainable in the long-term or merely a short-term outcome. None of the articles reported the intention of the participants to persist with their activities in the future. It is acknowledged that the limitations of this study are not only from the source of evidence, but there are also potentially both study selection and inclusion-related issues. As the English language was an inclusion criterion, some valuable literature published in languages other than English may have been excluded. Finally, it is noted that the studies were initially identified using the title and abstract screening technique, and this approach is prone to missing evidence.[61]

Conclusions

Despite the devastating and multidimensional impact of COVID-19 and the measures adopted for prevention, there have been unexpected positive health outcomes. Prevalence, morbidity and mortality for some health conditions were reduced due to a reduction in air pollution, increased personal preventive equipment usage, improved digital health approaches, reduced anxiety and improved social health. The continuation of activities that led to COVID-19–associated positive outcomes, while still reducing the adverse effects of the pandemic, should be promoted. In addition, it is recommended that further integrated studies are carried out to investigate the COVID-19 crisis and associated benefits.

Author statements

Ethical approval

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Competing interests

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.005.

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Review Paper

Key factors influencing paediatric COVID-19 vaccine hesitancy: a brief overview and Decision-making Trial and Evaluation Laboratory analysis

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ABSTRACT

Objectives: The purpose of this study was to examine the current literature on paediatric COVID-19 vaccine hesitancy among parents and identify key influencing factors, thus enabling targeted policy development and implementation.

Study design: This was a systematic literature review and Decision-making Trial and Evaluation Laboratory (DEMATEL) analysis.

Methods: A review of the quantitative and qualitative literature focusing on factors influencing paediatric COVID-19 vaccine hesitancy was conducted. Searches were performed in PubMed, ScienceDirect, SpringerLink and Embase. Because of the immediacy of the topic, commentaries were included in addition to research and review articles. Influencing factors were categorised according to the Health Ecology Theory and screened using the DEMATEL method.

Results: A total of 44 articles were included in the study, and 44 factors influencing paediatric COVID-19 vaccine hesitancy were identified. Of these, 18 were categorised as key factors using the DEMATEL method, including a history of COVID-19 infection in parents and perceived safety of the paediatric COVID-19 vaccine.

Conclusions: Policymakers and public health personnel should pay more attention to the key factors influencing paediatric COVID-19 vaccine hesitancy. The outcome of this research will benefit and motivate decision-makers to consider strategies to overcome various challenges of COVID-19 vaccine hesitancy.

Introduction

The novel coronavirus pneumonia (COVID-19) pandemic has resulted in more than 600 million confirmed cases, including approximately 6.6 million deaths.[1] In addition to the threat to health, COVID-19 also impacts the daily life and mental health of the public and thus continues to receive much attention from researchers worldwide.[1,2] According to the World Health Organisation, vaccines and vaccination are the most effective measures to halt the pandemic, thus emphasising the importance of vaccination.[3,4] Since the start of the pandemic, many countries have invested a lot of resources into the research, development and practical application of COVID-19 vaccines.[5–7] The age range of those eligible to receive the COVID-19 vaccination has extended from 18 to 59 years to ≥3 years in China[8] and was gradually liberalised from >12 years to all ages in Canada, meaning that children can also now receive the COVID-19 vaccination.[9]

Vaccine hesitancy refers to the delay in acceptance or refusal of vaccines, despite the availability of the vaccine. Vaccine hesitancy is complex and context specific, varying across time, place and vaccine.[10] The Strategic Advisory Group of Experts working group on vaccine hesitancy also recognised that vaccine hesitancy occurs along a continuum between full acceptance, including high demand for vaccines, and outright refusal of some or all vaccines, although acceptance of the vaccines was the norm in the majority of populations globally.[10] In this study, paediatric vaccine hesitancy refers to parental hesitancy about the paediatric vaccine because, in most cases, parents are the decision-makers regarding whether or not a child should be vaccinated.[2,11]

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Previous investigations into the factors influencing paediatric vaccine hesitancy often used specific theories and models (e.g. the Health Belief Model and the Theory of Planned Behaviour).[12,13] However, many researchers have pointed out that the insufficient inclusion of factors influencing vaccine hesitancy is a limitation of their studies,[14–16] and studies based on specific theoretical models may lack comprehensiveness. At the same time, a systematic review of the factors influencing influenza vaccine hesitancy noted that the review only described the influencing factors and could not judge their importance.[17] This is because when a factor is reported more frequently, it does not mean that it is more important but may simply be because of it being selected more often by the researcher or showing significance more often.[17] Therefore, comprehensive identification of the key factors influencing paediatric COVID-19 vaccine hesitancy can help to reduce the hesitancy rate and ultimately improve vaccination coverage.

According to previous research, the common theoretical models used in the study of influences on vaccine hesitancy include the Knowledge-Attitude-Practice Theory,[18,19] the Health Belief Model,[20,21] the Protection Motivation Theory[22] and the Theory of Planned Behaviour,[23] but they lack comprehensiveness to a certain extent. For example, these models lack policy-level constructs, such as culture and economics, when measured. In comparison, the Health Ecology Theory is more comprehensive and is derived from ecology theory.[24] McLeroy[24] applied ecology theory to the field of health promotion research in 1988 and argued that health promotion should focus on both individual and social factors, and more branches have since developed, including the Health Ecology Theory. According to the Health Ecology Theory, the determinants of health behaviours include (1) personal innate traits and disease biology; (2) personal psychology and behaviour; (3) interpersonal network; (4) living and working conditions; and (5) national and local social, economic, political, health, environmental conditions, and related policy factors.[24] The Health Ecology Theory emphasises that health behaviours are the result of the interdependence and interaction of many factors.

This study aimed to identify factors influencing paediatric COVID-19 vaccine hesitancy through a literature evaluation under the framework of the Health Ecology Theory and subsequently determine the key influencing factors through Decision-making Trial and Evaluation Laboratory (DEMATEL).

Methods

Literature search and selection procedure

The literature screening flowchart is shown in Fig. 1. The keywords used for the literature search included paediatric vaccine; paediatric vaccine hesitancy/hesitation; vaccine intention/willing/behaviour; influencing factor; factor; kid; child/children/parent/kids. The retrieval databases were PubMed, ScienceDirect, SpringerLink and Embase, and Boolean operators “AND,” “OR” and “NOT” were used for the combination of retrieval terms during the process. The two study authors (Yonyi Wang was responsible for reading, screening and excluding, while Xinping Zhang checked and proofread) screened the retrieved articles and eliminated those not meeting the study needs. The purpose of the included literature was to measure or evaluate factors influencing paediatric COVID-19 vaccine hesitancy. Case reports, clinical guidelines, recommendations and articles in non-English languages were excluded. We also excluded studies that investigated children with diseases because each vaccine may have specific considerations for particular populations and health conditions.[25]

In terms of selecting influencing factors, those with significant outcomes and those frequently reported in the literature were included. This selection process was checked by the two authors based on the principle of ‘consistency of content’ and then discussed to determine the correct categorisation. Some factors could be categorised without doubt (e.g. psychological factors could be categorised as Dimension 2). For controversial factors, reference was made to the previous DEMATEL literature.

DEMATEL

DEMATEL was proposed by Gabus and Fontela at the Geneva Research Centre for the Science and Human Affairs Program from 1972 to 1976. DEMATEL uses graph theory and matrix theory to (1) analyse the complex problems of interlocking influencing factors, (2) identify the causal relationship between complex system factors and (3) extract key elements.

The following steps were used in the current study to determine the key influencing factors:

Step 1. Factors influencing paediatric COVID-19 vaccine hesitancy were determined. A group of effective factors $S = \{S_1, S_2, \ldots \ldots, S_n\}$, with significant impact on the system were identified.

Step 2. An initial direct influence matrix was established. An expert panel was set up, including four experts in preventive medicine, two in paediatrics, two in social medicine and one in health management. Experts formulated the direct influence matrix $X=(x_{ij})_{n\times n}$ by indicating the influence that the factor S_i has on S_j, using an integer scale (0–4) of no influence (0); very low influence (1); small influence (2); moderate influence (3); very strong influence (4).

Step 3. A normalised direct influence matrix was calculated. The normalised direct influence matrix M can be obtained by normalising the initial direct influence matrix X according to the following equation.

$$M = X \Big/ \max_{1\le i\le n} \sum_{j=1}^{n} x_{ij}$$

Step 4. Based on matrix X, the total influence matrix $T = [t_{ij}]_{n\times n}$ was calculated by summing the direct effects and all of the indirect effects by

$$T = (t_{ij})_{n\times n} = M(I - M)^{-1}$$

where, I–identity matrix;

Step 5. The Prominence and Relation values were calculated

$$R_{i=} \sum_{j-1}^{n} t_{ij}\ , i = 1, 2, \ldots, n$$

$$C_{j=} \sum_{i-1}^{n} t_{ij}\ , j = 1, 2, \ldots, n$$

Prominence (R_i+C_j) describes the strength of influence given and received by a given factor. The Relation (R_i-C_j) shows the net effect that a given factor brings into the system and is the basis for ranking factors. If R_i-C_i is positive, then S_i belongs to a group of causes (impact the system). If R_i-C_i is negative, then S_i is the effect of the net impact of other system elements and is classified in the group of effects.

Step 6. A cause and effect diagram was plotted. According to the values of array ($R_i + C_j$, R_i-C_j), the causality diagram was drawn, with the Prominence as abscissa and the Relation as ordinate, the values of ($R_i + C_j$, R_i-C_j) were indicated in the figure (Fig. 2), and the visualised figure was used to represent the importance of factors in the system. A line was drawn with the mean of R + C values as the cut-off point to divide the causality map into four quadrants. Due to

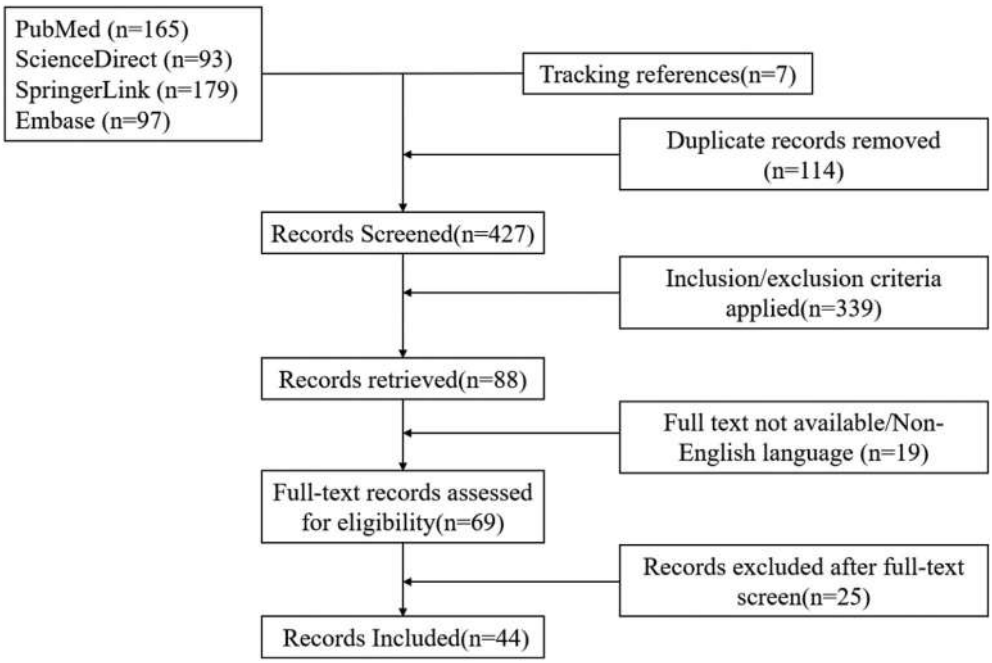

Fig. 1. Literature screening flowchart.

their location in a specific quadrant, factors are classified as most important, important, independent or indirect.[26]

Results

Systematic search results

Among the 44 articles identified during the search, 36 were cross-sectional studies, three were review articles, one was an intervention study, two were mixed methods studies (i.e. using both qualitative and quantitative research methods), one was a commentary and one was qualitative a study. The details of the selected studies are presented in Table 1. A total of 95,497 participants were involved in the studies included in this review.

From the included studies, most of the surveys were conducted using self-developed questionnaires. In these questionnaires, the outcome variable was parental paediatric COVID-19 vaccine hesitancy, and the questioning varied, mainly in terms of intention, willingness, propensity and attitude. Other main dimensions were sociodemographics (e.g. gender, age, region, economic status), vaccine safety, efficacy, priority, history of vaccination (e.g. influenza vaccination), perceived risk of COVID-19 and/or vaccine, negative COVID-19 experience, trust and psychological status. The current review identified 44 factors influencing paediatric COVID-19 vaccine hesitancy from the selected articles (Table 2).

DEMATEL analysis

Direct influence matrix, normalised direct influence matrix, total influence matrix and causality plots for dimension 1 are shown in Table 3 and Fig. 2 (data results for the remaining dimensions are shown in the Supplementary Material).

Key factors influencing paediatric COVID-19 vaccine hesitancy

Based on the method described earlier, the first quadrant, namely, the most important factors, were considered to be the key factors in this study. A total of 18 key factors were identified in this study. Of these, eight, five, five, two, and one factors were found in each of the five dimensions, respectively (see Table 4 for details).

Discussion

A total of 18 key factors influencing paediatric COVID-19 vaccine hesitancy were screened by the DEMATEL method.

Histories of illness of parents and children were found to be key influencing factors, regardless of whether their histories of illness were associated with COVID-19. First, paediatric COVID-19 vaccine hesitancy may be due to the fact that the vaccine itself has vaccination contraindications[67,68] (i.e. children who are in poor physical condition and have had allergic reactions after vaccination may be at risk of becoming more sensitive to drug reactions due to their vulnerability even if they do not meet the contraindications).[68,69] Second, parents with a history of disease may not have sufficient confidence and self-efficacy to take their children to healthcare facilities for vaccination.[70] From a genetic point of view, the physical condition of parents may also impact their children;[71,72] thus, parents may hold a wait-and-see attitude towards the COVID-19 vaccine in children because of concerns about the physical condition of their children. Parents who have previously been allergic to the vaccine may have concerns and fears about their children experiencing the same uncomfortable reactions, such as fever, nausea and dizziness.[64] In terms of the impact of parental history of COVID-19 infection on paediatric COVID-19 vaccine hesitancy, one explanation could be that people often experience unrealistic optimism in the face of familiar risks. Therefore, parents believe that the situation is largely under the control and will of the individual[73] and that they can protect their children well and do not need vaccines. If the child has been diagnosed with COVID-19, then their parents will think that infection with the virus will make the body produce antibodies and play a protective role, thereby reducing the perception of the necessity of the COVID-19 vaccine in children.[30]

The safety of COVID-19 vaccines has attracted much attention since their development and use. Due to the rapid spread of

Table 1
Literature information.

Author(s)	Study type	Region	Tool	Study period	Sample size
Humble RM et al.[9]	Cross-sectional study	Canada	Self-developed questionnaire	2020.12.20–2020.12.24	1702
Babicki M et al.[27]	Cross-sectional study	Poland	Self-developed questionnaire	2021.5.9–2021.5.14	4432
Zona S et al.[28]	Cross-sectional study	Italy	Self-developed questionnaire	2021.7.15–2021.8.16	1799
Kezhong A et al.[29]	Cross-sectional study	China	A 10-question adult vaccine hesitancy scale (aVHS)	2020.6–2020.7	13,451
Musa S et al.[30]	Cross-sectional study	Qatar	Vaccination scheduled records and information	2021.5.17–2021.6.3	4023
Skjefte M et al.[31]	Cross-sectional study	16 countries	Self-developed questionnaire	2020.10.28–2020.11.18	17,871
Fisher CB et al.[32]	Cross-sectional study	USA	Items from previous scales	2021.10	400
Xu Y et al.[8]	Cross-sectional study	China	Parental Attitudes About Childhood Vaccines (PACV)	2021.7.22–2021.8.14	917
Lackner CL et al.[33]	Cross-sectional study	Canada	Self-developed questionnaire	2020.5.15–2020.6.9	455
Wang Y and Zhang X[2]	Cross-sectional study	China	Parental Attitudes About Childhood Vaccines, PACV	2021.6–2021.7	382
Olusanya OA et al.[34]	Review	–	–	–	–
Kreuter MW et al.[35]	Cross-sectional study	USA	Self-developed questionnaire	2021.1.13–2021.1.31	1951
Russo L et al.[36]	Cross-sectional study	Italy	Self-developed questionnaire	2021.7.22–2021.8.31	1696
Cole JW[37]	Intervention study	USA	MOTIVE (MOtivational Interviewing Tool to Improve Vaccine AcceptancE)	2018.7–2019.6/ 2019.7–2020.3	2504/1954
Ellithorpe ME et al.[38]	Cross-sectional study	USA	Self-developed questionnaire	2020.11.13–2020.12.8	682
Phan TT[39]	Cross-sectional study	Mid-Atlantic	Self-developed questionnaire	2021.3.19–2021.4.16	513
Temsah MH et al.[40]	Cross-sectional study	Saudi Arabia	Vaccine Hesitancy Scale, VHS-Adjusted	–	3167
Alfieri NL et al.[41]	Cross-sectional study	USA	Self-developed questionnaire	2020.6.8–2020.6.29	1425
Teasdale CA et al.[42]	Cross-sectional study	USA	Self-developed questionnaire	2021.3.9–2021.4.11	1119
Xu Y et al.[43]	Cross-sectional study	China	Patient Health Questionnaire (PHQ-4) and self-developed questionnaire	2020.12.18–2020.12.31	4748
Bell S et al.[44]	Mixed Method Study	UK	Self-developed questionnaire	2020.4.19–2020.5.11	1252/19
Brandstetter S et al.[45]	Cross-sectional study	Germany	Self-developed questionnaire	2020.5.5–2020.5.28	612
Yılmaz M et al.[46]	Cross-sectional study	Turkey	Self-developed questionnaire	2021.2.8–2021.2.21	1035
Szilagyi PG et al.[47]	Cross-sectional study	USA	Vaccine Hesitancy Scale, VHS-Adjusted	2021.2.17–2021.3.30	1745
Gabriella DG et al.[48]	Cross-sectional study	Italy	Self-developed questionnaire	2021.4.18–2021.5.18	607
Ruggiero KM et al.[49]	Cross-sectional study	USA	Parental Attitudes About Childhood Vaccines, PACV	2020.11–2021.1	427
Teasdale CA et al.[50]	Cross-sectional study	USA	Self-developed questionnaire	2021.3.9–2021.4.2	2074
Urrunaga-Pastor D et al.[51]	Cross-sectional study	Latin America and Caribbean	Self-developed questionnaire	2021.5.20–2021.7.14	227,740
Kelly BJ et al.[52]	Cross-sectional study	USA	Self-developed questionnaire	2020.4	2247
Botha E et al.[53]	Review	–	–	–	–
Evans S et al.[54]	Mixed Method Study	Australia	Self-developed questionnaire	2020.4.8–2020.4.28/ 2021.1.18–2021.2.8	1094
Altulaihi BA et al.[55]	Cross-sectional study	Saudi Arabia	Self-developed questionnaire	–	333
Hetherington E et al.[56]	Cross-sectional study	Canada	Self-developed questionnaire	2020.5–2020.6	1321
Chemakina et al.[57]	Qualitative study	Russia	–	–	253
MacDonald NE and Dubé E[58]	Commentary	–	–	–	–
Wang Q et al.[14]	Cross-sectional study	China	Vaccine Hesitancy Scale, VHS	2020.9.21–2020.10.17	3095
Zhou Y et al.[59]	Cross-sectional study	China	Self-developed questionnaire	2020.7.1–2020.9.8	1071
Montalti M et al.[60]	Cross-sectional study	Italy	Self-developed questionnaire	2020.12–2021.1	5054
Aldakhil H et al.[61]	Cross-sectional study	Saudi Arabia	Vaccine Hesitancy Scale, VHS	2021.1.1–2021.2.28	270
Galanis P et al.[62]	Review	–	–	–	–
Middleman AB et al.[63]	Cross-sectional study	USA	Self-developed questionnaire	2020.8.11–2020.9.18/ 2021.2.4–2021.3.1/ 2021.6.10–2021.6.30	1613
Chiang, V. et al.[64]	Cross-sectional study	China	Medical records	2021.2–2021.6	1127
Goldman, R. D. et al.[65]	Cross-sectional study	USA	Self-developed questionnaire	2020.3.26–2020.5.31	1552
Wu Yue. et al.[66]	Cross-sectional study	China	Self-developed questionnaire	2021.6–2021.7	2538

COVID-19,[1] many countries invested in various resources to participate in vaccine development. Due to the urgency of the vaccine, there is a lack of long-term clinical trials and clinical evidence;[5,74] therefore, there are many doubts about the side-effects and potential future effects of COVID-19 vaccines.[27,40,44] Risk perception, including paediatric COVID-19 susceptibility, paediatric COVID-19 severity and paediatric COVID-19 transmission, can also influence vaccination decisions.[32] Since the start of the pandemic, official organisations in various countries, such as the World Health Organisation or the United States Food and Drug Administration, have issued a variety of information on vaccine research, development and vaccination. The level of public trust in official organisations/agencies, as well as in the online media messages they release, may seriously influence the vaccine decision-making process.[38,65] Willingness to vaccinate is stronger when the public trusts official organisations/institutions and when they provide a wealth of information on the development, testing and safety of the COVID-19 vaccine.[35] In addition, psychological distress,[43] that is, psychological status, has increasingly been shown to affect vaccination decisions, including but not limited to anxiety-depression.[51] In addition, some other psychological factors, such as psychological flexibility[2] and

Table 2
Factors influencing paediatric COVID-19 vaccine hesitancy from the selected articles.

No.	Factors	Details
a. Dimension 1. Personal innate traits and disease biology.		
S1	Gender[27,38,42,52,60,62]	
S2	Age[28,33,35,40,47,51,55,60,62]	
S3	Age of child/children[30,36,40,48,55,60]	
S4	History of COVID-19 infection in parents[30,51,65]	
S5	History of parental vaccine allergy[64]	
S6	History of parental immunodeficiency/immune disease[57]	
S7	History of parental critical/chronic illness[31]	
S8	History of COVID-19 infection in child/children[8,65]	
S9	History of child/children vaccine allergy[61,65]	
S10	History of childhood immunodeficiency/immune disease[49,61,65]	
S11	History of childhood critical/chronic illness[28,65]	
b. Dimension 2. Personal psychology and behaviour.		
S12	Perceived the safety for paediatric COVID-19 vaccine[8,14,27,28,31,32,36,42,44,47,49,50,53,55,56,61,63]	Side-effects of paediatric COVID-19 vaccine; rapid development leading to insufficient safety information and evidence; unclear potential future impact
S13	Perceived the need for paediatric COVID-19 vaccine[9,40,50]	Vaccinating children against COVID-19 is necessary or not
S14	Perceived the efficacy for paediatric COVID-19 vaccine[8,27,28,31,32,36,38,40,42,44,48,50,56]	Duration of protection for paediatric COVID-19 vaccine; vaccination can completely protect children from infection or not
S15	Perceived the importance for paediatric COVID-19 vaccine[31]	Importance and priority of paediatric COVID-19 vaccination
S16	Risk perception of COVID-19[31,32,36,48,53,54,62]	Paediatric COVID-19 susceptibility; paediatric COVID-19 severity; paediatric COVID-19 transmission risk
S17	Influenza vaccination[9,48,55,59,62]	History of influenza vaccination; willingness to receive influenza vaccination
S18	Paediatric influenza vaccination[38,39,49,62]	History of paediatric influenza vaccination; willingness to receive paediatric influenza vaccination
S19	COVID-19 vaccination[9,29,32,39,40,42,46–48,62]	History of COVID-19 vaccination; willingness to receive COVID-19 vaccination
S20	Paediatric routine vaccination[8,31,33,56,62]	Pay attention to vaccination within the childhood immunisation programme; routine vaccination for children is timely and complete
S21	Trust in health authorities/personnel and information issued[28,31,34,54,62]	Confidence in health authorities (e.g. hospitals)/personnel and information issued
S22	Trust in official agency/organisation and information issued[31,45,62]	Confidence in official agency/organisation (e.g. health committees) and information issued
S23	Compliance with infection prevention and control measures[31,51]	Compliance with mask-wearing, maintaining social distance, etc.
S24	Psychological avoidance[33]	Tend to avoid thoughts, negative emotions, or information about the outbreak
S25	Psychological distress[43,51]	E.g. mood disorder, depression, anxiety
S26	Coping style[2]	The methods and strategies adopted by individuals with personal characteristics in order to reduce or avoid stress and adapt to environment
S27	Self-efficacy[2,53]	A person's subjective judgement of whether he or she is able to successfully perform a behaviour
S28	Psychological flexibility[2]	Individual consciously adapts to the present and adheres to or changes behaviour guided by personal values
S29	Protection[14,44]	Protect people around; protect children
c. Dimension 3. Interpersonal network.		
S30	Occupation[8,9,28,46,59]	Occupation category; non-medical-related occupation and medical-related occupation
S31	Revenue[8,28,32,35,44,50,56,62]	Annual household income (RMB)
S32	Education level[14,28,32,40,47,50,51,53,56,59–61]	Education; education Level
S33	Community support[32]	Vaccine-related support from other parents or family members
S34	Cognition/attitude/suggestion/communication of healthcare providers[28,34,37,47,48,54,58]	Healthcare providers' perception and attitude towards paediatric COVID-19 vaccine; healthcare providers can provide effective advice; effectively communicate with healthcare providers
d. Dimension 4. Living and working conditions.		
S35	Accessible information sources[27,40,41,54,63]	Multiple sources of information such as media information, network information and official information are accessible
S36	Source of information relied on[60]	One or more sources of information that relied on
S37	Information content breadth[40,55]	The information content is extensive and covers content that has attracted much parental attention such as adverse events and vaccine information
S38	Experienced COVID-19[38]	Experienced the COVID-19 outbreak
S39	Participate in COVID-19 prevention and control[66]	Have participated in the work related to the prevention and control of COVID-19 epidemic
S40	History of exposure to vaccine adverse events in children[29]	Heard of adverse events to paediatric vaccines
e. Dimension 5. National and local social, economic, political, health, environmental conditions and related policy factors.		
S41	Permanent residence[8,30,51]	Resident area
S42	Household registration[8,30]	Consistent with or inconsistent with permanent residence; rural household registration or urban household registration
S43	Compulsory policy/measure[60]	E.g. School policy for compulsory COVID-19 vaccination of children
S44	Incentive policy/measure[34]	E.g. obtaining material rewards after vaccination

Table 3
Direct-influence matrix, normalized direct-influence matrix and total-influence matrix of Dimension 1.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
a. Dimension 1. Direct influence matrix.											
S1	0	1.0000	1.6667	2.2222	2.2222	2.3333	1.7778	1.8889	2.0000	2.2222	1.8889
S2	1.0000	0	1.8889	2.1111	1.8889	2.1111	2.0000	2.1111	2.0000	2.2222	2.2222
S3	1.5556	1.6667	0	2.5556	2.4444	2.4444	2.3333	2.5556	2.4444	2.5556	2.3333
S4	1.3333	1.6667	2.0000	0	2.1111	2.3333	2.0000	2.5556	2.7778	2.4444	2.1111
S5	1.1111	1.3333	1.7778	2.6667	0	2.4444	2.2222	2.5556	2.8889	2.5556	2.3333
S6	1.1111	1.5556	1.8889	2.5556	2.6667	0	2.4444	2.7778	2.6667	2.5556	2.4444
S7	1.4444	2.0000	1.7778	2.3333	2.2222	2.4444	0	2.3333	2.6667	2.3333	2.3333
S8	1.3333	1.7778	1.8889	2.4444	2.5556	2.2222	2.0000	0	2.4444	2.5556	2.3333
S9	1.3333	1.7778	2.5556	2.5556	2.7778	2.6667	2.3333	2.6667	0	2.4444	2.3333
S10	1.2222	1.5556	2.1111	2.4444	2.6667	2.8889	2.3333	2.4444	2.5556	0	2.3333
S11	1.2222	1.7778	2.4444	2.3333	2.4444	2.6667	2.4444	2.2222	2.3333	2.3333	0
b. Dimension 1. Normalised direct influence matrix.											
S1	0	0.0427	0.0711	0.0948	0.0948	0.0995	0.0758	0.0806	0.0853	0.0948	0.0806
S2	0.0427	0	0.0806	0.0900	0.0806	0.0900	0.0853	0.0900	0.0853	0.0948	0.0948
S3	0.0664	0.0711	0	0.1090	0.1043	0.1043	0.0995	0.1090	0.1043	0.1090	0.0995
S4	0.0569	0.0711	0.0853	0	0.0900	0.0995	0.0853	0.1090	0.1185	0.1043	0.0900
S5	0.0474	0.0569	0.0758	0.1137	0	0.1043	0.0948	0.1090	0.1232	0.1090	0.0995
S6	0.0474	0.0664	0.0806	0.1090	0.1137	0	0.1043	0.1185	0.1137	0.1090	0.1043
S7	0.0616	0.0853	0.0758	0.0995	0.0948	0.1043	0	0.0995	0.1137	0.0995	0.0995
S8	0.0569	0.0758	0.0806	0.1043	0.1090	0.0948	0.0853	0	0.1043	0.1090	0.0995
S9	0.0569	0.0758	0.1090	0.1090	0.1185	0.1137	0.0995	0.1137	0	0.1043	0.0995
S10	0.0521	0.0664	0.0900	0.1043	0.1137	0.1232	0.0995	0.1043	0.1090	0	0.0995
S11	0.0521	0.0758	0.1043	0.0995	0.1043	0.1137	0.1043	0.0948	0.0995	0.0995	0
c. Dimension 1. Total influence matrix.											
S1	0.6503	0.8667	1.0709	1.2811	1.2751	1.2987	1.1620	1.2715	1.3065	1.2792	1.1989
S2	0.7023	0.8400	1.0963	1.2968	1.2825	1.3106	1.1886	1.2994	1.3266	1.2990	1.2301
S3	0.8264	1.0370	1.1810	1.5024	1.4912	1.5144	1.3736	1.5054	1.5377	1.5003	1.4124
S4	0.7715	0.9780	1.1880	1.3185	1.3946	1.4239	1.2836	1.4198	1.4612	1.4109	1.3240
S5	0.7820	0.9898	1.2091	1.4552	1.3462	1.4628	1.3230	1.4544	1.5010	1.4492	1.3643
S6	0.8047	1.0268	1.2479	1.4930	1.4897	1.4104	1.3690	1.5039	1.5361	1.4908	1.4075
S7	0.7907	1.0096	1.2036	1.4369	1.4261	1.4562	1.2306	1.4398	1.4861	1.4349	1.3584
S8	0.7771	0.9892	1.1929	1.4236	1.4206	1.4309	1.2934	1.3320	1.4608	1.4255	1.3419
S9	0.8356	1.0633	1.3063	1.5347	1.5349	1.5545	1.4032	1.5418	1.4766	1.5287	1.4429
S10	0.8055	1.0224	1.2507	1.4833	1.4840	1.5144	1.3599	1.4865	1.5262	1.3867	1.3981
S11	0.7947	1.0168	1.2456	1.4592	1.4559	1.4863	1.3455	1.4583	1.4975	1.4571	1.2887

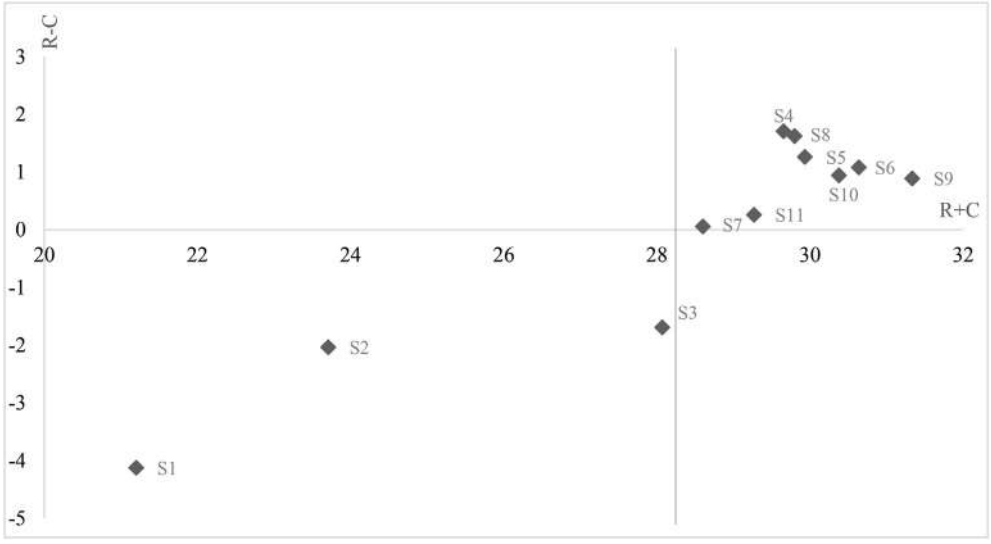

Fig. 2. Dimension 1. Cause and effect diagram.

trauma,[70] have also been reported to impact vaccine decision-making.

In general, the educational level of parents affects their perception of the paediatric COVID-19 vaccine; however, the impact of this effect is uncertain. Educational attainment is associated with greater participation in protective and preventive behaviours, which may be because higher education may help people engage in safe behaviour, while protecting them from the irrational fear of being infected or dying.[75] On the other hand, highly educated individuals usually possess high levels of self-

Table 4
Key factors influencing paediatric COVID-19 vaccine hesitancy.

No.	Factors	R+C	R − C
Personal innate traits and disease biology			
S4	History of COVID-19 infection in parents	29.6589	1.7106
S5	History of parental vaccine allergy	29.9378	1.2638
S6	History of parental immunodeficiency/immune disease	30.6427	1.0835
S7	History of parental critical/chronic illness	28.6055	0.0595
S8	History of COVID-19 infection in child/children	29.8009	1.6248
S9	History of child/children vaccine allergy	31.3389	0.8937
S10	History of childhood immunodeficiency/immune disease	30.3802	0.9449
S11	History of childhood critical/chronic illness	29.2729	0.2617
Personal psychology and behaviour			
S12	Perceived the safety for paediatric COVID-19 vaccine	29.1420	0.1584
S16	Risk perception of COVID-19	29.7677	0.5556
S22	Trust in official agency/organisation and information issued	29.0222	0.3786
S25	Psychological distress	27.8212	0.0557
S29	Protection	28.7056	0.5612
Interpersonal network			
S32	Education level	16.1452	0.5318
S34	Cognition/attitude/suggestion/communication of healthcare providers	16.4356	0.2530
Living and working conditions			
S38	Experienced COVID-19	33.4702	0.9357
S39	Participate in COVID-19 prevention and control	34.7912	0.9212
National and local social, economic, political, health, environmental conditions and related policy factors			
S44	Incentive policy/measure	10.0354	0.1046

efficacy[76] and are more confident in their ability to protect themselves and their children (i.e. believing in oneself outweighs believing in a vaccine where the risks remain). Unlike official organisations/institutions, healthcare providers are the most accessible professional help to parents. Healthcare providers' perceptions and attitudes towards paediatric COVID-19 vaccine and communication between parents and healthcare providers about the paediatric COVID-19 vaccine have all been shown to be important.[34,58] In addition, in terms of local practical policies, we found that some incentive schemes can encourage parents, to some extent, to vaccinate their children. It is easy to see from motivation-related theory that a certain degree of reward is an effective way to promote behaviour.[77]

Previous research has divided the Health Ecology Theory framework into upstream, midstream and downstream sections and formed a chain of health behavioural influences, with upstream influencing midstream and midstream influencing downstream.[78] Dimensions 3, 4 and 5 are upstream factors influencing health behaviour, dimension 2 is a midstream factor and dimension 1 is a downstream factor.[78] From a public health perspective, policy makers and public health personnel play an important role in upstream influencing. For example, they can work together to develop incentives or benefits to encourage health behaviours, train healthcare providers in health awareness and communication skills, and the government or official institutions can introduce policies to improve the level of education of individuals and increase the transparency of health information. As a result, the substantive and positive role played by policy makers and health professionals can spread from top to bottom.

This study has some limitations. First, the DEMATEL analysis relies on expert scores, which are highly subjective. Each expert has limited experience in dealing with paediatric COVID-19 vaccine hesitancy; further research and a larger study sample size would make the results more robust. Second, paediatric vaccine hesitancy involves multiple disciplines, such as preventive health, public health and health management, and experts from different specialities may have different views on the factors influencing paediatric COVID-19 vaccine hesitancy, which can lead to deviations between the results calculated by DEMATEL and the actual situation. Finally, the literature is constantly being updated, and additional factors influencing paediatric COVID-19 vaccine hesitancy may be discovered in the future.

Conclusions

Overcoming COVID-19 vaccine hesitancy and realising herd immunisation are worldwide common goals at present. This study used a comprehensive theory to screen for key factors influencing paediatric COVID-19 hesitancy. The study findings are in line with the Determinants of Vaccine Hesitancy Matrix reported by the Strategic Advisory Group of Experts working group on vaccine hesitancy. The key factors influencing paediatric COVID-19 hesitancy that have been identified in this study emphasise the importance of policy development, and prevention and control practice.

Author statements

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Ethical approval

The studies involving human participants were reviewed and approved by the ethics committee of Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei,

China. As the study used anonymous, pooled and retrospective data, the ethics committee waived the need for participants to provide written informed consent. The study complies with the Declaration of Helsinki. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

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Competing interests

None declared.

Author contributions

Y.W. contributed to conceptualisation; data curation; investigation; formal analysis; methodology; visualisation; and writing, reviewing and editing the article. X.Z. contributed to conceptualisation; project administration; supervision; validation; and reviewing and editing the article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.11.015.

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Review Paper

Older adults and social prescribing experience, outcomes, and processes: a meta-aggregation systematic review

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ABSTRACT

Objective: Social prescribing is a complex care model, which aims to address unmet non-medical needs and connect people to community resources. The purpose of this systematic review was to synthesize available evidence from qualitative methods (e.g. interviews or focus groups) on experience, outcomes, and processes for social prescribing and older adults (from the person or provider level).
Study design: This was a systematic review using the Joanna Brigg's meta-aggregative approach.
Methods: We searched multiple online databases for peer-reviewed studies, which included older adults aged ≥60 years (group mean age) and social prescribing experience, outcomes, or processes. We included all qualitative or mixed methods designs from all years and languages. Date of the last primary search was March 24, 2022. Two authors used online software to conduct the screening independently and then decided on the final list of included studies via notes and online discussion.
Results: We screened 376 citations (after duplicates) and included eight publications. There were 197 older adult participants (59% women), and many people were living with chronic health conditions. Few details were provided for participants' ethnicity, education, and related factors. We created five synthesized findings related to (1) the approach of social prescribing; implementation factors such as (2) relationships, (3) behavior change strategies, and (4) the environment; and (5) older adults' perceived health and psychosocial outcomes.
Conclusions: Despite the limited number of available studies, data provide an overview of people and processes involved with social prescribing, identified research and practice gaps, and possible next steps for implementing and evaluating social prescribing for older adults in primary care.

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Introduction

Social prescribing or social prescription is a person-centered health and social model of care, funded by the National Health Service in the United Kingdom[1] and investigated in smaller scale services and studies in other locations such as Australia[2] and Canada.[3] Other terms to describe the concept of social prescribing are community referrals and non-medical referrals. Social prescribing acknowledges health extends beyond "pathologies" to target other factors, such as unmet social needs. There is no accepted definition of social prescribing at present; however, it has been operationalized in several different pathways[4] ranging from providing information on community opportunities to connecting people to a collaborative hub of primary care practitioners (e.g. doctors, nurses, allied health) and community link workers (i.e. providers who connect people to a community program or service; "navigators"). It is a complex intervention[5] and consists of several phases: enrollment, engagement, and adherence (Supplementary Fig. 1).[4] Given its complexity, synthesizing evidence on social prescribing may be useful for organizations and providers seeking to understand how it functions within existing care structures.

Globally, the population is aging,[6] and consequently, the number of people living with chronic health conditions or non-communicable disease is increasing.[7] Older adults (e.g. people aged ≥60 years) may face health-related issues associated with increased social isolation, creating barriers to community mobility and social connections.[8] To our knowledge, there are only two systematic reviews specific to older adults and social prescribing.[9,10] However, in one review,[9] the authors did not locate any primary studies for inclusion in the synthesis; and in our previous review,[10] we only included data from quantitative study designs. Qualitative study designs provide the opportunity to look beyond effectiveness and related outcomes to explore perceptions and practices within social prescribing. Evidence from studies using qualitative methods can often provide information to understand the context and perceptions of interventions. Therefore, to inform our research and practice agenda focused on aging, our research question was, "For older adults and providers, what are the experiences, outcomes, and processes involved with social prescribing?" Our aim was to answer this question by synthesizing evidence based on qualitative research methods.

Methods

This was a systematic review guided by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA);[11] we registered the protocol with PROSPERO[12] before starting the review PROSPERO 2022 CRD42022320984.

We followed the Joanna Brigg Institute's (JBI) methods for conducting systematic reviews of qualitative literature (meta-aggregation) to synthesize evidence on social prescribing experience, outcomes, and processes related to older adults to inform our future research and practice agenda. An advantage of using meta-aggregation is it supports the policy making process.[13] When using meta-aggregation, the results from individual studies are not reinterpreted; rather, they are collected across included studies and grouped into similar clusters or ideas. We provide more specific information on the meta-aggregative approach in the Supplementary Material.

Search strategy

Information sources

We first used Epistemonikos[14] to locate published systematic reviews on social prescribing using the keywords "social prescribing" or "social prescription" in the title or abstract and identified several publications.[9,15–21] Following this stage, we then searched the following electronic databases: EBSCO (Cumulative Index for Nursing and Allied Health [CINAHL] Complete; APA PsycArticles and PsycINFO; and SPORTDiscus); Cochrane Controlled Trials and Cochrane Database of Systematic Reviews; Embase; Epistemonikos; MEDLINE Ovid; and Google Scholar (advanced feature title only). Supplementary Table 1 provides database search strategies. We also conducted a forward citation and backward (references) search for included publications using Google Scholar and Web of Science. We conducted our last search on March 24, 2022.

Eligibility criteria

We used a Population (Phenomena of) Interest, Context (PICo) framework to identify eligible studies: *population* = older adults aged ≥60 years (study group mean age: therefore, some participants may have been <60 years of age) or providers working with older adults within the same study of social prescribing: we did not include studies only examining providers' experiences because our research question specifically aimed to include social prescribing perspectives and experiences from the lens of older adults; *interest* = experience, outcomes, or processes; and *context* = we only included studies if the authors called the intervention social prescribing or prescription, as there is not a universally accepted definition of social prescribing. We included studies across all years and languages. We excluded gray literature, conference abstracts, and graduate theses.

Selection process and data collection

We followed standard procedures as outlined by PRISMA (Supplementary Material provides a full description of our methods).

Outcomes of interest

We included studies with older adults' and providers' (from the same study when available) social prescribing experience, outcomes, and processes. We discuss older adults as "participants" and providers from health and social care as "providers."

Critical appraisal

We used JBI Checklist aims to assess study quality: two authors (SG, MCA) independently adjudicated responses to 10 questions and met to confirm the final decision. The JBI approach does not recommend using scores to classify a study as low, moderate, or high risk; therefore, we included all studies in the synthesis regardless of the outcome of our appraisal.

Meta-aggregative approach

We followed the methods as outlined by JBI and used SUMARI (JBI, Adelaide, Australia) and Excel to extract findings from each included study of qualitative methods (e.g. interviews and focus groups).[22] We followed the stages in the meta-aggregative approach[23] (Section 2.5) after completing the screening and selecting of evidence phase. We provide a detailed description of our methods in the Supplementary Material document and outline the process in Fig. 1.

Results

Study selection

We screened 376 citations (after removing duplicates) at title and abstract (Level 1) and 61 publications at full text (Level 2). Seven studies (eight publications) were included in the synthesis.[3,24–30] Supplementary Fig. 2 is an overview of the screening

Fig. 1. Summary of the meta-aggregation approach with key terms and definitions.[23]

process outlined in the PRISMA flow diagram. One author of this systematic review (KM) was an author on one of the included studies[3] but was not involved in the screening or appraisal steps of the synthesis process.

Study characteristics

Table 1 provides a summary of the eight included publications. Study locations were Canada,[3] England,[24,26,28–30] Ireland,[27] and the Netherlands.[25] We included descriptive information on participants and settings (when available) using PROGRESS-Plus to guide data extraction. Most studies were located in urban settings. There were 197 participants (59% women), and many older adult participants were living with chronic health conditions; few details were reported on ethnicity (reported by three studies[3,26,28]) or education (reported by two studies[3,27]). One study provided information on income,[3] another study provided information on occupational social class,[28] and two studies reported recruiting participants from a lower resource community setting.[27,28,30] Two studies provided results from providers.[26,27] In one study from the United Kingdom,[26] interviews were conducted with seven general practitioners (GPs; two women and five men, average age 43 years), six link workers (two women and four men, average age 31 years), and three health coaches (one woman and two men, average age 48

Table 1
Description of included studies in the systematic review.

Author *First author, year, location*	Participants *N, gender* *Mean group age* *Additional information*	Intervention *Program description* *1. Referral; 2. Link worker; 3. Providers*	Methods *Qualitative approach*	Funding and conflicts *Funding* *Conflict of interest*
Bhatti, 2021, Canada[3] 11 community health centers in Ontario	*N* = 96, 59 women, 29 men, 8 intersex/transgender/two spirit/other Mean group age = NR Income (n = 75): <$60,000, *n* = 70 Ethnicity (n = 78): White = 63, Black = 5, Asian = 4, Indigenous = 2, Latin American = 3, Middle Eastern = 1 Education (n = 81): No formal education = 2, primary or equivalent = 9, secondary = 49, postsecondary = 21	Referred to LW or directly to activity; support given to attend activity 1. PCP; 2. LW; 3.CHC	Qualitative case study 8 individual interviews, 88 focus groups for remaining participants; conducted at different time points of the study (3, 6, and 12 months)	Health and Wellbeing Grant from the Ontario Ministry of Health None declared
Esmene, 2020, South West England[24]	N = 24, 12 women, 12 men Mean group age = NR People with diabetes	Prescribed walking program 1. GP; 2. SP navigator; 3. voluntary and charity sector organization	Qualitative case study 24 participants in 64 discussions, 7 in-depth interviews, and 1 group interview with 6 participants Conducted over 12 weeks	NR
Heijnders, 2018[25], Nieuwegein, the Netherlands	N = 10, 5 women, 5 men 69 years (range 48–91 years) Referral reason: social issues = 6; psychological issues = 4	Work with coach to choose activity 1. GP/PCP; 2.well-being coach; 3. community well-being organization	Qualitative Study 10 semistructured in-depth interviews	ZonMw Grant from The Netherlands organization for Health Research and Development None declared
Kellezi, 2019, East Midlands, England[26]	N = 19, 12 women, 6 men, 1 prefer not to say 60.4 years (range 29–85 years) Ethnicity: White and/or British = 16 Employment: retired = 10, working = 9 Reason for referral: people living with LTC and loneliness	Referred to self-management or LW, who initiates connections with programs 1. GP; 2. LW; 3. Self-management or third sector groups	Mixed methods study Study 1: semistructured interviews	ImROC (Implementing Recovery Through Organisational Change) None declared
Kiely, 2021, "located in an area of deprivation" p.2, Ireland[27]	N = 6, 4 women and 2 men 66.3 years (baseline data) Baseline data: employed = 18%; Lives Alone: 33%; education = 33% primary education only Number of self-reported health conditions: 2.8 Participants recruited from GP practice in an area of deprivation.	LW support over 6 weeks 1. GP; 2. LW; 3. Community resources	Pilot study Structured interviews	Health Research Board Ireland Collaborative Doctoral Award & Department of Health Slaintecare Integration Fund None declared
Moffatt, 2017 England Inner-city area in West Newcastle upon Tyne England[28]	N = 30, 14 women, 16 men 62 years (range 40–74 years) Unemployed = 12, employed = 4, retired = 14 Representation from across Occupational Social Class except Class 1 (managerial, professions) Ethnicity: Black/minority = 5, White British = 24, White Irish = 1 Most participants had LTC, mental health issues, low confidence, and social isolation	LW support to participate in community or volunteer programs or return to work 1. PCP; 2. LW; 3. Community groups	Qualitative study Semistructured interviews	Cabinet Office of the UK Government Fund None declared
Wildman, 2019, Inner-city area in West Newcastle upon Tyne, England[30]	N = 24, 11 women, 13 men 62 years (range 40–74 years) 23 participants with multiple LTCs and 16 participants experienced mental health issues and social isolation. Participants involved SP service for 12–24 months	Follow-up for Moffatt 2017 study	Qualitative study 30 semistructured interviews	Newcastle University Institute for Ageing None declared

Table 1 (*continued*)

Author	Participants	Intervention	Methods	Funding and conflicts
First author, year, location	*N, gender* *Mean group age* *Additional information*	*Program description* *1. Referral; 2. Link worker; 3. Providers*	*Qualitative approach*	*Funding* *Conflict of interest*
Vogelpoel, 2014 Central Rotherham England[29]	N = 12, 9 women, 3 men ≥80 years (range 61–95 years) All participants self-identified with sensory impairments and socially isolated	Arts-based intervention 1. GP; 2.NR; 3. Arts workshop program	Mixed Methods Study Semistructured interviews	NR Authors worked at organization providing intervention

CHC, community health center; GP, general practitioner; LTC, long-term condition; LW, link worker; NR, not reported; PCP, primary care provider; SP, social prescribing.
Two studies[26,27] included older adult participants and providers, but we provide details of participants only in this table.

years); all providers were identified as White. In the second study from Ireland,[27] interviews were conducted with two GPs and one link worker from a single GP practice.

Overall, studies focused on participants' experiences with elements of social prescribing pathways and potential mental and physical health benefits (n = 6 studies). One study, with two publications,[28,30] interviewed participants at baseline ($N = 30$) and up to 2 years later (N = 24) to provide insights into the program over time. Three studies used a mixed methods approach.[26,27,29] In the pilot study,[27] we only extracted participants' and providers' data on the acceptability/feasibility of social prescribing but not related to the process of conducting a clinical trial (e.g. retention and recruitment rates) as our aims were to understand social prescribing in practice.

Quality assessment

Supplementary Table 2 is a summary of the ratings. Overall studies were given positive scores across most of the 10 questions. In almost all studies, areas where information was unclear were for "locating the researcher culturally or theoretically" and "influence of the researcher on the research, and vice-versa, addressed."

Table 2
Reported themes and subthemes from included studies.

Study	Themes	Subtheme or subtitle
Bhatti 2020 (n = 9)	Context of care provided	**Individualized care** CHC is a **safe space**
	Processes of social prescribing	**Aligned with interests** **Supportive staff**
	Positive outcomes through engaging with social prescriptions	**Social connections** **Sense of community** **Improvement in self-management of health** **Improvement in mental health** **Positive impact on others**
Esmene 2020 (n = 3)	**Sociability** **Place** **Storytelling**	
Heijnder 2017 (n = 6)	**Life events** The **referral and intake process** **Strength and responsibility** **Self-reliance** **Social activation/participation** **Impact of SP** (Welzijn op Recept)	'I am not doing so well, of course' 'This just might be good for me' 'Getting your life back on track and finding new social contacts' 'What you need is a big stick and a stimulus to continue' 'An activity that fits your wishes and abilities and who you are'
Kellezi 2019 (n = 4)	GP perspective LW/HC perspectives Patients' perspective	**Social factors** and the need for a holistic service **Social needs and community** **Relationship with LW/HC** **Building social connections**
Kiely 2021 (n = 1)	**Feasibility and acceptability**	GPs and link worker Participants
Moffatt 2017 (n = 6)	**Impact of LTC and multimorbidity** LW Roles	**Connecting with service users** **LW approach**
	Positive impact of LW SP programme	**Health-related behaviors** **Mental health** **LTC management**
Vogelpoel 2014 (n = 4)	**Increased self-confidence** **Reduced social isolation** **Establishing new friendships, belonging and group cohesion** Artmaking, **self-value**	
Wildman 2019 (n = 5)	The **importance of the service user/LW relationship** Making and maintaining progress in BC and LTC self-management	**Nature of BC and LTC self-management** **Factors associated with making and maintaining progress in BC and LTC self-management**
	Setbacks and barriers to making and maintaining change **Fluctuating levels of engagement** with SP	

BC, behavior change; GP, general practitioner; HC, health coaches; LTC, long-term conditions; LW, link worker; SP, social prescribing.
Bolded items are the terms/wording used in the synthesis (Table 3).

Table 3
Synthesis of the included studies using the meta-aggregation approach.

Personalized experience	Providers and connectors	Behavior change	Environment	Outcomes
Address needs	***GP***	***Goal setting and maintenance***	***Place***	***Health and lifestyle***
Life events: "Participants stated that they were in a deep hole and were highly emotional or stressed. … They no longer wanted to spend so much time sitting around the house; they wanted to feel less depressed and anxious and to have something to occupy themselves with or somebody to talk to." (Heijnders and Meijs, 2018) ***Impact of LTC and multimorbidity:*** "*I want to get back to work. I was used to doing things and it is really hard not being able to do all the things I used to do, yes, and I was depressed at the time as well …*" (Moffatt et al., 2017)	***Feasibility and acceptability:*** "When asked why they had taken part, most patients cited the GP phone call as a critical step, either to encourage or reassure." (Kiely et al., 2021) [a]***Social factors:*** "This GP describes how GPs are overwhelmed and cannot provide support for social determinants of health such as social isolation, leading to patients being overlooked." (Kellezi et al., 2019) "GPs also discussed concerns about referring due to limited knowledge and understanding of the pathway and poor feedback on their referrals." (Kellezi et al., 2019) "challenges that primary care faces at a time of limited resources and increasing demand..." (Kellezi et al., 2019)	***Factors associated with making and maintaining progress in BC and LTC self-management:*** *"You can't [stop making health improvements]. You really, really can't because then it's the slippery, slippery slope back down."* (Wildman et al., 2019) ***Fluctuating levels of engagement:*** "It was quite intense when [previous link worker] was first there. This guy now [current link worker] I've only met him twice, but everything seems sorted out. All I need is somebody to keep going." (Wildman et al., 2019) ***LTC Management*:** "… service users were directed to by Link Workers were highlighted as extremely helpful, particularly the combination of expert and peer-led advice on coping and symptom management strategies." (Moffatt et al., 2017) "[SP] supported realistic, progressive and personalized goal setting. Participants' expectations of progress were therefore achievable and reflected that a long-term approach was necessary to make improvements, helping people to live with their conditions and improve their well-being." (Moffatt et al., 2017) "*I am on the road, but it is slow … work in progress… if it was easy, I would have done it years ago… I have been well impressed [with Ways to Wellness]… because they have a very practical approach and know that it has got to be incremental."* (Moffatt et al., 2017) ***Nature of BC and LTC self- management:*** "Many participants felt confident they could continue with the coping strategies and changes they had made earlier in their engagement with the intervention, or at least were growing in confidence". (Wildman et al., 2019) ***Setbacks and barriers:*** "*Well, I don't get as much support now. My first worker left, I used to see her a lot. I was put onto another one, who I've only seen about two or three times. Now she's left and they've put me onto somebody else… I feel a bit let down because my first one was brilliant."* (Wildman et al., 2019) [a]***Social needs and community:*** "They articulated how SP can help combat loneliness/isolation through patients receiving social support from others undergoing the same experiences." (Kellezi et al., 2019)	***Place:*** "Others focused on the seasonal variations of the botanical garden, but significantly all participants contemplated how change conditioned their sense of place …" (Esmene et al., 2020) "Sense of place was also bound up with safety. On the whole, walking groups provide individuals with a safe environment to pursue physical activity" (Esmene et al., 2020) "… valuable connections can be enhanced through channelling individuals towards venues they have previous links to." (Esmene et al., 2020) ***Safe space:*** "Patients described their centres as a safe space where they felt welcomed and not judged for talking about personal issues or life experiences. They credited staff for creating a space that accepted people from all walks of life." (Bhatti et al., 2021) ***Storytelling:*** "… this process demonstrates how imagined places act as a positive mechanism to establish sociability amongst walking group participants." (Esmene et al., 2020)	***Health-related behaviors:*** "*I really enjoyed it … When I first started off, I was doing five min on the cycling machine and … I had that up to* 20 min *… I was up to* 15 min *on [the cross trainer] and I was pulling weights … "* (Moffatt et al., 2017) ***Impact of SP:*** "… participants mentioned the following ways in which they benefitted from [SP]: gaining new experiences – again, meeting new people, exercising more and feeling good about it, having something to look forward to, regaining control, becoming more self-reliant, regaining perspective and experiencing improved health." (Heijnders and Meijs, 2018) ***Improvement in mental health:*** "Patients attended programmes because it improved their moods, helped them manage anxiety, or allowed them the opportunity to take a moment for themselves." (Bhatti et al., 2021) ***Improvement in self- management of health:*** "Social prescriptions helped patients learn how to manage different aspects of their health, ranging from managing a new disability to living with anxiety and depression." (Bhatti et al., 2021) ***Mental health:*** "*Before [SP], I used to just stay in. But they explained that if you get out and about, it helps you, which has* proven right ... there were times when I wasn't feeling too good, and I thought, 'I can't be *bothered,' but I've pushed myself. By the time I've got out and got back, I've felt 100% better ... my health has changed a lot …"* (Moffatt et al., 2017) ***Self-reliance:*** *"Since I started swimming, I have the feeling that my health is improving, and I feel much better. I've met new friends. I cannot join a walking group, but besides walking there are many other things I am able to do. That is a thing that I have learned lately. I have to keep that feeling."* (Heijnders and Meijs, 2018)

Person-Centered	Link worker	Motivators	Socialization
Aligned with interests**:** " *[I] could draw upon my strengths, my needs, and could be fairly flexible...*" (Bhatti et al., 2021) ***Connecting with service users:*** "Participants appreciated the flexibility and 'open door' nature of [SP], although this could be limited for those who were working." (Moffatt et al., 2017) *"It's the kind of thing if you need them, you phone them,and they'll get straight back to you. They're there, I know they're there … if something happens to me now."* (Moffatt et al., 2017) ***Individualized care:*** *"They always make you feel like–when you go there, especially the medical side, they make you feel like you have their undivided attention and they seem to be– you know, they're concerned for your wellbeing." (Bhatti et al., 2021)* ***Supportive staff:*** *"Yes, another thing that I find for which I'm very grateful and surprised is how understanding people here are. It's about one of the very few places that I feel welcome and respected as I am."* (Bhatti et al., 2021)	***Importance of the service user/LW relationship:*** "Service users described how the link worker had played an important role in introducing them to new, beneficial activities and services they would otherwise have avoided." (Wildman et al., 2019) *"They [link workers] make you feel normal, that it's just not your fault. Whatever you're feeling is fine. Whatever you say is fine."* (Wildman et al., 2019) *"They've helped me, sorted my finances and that out and they helped me with getting in touch with certain groups of people on my finances, which I was worried about at the time …."* (Wildman et al., 2019) ***LW Approach:*** "Participants consistently reported feeling at ease and relaxed with their Link Worker, which enabled them to develop an open and trusting relationship." (Moffatt et al., 2017) ***Referral and intake process:*** The participants mentioned that they appreciated the intake session and the bespoke service it provided. Most people indicated that they needed a 'big stick' and also that going somewhere alone presented a major obstacle." (Heijnders and Meijs, 2018) ***Relationship with LW/HC:*** *"And then when you go and see a counsellor, or you go and see your support worker, you have that full hour, and I wasn't really used to that at the time, that expanse of time where you can just relax and talk."* (Kellezi et al., 2019)	***Increased self-confidence:*** "Self- belief, in art-making skills as well as recognising self-potential to improve skills was a notable development..." (Vogelpoel and Jarrold, 2014) ***Positive impact on others:*** *"…it makes me feel good because I feel like I have helped other people, and that they are getting something from something that I'm doing"* (Bhatti et al., 2021) ***Self-value:*** *"Participant F was unwilling to take part in the art- making activity and notably withdrawn from the group. However, when contacted the following week… Participant F's wife explained that he had not stopped talking about the group that week and could not wait for the next session. She explained that his interest in art had been revived by attending the session …"* (Vogelpoel and Jarrold, 2014) ***Strength and responsibility***: "… participant's own strength and responsibility were frequently mentioned. The term 'own strength' refers to the power to find one's own solutions to problems." (Heijnders and Meijs, 2018) ***Social activation/participation:*** "The increase in social participation and the accompanying increase in social contacts led to a sense of satisfaction about the life they were now leading." (Heijnders and Meijs, 2018)	***Building social connections:*** *"…there are lots of people out there like me and we're like a little tribe. And there's little places we can go and hook up and just kind of like talk about anything you want, or not talk at all. And I just think it saved me."* (Kellezi et al., 2019) "…the participants highlight their disappointment in not feeling well treated or having their needs understood, especially after a lot of effort was required to make the first step ('leave the house'). Thus, rather than fostering connection, group participation seems to add to the issues rather than address them." (Kellezi et al., 2019) ***Establishing new friendships, belonging and group cohesion:*** *"Before I came to the group, I didn't see anyone, and now I meet people here and take the artwork home to do so I have something to occupy me at home too." (Vogelpoel and Jarrold, 2014)* ***Reduced social isolation:*** "the group had become a significant aspect of her social interaction, *"I'd like to come all day because it makes me feel better."* (Vogelpoel and Jarrold, 2014) ***Sense of Community:*** "… patients discussed how [SP] led to developing a sense of community at the centre; for example, it was seen as a place of belonging where people cared for one another." (Bhatti et al., 2021) ***Sociability:*** "However, in this study, an interesting feature materialised: the emergent quality of close friendships through a common narrative of diabetes as a shared health condition." (Esmene et al., 2020) ***Social Connections:*** "They valued connecting with individuals with similar lived experiences (for example, traumatic brain injury, bereavement, and so on) as this helped them feel less alone." (Bhatti et al., 2021)

[a] Quote from provider; BC = behavior change; CHC = community health centres; GP = general practitioner; HC = health coaches; LTC = long-term conditions; LW = link worker; SP = social prescribing.

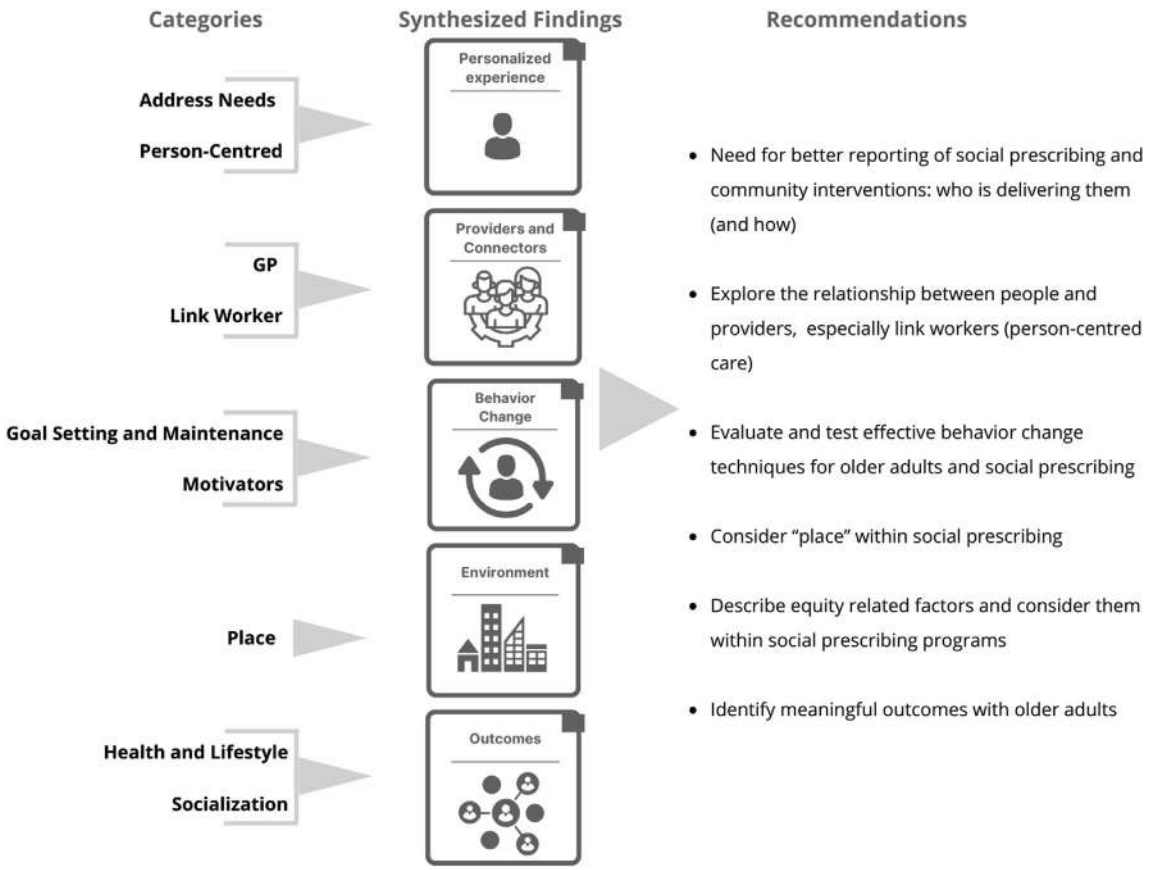

Fig. 2. Overview of results synthesized from extracted data from included studies and study recommendations. The first column includes the nine categories generated from 38 study findings, and the middle column are the five synthesized findings. The last column includes the recommendations generated from this synthesis.

Results of syntheses

After a comprehensive iterative process, we identified 38 findings from publications (with quotes) and created nine categories and five synthesized findings. Specifically, the synthesized findings were created by sorting the nine categories into groups with similar themes related to social prescribing (Tables 2 and 3 and Fig. 2). As mentioned previously, two studies[26,27] included participants and providers within their study design. The synthesized findings discussed below were based predominantly on the perspective of the older participant, but there were two synthesized findings, which included one provider perspective for each synthesized finding (Table 3).

The nine categories included addressing needs and person-cenetred care and contained elements related to the "*why*" and "*how*" for social prescribing. Together, these categories were combined into the synthesized finding Personalized Experience (six findings from three publications[3,25,28]). The findings summarized the impact of living with chronic health conditions and why a person-centered (personalized) approach was seen as positive by participants (e.g. individualized and aligned with a person's interests).

Providers and connectors (seven findings from five publications[25–28,30]) consisted of two categories: GPs and link workers or the providers who interacted within social prescribing programs or services. Within the findings, older adults described feeling reassured by their GPs' phone call to social prescribing programs and were encouraged to attend.[25,27] Older adults also expressed link workers made people feel more comfortable and at ease;[30] and link workers were able to provide more holistic care to older adults, such as by helping them navigate their finances and facilitate socialization.[30]

In the behavior change synthesized findings (11 findings from six publications[3,25,26,28–30]), we combined results related to behavior change and motivation. Studies reported behavior change techniques or strategies,[31] such as goal setting and pursuit,[28] coping plans,[28,30] and social support.[26] Studies also reported on factors that motivated older people to engage or adhere with social prescribing programs, such as having a positive effect on others,[3] and finding "*one's own solutions to problems.*"[25]

There was only one category (Place) within the environment synthesized finding (three findings from two publications[3,24]). For example, the environment older adults were in had the potential of creating a sense of safety, which further encouraged engagement in the activities, such as participation in walking groups.[24] Furthermore, some participants reported being able to create more valuable connections with their group members and the activity itself if the place was familiar.[24] The place participants were in also facilitated storytelling and thus a deepening of the social bonds they were starting to make, as seen in walking groups.[24]

Finally, the largest synthesized findings were outcomes (12 findings from six publications[3,24–26,28,29]) consisting of two categories, health and lifestyle related and socialization, which may have been impacted by social prescribing. Participants reported being involved with social prescribing activities helped them better manage their anxiety and depression while increasing their self-reliance and self-confidence from the skills they were learning.[3,25,28] Studies also reported social prescribing provided opportunities to build new social connections. Friendships resulted in older adults experiencing a sense of belonging and community

within their groups.[3,26,29] Both the improvement in self-management of their health and social connections may have acted as motivators for older adults to continue engaging in the programs and possibly played a role in positive behavior change.

Recommendations generated from this synthesis to consider for future research and practice for social prescribing and older adults are provided in Fig. 2.

Discussion

This is the first meta-aggregation synthesis of older adults' and their providers' experiences and perspectives for social prescribing. Although studies varied in their aims and outcomes, our synthesis aligns well with the pragmatic nature of meta-aggregation—to provide useful information for future research and possibly policy. We generated five main synthesized findings. One cluster was specific to health and psychosocial outcomes, while for the remaining clusters, process and outcome information exemplified two distinct components for social prescribing: the intervention and how it is delivered, enacted, and maintained at the provider and individual level (implementation factors). Beyond the findings contained with the studies, another factor for consideration in the future is the need for better reporting within social prescribing studies. Taken together, this synthesis presents useful information to guide future social prescribing research and practice focused on older adults.

Personalized experience

From an implementation perspective, many important elements should be considered when delivering social prescribing, such as ensuring older adults are involved in the development and delivery of interventions to address their specific needs.[19] Strategies should include designing programs aligned with older adults' interests and focused on a holistic view of the person[3,26] rather than care focused on diagnoses and possible impairments within the traditional medical model. A number of studies reported on the needs of older adults who were impacted by the effects of living with chronic health conditions.[25,26,28] There may be physical and psychosocial barriers to attending community-based programs in general and/or when socially prescribed, especially for older adults who may experience poor health, possibly as a result of living with a chronic health condition,[32] reduced mobility,[29] or lack of transportation.[33] Engaging older adults using a person-centered approach may facilitate uptake and maintenance of positive health behaviors.[34] Although, in general, knowledge gaps remain for the implementation of person-centered care in practice,[34–36] the results from this review highlight relationships with providers play an important role in creating a positive environment within social prescribing.[3,28]

Providers and connectors

Social prescribing programs should consider the providers and leverage their individual strengths and responsibilities working in a collaborative way, as indicated in our second synthesized finding. Primary care providers and specifically GPs play an important role in the referral and intake process. However, social prescribing programs should not aim to remove the goal of addressing unmet social needs from primary care practice,[37] that is, health providers only acting as the referral source. Furthermore, not all GPs were aware of the social prescribing referral process,[26] and organizations should work together with providers to ensure GPs have an adequate understanding of both the program and referral process.[38] This could potentially help bridge gaps in the intake process and facilitate accessible delivery of the program. Social prescribing programs could help alleviate some of GPs' pressure to address older adults' unmet social needs, especially given the challenges of limited resources and increased demands in primary care.[26] However, limited resources for primary care may also be a barrier to engaging in social prescribing.

These findings highlight the importance of relationships between link workers and older adults. Having well-trained link workers and staff in social prescribing programs may support people to feel engaged and welcomed.[39] To support the seamless integration of social prescribing within the overall healthcare system, it is essential to understand the specific role of the link worker and their perspectives and experiences with programs or services. In particular, identifying facilitators and barriers link workers may face when implementing social prescribing is key to delivering and sustaining programs in the community.[40]

Behavior change

Health and lifestyle interventions (and their implementation) rely on changing behavior, possibly at the person or provider level. However, low rates of adherence to social prescribing have been noted,[10] possibly due to physical barriers, such as limited access to transportation[33] or people's possible misunderstanding and/or expectations for social prescribing.[41] Moving forward, a greater emphasis on developing and testing strategies for social prescribing and community program referral uptake and maintenance is a priority.

Environment

A novel finding from the synthesis was the role of the physical environment. The physical place in which programs occurred plays a role in shaping the experiences of older adults for many reasons, such as familiarity and safety. Walkability or accessibility is also important, but not all communities in which social prescribing occurs are physically accessible or "walkable" for all older adults, and especially for people with mobility limitations. Our previous work explored factors related to the built and social environment and older adults' community mobility.[42] We identified areas for consideration related to physical infrastructure such as the presence and design of sidewalks, cross-walks, and related features in the neighborhood. Thus, when considering these social prescribing findings collectively, data align well with the social–ecological model[43] in which people are part of a larger community of people and community structures and policies.

This current synthesis generates hypotheses on place and its potential to encourage or deter social engagement with community programs. However, to address health inequities within communities (e.g. Quintuple Aim[44] and PROGRESS-Plus[45,46]), other equity factors should be reported and carefully considered when implementing programs.[21,44] In particular, less is known about social prescribing in some settings, such as rural and remote geographic locations. However, the social–ecological model[43] is a reminder that factors that influence social determinants of health require structural and/or policy changes, often beyond the scope of social prescribing.

Outcomes

In the last synthesized finding, we identified positive outcomes of social prescribing for older adults. The findings were generally positive and provide clues for moving forward with future research. We found similar findings in our systematic review of quantitative evidence for social prescribing and older adults.[10] Based on the synthesis of seven studies (with only one study overlapping with this review[29]), there was limited evidence social prescribing

improved some psychosocial (well-being) and physical (activity) outcomes for older adults. However, studies were generally small, with a short follow-up period, and (similar to this review) implementation details were missing, and only two-thirds of participants completed the program/returned for the final assessment.[10] As mentioned earlier, future studies need to address longer term maintenance of engagement in health behaviors. Furthermore, future research should include working with older adults and providers to identify their meaningful outcomes in future studies.

Despite the importance of these data as a first step in exploring perceptions and operationalization of social prescribing for older adults, the studies in this review are not without limitations. For example, we recognize there were few studies (from a limited number of geographic locations) available to include in this synthesis of qualitative studies. In addition, there were variations in the aims among studies. Some studies were designed to look at program/research acceptability and feasibility, whereas others were focused on outcomes and/or implementation variables. Despite these limitations of the original studies, there were common elements within publications to set the stage for the next phase of research in this area. For conducting the synthesis, we aimed to follow the meta-aggregation approach as closely as possible. We set up rules and guidelines to try to minimize bias between authors who extracted, confirmed, and synthesized data. In addition, we provided opportunities for co-authors to provide input into data synthesis. Finally, although our aim was to inform policy, because of the limited evidence, we only provide recommendations, which may be more relevant to the research community.

Conclusions

This review of qualitative evidence aimed to summarize the social prescribing experience, outcomes, and processes of older adults and their providers. Overall, the findings summarize facilitators and other implementation factors, which should be carefully considered when designing and planning accessible and equity-driven programs by community organizations, healthcare providers, and policy makers to ensure the experience is coordinated, individualized, and accessible. These data also highlight social prescribing may provide some health benefits for older adults. Finally, the information from this review could be informative for policy makers, especially those who may be in the early stages of developing a social prescribing program.

Author statements

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Ethical approval

This is a systematic review, and an ethics review was not required.

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Competing interests

None declared.

Data collection

Data were synthesized in Canada.

Authors' contributions

S.G. contributed to conceptualization, writing the original draft, reviewing and editing the article, and funding acquisition. P.S. contributed to conceptualization, writing the original article, and reviewing and editing the article. G.S.N. reviewed and edited the article. A.P. contributed to conceptualization and reviewing and editing the article. A.M.C., J.L., C.M., W.C.M., W.B.M., K.M., C.N., G.P., B.P., K.L.R., B.S., and R.J.P. contributed to reviewing and editing the article and funding acquisition. M.C.A. contributed to conceptualization, writing the original draft, reviewing and editing the article, visualization, project administration, and funding acquisition.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.016.

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Public discourse and sentiment during Mpox outbreak: an analysis using natural language processing

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ABSTRACT

Objectives: Mpox has been declared a Public Health Emergency of International Concern by the World Health Organization on July 23, 2022. Since early May 2022, Mpox has been continuously reported in several endemic countries with alarming death rates. This led to several discussions and deliberations on the Mpox virus among the general public through social media and platforms such as health forums. This study proposes natural language processing techniques such as topic modeling to unearth the general public's perspectives and sentiments on growing Mpox cases worldwide.
Study design: This was a detailed qualitative study using natural language processing on the user-generated comments from social media.
Methods: A detailed analysis using topic modeling and sentiment analysis on Reddit comments (n = 289,073) that were posted between June 1 and August 5, 2022, was conducted. While the topic modeling was used to infer major themes related to the health emergency and user concerns, the sentiment analysis was conducted to see how the general public responded to different aspects of the outbreak.
Results: The results revealed several interesting and useful themes, such as *Mpox symptoms, Mpox transmission, international travel, government interventions, and homophobia* from the user-generated contents. The results further confirm that there are many stigmas and fear of the unknown nature of the Mpox virus, which is prevalent in almost all topics and themes unearthed.
Conclusions: Analyzing public discourse and sentiments toward health emergencies and disease outbreaks is highly important. The insights that could be leveraged from the user-generated comments from public forums such as social media may be important for community health intervention programs and infodemiology researchers. The findings from this study effectively analyzed the public perceptions that may enable quantifying the effectiveness of measures imposed by governmental administrations. The themes unearthed may also benefit health policy researchers and decision-makers to make informed and data-driven decisions.

Introduction

The World Health Organization has declared Mpox[c,d] a public health emergency since July 2022.[1] This has initiated several discussions and deliberations on the virus spread, symptoms, and management[2,3] and also on not to declare Mpox as a pandemic.[4] For many countries still fighting against the COVID-19 pandemic, the Mpox emergency turned out to be a double-headed sword.[5,6] In general, people often relate the case of the Mpox epidemic with the COVID-19 pandemic, which has caused serious concerns and stigma, thinking that the governments may go with travel restrictions and other lockdown measures. This has allured them to express their concerns and thoughts on the Mpox health emergency on social media platforms such as Twitter and Reddit.[7,8]

Social media have played a crucial role during the outbreak of Mpox and may continue to do so in the coming days as well.[9] Platforms such as Twitter and Reddit have seen many posts and

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[d] https://www.who.int/news/item/28-11-2022-who-recommends-new-name-for-monkeypox-disease.

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comments discussing the symptoms, treatments, side-effects, and other opinions of individuals concerning the Mpox virus. It is important to analyze these user-generated contents to identify patterns and trends. This would enable the governments and public policy-makers to prioritize their strategies to combat the emergency in an elucidated manner. During the COVID-19 pandemic, these platforms were primary sources of sharing information and used as data sources for many analyses,[10–12] and the same strategies may be used in the case of Mpox as well. There are very limited early studies reported for understanding the general public's attitude toward Mpox or general analysis,[13] but a detailed analysis should be carried out to get a clear picture of the trends and facts.[14]

The first public data set for Mpox analysis was released by Thakur et al.[15] that collected 255,000 Twitter posts related to the Mpox outbreak from May 7, 2022. Jahanbin et al. used Twitter and web news as the source for predicting the Mpox virus.[16] The authors collected the Tweets between May 16–22, 2022, to analyze the Mpox outbreak trends and the country-specific statistics to find relevant information. During the COVID-19 pandemic, Reddit[e] has been used as one of the vital sources of public discourse analysis.[17–19] The present study uses Reddit posts and related comments to respond and add knowledge to our understanding of the Mpox health emergency. With the aim of exploring public discourse and reactions during the early stages of Mpox, we use unsupervised machine learning techniques to examine (1) What latent topics related to the Mpox virus can we identify from Reddit posts and comments? (2) What are the themes of the topics discovered? (3) How do Reddit users emotionally react to the Mpox health emergencies? The qualitative analysis of user-generated comments and discussions may unearth better insights and patterns to aid in better policy management and informed decision-making processes. This study uses unsupervised natural language processing techniques such as topic modeling and sentiment analysis to analyze public discourse on the Mpox virus qualitatively. The specific objectives of this work are (1) to conduct a qualitative public discourse and sentiment analysis on the Mpox emergency using user-generated content and (2) to analyze major themes of discussion among users on different aspects of Mpox, such as *international travel*, *governmental interventions*, and *homophobia*.

Methods

Study design

This study uses an observational design and a purposive sampling approach to select all the comments from Reddit pages related to Mpox (such as https://www.reddit.com/r/Monkeypox/ and https://www.reddit.com/r/Monkeypoxpositive/). We use natural language processing approaches to unearth salient topics and terms related to Mpox, and our data mining process includes data preparation and analysis. The sampling, data collection, and preprocessing were carried out to build the experiment-ready version of the data set. During the analysis phase, we implemented unsupervised machine learning (topic modeling), qualitative analysis, and sentiment analysis by taking individual Reddit comments as the unit of analysis.

Data sources, preparation, and measures

We have collected comments posted by Reddit users, specifically on the pages that discuss Mpox using Reddit's open application programming interface available at https://www.reddit.com/dev/api/. The comments posted between June 1, 2022, and August 5, 2022, are collected for this study using PRAW: The Python Reddit API Wrapper available at https://praw.readthedocs.io/en/stable/. As shown in Fig. 1, we have collected a total of 437,812 comments, of which 51,273 comments that are not written in English are removed. Of the remaining 386,539 comments, 97,466 were found duplicates or irrelevant and removed. The data collection method used in this study is strictly complied with Reddit's terms of service and developer agreement policies. Fig. 2 shows the number of comments on the Reddit platform during the specified period. As this study deals with analyzing user-generated content, there may be a significant amount of noise and irrelevant content as part of the comments collected. We have preprocessed the comments collected data to ensure quality by adopting the following measures.

1. We removed user mentions, Uniform Resource Locator (URL), and other special symbols along with punctuation and numbers as they do not contribute significantly to the message analysis.
2. We removed emojis using the *demoji* library available at https://pypi.org/project/demoji/
3. We removed all non-English letters and other characters, as this study concentrates on the analysis of English comments
4. We removed repeated characters from words if found unnecessary (e.g. “soooo painful” has been changed to “so painful”)

Data analyses

This study uses an unsupervised machine learning algorithm to analyze the patterns from the unstructured comments, as this approach was commonly used in scenarios dealing with limited observations. As the approach is unsupervised, the algorithm may automatically cluster similarities where qualitative analysis may fail when dealing with large unstructured text data. In natural language processing, topic models are a suite of text-understanding algorithms that unearth the latent patterns from large bodies of unstructured text. There are several topic modeling algorithms already reported in the machine learning and natural language processing literature,[20,21] and they differ in how they make assumptions to generate hidden word collections called “topics.” The primary assumption of most of the previous topic modeling algorithms is that a document contains only one topic, but that is not the case with real-world documents. The Latent Dirichlet Allocation (LDA)[22] algorithm introduced later in the literature by David M. Blei could model this assumption and become very popular among natural language processing researchers and enthusiasts. We used the LDA algorithm in this study to infer latent topics from the comments posted by Reddit users, which helped us categorize the text based on the features and patterns. Topic modeling is already proven to be efficient in analyzing large quantities of user-generated unstructured in social science research.[23–25]

Qualitative analysis is required to dive deep into the data to analyze better the trends, patterns, and themes.[26] Analyzing and interpreting topics generated by the topic modeling algorithms required human efforts, and during this qualitative analysis, we performed the same. The topic words are analyzed and contextualized to map them to different themes relevant to the Mpox emergency that enabled the deeper qualitative dives into the comments collected. This human-in-the-loop qualitative analysis help derives in-depth interpretations from identifying public discourse[27] better. Sentiment analysis is a natural language processing approach that attempts to analyze the sentiment and emotions of people expressed in unstructured text.[8,28,29] This technique has been widely used in social science research for analyzing the general public's sentiment toward products, services, and any social phenomenon.[30–32] This study uses the VADER

[e] https://www.reddit.com/.

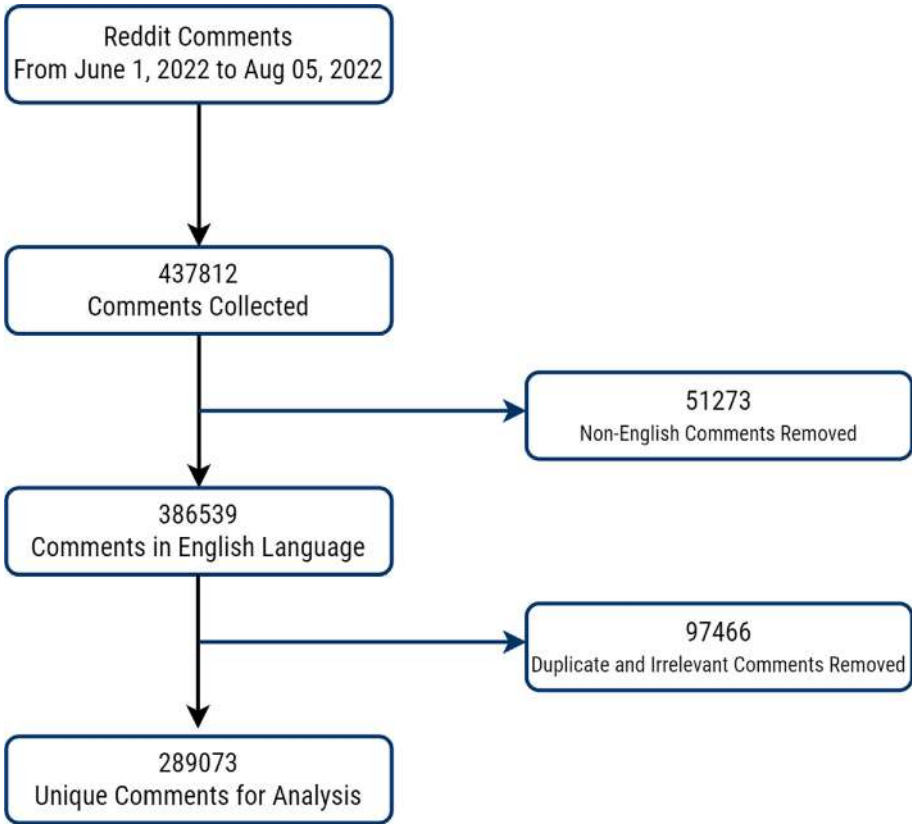

Fig. 1. Dataset preprocessing steps.

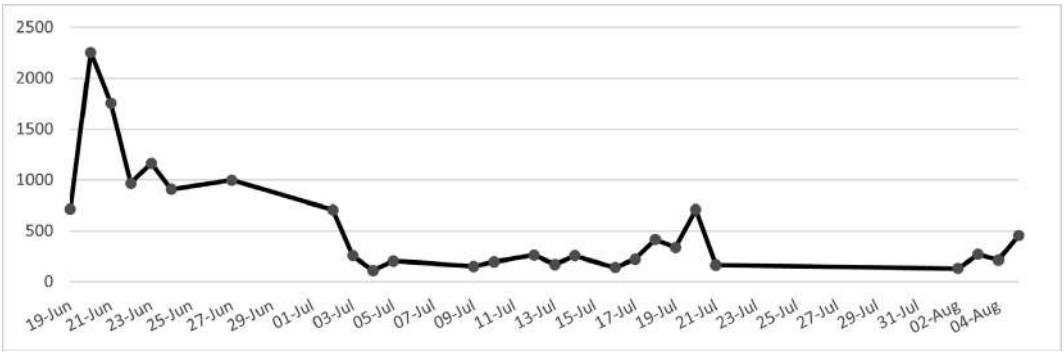

Fig. 2. Number of comments for the specified period.

Sentiment Analysis technique[33] for classifying individual comments into negative, positive, or neutral. The Python library available at https://pypi.org/project/vaderSentiment/ has been used for classifying the sentiments.

Findings

The LDA topic modeling algorithm generated common topics that contain common co-occurring words from the comments collected. This study uses the topic coherence score to compute the number of topics to be generated for the LDA algorithm. For this experiment, we have set the number of topics to be 10 based on the coherence estimation given by *gensim* library[34] available at https://radimrehurek.com/gensim/. For better interpretation and thematic mapping of the topics generated, we have created 10 topic labels, namely, *Mpox Symptoms*, *Mpox Transmission*, *Affected Body Parts*, *International Travel*, *Social Media*, *Safety Measures*, *Government Interventions*, *Mpox Vaccination*, *Anti-government*, and *Homophobia*. We have manually assigned these topic labels to all the 10 topics generated by the LDA model, and the results are presented in Table 1. Table 2 presents a snapshot of some comments along with their sentiment score and label. We have observed that people expressed fear and uncertainty about the Mpox virus across all topics.

From Table 1, it may be noted that Mpox symptoms have been reported using words such as *red*, *pimple*, *infection*, and *blood*, where people describe the Mpox indicators they might have. The Mpox transmissions are expressed using words *sex*, *bisexual*, *partner*, and *safe*, which show the major way of transmission of the infection. The body parts affected by the infection may be inferred

Table 1
Topic words and corresponding topic labels for ten topics.

Topic #	Topic words	Topic label
Topic #0	Monkey, pox, giant, pimple, red, base, small, skin, infection, blood	Mpox Symptoms
Topic #1	Woman, monogamous, sex, male, sexual, guy, kissed, bisexual, partner, safe	Mpox Transmission
Topic #2	Mucous, membrane, pink, moist, face, palm, hand, foot, oral, genitalia, conjunctiva, cornea, macule	Affected Body Parts
Topic #3	International, flight, travel, infected, west, Nigeria, London, landed, hospital, festival, patient	International Travel
Topic #4	Instagram, social, medium, reliable, source, information, public, health, information, medical, professional, distress	Social Media
Topic #5	Mask, indoors, respect, covering, clothing, community, vaccine, crowd, precaution, safe	Safety Measures
Topic #6	Lockdown, government, travel, restrictions, western, acted, public, contamination	Government Interventions
Topic #7	Covidpfizer, shot, Monkeypox, vaccine, reaction, waiting, tetanus, smallpox, transmission, medication	Monkeypox Vaccination
Topic #8	Frustration, pandemic, public, health, pandemic, homophobia, elections, government, idealistic, education	Anti-government
Topic #9	Gay, homophobic, stigma, STI, anonymous, food, shelter, community, sex, transmitted, unfortunate, spread	Homophobia

Table 2
Representative Reddit comments within themes.

Theme	Comment sample
Mpox Symptoms	"……pox means pustules - like big pus-filled pimples. Pustules break open and leak fluid. The fluid can spread the disease. They leave scars called poxmarks, too……." "……symptoms typically present themselves within 1–4 weeks of exposure……" "……I have a question about swollen lymph nodes. I realize this commonly presents in the early stages, but is there a timeframe that we know of when the swelling subsides?……"
Mpox Transmissions	"……spreads through surface transmission (cups etc) as does Meningococcal disease, which is fatal……" "……unless we see significant changes in viral behavior towards more transmission from casual contact or surfaces, it's unlikely……" " ……question: are shoes (meaning, the soles of your shoes) a concern in regards to the spread? As in, if I walk around a public place and virus has been shed, is it likely I could track it in my home/other places via shoes?……"
Affected Body Parts	"……it can enter in through broken skin such as cuts, scrapes, scratches, as well as the mucous membranes that you mentioned……" "……effects your mucous membrane (wherever you are pink and moist)……." "……it actually happened to me right as covid was blowing up, testing wasn't a thing and i still wonder if it was covid rash. hands, palms, arms, chest and back, legs, feet, toes and soles……"
International Travel	"……one person arrives with the virus at the airport, infects 2 people, those 2 people fly back to their countries, those 2 infect 4 more, those 4 fly back to their countries and infect 16 more……" "……that would require someone to willingly travel to Alabama to be Patient Zero……" "……I just read Monkeypox has been pretty common in Africa for a long time. I think we can blame more international travel for all of these pandemics……"
Social Media	"……instagram and other social media aren't reliable sources of information (outside of the pages of actual public health organizations and sometimes medical professionals, although even there your milage may vary)……" "……concerned at the number of women online on Tik Tok who have had this and I suspect the numbers will change rapidly with it now being a reportable disease to the CDC……" "……it stops if you get off the social media tit. Seriously. Search your feelings, you know its true……"
Safety Measures	"……I wore a mask and stayed indoors when I could and got my shots, boom done……" "……it's just chickenpox, no one will notice with my mask anyways……." "……we do not have a vaccine for this we have it for smallpox a it seems given the similarities that one 'works'."
Government Interventions	"……the sense I'm getting isn't that people are afraid of dying but of catching it in general and there being another round of lockdowns (or similar restrictions again)……" "….the good news is that in the real world, our governments have always been truthful and honest and never done any shady shit ever and always looked out for our best interests……" "……the lockdowns were insanely ineffective, funneled money to big pharma and amazon as well as improved the democrats chances……"
Mpox Vaccination	"……we're about to go into pride weekend. We could easily target advice and vaccinations to people most likely to be impacted……" "……pfizer gonna roll out a vaccine for this one too?……" "……you really don't know what you're taking about. One of the required vaccines for kids (and adults get boosted every 10 years) is DTaP, for diphtheria, tetanus, and pertussis……"
Anti-Government	"……big pharma continuing to get massive government contract……" "……because the US government doesn't have any desire to take action on a public health emergency again after COVID……" "……this happened with HIV, governments just ignored the suffering and pushed stigmatisation to protect the people they gave a shit about……"
Homophobia	"……wildfire in the gay community and its going to be seen as homophobic to target the gale (male) community……" "…….it's not just homophobic, it's also a strategy that has never worked in history. People got laid on Tinder even during the COVID lockdowns……" "……this kind of homophobic attitude is precisely how the AIDs crisis got so out of control……"

by the associated topic words, such as *mucous*, *membrane*, *face*, *palm*, and *genitalia*, and the words such as *flight*, *travel*, *festival*, *patient*, and *international* depict the concerns of the international travelers.

The other topic labels such as *Safety measures* and *Social media* that discuss the precautionary measures such as wearing mask and vaccinations and the support and information dissemination through social media platforms such as Instagram, respectively. The *Government interventions* shows the public opinion on implementing lockdown and other travel restrictions. Some indications of frustrations toward the government are evident in the topic label *Anti-government*. Other topic labels such as *Homophobia* and *Mpox vaccinations* are also evident in the public discourse on Mpox-related discussions.

In Table 1, representative comments from Reddit are mapped to the manually created topic labels to classify user reactions. For instance, people pose questions like "can Mpox be transmitted through the shoes if someone walks in a public place," which indicates concerns and doubts about the spread of Mpox infection among the general public. People also question the credibility of

information shared on social media such as Instagram and criticize that governmental interventions such as lockdowns may not work effectively as the money will be funneled to big pharmaceutical companies and amazon.

We could also find that there are significant discussions that can be classified as anti-government, where people pointed out that larger pharmaceutical manufacturers will get massive government contracts and the governments are least bothered to take action on this public health emergency. The stigma and fear associated with the Lesbian, Gay, Bisexual, Transgender, and Queer communities are also evident in the findings, and they fear that homophobic attitudes toward gay males will rise during the Mpox outbreak.

The comment, sentiment score, and associated sentiment label for some of the comments (representative) are shown in Table 3. We found that out of all the comments considered for this experiment, nearly 35% were positive, 34% were negative, and 31% were neutral.

Discussion

This study reports Reddit users' discourse and sentiments on the ongoing Mpox health emergency from June 1, 2022, to August 5, 2022. The findings from this study enable an understanding of the general public's attitude and sentiment, which will be of high importance to the government and other public policy-makers to frame health policies in a better manner. This study also derives insights from the user-generated content that could facilitate implementing better surveillance to tackle the situation. The latent themes and patterns unearthed from the vast public comments may be important for planning and guiding targeted health intervention programs. Governments can also verify the effectiveness of imposed measures and amend their strategies and policies using these data-driven decision-making interventions.

The major insights from this study show that most discussions on Mpox are centered around the gay community. Many people have commented that Mpox will be spread through gay sex, and this has caused stigma among such people. Also, several posts and comments were found to be homophobic, spreading incorrect information on the contamination and spread of this virus. Although it is true that the Mpox virus spreads through direct physical contact with an infected person, it need not be necessarily through sex. The virus may also be spread through respiratory droplets while sneezing or coughing. While body contact is a major route in modes of transmission, there are pieces of evidence on very little transmission in family groups, even when in close quarters, and the very few cases that have occurred in that fashion were reported when children were nursed by parents with open lesions.[35,36] Several countries had the transmission in this way, but now the isolation procedures also consider these factors. While respiratory transmission of Mpox is theoretically possible, this does not seem to be significant in endemic countries, where the Reproduction number is estimated to be around 0.3—not what one would expect from the spread as a respiratory infection.

In the present Mpox outbreak situation, the risk of sexual transmission is overwhelming but not exclusively sexual, as reported by several studies. Furthermore, the risk of transmission is greatly increased by the number of partners, the promiscuity in some groups, even of established partners, and the reality that some forms of sex are inherently traumatic and increase the risk of transmission.[37,38] This study raises the question of homophobia and related stigma that has been a concern from the very beginning of the outbreak. One of the significant challenges with the Mpox outbreak and other outbreaks is getting messages out on the disease in the public domain.

There are several risks associated with stimulating stigma and hate in particular groups, in the present study context, the LGBTQ communities. One such risk is that these hate groups feel shame, hopelessness, and isolation, which may make them reluctant to ask for help or to get treatment. Other risks may include discrimination by family and friends that may lead to bullying, physical violence, or harassment. A larger number of topics generated by our methodology show the indicators of the homophobic attitude of individuals. Still, the authors strongly recommend a more detailed analysis to affirm the same.

Although gay communities and topics around them are the subjects of the vast bulk of talks on Mpox, it does not mean that the analysis highlights only such themes. There are several other themes such as *Symptoms*, *Affected Body Parts*, *International Travel*, and *Social Media*, to name a few, that are of significant importance to the Mpox discussions. Remarkable diligence needs to be exercised considering the themes obtained while the public policies related to the Mpox epidemic avoid any potential biases toward the themes unearthed. Other highly evident themes were found to be *international travel*, *safety measures*, *government interventions*, *vaccination*, *social media*, *virus transmission*, and *symptoms*. Many people raised their concerns about travel restrictions, and they doubt the governments may impose strict bans on international travel. They relate the case to COVID-19 restrictions and fear countries may close their borders to avoid spreading. They are also unaware of the safety precautions that need to be taken while traveling, and many of them expressed that it is better to abstain from traveling for a few weeks to check for the virus spread.

On careful analysis, we could also find some anti-governmental topics where people say governments will pump huge amounts of money into the vaccine manufacturers like what they did for the COVID-19 pandemic. Some people pointed out that the public health policy of many countries needs to be revised to cope with similar health emergencies in the future. Another major theme was *vaccination*, where discussions were on using vaccines for smallpox and tetanus for treating Mpox infections.

Our findings suggest many ways health policy-makers can make data-driven, informed decisions on prioritizing the governmental

Table 3
A snapshot of the comments with sentiment score and labels.

Comment	Sentiment score	Sentiment label
Those asking, below thread is peoples experiences of timeframes from exposure to symptoms.	0.0000	neutral
A lot of the MPX photos have the dimple characteristic. If you google 'umbilication' you can see images	0.0000	neutral
Thank you for responding! He's NOT having skin to skin contact with students haha. However, he is in a packed room with 45 students playing instruments for 8 h a day	0.7247	positive
Mine was swollen for 3 weeks. At the beginning of week 4, it started to calm down dramatically each day	0.3182	positive
I got exposed on July 5, vaccinated on July 6, and symptoms appeared on July 10	−0.5423	negative
I got a series of judgmental texts from a friend. Now that friend is irrationally angry due to his own fear and not talking to me.	−0.8402	negative

measures to help prevent the Mpox outbreak. For example, the user-generated responses collected and analyzed from social media and news aggregators identify outbreak clusters and hate groups, aiding in implementing health surveillance measures. Another area would be to discover public sentiment toward the measures taken by governments and public health organizations so that they can change their strategies and prioritize the action items. It is also worth noting that there may be many stigmas related to disease outbreaks, which often target some underrepresented groups or sectors in society.

Limitations

There are several limitations to this study. We have used limited Reddit pages for collecting public comments, and as this is an evolving discussion, many comments might have happened while preparing this manuscript. The second limitation is that we cannot consider Reddit users representative of the general public, as only online users may share their views on such a platform. However, there are many studies already reported in the literature on using Reddit as a platform for public discourse and emotion analysis.[39] Furthermore, our analysis shows that the hate groups shout the loudest and most frequently during such disease outbreaks or pandemics, which may bias the output or findings of this study. The other limitation of this study is that we have only analyzed the comments written in English. Many representative comments might have missed out on other languages, such as Chinese, Arabic, and German. Several future research is recommended to address the challenges associated with limited data sampling and multilingual comment analysis.

Author statements

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Ethical approval

Institutional review board approval and informed consent were not required because all data were obtained from public domain databases and were deidentified.

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Competing interests

There is no conflict of interest

Author contributions

V.S. and S.S. contributed to the concept and design. All authors contributed to the acquisition, analysis, or interpretation of the data; and critical revision of the article for important intellectual content. V.S. drafted the article, and S.S. contributed to the statistical analysis. V.S. contributed to administrative, technical, or material support and supervision.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.02.018.

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Short Communication

Rapid rise in COVID-19 among young people in England – learning for the future

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ABSTRACT

Objectives: We determined the age and sociodemographic distribution of COVID-19 cases between January and September 2020 to identify the group with the highest incidence rates at the beginning of the second wave in England.
Study design: We undertook a retrospective cohort study design.
Methods: SARS-CoV-2 cases in England were linked with area-level socio-economic status indicators using quintiles of the Index of Multiple Deprivation (IMD). Age-specific incidence rates were stratified by IMD quintile to further assess rates by area-level socio-economic status.
Results: Between July and September 2020, SARS-CoV-2 incidence rates were highest amongst those aged 18–21 years, reaching rates of 213.9 (18–19 years) and 143.2 (20–21 years) per 100,000 population by week ending 21 September 2022. Stratification of incidence rates by IMD quintile evidenced that despite high rates observed in the most deprived areas of England amongst the very young and older age groups, the highest rates were observed in the most affluent areas of England amongst the 18- to 21-year-olds.
Conclusions: The reversal of sociodemographic trend in COVID-19 cases in England for those aged 18–21 years at the end of the summer of 2020 and beginning of the second wave showed a novel pattern of COVID-19 risk. For other age groups, the rates remained highest for those from more deprived areas, which highlighted persisting inequalities. Combined, this demonstrates the need to reinforce awareness of COVID-19 risk for young people, particularly given the late inclusion of the 16–17 years age group for vaccination administration, as well as continued efforts to reduce the impact of COVID-19 on vulnerable populations.

Introduction

Following the peak in the first COVID-19 wave in late April 2020 in England, incidence steadily declined after the introduction of a suite of non-pharmaceutical interventions (NPIs) by the UK Government. Throughout the months of March to May, the highest incidence rates of COVID-19 were seen in those aged ≥80 years; there were also disproportionately higher rates among men, people of Black, Asian and Minority Ethnicities and people living in the most deprived areas of England.[1]

Incidence rates declined until late June, after which an accelerated rise was noted in August, accompanied by a marked shift in the age distribution of cases. Here, we describe the epidemiological patterns in COVID-19 rates by age group and area-level deprivation between July and September 2020.

Methods

Data sources

COVID-19 is a notifiable disease in England, and positive tests are reported from public health, National Health Service (NHS) and

Abbreviations: NPIs, Non-pharmaceutical interventions; IMD, Index of Multiple Deprivation; ONS, Office for National Statistics'.

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private laboratories performing SARS-CoV-2 testing. These data are collected using the Second Generational Surveillance System, a routine national laboratory-based surveillance system for notifiable diseases.[2] The address of each case of COVID-19 was assigned using their NHS Digital Patient Demographic Service record. Area-level socio-economic status was defined using quintiles of the Index of Multiple Deprivation (IMD),[3] a measure of relative deprivation; these data were linked to the residential lower super area (small-area geographical unit with an average population of 1614)[4] of each patient. Cases with specimen dates between 27 January 2020 and 27 September 2020, inclusive, comprised the final data set.

Study design

A retrospective cohort study design was used to determine age-stratified COVID-19 rates over the study period between January to September 2020. After identifying the peak age groups, we further stratified these into 2-year age groups to examine incidence rates and test positivity, particularly for the second wave, which began from week of 29 June 2020. We also examined trends by IMD quintiles and region of residence.

Results

Between July and September 2020, COVID-19 rates increased across all age groups, but to the largest extent in 20- to 29-year-olds; among whom the weekly rate increased 10-fold from 9.3 to 95.5/100,000 population (Supplementary Fig. 1). There was also a surge in incidence among those aged 10–19 years with the second highest rate (75.9/100,000) in the week of 21 September.

Among young people, the highest rates were in those aged 18–19 years (213.9/100,000 population) and 20–21 years (143.2/100,000 population) in the week of 21 September (Supplementary Fig. 2A). Although testing rates also increased,[1] test positivity was highest in 18–21 years (Supplementary Fig. 2B).

From mid-August 2020 to the end of the study period, the highest rates in 18- to 19-year-olds nationally were reported in those from the least deprived quintile; among 20- to 21-year-olds, the rates in those from the least deprived quintile increased to the largest extent and, as of September 2020, exceeded but were similar to those from the most deprived quintile (Fig. 1). The inverse relationship between deprivation and cumulative rates among 18- to 21-year-olds observed in all regions of England except Yorkshire and the Humber (Supplementary Fig. 3). The relative shift in rates by IMD quintile was not observed among people of other age groups, where the highest rates have consistently been among those from the most deprived quintile (Fig. 1). While a marked deprivation gradient was observed in other age groups, this was not seen in the 18–21 years group (Fig. 1).

Discussion

In the summer of 2020, COVID-19 cases increased sharply in England, with the highest incidence rates among 18- to 21-year-olds at the beginning of the autumn. During this period, although the overall COVID-19 rates (in people of all ages) were highest among people living in the most deprived areas of England, the highest age-specific rates for 18- to 21-year-olds were among those living in the least deprived areas. However, there did not appear to be a marked difference between deprivation quintiles for this age group. In comparison, there was a clear gradient for other age groups, with the highest rates observed in the most deprived quintile and the lowest rates in the least deprived quintile.[1]

This analysis included comprehensive, individual-level data from the national COVID-19 surveillance system linked to a robust measure of socio-economic status; it therefore included all cases in

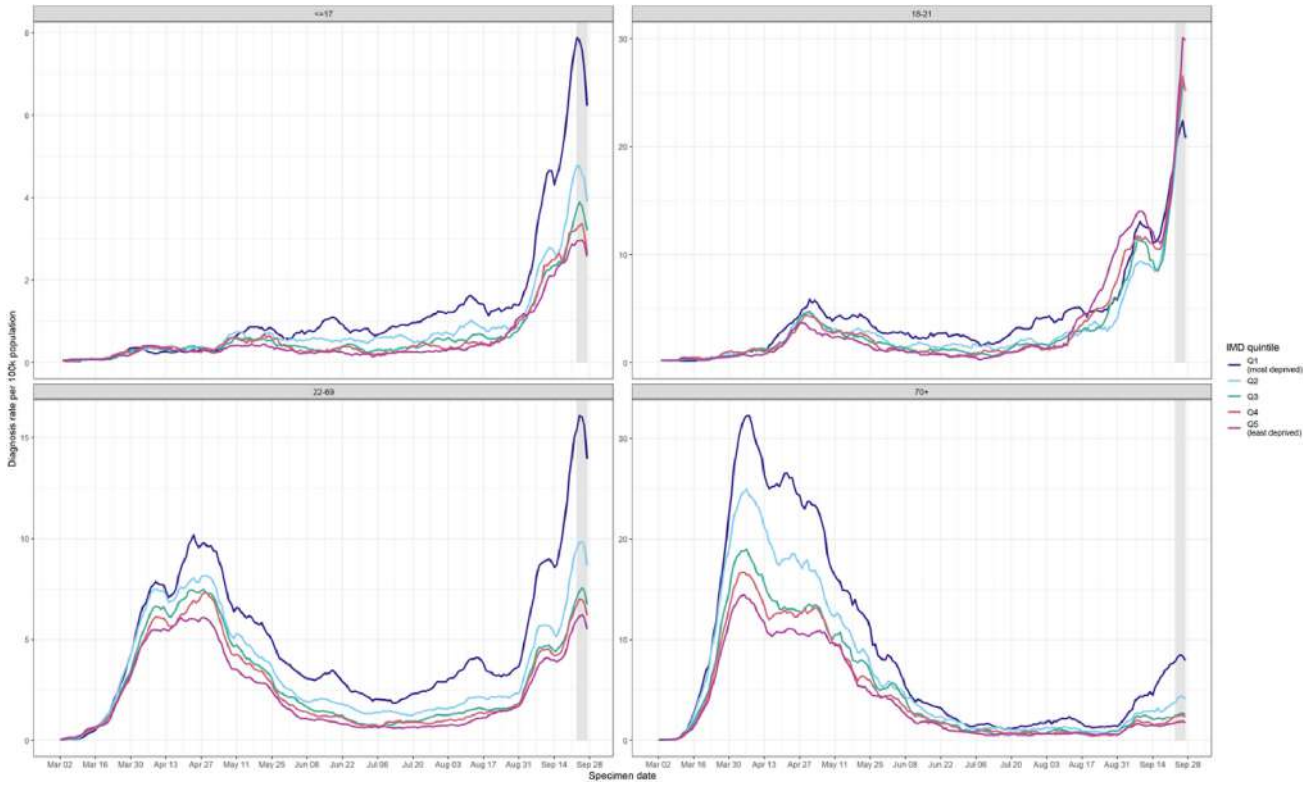

Fig. 1. Rolling 7-day average incidence rates of COVID-19 by Index of Multiple Deprivation quintile and age group, 2 March to 29 September 2020, England.

England and is not subject to the selection bias inherent to survey sampling. The limitations of this study include lack of information on the reasons for COVID-19 testing, including travel history or whether testing occurred because of contact tracing. In addition, due to the absence of population data by ethnicity, age group and IMD quintile, we could not determine rates combining these factors, which would have provided further details on potential inequalities in COVID-19 rates. Although IMD is widely used in England for research, it is a measure of area-level, rather than individual-level, socio-economic status and is therefore subject to the ecologic fallacy. Finally, 18- to 21-year-olds can be a mobile population, and their case details may be attributed to previous residential geography if recent relocations are not yet reflected in their NHS records. However, there is evidence that family socio-economic status can have an impact on longer-term outcomes and might be a reliable indicator of deprivation level, resources and accessibility.[5]

Surveillance data until mid-May 2020 highlighted older people and people living in the most deprived areas of England as higher risk groups, which likely reflected the prioritisation of testing at that time.[3] There is evidence that COVID-19 testing rates in young people disproportionately underestimated incidence in March and April, as seroprevalence reported from the REACT-2 study in late June was highest among people aged 18–24 years (6.9%), most of whom were not tested when they were experiencing symptoms.[6]

The increased detection of COVID-19 among younger people, mainly those aged 20–29 years, was also reported in other European countries, such as Austria, Croatia, the Netherlands and Norway, at the end of the summer 2020.[7] In England, the risk of infection may have changed disproportionately between different age groups and socio-economic backgrounds due to differential changes in behaviour during the easing of NPIs, including activities such as more frequent or larger social gatherings, or overseas travel in the summer holiday season.[8] Our results substantiate findings from a smaller number of cases detected through the Office for National Statistics' COVID-19 Infection Survey, which highlighted increased positivity among those aged 17–24 years and for those aged <35 years from less deprived areas.[9]

Young people reported higher anxiety, depression and loneliness during and after periods of lockdown.[5] Desire for access to supportive social circles and a feeling of normalcy may contribute to less strict adherence to recommended precautions, both throughout the summer of 2020 and potentially in response to future NPIs.[10] Further monitoring of the underlying risk factors for infection in young people, as well as severe or long-lasting outcomes such as long COVID, will become of increasing importance as we adapt to this next phase of mitigating the transmission of COVID-19.

Furthermore, given sustained higher rates overall in people living in the most deprived areas, ongoing, proactive monitoring of the relationships between deprivation and COVID-19 infection should be prioritised to ensure public health measures and policies are delivered equitably.

This study has highlighted the importance of monitoring the effect of changes in NPIs on the relationship between age-specific groups and deprivation to inform public health action during the continued COVID-19 pandemic as well as in future pandemics and outbreaks of respiratory viruses.

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Ethical approval

In its role providing infectious disease surveillance, Public Health England has permission to handle data obtained by the Respiratory Datamart and the Second Generation Surveillance System under Regulation 3 of the Health Service (Control of Patient Information) Regulations 2002.

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Competing interests

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.01.001.

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Review Paper

Relationship between formaldehyde exposure, respiratory irritant effects and cancers: a review of reviews

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ABSTRACT

Objectives: Formaldehyde is an organic compound used in the production of resins, paper, wood plywood, solvents and cleaning products. Formaldehyde is also present when tobacco is smoked. Formaldehyde has been defined as an irritant and is classified as a human carcinogen by the International Agency for Research on Cancer. The purpose of this study was to demonstrate the following two distinct correlations: (1) the association between formaldehyde exposure and development of irritant diseases affecting the respiratory tract, mainly asthma; and (2) the association between formaldehyde exposure and development of neoplastic diseases.

Study design: This was an umbrella review.

Methods: A search was conducted in the three main electronic databases of scientific literature: PubMed, Scopus and Web of Science. The search included systematic reviews and meta-analyses published in the previous 10 years. Initially, titles and abstracts of retrieved articles were evaluated, then full-text assessments of selected articles took place. Data extraction and quality assessment were performed according to Assessing the Methodological Quality of Systematic Reviews (AMSTAR) score.

Results: A total of 630 articles were initially collected. Nine articles concerning the association between formaldehyde exposure and asthma were included in the present review, and the majority of these reported good association. In addition, 27 articles investigating the association between formaldehyde exposure and neoplastic diseases were included in the review. These studies showed that nasopharyngeal cancer and leukaemia were the most represented neoplastic diseases; however, only a weak association was reported between formaldehyde exposure and cancer.

Conclusions: Although the studies included in this review did not show a strong association between exposure to formaldehyde and irritant or neoplastic diseases, the World Health Organisation recommends that levels of formaldehyde do not exceed the threshold value of 0.1 mg/m^3 (0.08 ppm) for a period of 30 min. It is recommended that preventive measures, such as ventilation in workplaces with high exposure to formaldehyde and environmental monitoring of formaldehyde concentrations, are implemented.

Introduction

Formaldehyde is an organic compound and is the simplest form of aldehyde. At room temperature, it is a colourless gas with a pungent odour. It is one of the most common indoor pollutants and is the main precursor of many other chemical compounds, especially polymers. Formaldehyde is used in the production of formaldehyde resins, particle board, paper, plywood and urea-formaldehyde foam.[1] The main internal sources of formaldehyde are pressed wood products, insulation materials, paints, varnishes, household cleaning products and cigarettes.[2] Formaldehyde is also present as an antimicrobial agent in many cosmetic products.[3]

Since the early 1980s, the National Institute for Occupational Safety and Health has recommended that formaldehyde should be considered a potential occupational carcinogen and that appropriate measures should be taken to reduce workers' exposure.[4] The toxicology and epidemiology of formaldehyde were discussed at the second International Formaldehyde Science Conference in

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Madrid, Spain, 19–20 April 2012. It was noted that a substantial amount of new scientific data has appeared since the first conference in 2007.[5]

According to the Scientific Committee on Occupational Exposure Limits, formaldehyde is considered a 'genotoxic carcinogen, for which a practical threshold is supported' and an occupational exposure limit of 0.2 ppm has been recommended.[6] However, in accordance with recent epidemiological results, the World Health Organisation (WHO) recommends a formaldehyde threshold value of 0.08 ppm, which is preventative for carcinogenic effects.[7]

Absorption, distribution, metabolism and elimination

Because of the high water solubility and reactivity of formaldehyde, when dispersed in the air, it is primarily absorbed (90%) in the upper airways.[8] In tissues, formaldehyde reacts with water and forms methylene glycol (methanediol), which represents over 99.9% of the total formaldehyde in the aqueous phase.[9] Furthermore, formaldehyde reacts with DNA, RNA and proteins forming covalent bonds. Formaldehyde is also an endogenous metabolite, and its concentration in the blood is approximately 2–3 mg/L. The half-life of formaldehyde in the blood is 1–1.5 min.[8,10] It is interesting to note that endogenous formaldehyde is produced by numerous biochemical pathways that are fundamental to life, it can cross-link both DNA and proteins, and it can be carcinogenic according to Dingler et al.[11] and Pontel et al.[12] Moreover, Umansky et al. identified formaldehyde as an endogenous molecule that can cause oxidative stress and cytotoxicity.[13]

An important scientific advancement has been the ability to differentiate between exogenous DNA-damaging and endogenous (normal) forms of formaldehyde. Following inhalation of isotope-labelled formaldehyde (13CD2O), DNA-13CD2-DNA cross-links were noted in the nasal tissue. In contrast, endogenous formaldehyde was detected in all tissues.[14]

In addition, substantial variation in individual responses to formaldehyde in humans has been reported. Tan et al. demonstrated that in cells bearing BRCA2 heterozygous mutations, formaldehyde was capable of stalling and destabilising DNA replication forks, resulting in structural chromosomal aberrations.[15]

Related diseases

The effects of formaldehyde can be divided according to the concentration of exposure. At the lowest concentrations, there is the perception of smell, followed by sensory irritation of the eyes, nose and throat, the upper respiratory tract, up to asthmatic symptoms, such as dyspnoea and wheezing.[16] On the other hand, in 2000, the WHO air quality guidelines for Europe underlined that there was epidemiological evidence for associations between relatively high occupational exposure to formaldehyde and both nasopharyngeal and sinonasal cancers.[7] Consequently, it is important to determine the concentration of formaldehyde that is associated with the onset of sensory irritation symptoms, rather than the simple detection of smell.

It is important to emphasise that sensory irritation and olfactory perception are two different and distinct phenomena: smell is the sensation carried by the olfactory nerve, whereas sensory irritation involves the stimulation of the trigeminal nerve. The latter response of the organism is however considered a physiological and non-toxic event, as it does not occur in conjunction with tissue damage or cellular lesions.[17–20] Formaldehyde-induced cytotoxicity does not occur at concentrations above those necessary to activate the sensory irritation system (i.e. $\geq$2 ppm).[21] A guidance document[22] notes that the odour threshold for formaldehyde is 0.8 ppm but also states that people with sensitive noses can detect formaldehyde at levels as low as 0.1 ppm. Another study by Noisel et al.[23] reported an odour detection level of 0.75 ppm, with a minimum irritant level of 1.0 ppm, whereas the US Environmental Protection Agency (EPA)[24] reported an odour detection level of 0.5 ppm (consistent with the Agency for Toxic Substances and Disease Registry), with a minimum irritation level of 1.5 ppm.

For formaldehyde-induced sensory irritation, there are essentially no significant differences between short- and long-term exposure.[25–27] The Organization for Economic Co-operation and Development Screening Information Data Set[28] reported, 'Studies in the literature have reported a variety of responses induced by exposure to gaseous formaldehyde, which generally begins in 0.3–0.5 ppm range for eye irritation. However, the severity of the response at these levels is generally mild and only a small portion of the population can respond.'

The purpose of this study was to demonstrate the following two distinct correlations: (1) the association between formaldehyde exposure and development of irritant diseases affecting the respiratory tract, mainly asthma; and (2) the association between formaldehyde exposure and development of neoplastic diseases.

Methods

Study design

This study was an umbrella review. A detailed protocol for the review has been registered with the International Prospective Register of Systematic Reviews (PROSPERO CRD42021232563).[29] The Preferred Reporting Items for Systematic reviews and Meta-Analyses statement and the guidelines developed by Aromataris et al. were followed to perform an umbrella review.[30]

Search strategy

The identification of relevant studies for this review was obtained by searching PubMed, Scopus and Web of Science electronic databases of scientific literature. The search strings used were as follows:

'(Formaldehyde) AND (Cancer OR tumor OR neoplasm OR malign)'; and '(Formaldehyde) AND (asthma OR allergy OR reactive airway disease)'. The search was performed without language restrictions for articles published in the previous 10 years.

Study selection

Identified articles were uploaded on the JabRef 5.2 software, and duplicates were removed. The selection process was divided into two phases. In the first phase, titles and abstracts of the articles were evaluated; in the second phase, articles selected after the first phase assessment underwent full-text evaluation to deem whether they met the inclusion criteria.

Inclusion criteria

Selected studies consisted of systematic reviews and meta-analyses. Primary studies, narrative reviews and all studies that did not have a systematic review approach were excluded. Studies published within the last 10 years were selected.

The inclusion criteria are described according to the Population, Intervention, Comparison and Outcomes (PICOS) approach, as follows.

- Population: Human population exposed to formaldehyde;
- Phenomenon of interest: (1) Association between formaldehyde exposure and reactive airway diseases; (2) Association between formaldehyde exposure and Cancer;
- Comparators: Nobody;
- Results: All;
- Time window: Last 10 years;
- Type of study: Systematic reviews and meta-analyses.

Data extraction and quality assessment

Data extracted from the articles included year of publication, type of study, characteristics of the population under study and effects of exposure to formaldehyde, such as cancer and respiratory diseases. A quality assessment was performed using Assessing the Methodological Quality of Systematic Reviews (AMSTAR) 2 for systematic reviews and meta-analyses. The overall final quality of each systematic review/meta-analysis was rated as high, low or critically low.

Results

Initially, 630 articles were retrieved from the literature search of the three electronic databases (PubMed, Scopus and Web of Science).

Formaldehyde exposure and asthma

In total, 153 articles investigated the association between formaldehyde exposure and asthma. After duplicate removal, 95 articles remained. In the first phase, titles and abstracts of the articles were evaluated, which led to the removal of a further 73 articles. The remaining 22 articles underwent a second phase evaluation, where careful reading of the full text took place. Finally, nine articles were included in the review (see Fig. 1).

Characteristics of the asthma studies

The characteristics of the selected systematic reviews and meta-analyses investigating the association between formaldehyde exposure and asthma are shown in Table 1.

Children were the primary population group investigated in the selected studies, as the impact of formaldehyde exposure on asthma appears to be greater in children. The differences in outcomes of formaldehyde exposure on asthma between adults and children can be explained as follows: first, children spend more time indoors than adults, leading to a greater indoor formaldehyde exposure, causing a more noticeable asthmatic effect[31]; second, children are generally more susceptible to air pollution than adults because of a faster respiratory rate and a respiratory volume that is 50% higher than adults[32]; and third, due to the physiologically immature immune system, children may be more susceptible to the negative effects of formaldehyde.

According to Yu et al.,[33] children exposed to low formaldehyde concentrations ($\leq$22.5 $\mu g/m^3$) had a significantly increased risk of asthma, and each 10 $\mu g/m^3$ increase in exposure to formaldehyde induced a 10% increase in the risk of asthma in children (odds ratio [OR] 1.10; 95% confidence interval [CI] 1.00–1.21). Formaldehyde exposure may also be associated with an increased risk of asthma among adults if exposed at high doses (formaldehyde > 22.5 $\mu g/m^3$; OR 1.81; 95% CI 1.18–2.78).

According to the article by Yao et al.,[34] the weighted mean difference in formaldehyde concentration is 0.021 (95% CI 0.009–0.033); thus, the mean formaldehyde concentration in the group of people with asthma is higher than the mean formaldehyde concentration in the control group in the environment. These results confirm the hypothesis that exposure to formaldehyde is related to the onset of asthma.

Vardoulakis et al.[35] underline that the concentration of indoor formaldehyde varies in a range of 7.5–134 g/m^3, which includes values of formaldehyde that could induce irritant diseases such as asthma. Nielsen et al.[8] collected the results of many studies that established an association, albeit weak, between exposure to formaldehyde and asthma and reported an OR of 1.31 (95% CI 1.10–1.57).

The study by McGwin et al.[36] differs from the other selected studies, as it provides a specific analysis of data describing the correlation between formaldehyde exposure and asthma. McGwin et al. calculated the OR in random models and in fixed effects models; the first OR is 1.17 (95% CI 1.01–1.369), and the second OR is 1.03 (95% CI 1.02–1.04).

Finally, in the study carried out by Golden,[9] the association between asthma and formaldehyde exposure is represented by an OR of 1.4 (95% CI 0.98–2.0).

Quality assessment of the included asthma studies

The methodological quality of the included studies that analysed the association between formaldehyde exposure and asthma is shown in Table S1 in the supplementary material. The methodological quality assessment according to AMSTAR highlights that 45% of the articles had a high total score, thus reaching a good methodological quality. However, the remaining 55% had weak methodological quality, and 22% of these were defined as critically low.

Formaldehyde exposure and cancer

The database search identified 477 articles that analysed the association between formaldehyde exposure and cancer. After duplicate removal, 213 articles remained. In the first phase, titles and abstracts of the articles were evaluated, which led to the removal of a further 152 articles. The remaining 61 articles underwent a second phase evaluation, where careful reading of the full text took place. Finally, 27 articles were included in the review (see Fig. 2).

Characteristics of the included cancer studies

The articles included in this review analysed the association between formaldehyde exposure and neoplastic diseases, reporting the evidence and studying the data that either confirm or reject this hypothesis. The characteristics of the included systematic reviews and meta-analyses are shown in Table 2.

Formaldehyde and nasopharyngeal cancer

The study by Nielsen et al.[8] explored the association between formaldehyde exposure and nasopharyngeal cancer and detected a higher incidence of neoplasia among workers exposed to a formaldehyde concentration above four ppm. These results are in line with the WHO guidelines that indicate the average level of exposure to formaldehyde must be less than one ppm.

Another study by Nielsen et al.[37] reported epidemiological studies that analysed the association between formaldehyde exposure and nasopharyngeal cancer, indicating that the WHO guidelines (<0.1 mg/m^3) are highly precautionary due to a non-linear exposure–response and the epidemiological effects

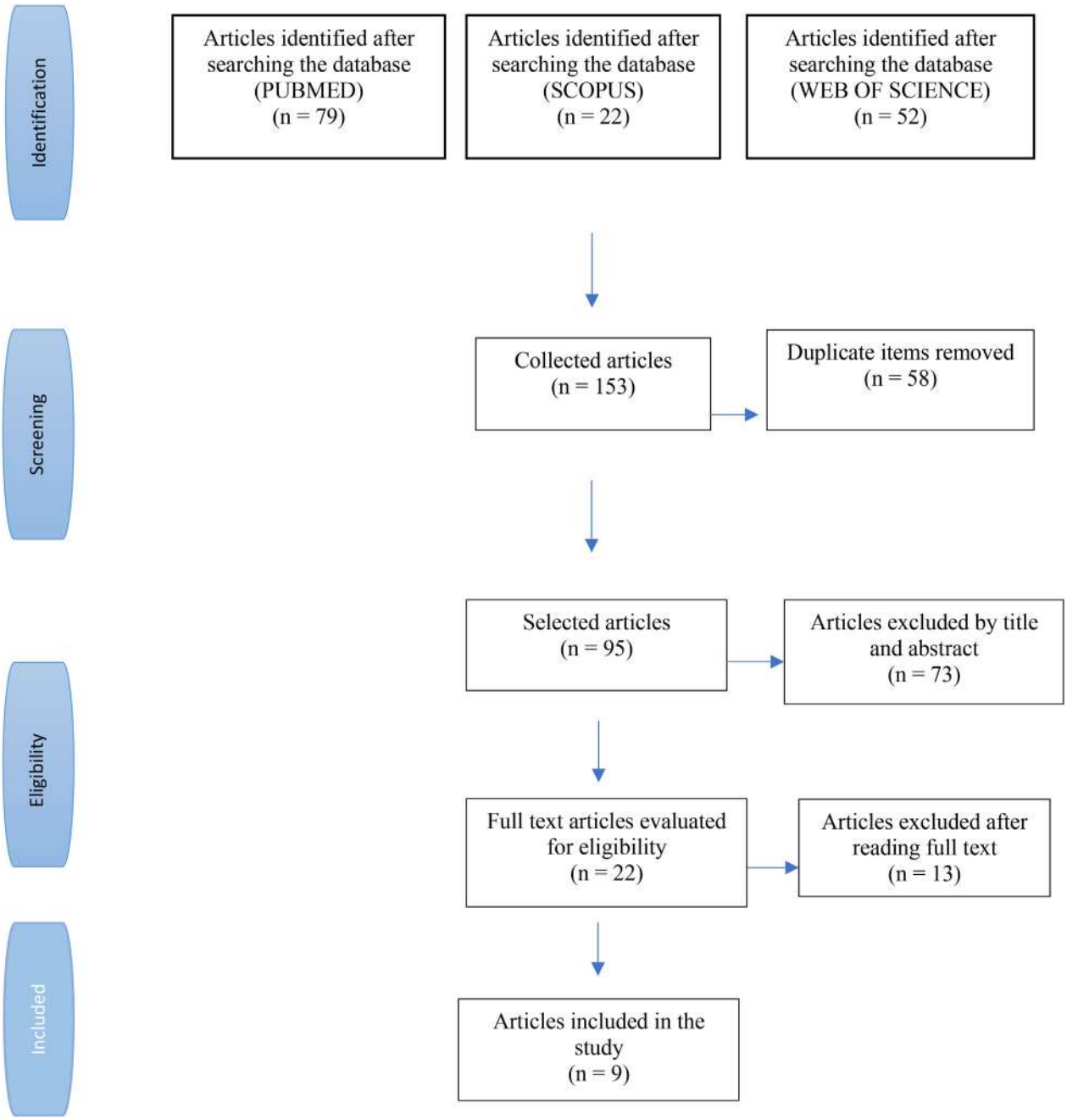

Fig. 1. PRISMA flow chart – association between formaldehyde exposure and asthma.

following exposure to formaldehyde concentrations, which were far higher than those indicated by the WHO guidelines.

The reviews carried out by Charbotel et al.[38] and Binazzi et al.[39] investigated the association of formaldehyde and cancer, demonstrating a weak association with nasopharyngeal cancer (OR 1.22; 95% CI 1.00–1.50) and cancer of the nasal and sinus cavity (relative risk [RR] 1.68; 95% CI 1.37–2.06), respectively.

Bachand et al.[40] included 35 primary studies (cohort and case–control studies) and indicated a lack of association between exposure to formaldehyde and neoplastic diseases, such as nasopharyngeal cancer (RR 0.72; 95% CI 0.40–1.28).

On the other hand, another meta-analysis analysed studies that supported the association between formaldehyde exposure and nasopharyngeal cancer (OR 2.7; 95% CI 1.2–6.0); however, the study did highlight that the risk increases with a longer duration of exposure to formaldehyde.[41]

Formaldehyde and leukaemia/lymphoma

One study, by Rhomberg et al.,[42] states that researchers report the lack of possible association between formaldehyde exposure and leukaemia. This study states that there is a lack of scientific evidence about toxic-kinetic and mechanistic biological plausibility to prove an association between formaldehyde exposure and cancer.

The review carried out by Polychronakis et al.[43] investigates the association between formaldehyde exposure and leukaemia, and despite showing an RR of 1.42 (95% CI 0.92–2.18) with formaldehyde exposure >4 ppm and finding greater genetic aberrations

Table 1
Characteristics of selected studies investigating the formaldehyde-asthma association.

Author	Year of publication	Number of studies/patients	Types of studies	Exposed occupational group	Results	AMSTAR quality judgement
Mc Gwin et al.[36]	2010	10/6387	Cohort studies; case–control studies; cross-sectional studies	Children at home, at school and outdoors	Good association OR 1.17; 95% CI 1.01–1.36	High (7)
Wolkoff et al.[55]	2010	12/4443	Case–control studies; cross-sectional studies	- Workers exposed to wood and resin - Children at home exposed to solvents, household products	Good association OR 1.40; 95% CI 0.98–2.00	Low (5)
Golden[9]	2014	13/not reported	Cohort studies; case–control studies	- industrial workers - Children at home	Good association OR 1.4; 95% CI 0.98–2.0	Critically low (2)
Nielsen et al.[8]	2013	12/657	Cohort studies; case–control studies; cross-sectional studies	- Pathologists - Woodworkers - Anatomists - Laboratory workers	Weak association OR 1.31; 95% CI 1.10–1.57	Critically low (2)
Nurmatov et al.[57]	2015	14/not reported	Cohort studies; case–control studies; cross-sectional studies	- Laboratory workers - Children at home	Good association From OR 1.58; 95% CI 1.04–1.83 to OR 2.51; 95% CI 1.4–3.6	High (7)
Tagiyeva et al.[56]	2014	30/not reported	Interventions; cohort studies; case–control studies; cross-sectional studies	- Woodworkers, exposed to cosmetics, textiles, household products - Children indoors	Good association Children: OR 4.3; 95% CI 2.1–8.8 Adults: OR 2.6; 95% CI 1.8–3.6	Low (5)
Yao et al.[34]	2015	6/356	Cohort studies; case–control studies	- Children outdoors	Good association WMD 0.021; 95% CI 0.009–0.033	High (9)
Yu et al.[33]	2020	13/10,458	Cohort studies; case–control studies; cross-sectional studies	- Adults (industrial workers and exposure at home) - Children at home and at school	Children: OR 1.10; 95% CI 1.00–1.21 Adults: OR 1.33; 95% CI 1.18–2.78	High (9)
Vardoulakis et al.[35]	2020	33/not reported	Case–control studies; cross-sectional studies	- Workers of wood and house products	Good association OR 1.37; 95% CI 1.01–1.89	Low (5)

CI, confidence interval; OR, odds ratio; WMD, weighted mean difference.

among workers exposed to formaldehyde than those not exposed, the study reports a consistent scepticism towards the association between formaldehyde exposure and leukaemia. These results are supported by the inconsistency of the epidemiological data and a lack of plausibility of the formaldehyde action model in leukaemia.

Mundt et al.[44] analysed the frequency of aneuploidy among workers exposed to formaldehyde in a resin factory. The results showed the absence of association between the exposure to formaldehyde and myeloid leukaemia (of which aneuploidy is considered a risk indicator).

A meta-analysis focuses on chromosomal studies of samples from workers exposed and not exposed to formaldehyde. This study deduced that the observed chromosomal aberrations, namely, monosomy 7 and trisomy 8, attributable to high exposure to formaldehyde, could have arisen during *in vitro* culture and not *in vivo*. Therefore, the results of these data, in combination with toxicological and mechanistic studies, do not support the causal association between exposure to formaldehyde and myeloid or lymphoid neoplasms.[45]

However, another study investigated the frequency of lymphocyte micronuclei in formaldehyde-exposed vs unexposed groups (case–control study). The results indicated a two-fold increase in lymphocyte frequency in those exposed compared with the control cases ($P < 0.0001$). Furthermore, the increase in the frequency of micronucleus (MN) in lymphocytes in exposed individuals compared with non-exposed individuals was strongly associated with the duration of exposure to formaldehyde, suggesting the need to better understand the potential for genomic instability induced by chronic formaldehyde exposure.[46]

A systematic review carried out by Awan et al.,[41] investigating industrial cohort studies and professional cohort studies on the association between formaldehyde exposure and lymphohematopoietic neoplasms, showed inconsistent results with RR values close to zero (RR 1.78; 95% CI 0.87–3.64 for myeloid leukaemia; RR 1.42; 95% CI 0.92–2.18 for non-myeloid leukaemia).[41]

The study by Charbotel et al.[38] considers the association of formaldehyde exposure and leukaemia and identifies a significant association with chronic and acute myeloid leukaemia (RR 2.47; 95% CI 1.42–4.27).

The meta-analysis by Catalani et al.[48] investigated 12 reports of workers exposed to formaldehyde with the aim of finding a connection with the onset of Hodgkin's lymphoma; however, the results, with an RR of 0.93 (95% CI 0.83–1.04) do not support an association. Another study performed in 2010 by Nielsen et al.,[49] collected 35 primary studies (cohort and case–control studies) and highlighted a lack of association between formaldehyde exposure and leukaemia (RR 1.05; 95% CI 0.93–1.20).

Allegra et al.[50] analysed results from 81 primary studies and reported a lack of evidence to support the hypothesis that formaldehyde is a cause of acute myeloid leukaemia.

In the study by Albertini et al.,[51] DNA damage in the lymphocytes of workers exposed to formaldehyde was measured; however, the results of this investigation showed that changes in human bone marrow or hematopoietic cells had confounding exposures, and *in vivo* and *in vitro* events could not be distinguished. Therefore, genetic changes reported in the analysed studies do not provide convincing data in support of the classification of formaldehyde as a human leukemogen.

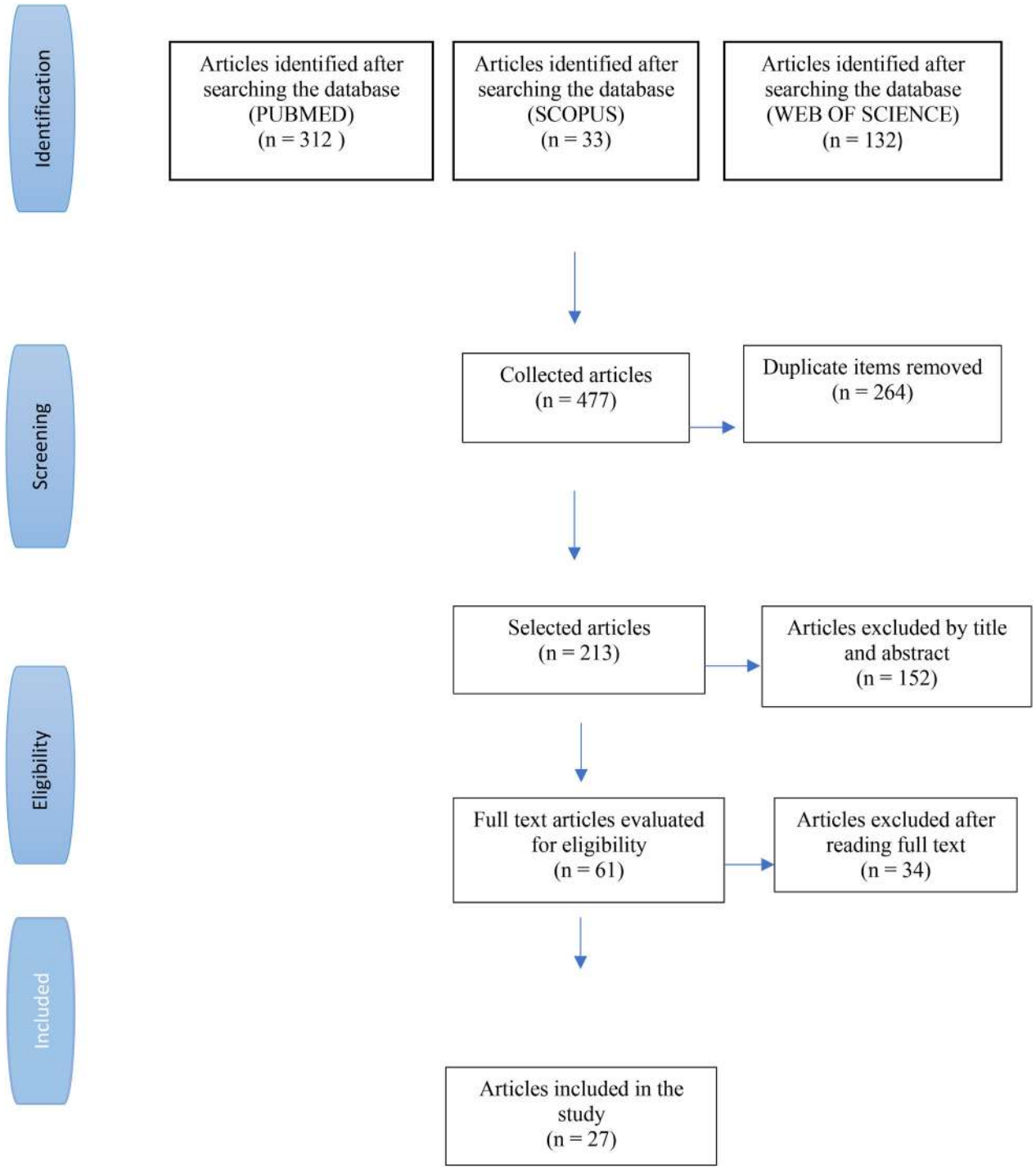

Fig. 2. PRISMA flow chart – association between formaldehyde exposure and cancer.

The meta-analysis by Shallis et al.[52] considers seven different prospective and retrospective cohort studies that present conflicting results; some report a weak association (not statistically significant) between formaldehyde exposure and leukaemia with an RR of 1.78 (95% CI 0.87–3.64), whereas others support a strong association (statistically significant) between formaldehyde exposure and myeloid leukaemia with an OR of 13.6 (95% CI 1.6–119.7).

Formaldehyde and other cancers

The study by Paget-Bailly et al.[53] evaluated case–control studies reporting data that do not support the hypothesis of an association between laryngeal cancer and formaldehyde exposure with an RR of 1.13 (95% CI 0.98–1.31).

Kwak et al.[54] made a quantitative assessment of the data from a review of 30 articles and found that there was no significant increase in lung cancer risk with formaldehyde exposure.

Table 2
Characteristics of selected studies investigating the formaldehyde-cancer association.

Author	Year of publication	Cancer type	Number of studies/ participants	Type of studies	Occupational group	Results	AMSTAR quality judgement
Bachand et al.[40]	2010	NPC, leukaemia	18 for NPC 17 for leukaemia/ 161,718	Cohort studies; case −control studies	- Embalmers - Pathologists - Paper workers	Weak association OR 1.10; 95% CI 0.80−1.50	High (9)
Nielsen et al.[49]	2010	NPC, leukaemia	12 for NPC 18 for leukaemia/657		- Pathologists - Anatomists - Embalmers	Weak association r 1.33; 95% CI 0.69−2.56	Low (5)
Golden[9]	2011	NPC, leukaemia	14/not reported	Cohort studies; case −control studies	- Industry workers	Weak association r 0.72; 95% CI 0.40−1.28	Critically low (2)
Rhomberg et al.[42]	2011	Leukaemia	53/458,782	Cohort studies; case −control studies	- Pathologists - Medical laboratory technicians - Embalmers	Weak association OR 1.20; 95% CI 0.60−2.30	High (8)
Checkoway et al.[47]	2012	Leukaemia	37/293,060	Industrial cohort studies; professional cohort studies; population-based case −control studies	- Pathologists - Anatomists - Woodworkers - Chemical industry workers	Weak association Myeloid leukaemia: r 1.78; 95% CI 0.87−3.64 Other (non-myeloid) leukaemia: r 1.42; 95% CI 0.92−2.18	High (7)
Paget-Bailly et al.[53]	2012	Cancer of the larynx	11/not reported	Cohort studies; case −control studies	- Metal industry workers	Weak association OR 1.3; 95% CI 0.5−3.3	High (10)
Gentry et al.[45]	2013	Leukaemia	1/94	Meta-analysis	- Industry workers	Weak correlation $P = 0.10$	Low (4)
Nielsen et al.[8]	2013	NPC	8/657	Cohort studies; case −control studies	- Pathologists - Woodworkers - Anatomists - Laboratory workers	Weak association OR 1.13; 95% CI 0.98−1.31	Critically low (2)
Polychronakis et al.[43]	2013	Leukaemia	4/not reported	Cohort studies; case −control studies; epidemiological or molecular study; letter to the editor	- Embalmers	Weak association r 1.37; 95% CI 1.03−1.81	High (7)
Bayer et al.[63]	2014	Cancer of the larynx	21/17,722	Cohort studies; case −control studies	- Wood and paper workers	Weak association OR 1.20; 95% CI: 1.02−1.40	High (9)
Charbotel et al.[38]	2014	- Nasal-pharyngeal cancer - Cancer of the nasal and paranasal cavity - Acute and chronic myeloid leukaemia - Salivary gland cancer	6/not reported	Meta-analysis; Case−control studies	- Woodworkers	Weak association for cancer of the nasal and paranasal cavity: OR 1.22; 95% CI 1.00 −1.50 and OR 9.5; 95% CI 2.62−34.20 Good association for leukaemia: OR 2.47; 95% CI 1.42−4.27 Good association for salivary gland cancer: OR 1.61; 95% CI: 1.30−2.00	Low (4)
Fenech et al.[46]	2015	NPC	17/952	Cohort studies; case −control studies	- Anatomists - Workers exposed to FA from resins and wood manufactures	Good correlation r 0.779; $P < 0.0001$	High (8)
Binazzi et al.[39]	2015	Sinus cancer	7/not reported	Cohort studies; case −control studies	- Woodworkers	Good association r 1.75; 95% CI 1.21−2.43	High (9)
Albertini et al.[51]	2016	Leukaemia/lymphoma	53/not reported	Cohort studies; case −control studies	- Pathologists - Anatomists - Woodworkers - Chemical industry workers	Good association r 1.31; 95% CI 1.07−1.60	Low (4)
Chappell et al.[60]	2016	NPC, leukaemia	4/not reported	Not specified	Industry workers		Low (5)

						Good correlation r 0.384; $P = 0.001$	
D'Ettorre et al.[58]	2016	NPC, myeloid leukaemia	31/not reported	Cohort studies; case−control studies	Pathological anatomy workers	Good correlation $P < 0.05$	Low (5)
Gurbuz et al.[59]	2016	NPC	27/not reported	Cohort studies; case−control studies	Laboratory workers	Good correlation $P < 0.05$	Low (4)
Nielsen et al.[37]	2017	NPC, leukaemia	8/657	Cohort studies; case−control studies	- Pathologists - Woodworkers	Good association for NPC: r 7.7; 95% CI 0.9−62 Weak association for leukaemia: r 1.15; 95% CI 0.97−1.36	Critically low (3)
Menicagli et al.[62]	2017	NPC	Not specified	Cohort studies; narrative reviews	Rubber and wood workers	Good correlation $P < 0.05$	Critically low (1)
Mundt et al.[44]	2017	Myeloid leukaemia	1/not reported	Cross-sectional studies	Industry workers	Weak association OR 0.80; 95% CI 0.70−0.92	Low (5)
Awan et al.[41]	2018	NPC, hypopharyngeal cancer	2/not reported	Case−control studies	Wood and solvent workers	Good association OR 2.7; 95% CI 1.2−6.0	High (8)
Allegra et al.[50]	2019	Acute myeloid leukaemia	81/not reported	Cohort studies; epidemiological molecular studies; literature review	Laboratory personnel	Good association OR 2.45; 95% CI 1.32−4.52	Low (5)
Beigzadeh et al.[61]	2019	NPC	7/13,296	Cohort studies; case−control studies	woodworkers	Good association OR 1.5; 95% CI 1.09−2.07	High (9)
Catalani et al.[48]	2019	Non-Hodgkin's lymphoma	12/318	Cohort studies	- Embalmers - Anatomists - Wood industry workers - Laminated plastic workers	Weak association r 0.93; 95% CI 0.83−1.04	High (9)
Kwak et al.[54]	2020	Lung cancer	31/1,339,927	Cohort studies; case−control studies; PMR/PIR studies	- Medical technicians - Embalmers - Chemists	Weak association OR 1.04; 95% CI 0.97−1.12	High (9)
Shallis et al.[52]	2020	Acute myeloid leukaemia	7/39,633	Retrospective cohort studies; prospective cohort studies; meta-analysis, case−control studies	- Embalmers - Funeral home workers - Anatomists - Pathologists	Weak association r 1.42; 95% CI 0.92−2.18	High (7)
Vardoulakis et al.[35]	2020	Nasopharyngeal cancer	33/not reported	case−control studies; cross-sectional studies	Woodworkers and household products	Good association OR 1.37; 95% CI1.01−1.89	Low (5)

CI, confidence interval; FA, formaldheyde; NPC, nasopharyngeal cancer; OR, odds ratio; WMD, weighted mean difference.

The study by Charbotel et al.[38] analyses the association of formaldehyde with multiple types of rare neoplasms; among others, it shows a weak association with salivary gland cancer (OR 1.6; 95% CI 1.30–2.00).

Quality assessment of the included cancer studies

The methodological quality of the included reviews that analysed the association between formaldehyde exposure and cancer, performed according to AMSTAR scale, is shown in Supplementary Table S2. In total, 48% of the articles reported good scores for methodological quality; however, 37% had weak methodological quality, and 15% had a critically low methodological quality.

Summary of the results

Table 3 shows a summary of the associations found between formaldehyde exposure and different diseases.

Almost all the articles (8 of 9) demonstrate a positive association between formaldehyde exposure and asthma[9,33–36,55–57]; only the study by Nielsen et al.[8] showed a negative association between exposure to formaldehyde and asthma.

In total, 64% of the reviews showed evidence for the association between formaldehyde exposure and nasopharyngeal cancer, whereas only 33% supported the association between formaldehyde exposure and leukaemia/lymphoma. Among these articles, the association between exposure to formaldehyde and myeloid leukaemia was discussed.[43,44,50,52,58]

Discussion

The purpose of this study was to demonstrate the following two distinct correlations: (1) the association between formaldehyde exposure and development of irritant diseases affecting the respiratory tract, mainly asthma; and (2) the association between formaldehyde exposure and development of neoplastic diseases.

Some articles included in this review highlighted that children were most significantly impacted by formaldehyde exposure. Some articles[8,9,33,35,55,56] are in agreement with the WHO guidelines that state the concentration of formaldehyde must not exceed 0.1 mg/m^3 (0.08 ppm) for a period of 30 min.

From the selected cancer articles, the most common neoplasms associated with formaldehyde exposure were shown to be nasopharyngeal cancer and leukaemia[8,9,35,37,40,42–52,58–63] A small number of articles considered the association between exposure to formaldehyde and other types of cancers; Paget-Bailly et al.[53] and Bayer et al.[63] investigated the risk of laryngeal cancer among formaldehyde-exposed workers. In addition, the meta-analysis by Kwak et al.[54] analysed the risk of lung cancer following formaldehyde exposure in professional employment. Another study also mentioned rare neoplasms, such as salivary gland cancer.[38] Finally, in the systematic review by Binazzi et al.,[39] the association between cancer of the nasal cavity and paranasal sinuses in workers exposed to formaldehyde was studied.

Table 3
Number of reviews describing an association between formaldehyde exposure and different diseases.

Type of disease	Association	
	No	Yes
Asthma	1	8
Nasopharyngeal cancer	5	9
Leukaemia/lymphoma	10	5
Larynx cancer	2	0
Salivary gland cancer	0	1
Sinus cancer	0	1
Lung cancer	1	0

The selected articles show that the workers who are most at risk of exposure to formaldehyde include laboratory workers (anatomists, pathologists, and chemists), embalmers and those who work in the production of plywood and resins, with wood dust and solvents.[8,39–42,46–49,52,54,58,59,61,63]

The WHO guideline threshold values of formaldehyde exposure (i.e. 0.1 mg/m^3 [0.08 ppm] for a period of 30 min) were taken as referral values in many of the included studies.[8,9,35,37,49,59]

Future research should include surveillance studies that are capable of adequately measuring the level of formaldehyde exposure and the occurrence of diseases in cohort or case–control studies.

The main implications for public health practice and policy, as well as for health and safety or occupational health, are related to the implementation of the WHO guidelines threshold values of formaldehyde exposure (i.e. 0.1 mg/m^3 [0.08 ppm] for a period of 30 min). If this concentration is exceeded in occupational/workplace settings, strategies must be implemented to reduce exposure, such as reducing the number of workers exposed, reducing the duration of exposure, better collection and ventilation systems, and use of appropriate personal protective equipment.

Limitations and strengths

This review had several limitations that should be acknowledged. The study populations in the analysed reviews are very specific (i.e. school-aged individuals with regard to the association between formaldehyde exposure and asthma; and professional workers with regard to the association between formaldehyde exposure and cancer). Only articles published in the previous 10 years were included, thus excluding studies published before 2010. In the meta-analyses included in this review, the authors underline that among the primary studies analysed, there were, in some cases, a high risk of bias. Moreover, it should be noted that the studies included in the systematic reviews and meta-analyses were performed with relatively small groups of people, and it was difficult to retrieve any information about ethnicity or gender.

However, this review also has several strengths. The results provide a global view of the association between exposure to formaldehyde and the potential associated pathologies. In addition, a dual analysis was performed, assessing how the exposure to formaldehyde could impact individuals by causing both irritant and neoplastic pathologies. The review also included an assessment of the AMSTAR methodological quality.

Conclusions

The present review showed a positive association between exposure to formaldehyde and irritant diseases, such as asthma, as seen in 89% of the articles analysed. However, a weak association between exposure to formaldehyde and neoplastic pathologies was seen; 60% of the studies analysed did not report valid evidence to support the association.

It is recommended that the WHO guidelines regarding formaldehyde exposure thresholds are followed and adhered to. Formaldehyde exposure prevention programmes, based on ventilation in the workplace and environmental monitoring to control the concentration of formaldehyde in the atmosphere, are recommended.

Author statements

Ethical approval

Not required as this is an umbrella review.

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Competing interests

The authors declare there are no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.03.009.

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Themed Paper — Short Communication

Rethinking local resilience for extreme heat events

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ABSTRACT

Objective: This study aims to provide insights into how local resilience structures in England can be leveraged to deliver a whole-of-society approach to managing a national response to extreme heat events during summer months.
Study design: A communication based on the literature review of currently available research on health emergency response and extreme heat events in England.
Methods: This communication draws insights from the authors' research programmes, which examined national-level public health emergency response during the COVID-19 pandemic and literature review of the latest available English research on health and extreme heat events.
Results: Periods of extreme heat are on the rise in England. Local resilience forums (LRFs), due to their multiagency nature, offer a shared situational awareness and understanding of the need in their local communities. Such information is critical to ensure messaging about heat risks and available resources are tailored to reach specific targeted groups within their communities. Scenario planning and adaptation efforts require a more local articulation which LRFs are well placed to manage.
Conclusions: LRFs are well suited as key structures in the English emergency response to extreme heat events. We suggest that English public health and hospital organisations, working with community partners via the LRFs, must develop their thinking about pressures from adverse weather in the summer months.

Introduction

Although cold weather and the 'winter pressures' it places on the English public healthcare system are well documented, the health risks brought about by extreme heat and the pressure it places on health services are less well understood. In particular, how the resilience of local communities and the health systems that support them can be future-proofed against a rising global temperature, and the risks it brings warrant the immediate attention of emergency planners and researchers in the field of public health emergencies. Four of the five hottest summers since records began have occurred in England since 2003.[1] These heat events are defined as days where the mean temperature is above 20°C. While in the summer of 2022, some places in England experienced temperatures of over 40°C for the first time. During the period of extreme heat between June and August 2022, there were 3271 more deaths than the 5-year average, representing a six percent increase, and one of the highest levels of deaths ever recorded during a period of extreme heat.[1] In this commentary, we call for a necessary rethink in how the English public healthcare system work alongside local resilience forums (LRFs) to prepare for extreme heat events. Building on the lessons learned from the COVID-19 pandemic[2,3], we present how future national preparedness and resilience for extreme heat-related emergencies should be enhanced.

Background

The COVID-19 pandemic is one example of how global connectedness increases our exposure to public health risks. It also illustrates how public health emergencies are more than just health sector incidents but are challenges for the whole of society, specifically the community level, which necessitates a wider response. There are rising concerns over the strain on health systems caused by increasing severity and incidence of disasters resulting from climate change.[4,5] Extreme weather events induced by climate change, including heat waves, have become more intense, frequent and costly, impacting infectious disease transmission and undermining peoples' mental health and livelihoods.[6] Recent modelling shows

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increasing demand on the English National Health Service, rising hospital admissions and increased patient length of stay during summer months are already evidenced but likely to be much higher in the decades to come with increased temperatures.[7] Projections suggest that by 2050, the mean number of additional beds required during hot summer months will be similar to the current number of beds required during winter. Links between heat, increased mortality and worsening mental health, including suicide, are established among vulnerable populations, including the elderly.[8] Vulnerability to heat emergencies is compounded by inequity, intersectionality and marginalisation linked to gender, ethnicity and low-income status, as well as strong variation by geographic region.[6]

In England, planning for risks such as extreme heat events is facilitated by a piece of legislation, the Civil Contingencies Act 2004. Civil Contingencies Act outlines the doctrine, structures and processes to manage emergencies when they are declared in the United Kingdom. This national resilience structure includes the design and connections between local and national elements, such as local Strategic Coordinating Groups and the national Cabinet Office Briefings or Situation Centre. Across England, the resilience structures that manage major incidents are local partnerships of emergency, essential, public and civic services, including the police, fire, ambulance, health, highways agency, the Met Office, coal authority, environment agency and the local authority, termed LRFs. For public health emergencies, such partnerships are well placed to coordinate the emergency preparedness, mitigation, response and recovery activities.

What can we learn from the role of LRFs during the COVID-19 pandemic?

LRFs were critical and successful in bringing the health sector, including public, social, primary and acute care, together with other partners for health emergency preparedness during the COVID-19 pandemic.[9] The multidisciplinary focus of an LRF helps to remedy a narrow 'hospital-centric' approach to emergency preparedness.[10] Local strategic decision makers knew their local communities and resources very well, and the community connectedness is a key benefit of the LRF model. As such, LRFs were able to act quickly, effectively and across a broad range of critical activity during the response to the COVID-19 pandemic.[1]

Rethinking local resilience for extreme heat events

Given the increasing general demand in the healthcare system, local resilience structures need to draw from community-level intelligence to mitigate health risks due to warm weather. At present, there is a great demand for emergency health care in England during winter resulting from seasonal influenza and other respiratory diseases, which consume hospital resources. While 'winter pressure' can dominate media headlines, emergency planners must be prepared for all seasons and the range of adverse weather that can occur. In the summer of 2020, there was greater than the expected number of deaths for people aged >65 years in their own homes, care homes and hospitals.[8] These deaths resulted from circulatory and respiratory diseases, Alzheimer's and dementia. Contributing factors resulted from more time spent at home, high indoor temperatures and lack of respite due to high night-time temperatures.

We posit that emergency planners must rethink how the health system integrates with local resilience structures to protect human health during hot weather. English hospitals and public health, working with their community partners through LRFs, must develop their thinking about pressures from adverse weather in the summer months. We propose two possible ways that LRFs can work in tandem with the public healthcare system to build preparedness and enhance response effectiveness: first, to ensure the health needs of the local community, including vulnerable groups, are well understood and to use that information to tailor messaging and direct individuals towards local resources; and second, to aggregate data across regions to create a shared situational awareness and understanding of need in their communities and to allow cross-jurisdictional information sharing and enhanced coordination.

Addressing the first recommendation, LRFs are adept at understanding and responding to community needs and risks. LRFs can leverage their greater awareness of the health needs of the local community to direct groups and individuals to resources, including, for example, support for older adults, making people aware of cool banks in their area and working with care home providers. While the Met Office, the National Health Service, in conjunction with the Environment Agency, push out alerts and bulletins about the health risks of hot weather via conventional and social media, LRFs can ensure messaging is tailored to reach specific targeted groups within their communities. For example, in the summer of 2022, the Swindon and Wiltshire LRF wrote a blog post containing health and safety executive guidance targeting local employers whose staff work outside in hot temperatures (https://wiltshireandswindonprepared.org.uk/blog/working-in-hot-temperatures).

In consideration of our second recommendation, adverse weather events such as heatwaves, flooding and strong wind can emerge concurrently, meaning these events will likely be experienced across several local authority areas and across boundaries within a region. It is important to think about how emergency response to extreme weather may operate in a region containing multiple LRFs where there is no primacy of geographical area. This may result from a geographically spread weather event, such as strong winds and storms, extensive flooding or coastal sea rises, which would impact across a number of areas. With health operating typically at different geographical boundaries to the LRFs, this will bring many challenges to coordinate agencies and political contexts. The nature of large-scale impactful weather events across a large proportion of the local populations, where there are complex connected events in quick succession, also brings the challenge of protracted response and recovery. To help unify the response across multiple regions, LRFs can, for example, work to aggregate data across the jurisdictions to create a shared situational awareness and understanding of need in their communities. How the LRFs and their hospital and public health partners coordinate their emergency management to these events will be complex, as the national resilience structures at present make little provision for regional structures for coordination. In the future, it should be possible for regions in the United Kingdom to use the National Situation Centre, a new centralised emergency response facility established in 2021, to provide this function and feed the situation report back to the resilience structure of each LRF.

In closing, we have highlighted the potential role that English LRFs could contribute in delivering a whole-of-society approach to national resilience for extreme heat events. As key multiagency structures in the English emergency response, the situational awareness these local partnerships bring to the emergency planning of public health care must not go underappreciated so that they can be leveraged in the national efforts, now and into the future, to support resilience against extreme heat events. Finally, the learning from the COVID-19 response, including the enhancements to LRFs via the UK Government Resilience Framework (released in December 2022) and the opportunities created through the establishment of the National Situation Centre, must be incorporated into the community-level response so that opportunities to enhance resilience can be clearly identified and improvements put in place to protect against future emergencies.

Authors statements

Ethical approval

No ethical approval was required for this article as it is a commentary and does not involve any participants.

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Competing interests

There are not any competing interests to declare. The views expressed in this article are those of the authors and not necessarily those of any LRF or their multiagency partners.

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Themed Paper – Original Research

Science communication in the media and human mobility during the COVID-19 pandemic: a time series and content analysis

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ABSTRACT

Objectives: The relationship between human mobility and nature of science (NOS) salience in the UK news media was examined.
Study design: This is a mixed-method study.
Methods: A time series NOS salience data set was established from the content analysis of 1520 news articles related to non-pharmaceutical interventions of COVID-19. Data were taken from articles published between November 2021 and February 2022, which correlates with period of the change from pandemic to endemic status. Vector autoregressive model fitting with human mobility took place.
Results: The findings suggest that it was not the number of COVID-19 news articles nor the actual number of cases/deaths, but the specific NOS content that was associated with mobility change during the pandemic. Data indicate a Granger causal negative direction ($P < 0.1$) for the effect of the NOS salience represented in the news media on mobility in parks, as well as the effect of scientific practice, scientific knowledge and professional activities communicated in news media on recreational activities and grocery shopping. NOS salience was not associated with the mobility for transit, work or residential locations ($P > 0.1$).
Conclusions: The findings of the study suggest that the ways in which the news media discuss epidemics can influence changes in human mobility. It is therefore essential that public health communicators emphasise the basis of scientific evidence to eliminate potential media bias in health and science communication for the promotion of public health policy. The present study approach, which combines time series and content analysis and uses an interdisciplinary lens from science communication, could also be adopted to other interdisciplinary health-related topics.

Introduction

Non-pharmaceutical interventions (NPIs), such as travel restrictions, have been the core of COVID-19 policies around the globe.[1] Individual efforts to fight the epidemic were unprecedented during this crisis. 'Responsible transport' policies,[2] which emphasise the collective efforts to mitigate the spread of epidemics, reaffirm the importance of individual responsibilities. In this regard, risk communication is key to engaging with the public on NPIs, as unbiased communication promotes acceptance, compliance and policy support. Mass media, such as newspapers, provide a medium to reach a large audience through mass communication, which can have great influence on not only the general public but also the government and transport operators.[3–5]

While pandemics qualify as a form of health crisis,[6] individuals are neither prepared nor possess knowledge of how to deal with such situations.[7] In addition, to support the guidance from experts and governments, information must be disseminated to mobilise the public. Perceivably useful and trustworthy information is usually based on scientific facts.[8] In the case of a health crisis, one of the objectives of science communication is to raise public awareness of the new aspects of scientific evidence, so that they can adhere to preventive measures.[9,10]

This article aims to contribute to the public health literature by focusing on the scientific aspect of risk communication and its relationship with the public mobility response. In particular, this study focuses on the representation of science from a meta-perspective, often referred to as 'nature of science' (NOS), in risk

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and health communication by defining science as a cognitive-epistemic and social-institutional system.[11–14] NOS refers to different aspects of science. It is a meta-level orientation to describe how science works. In other words, NOS provides a bird's-eye view on science, highlighting its various dimensions such as the characteristics of scientific knowledge.[15] The process of generating scientific knowledge behind communicating pandemic health advice involves various NOS categories[11,16] (Table 1). A recent sentiment analysis[17] revealed that the public generally responded positively to scientific method behind COVID-19 vaccines and treatments in tweets. However, it is not yet known whether these NOS aspects influence the tendency of the public to adhere to NPIs.

This study adopted the NOS framework and characterised scientific aspects of health and risk communication by news media. Focusing on NOS enables risk communication researchers to determine whether news media sufficiently articulates how scientific information is generated in risk communication, for example, in the context of the COVID-19 crisis.

Methods

Aims and contributions of the study

This study had two important objectives, as follows: (1) to investigate scientific information represented in UK news articles related to NPIs, such as travel restrictions, and responsiveness of individual actions to curb the spread of disease; and (2) to explore the relationship between the NOS salience in news articles and human mobility responses. A time series NOS salience data set was established from content analysis, and this was combined with a national mobility data set. To the best of the authors' knowledge, to date, there is no research of this nature in the public health literature, and it is important to explore whether the scientific aspect of risk communication is relevant to health policies and practices. In the empirical study, a time series analysis with VAR models was used. This method converted qualitative data from the content analysis into time series big data and is a promising approach for interdisciplinary public health research.

Content analysis

Two coders manually performed a content analysis of 1520 news articles from November 2021 to February 2022. These news articles were surveyed from four major newspaper outlets that cover the range of the political spectrum (The Guardian, The Times, The Telegraph and The Daily Mail).[18] These news articles were obtained from the news database Factiva.[71] The following keywords were used in Factiva: 'COVID-19', 'coronavirus', 'epidemic', 'outbreak', 'pandemic' or 'SARS-CoV-2'.[18] The results returned a total of 7760 news articles. These articles were then screened, and 1520 articles were selected on the basis that they included scientific information in communicating COVID-19 risks related to NPIs.

Next, the NOS framework[11] was used to analyse the inclusion of NOS in communication of COVID-19 NPIs by news media. The NOS framework enables the articulation of different aspects of science in a nuanced manner such that they can be differentiated and clarified. The framework comprises 11 categories that depict how scientific knowledge is formed, certified and affected by different social-institutional factors: aims and values, scientific knowledge, scientific practices, scientific methods, social values, social certification and dissemination, professional activities, scientific ethos, social organisations and interactions, financial systems and political power structures (see Table 1 for definitions). The salience of these NOS categories in newspapers was examined by content analysis. A deductive coding was carried out according to an existing framework[11] that guides the analysis of NOS included in

Table 1
Nature of science categories, aspects of risk communication and excerpts from eligible news articles.[21]

Category	Definition	Excerpts from news articles
Aims and values	The goals that scientific activities desire to fulfil.	"Professor Graham Medley, chair of the Scientific Pandemic Influenza Group on Modelling (SPI-M) … 'Our job is *to lay out a range of possibilities for the future*…'".[22]
Methods	The systematic approaches used to obtain reliable knowledge.	"However, cases are already running far above the numbers being confirmed by PCR testing and the UK is already *relying on other methods*, such as the Office for National Statistics Infection Survey, to assess levels of prevalence".[23]
Practices	A diverse set of activities, such as modelling and analysing data, that help obtain scientific knowledge.	"A travel ban on Britons means "we are successfully putting the brakes on Omicron" while virologists *estimate* the real number of new variant cases is ten times higher than the official figure of 347"[24]
Knowledge	The status of knowledge, such as its certainty and forms (i.e. theories, models).	"It committed the government to examine international public health *models*, learn from best practice, and *reshape* the health system to ensure 'an agile and well-planned response to future epidemics'"[25]
Social certification and dissemination	The peer review process and quality control of scientific processes and products.	"During the audit the firm was being *assessed* by the UK Accreditation Service (UKAS) *to see whether it could be awarded full accreditation* for processing tests".[26]
Scientific ethos	The set of norms, such as scepticism about claims, that scientists engage with	"Reicher's comments risk further undermining confidence in the political *impartiality of scientists* advising UK politicians on coronavirus strategy".[27]
Social values	A set of values agreed by the public in society, such as protecting the vulnerable, fulfilling personal reasonability and restoring the norm by "living with the virus".	"I think it is the wrong course of action for people to take because we have a serious situation we have got to manage and we encourage *everybody to play their part in addressing that*".[28]
Professional activities	Activities for communicating scientific research, such as attending conferences and publishing papers.	"Speaking at a Downing Street *press conference*, Johnson said anyone arriving in England will be asked to take a PCR test".[29]
Social organisations and interactions	The role of institutions, staff unions and research centres in influencing scientific work.	"O'Leary also said that the National Transport Authority (NTA) had not been responsive to *concerns raised by the union* since the onset of the pandemic".[30]
Financial systems	The role of economics in scientific research and economic impact on business.	"Hit hard by pandemic restrictions on travel, *sales in the eight weeks from 6 December were only 57%* of the equivalent in pre-pandemic 2019, the company said in a trading update".[31]
Political power structures	The role of how different political factors, such as politicians, affect scientific work.	"It is also a sign of desperation in Downing Street to avoid a lapse back into more severe restrictions, such as those the *prime minister was forced to introduce* – with great reluctance – last Christmas".[32]

news articles.[19] Initially, excerpts from COVID-19 news articles published in four news outlets corresponding to each NOS category were extracted by the first and second authors. To mark an instance of NOS, the excerpt should have keywords or phrases mentioning how scientific and health information in the crisis was obtained, for example, how the Prime Minster shapes public scientific advice during the COVID-19 pandemic. The first and second authors discussed whether these excerpts aligned with a specific NOS category, as well as refining the definitions of each NOS category based on the chosen excerpts. Coding was applied to each article, and more than one NOS category could be applied to each article (see Table 1 for examples of excerpts from news articles). In total, 10% of the articles were randomly selected and analysed by both coders (i.e. the first and second authors). Intercoder reliability, reflecting agreement of coding between both authors, was calculated.[19] The final Cohen's kappa coefficient was 0.81, which indicated an acceptable threshold of reliability.[20] The remaining news articles were analysed by both coders independently.

To operationalise content analysis in the time series analysis, the salience of an NOS category was defined as the proportion of codes addressing a specific NOS category per day. The proportion was calculated by dividing the number of codes addressing a specific NOS category by the number of codes on that day. The cumulative daily proportion of the NOS salience always summed to 1. Table 2 presents the mean number of articles addressing an NOS category each day.

Time series analysis

The association of the percentage of daily NOS salience in the UK national media on national-level mobility indicators was examined. Human mobility data were obtained from the community mobility report developed by Google,[33] which has been used in many empirical studies in the literature.[34–36] The data set shows how visits and length of stay at different location categories, including retail and recreation (e.g. restaurants, cafes, shopping centres), grocery and pharmacy (e.g. grocery supermarkets), parks (e.g. parks and public beaches), transit (e.g. public transport hubs), workplaces and residential areas, change compared with a baseline (i.e. the median value for the corresponding day of the week during the 5-week period from 3 January to 6 February 2020). COVID-19 situation data were obtained from the Oxford COVID-19 Government Response Tracker and details can be found in the study by Hale et al.[37] Table 2 presents the descriptive statistic of mobility and COVID-19 situation data.

First, the augmented Dickey–Fuller test (ADF) was used to determine the stationarity of variables and their order of integration. Dickey and Fuller[38] tests determine the presence of a unit root (then, the series can be considered as non-stationary) or not (the series is stationary). The Dickey–Fuller test is testing if $\gamma = 0$ in this model of the data:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_2 \Delta y_{t-2} + \ldots$$

where y_t is the time series data. A linear regression of Δy_t against t and y_{t-1} was conducted for testing if γ is different from 0. If $\gamma = 0$, then there was a random walk process, otherwise there was a stationary process.

The null hypothesis for both tests was that the data were non-stationary. The analysis started by applying a unit root test on the variables included in the data set. As can be seen in Table 2, the null hypothesis that each of the variables contains a unit root was rejected at the 10% critical level, except for 'hospitalisation' and 'stringency'. Analytically, the ADF t-statistics for the first difference of the variables were statistically significant, leading to the rejection of the null hypothesis that the first differences are non-stationary. That is, hospitalisation and stringency were characterised by integration of degree one, whereas all the other variables of interest were stationary.

Table 2
Descriptive statistic and unit root test of mobility, NOS salience and COVID-19 situation data.

Variable	Mean	SD	Minimum	Maximum	ADF (levels)			ADF (first differences)		
					t-stat	Critical values	Stationarity	*t*-stat	Critical values	Stationarity
Mobility (location)										
Recreation	−0.14	0.11	−0.87	0.07	−6.007	−2.889	Yes	–	–	–
Grocery	0.01	0.13	−0.88	0.42	−6.808	−2.889	Yes	–	–	–
Parks	0.08	0.14	−0.49	0.42	−7.444	−2.889	Yes	–	–	–
Transit	−0.33	0.10	−0.81	−0.17	−3.946	−2.889	Yes	–	–	–
Work	−0.27	0.16	−0.78	−0.01	−5.736	−2.889	Yes	–	–	–
Residential	0.08	0.04	0.00	0.21	−5.654	−2.889	Yes	–	–	–
Media										
NOS category										
Aims and values	0.03	0.04	0.00	0.17	−10.197	−2.889	Yes	–	–	–
Methods	0.03	0.03	0.00	0.12	−10.920	−2.889	Yes	–	–	–
Practices	0.13	0.06	0.00	0.35	−8.908	−2.889	Yes	–	–	–
Knowledge	0.09	0.06	0.00	0.38	−9.768	−2.889	Yes	–	–	–
Social certification and dissemination	0.03	0.03	0.00	0.17	−9.358	−2.889	Yes	–	–	–
Scientific ethos	0.01	0.02	0.00	0.14	−10.291	−2.889	Yes	–	–	–
Social values	0.12	0.06	0.00	0.29	−9.237	−2.889	Yes	–	–	–
Professional activities	0.10	0.06	0.00	0.29	−10.756	−2.889	Yes	–	–	–
Social organisations and interactions	0.05	0.04	0.00	0.20	−9.994	−2.889	Yes	–	–	–
Financial systems	0.10	0.07	0.00	0.38	−9.401	−2.889	Yes	–	–	–
Political power structures	0.31	0.07	0.14	0.50	−8.467	−2.889	Yes	–	–	–
Daily number of COVID-19 news articles	12.6	6.21	2	32	−6.051	−2.889	Yes	–	–	–
COVID-19 situation										
Cases	82435.62	83359.83	29843	847371	−8.166	−2.889	Yes	–	–	–
Deaths	174.74	137.27	3	1121	−7.470	−2.889	Yes	–	–	–
Hospitalisation	11857.54	4175.40	7251	20062	−0.605	−2.889	No	−4.768	−2.889	Yes
Stringency	44.13	5.05	23.15	48.61	2.062	−2.889	No	−8.162	−2.889	Yes

ADF, augmented Dickey–Fuller; NOS, Nature of science; SD, standard deviation.

If the series presents the same order of integration, a risk of cointegration between variables was possible. Cointegration tests must be undertaken. The existence of a possible cointegration relationship implies that variables must be non-stationary. The Johansen[39] cointegration tests were used to determine the number of cointegration relationships. These tests require the selection of the optimum lags of the VAR model, which were determined with the likelihood ratio, final prediction error criterion, Akaike information criterion, Hannan-Quinn information criterion and Schwarz information criterion. Lag-order selection statistics for VARs were obtained using the 'varsoc' function in Stata/SE 17.0. Then, the lag length (p) was selected through the estimation of an unconditional VAR model (Table 3). Equations of the test are detailed in a study by Khan and Khan.[40]

Results

Mobility at all locations was generally stable throughout the study period, except during the omicron outbreak from mid-December 2021 to mid-January 2022. Residential mobility maintained a slightly higher level than at baseline, whereas mobility at the other locations declined rapidly after the outbreak. Locations categorised as retail and recreation, grocery and pharmacy, and parks sharply increased after a one week time frame, whereas locations of transit and workplace gradually returned to the pre-outbreak levels. From the VAR model, it can be seen that mobility in some locations was associated with mobility in other locations. Transit, being a fundamental location for transport services, was positively associated with all locations, except parks. These results support the usefulness of mobility data in the case of the United Kingdom.

Next, the NOS salience in COVID-19–related news (Table 2) was examined. The political and power structures was the most prominent NOS category in risk communication in COVID-19 news (mean = 0.31); the practices category was the second most prominent (mean = 0.13); and social values was the third most prominent category (mean = 0.12). Scientific ethos was the least prominent among all 11 NOS categories (mean = 0.01). These results suggested that while a great deal of emphasis was placed on the politics in news media whereas the ethos of science, in terms of scepticism and universalism, was overlooked.

Finally, relationships between mobility and the NOS salience were examined. Granger causality tests performed on the VAR models showed that there was instantaneous causality between the media frames and mobility in almost every model for the containment and social frames and Granger causality in some. Table 4 details the coefficients in six models. A Granger causal direction ($P < 0.1$) represents an effect of the NOS salience in news media on mobility and can be seen in public parks, as well as the effect of scientific practice, knowledge and professional activities represented in news media on recreation and grocery. The directions of association were all negative, meaning that higher NOS salience represented in news media contributed to decreased mobility. NOS salience communicated in news media was not associated with mobility at transit, work or residential locations ($P > 0.1$).

Fig. S1 in the supplementary material shows a graphical representation of human mobility, NOS salience and COVID-19 situation indicators over study period.

Table 3
Lag selection.

Lag	FPE	AIC	HQIC	SBIC
0	3.00E-23	7.73824	7.94505	8.24796
1	6.80E-25	3.84369	8.39348	15.0575
2	8.50E-25	3.30045	12.1932	25.2183
3	2.10E-25	−0.508144	12.7276	32.1138
4	1.60E-27	−11.9945	5.58422	31.3315
5	7.e−244[a]	−536.005[a]	−514.084[a]	−481.975[a]

FPE, final prediction error criterion; AIC, Akaike information criterion; HQIC, Hannan-Quinn information criterion; SBIC, Schwarz information criterion.
[a] Optimum lags.

Discussion

This empirical study examined the relationship between NOS salience in news media and public mobility. The results suggest that it is not the number of COVID-19 news articles,[41,42] but it was the amount of NOS content in news media that was associated with pandemic mobility. Specifically, scientific practices and knowledge, which refer to the scientific activities that lead to the generation of scientific knowledge and the sources and forms of knowledge in risk communication, respectively, were associated with decreased time spent in recreation, grocery and park locations, given that the two variables are complementary and therefore tend to be opposite in direction. In other words, it was not the exact number of COVID-19 cases, but the salience of scientific practices (e.g. analysing COVID-19 case data by the government) and knowledge (e.g. uncertainty in trends of COVID-19 cases) related to the COVID-19 situation reported in the media that impacted mobility changes (i.e. decrease in overall mobility and an increase in time spent at home). Meanwhile, the NOS (represented by news media) was highly associated with decreased time spent in park areas. However, the impacts of mobility at transit, work and residence locations were not significantly associated with NOS salience. This could potentially be explained from the transport perspective, in that transit and work are essential trips unless the government implement social distancing practices (e.g. work from home). The findings for the residence location tended to be in the opposite direction to transit and work locations. Recreation, grocery and park locations can be deemed as relatively optional (i.e. non-essential trips). Although most associations were instantaneous (making it impossible to determine the causal direction of effects), the Granger causality tests suggested directional effects of NOS salience in news media on mobility in public parks. The data suggested that it was more likely that the media influenced mobility and not *vice versa*.

Implications

In the 'opening-up' period during the COVID-19 crisis, travel behaviours were mainly driven by public perception of viral risks and uncertainties. Uncertainties perceived by people led them to actively practise social distancing (e.g. to avoid gathering in public areas such as grocery supermarkets, transit areas and workplaces) and shift to more open areas, such as parks.[43–46] As public transport was unjustifiably stigmatised by media, authorities and citizens,[47,48] passengers who were concerned about the risk of infection tended to drive more and avoid public transport,[49,50] which continues in the post-pandemic period.[51]

News media is the major source where the public obtains risk information in the COVID-19 pandemic[52] to make informed decisions. According to risk communication models,[53,54] the public should be informed about risks (health and social) and responses (individual and organisational). Owing to a flow of misinformation in mass media, news plays a role in alerting the public to danger and reassuring the public in the trustworthiness of scientific information.[55] However, risk communication in news media often lacks robust information on the sources and reliability of scientific knowledge.[56,57] In the healthcare pandemic crisis, news media

Table 4
VAR model coefficients.

Independent variable	Dependent variable											
	Recreation		Grocery		Parks		Transit		Work		Residential	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Mobility (location)												
Recreation	−0.89[a]	0.30	−1.14[a]	0.38	−0.62	0.38	−0.70[a]	0.23	−0.68	0.45	0.01	0.12
Grocery	0.38[b]	0.20	0.30	0.26	0.32	0.26	0.02	0.16	−0.32	0.31	0.12	0.08
Parks	−0.15[b]	0.09	−0.04	0.11	−0.14	0.12	0.08	0.07	0.36[a]	0.14	−0.07[c]	0.04
Transit	1.25[a]	0.34	1.24[a]	0.42	0.34	0.43	1.58[a]	0.26	1.98[a]	0.51	−0.41[c]	0.13
Work	−0.35[b]	0.19	0.01	0.24	−0.05	0.24	−0.16	0.15	0.31	0.29	0.00	0.08
Residential	−0.27	0.84	0.44	1.06	0.17	1.06	1.24[b]	0.66	3.96[c]	1.27	−0.61[b]	0.33
Media												
NOS category												
Aims and values	−0.66	0.47	−0.60	0.59	−2.03[a]	0.59	−0.09	0.36	0.48	0.70	−0.06	0.18
Methods	−0.47	0.46	−0.36	0.57	−1.23[c]	0.58	−0.07	0.36	0.40	0.69	−0.06	0.18
Practices	−0.98[c]	0.42	−0.95[c]	0.52	−1.57[a]	0.53	−0.31	0.33	0.30	0.63	−0.07	0.16
Knowledge	−0.70[b]	0.42	−0.73	0.53	−1.47[a]	0.53	−0.12	0.33	0.56	0.63	−0.09	0.16
Social certification	−0.57	0.53	−0.58	0.67	−0.88	0.67	−0.15	0.41	−0.05	0.80	0.01	0.21
Social values	−0.62	0.43	−0.70	0.54	−1.14[c]	0.54	0.00	0.33	0.50	0.65	−0.11	0.17
Professional activities	−0.77[b]	0.46	−0.83	0.58	−1.70[a]	0.58	−0.08	0.36	0.62	0.69	−0.13	0.18
Social organisations	−0.68	0.48	−0.87	0.61	−1.52[c]	0.61	0.00	0.38	0.68	0.73	−0.18	0.19
Financial systems	−0.66	0.41	−0.73	0.51	−1.59[a]	0.52	−0.01	0.32	0.74	0.62	−0.13	0.16
Political power structures	−0.68	0.41	−0.73	0.52	−1.54[a]	0.52	−0.08	0.32	0.62	0.62	−0.14	0.16
No. of COVID-19 news articles	0.00	0.00	0.00[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COVID-19 situation												
Cases	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deaths	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hospitalisations	0.00	0.00	0.00	0.00	0.00[b]	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stringency	0.00	0.01	0.00	0.01	0.03[c]	0.01	0.00	0.01	−0.02	0.01	0.00	0.00
Constant	0.77[b]	0.40	0.94[b]	0.50	1.59[c]	0.51	0.05	0.31	−0.52	0.60	0.11	0.16

Scientific ethos omitted because of collinearity. The cumulative daily proportion of the NOS salience always sums to 1 and thus one category could not be put together in the model due to multicollinearity.
NOS, nature of science; VAR, vector autoregressive model.
[a] Significant at the 0.01 level.
[b] Significant at the 0.1 level.
[c] Significant at the 0.05 level.

often uses sensationalism to heighten public concerns.[58] For example, the scientific frame focused mainly on the biology of the virus and health impacts (e.g. symptoms and case/deaths) but lacked practical advice for individuals and communities.[59] This suggests that the media did not provide the public with the necessary information to make informed decisions.

In addition, social media platforms provide alternative means for public engagement in scientific communication during pandemic crises.[17,60] However, this could lead to the unintentional spread of misinformation.[61] Poor adherence, mistrust and public fear are factors that threaten the effectiveness of the public health measures to prevent the spread of diseases.[62] The present study, by identifying certain types of NOS salience in news media that were associated with changes in public mobility, can help the government and media publishers understand how scientific content in the media mediates community responses in future health crises. To help individuals make informed decisions and minimise the effects of the pandemic, it is important to disseminate scientific content in (social) media to prevent further spread of the virus in an effective and sustainable manner.[63]

Limitations

The present study was subject to several limitations. First, the study was limited by a lack of information on the distribution and size of the mobility data collected by Google. Furthermore, the data were only available for Android users whose location history had been turned on. Despite these constraints, multiple scholars have found that the data can be useful in predicting social phenomena.[34–36] In addition, although the Granger test results suggested that directionality was applicable for some variables, causality should be taken with a caution, as this study did not directly examine how exposure to news articles impacted individuals' behaviours. In addition, the manual coding of news articles might be influenced by the background and expertise of the coders. As NOS is a meta-characterisation of how scientific information was obtained in communicating public health crises, using a machine learning technique for processing news articles might not accurately capture holistic aspects of scientific works. This is counterbalanced by calculating intercoder reliability and providing an explanatory and transparent procedure of coding.

The study findings demonstrate the need to cover epidemics in responsible ways that emphasise how scientific information is generated and how risk information is shared. Even after the effects of COVID-19 have diminished, the public remain concerned and fear for their safety on public transport.[51] To restore public trust in public transport, the government and general practitioners need to promote and introduce specific measures,[64–68] possibly starting with the justification of sources and forms of scientific information in the news media.

Future research could further examine the geographical disparities and exposure to different media platforms within the same country or among different countries. The present study approach combines time series and content analysis, as well as using an interdisciplinary lens from science communication. This approach can be adopted to other interdisciplinary public health topics, such as air pollution in relation to climate change and physical activity in relation to emerging transport innovations, such as the e-scooter.

Finally, using a nuanced approach to the characterisation of science in health and risk communication, namely, through a robust framework on NOS, researchers may potentially uncover what aspects of science in health and risk communication in news media need to be clarified and emphasised for enhanced mobility response to crises such as the COVID-19 pandemic.[69,70]

Author statements

Ethical approval

Not applicable.

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Competing interests

The authors declare that they have no competing interests.

Author contributions

H.-Y.C. contributed to conceptualisation, data curation, methodology, software, visualisation and writing, reviewing and editing. K.K.C.C. contributed to conceptualisation, data curation, methodology, writing, reviewing and editing. S.E. contributed to conceptualisation, supervision, and review and editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2023.03.001.

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Original Research

Socio-economic inequalities in undiagnosed, untreated, and uncontrolled diabetes mellitus in Bangladesh: is there a gender difference?

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ABSTRACT

Objectives: We aimed to determine: (1) the prevalence and socio-economic distribution of undiagnosed, untreated, and uncontrolled diabetes mellitus (DM); (2) the relationship between socio-economic status (SES) and undiagnosed, untreated, and uncontrolled DM; and (3) if this relationship is mediated by gender.
Study design: Cross-sectional nationally representative household-based survey.
Methods: We used data from the Bangladesh Demographic Health Survey from 2017 to 18. Our findings were based on the responses of 12,144 individuals aged 18 years and older. As a measure of SES, we focused on standard of living (hereinafter referred to as wealth). The study's outcome variables were prevalence of total (diagnosed + undiagnosed), undiagnosed, untreated, and uncontrolled DM. We used three regression-based approaches—adjusted odds ratio, relative inequality index, and slope inequality index—to assess different aspects of SES differences in the prevalence of total, undiagnosed, untreated, and uncontrolled DM. We used logistic regression analysis to look at the adjusted association between SES and the outcomes after gender stratification to see whether gender status moderates the association between SES and the targeted outcomes.
Results: In our sample analysis, the age-adjusted prevalence of total, undiagnosed, untreated, and uncontrolled DM was 9.1%, 61.4%, 64.7%, and 72.1%, respectively. Females had a higher prevalence of DM and undiagnosed, untreated, and uncontrolled DM than males. When compared to people in the poor SES group, people in the rich and middle SES groups had 2.60 times (95% confidence interval [CI] 2.05–3.29) and 1.47 times (95% CI 1.18–1.83) higher chance of developing DM. When compared to individuals in the poor SES group, those in the rich SES groups were 0.50 (95% CI 0.33–0.77) and 0.55 times (95% CI 0.36–0.85) less likely to have undiagnosed and untreated DM.
Conclusions: In Bangladesh, rich SES groups were more likely than poor SES groups to have DM, whereas poor SES groups with DM were less likely than rich SES groups to be aware of their disease and obtain treatment. The government and other concerned parties are urged by this study to pay more attention to developing suitable policy measures to reduce the risk of DM, particularly among rich SES groups, as well as targeted efforts to screen for and diagnose DM in socio-economically disadvantaged groups.

Introduction

Diabetes mellitus (DM), a chronic metabolic condition, has become a major public health concern around the world.[1] In 2017, the prevalence of DM in persons over the age of 18 years grew from 4.7% to 8.8% globally, approaching epidemic proportions.[2] The essential measures for preventing DM complications and deaths are early diagnosis and treatment.[3–5] Undiagnosed and untreated DM have been linked to serious health consequences.[6–9] The number of persons with DM is growing worldwide, according to reports, and many of these people are still unknown.[10] One in every

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two persons (50.1%), or 231.9 million of 463 million adults with DM, is uninformed that they have the disease.[11]

Bangladesh has 8.4 million patients with DM, accounting for 10% of the South Asian population; the number of diabetic patients is expected to double to 16.8 million by 2030, placing Bangladesh in the top 10 countries with the richest prevalence of the disease.[12] Recent small-scale[13,14] and statewide[15,16] research have revealed that in Bangladesh, the percentage of diabetic patients who are aware of their condition (34.7%–41.2%) and the percentage of diabetic patients using anti-diabetic medication (25%–36.9%) are both quite poor. As a result, a lack of patient awareness and treatment regarding their DM status is a problem that must be addressed, which is usually avoidable with early identification of risk factors.

One of the important independent factors is socio-economic status (SES), and the impacts of SES on health and well-being are well known.[17,18] SES inequality exists in the prevalence, awareness, and control of DM in both developed and low-middle-income countries (LMICs),[13–15,19–22] according to evidence. DM is more common among poorer socio-economic categories in rich-income countries.[19,20,23,24] Evidence on the socio-economic gradient of DM in LMICs is equivocal, which could reflect changes in the gradient as nations progress through the epidemiological transition. However, there is evidence that people with social disadvantages in LMICs,[13–16,20–22,25,26] particularly Bangladesh,[13–16] where DM prevalence is among the highest in the world,[12] have less access to DM care and a higher risk of developing complications associated to the disease. These in turn may have a negative impact on social interactions, career possibilities, mental health, and educational opportunities, furthering the socio-economic and psychological conditions of DM individuals from low SES groups.[27] Surprisingly, initiatives to prevent and control DM in LMICs have not paid much attention to SES differences. Even in Bangladesh, the national health strategy to prevent and provide access to care for DM does not include an action plan to address SES inequalities. It is essential to have a better knowledge of the socially disadvantaged populations that experience the greatest barriers to accessing DM diagnosis and treatment in low-resource settings like Bangladesh, where rapid industrialization and urbanization over the past decades have increased SES inequalities.[28] The examination of SES inequality in the prevalence and care of DM in Bangladesh may be useful in other low-resource settings where there is high SES inequality and increased prevalence of DM but limited access to care.

Furthermore, in a patriarchal country like Bangladesh, where females were submissive to males in all aspects of their lives,[29] SES inequality in diagnosis, treatment, and control of DM needs to be explored in greater detail according to gender. Evidence reveals that there is a considerable difference in DM diagnosis, treatment, and control between males and females in Bangladesh[15,30] and other LMICs,[31,32] with DM affecting males more than females due to the fact that more males are diagnosed with the disease. Women were also found to be less likely than men to have untreated and uncontrolled DM. Men and women may have different rates of undiagnosed, untreated, and uncontrolled DM due to socio-economic inequalities.

DM women of poor SES may be at a distinct disadvantage when it comes to managing their disease because limited resources can limit their lifestyle-related behaviors, educational opportunities, healthcare-related knowledge, and access to health care and these likely drives a lack in acquiring DM-related awareness and a willingness to diagnose DM. As a result, a comparison analysis is needed to see if gender, which has an independent relationship with SES and/or DM care, can help to moderate the link between SES and undiagnosed, untreated, and uncontrolled DM.

Furthermore, although many have examined total DM prevalence (diagnosed DM plus undiagnosed DM)[21,22,25,26,33] and related risk factors, few population-based studies on the prevalence and risk factors for undiagnosed DM[6,7,13] have been conducted to date. The failure to diagnose DM is attributed to delayed access to DM therapy, which increases management expenses and worsens the disease's prognosis.[34] In addition to late diagnosis, managing DM is a difficult problem in Bangladesh and many other LMICs because few people with diagnosed DM seek therapy.[15,16,30,32] The long-term effects of DM could be fatal if untreated.[34] Furthermore, although DM treatment and management are significant public health interventions aimed at reducing morbidity and mortality and improving quality of life, prior research[21,22,25–27] on the prevalence of untreated and uncontrolled DM was scarce.

Until now, no studies have looked at socio-economic disparities in undiagnosed, untreated, and uncontrolled DM. Furthermore, although the scale of gender-based health inequities and the socio-economic factors that support them have been extensively established,[15,30–32] no research has been performed to see how the impact of SES differs between men and women with undiagnosed, untreated, and uncontrolled DM. The objectives of this research are to determine: (1) the prevalence and socio-economic distribution of undiagnosed, untreated, and uncontrolled DM; (2) the relationship between SES and undiagnosed, untreated, and uncontrolled DM; and (3) if this relationship is mediated by gender.

Methods

Data source and study population

The Bangladesh Demographic and Health Survey (BDHS) 2017–18 data were used in this study. The National Institute of Population Research and Training of Bangladesh's Ministry of Health and Family Welfare carried out the BDHS, a household-based probability sample of men and women that is nationally representative.[35] The BDHS 2017–18 gathers data on fasting blood glucose (FBG) biomarker readings, as well as other relevant data and social and economic features. As part of the DHS Program, ICF International offered technical assistance, whereas the US Agency for International Development provided financial help.

The BDHS uses a two-stage stratified sample of houses, with strata for rural and urban areas. In the first stage, primary sample units (PSUs) were chosen from the most recent 2011 Bangladesh census enumeration areas, with each PSU including an average of 120 houses. In BDHS 2017–18, a total of 675 PSUs were chosen, with a likelihood proportionate to PSU size.

The study contained 672 PSUs (three PSUs were not sampled due to floods), with 192 PSUs from urban areas and 480 PSUs from rural areas, respectively. The second stage involved randomly selecting 30 houses in each PSU to create statistically reliable estimates of health outcomes for the country as a whole, each of the eight divisions, and urban and rural areas separately.

Interviews were conducted in 19,457 of the 19,584 eligible households, resulting in a household response rate of 99.4%. One-fourth of the chosen families were interviewed for biomarker measurement, and 12,299 females and males aged 18 years and older were chosen for blood glucose testing. After removing the subjects with missing data, we were left with a total of 12,144 people to study (Fig. 1).

Measures

Outcomes

In the 2017–2018 BDHS, the blood glucose level was measured in whole blood obtained by finger prick from the capillaries in the

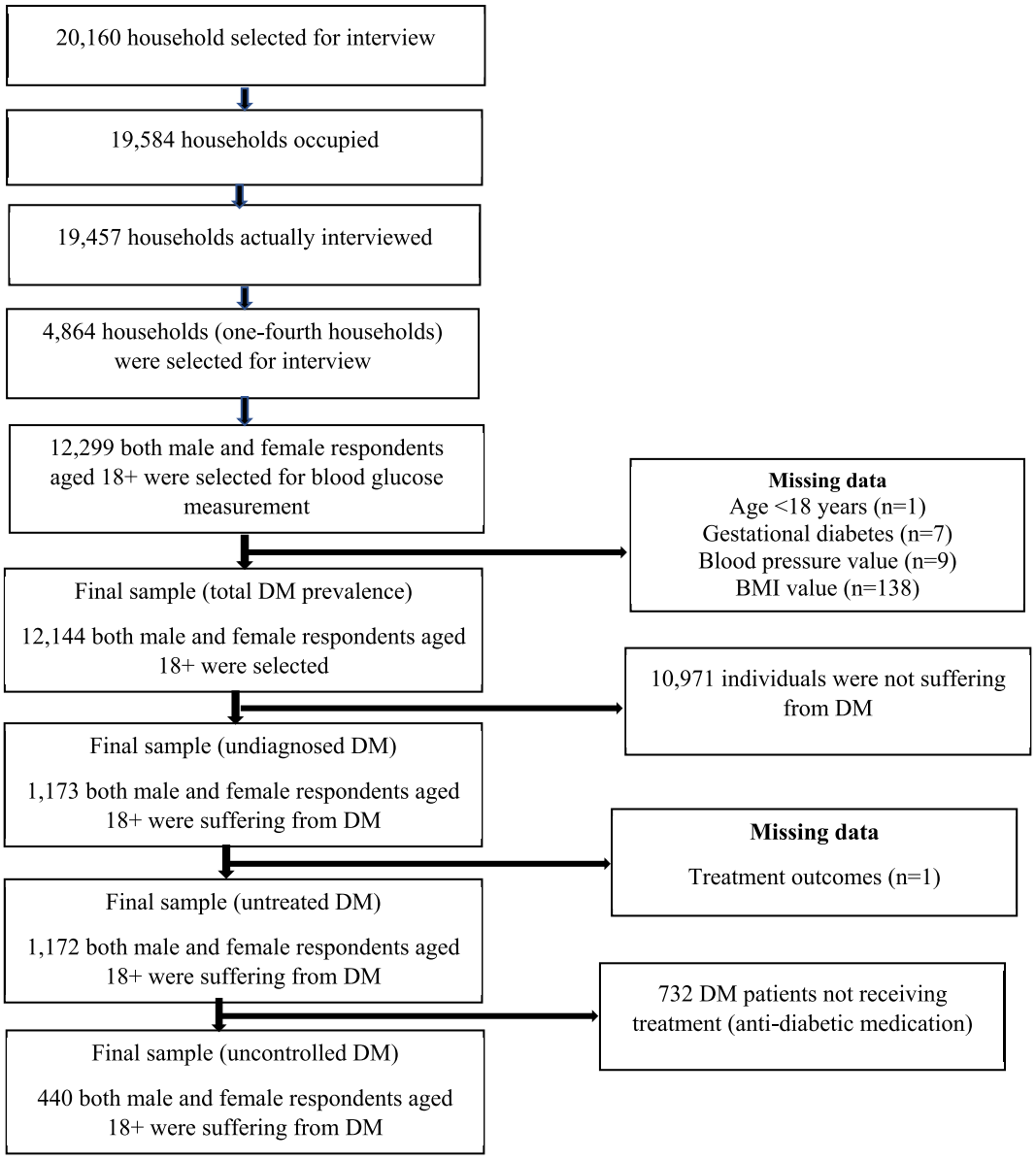

Fig. 1. Selection of the sample.

middle or ring finger after an overnight fast using the Hemocue 201+ blood glucose analyzer (Teleflex Medical L.P., Markham, Canada)—an approach that is widely used in resource-limited settings.[15] DHS adopted the definition of 'DM,' which is fasting plasma glucose greater than or equal to 7.0 mmol/L or use of anti-diabetic medication. The cutoff point for fasting plasma glucose according to this classification of 'DM' was based on WHO recommendations.[36]

Those classified as having DM were then categorized as: a) undiagnosed, if they reported never having been diagnosed (DM undiagnosed); b) untreated, if they reported not taking anti-diabetic medication (DM untreated); and c) uncontrolled, if the patients with DM reported currently using anti-diabetic medication and fasting plasma glucose ≥7.0 mmol/L (DM uncontrolled).

Exposure

We used a wealth index to proxy SES to evaluate socio-economic inequalities in DM and its diagnosis, treatment, and control. The BDHS wealth index is based on data on household assets, such as the proprietorship durable products (e.g. TVs and bicycles) and housing (e.g. source of drinking water, sanitation facilities, and construction materials). Each asset was given a weight (factor score) based on principal component analysis.[35] Following that, the asset scores were normalized using a conventional normal distribution with a mean of zero and a standard deviation of one. For each home, each asset was assigned a score, which was then summed together. The sample was then divided into population terciles, each of which was assigned a rating of zero (poor), one (medium), or two (rich). Individuals were ranked according to the total score of the house in which they lived.

Moderator

We categorized gender as a dichotomous variable (either male or female).

Covariates

This research also identifies several socio-economic and demographic factors that have been conceptually and practically

connected to the prevalence, diagnosis, and management of DM.[3,6–33] The respondents' ages were categorized as follows: 18–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, and 65+ years. We first categorized the age group of 18–34 years because DM used to be known as an adult-onset disease and there is evidence that the likelihood of developing the condition dramatically increases after the age of 34 years.[15,16,37] Then, because the patterns were generally consistent across all age groups after this, other groups were considered with a five-year interval. No education (0 year), primary education (1–5 years), secondary education (6–10 years), and richer education (11 years and more) were used to categorize the respondents' educational qualifications in terms of Bangladesh's official education system. The respondents were separated into two groups: patriarchal and non-patriarchal households.

The habitation location was classified as either rural or urban. Respondents' present marital status and employment position were also classified as no or yes categories. There were three categories for the number of adults in the family: 1–2, 3, and ≥4. There were two sorts of families in our study sample: small and large. The body mass index (BMI) was computed by multiplying the weight in kilograms by the squared height in meters (kg/m^2). According to the 2017–2018 BDHS report, for both men and women, a BMI of less than 18.5 kg/m^2 was deemed underweight, 18.5–24.99 kg/m^2 was regarded normal, 25–29.99 kg/m^2 was considered overweight, and 30 kg/m^2 or over was labeled obesity.

Statistical analyses

Using a direct standardization method, we calculated the age-adjusted prevalence of total DM (diagnosed + undiagnosed) in people. We used the age-specific Bangladeshi population aged 18 years and older for the census year 2011 to create a reference population for the age-adjusted prevalence estimates. We used the age distribution among DM in the study subjects as a reference population to estimate the age-adjusted percentage of undiagnosed, untreated, and uncontrolled DM.

To quantify several dimensions of socio-economic inequalities in the prevalence of total (diagnosed + undiagnosed), undiagnosed, untreated, and uncontrolled DM, we used three regression-based approaches: (1) adjusted odds ratio (AOR); (2) relative index of inequality (RII); and (3) slope index of inequality (SII). The RII and SII are regression-based inequality measures that consider the prevalence of total, undiagnosed, untreated, and uncontrolled DM across the entire socio-economic distribution in the study population, whereas the AOR only compares relative differences in total, undiagnosed, untreated, and uncontrolled DM between the most affluent and the most deprived groups.

According to Mackenbach and Kunst's directions, the SII was calculated.[38] The gradient was estimated using linear regression, with the age-adjusted prevalence as the outcome variable and the relative rank of the socio-economic measurement factor as the predictor variable. A negative SII means that the unfavorable health indicator decreases as SES increases, whereas a positive SII indicates that the health indicator increases as SES increases; a value of 0 indicates that there is no association between unfavorable health and SES.

For the relative rank of social class, the cumulative proportion of the sample in each category of social class was estimated. The midpoint was used as the code for the respective social classes. For example, for DM prevalence data, the poorest social class category included 33.8% of the individuals and therefore had a value of 0.169 (33.8/2), the middle social class category included 32.5% of the individuals and was assigned the value of 0.509 (0.338 + [0.342/2]) and the richest social class category included 33.7% of the individuals and was assigned the value of 0.841 (1 − [0.318/2]).

We used a modified Poisson's technique, as described by Zou,[39] to compute RII, which produces more robust estimates than the binary approach. When the RII is less than one, the poor are more likely than the wealthy to suffer unfavorable SHS repercussions. To assess each binary outcome variable, we developed four fully adjusted models, each of which included SES.

To see whether gender status moderates the association between SES and prevalence of total, undiagnosed, untreated, and uncontrolled DM, additionally, we conducted logistic regression analyses to examine the adjusted association between SES and the total, undiagnosed, untreated, and uncontrolled DM after stratification by gender. All of the covariates were entered into the multiple regression models at the same time. The absence of multicollinearity was determined by assessing the variance inflation factors, which were 2.0, indicating no multicollinearity.

To analyze the strength of the associations, we calculated the odds ratios and used the 95% confidence intervals (CIs) for significance testing. For all analyses, the significance level was fixed at $P < 0.05$. The results of this study were presented using the guidelines for Strengthening the Reporting of Observational Studies in Epidemiology. To account for sample weights based on the complicated survey design of the BDHS, all analyses were undertaken using Stata version 14.0 (StataCorp. LP, College Station, USA).

Ethical considerations

The data collection techniques for the BDHS were authorized by the ORC macro institutional review board. The National Ethics Review Committee of Bangladesh's Ministry of Health and Family Welfare examined and approved the survey protocol. Individual respondents' informed consent was sought before the interview began, followed by an oral explanation by the interviewers, as per the BDHS guidelines. Before the investigations, respondents were briefed and instructed about the relevance of fasting states. This study was exempted from full review as it was based on public usage of a secondary data collection that was anonymous and had no identifying information about the survey respondents. All study protocols were carried out in accordance with the principles of the Declaration of Helsinki as revised in 2013.

Results

Descriptive statists

Sociodemographic profile of the respondents

The sociodemographic characteristics of the respondents are shown in Table 1. This study included a total of 12,144 respondents. 73.4% of the respondents lived in rural areas, 88.1% of the respondents were in patriarchal families, and 45.1% of the respondents were between the ages of 18 and 34 years. Nearly 61% of respondents reported having jobs, 62.8% said they were part of a small family, and 36.3% said they had one or two adult family members. 90.2% of the respondents were currently married, and around 30% of respondents had only a primary education.

BMI calculations showed that 4.1% of the respondents were obese, 19.9% were overweight, 58.6% were normal weight, and 17.3% were underweight. In addition, around 34% of respondents were from the poor SES group, 34.2% were from the middle SES group, and the remaining 31.8% were from the rich SES group. The

Table 1
Descriptive statistics according to the age-adjusted prevalence of total, undiagnosed, untreated, and uncontrolled DM among individuals aged 18 years or older: 2017–2018, Bangladesh Demographic and Health Survey.

Measure	*n* (%)	Age-adjusted prevalence (95% CI)			
		DM (n = 12,144)	DM undiagnosed (n = 1173)	DM untreated (n = 1172)	DM uncontrolled (n = 440)
Age, yrs					
18–34	5443 (45.1)	5.1 (4.4–5.9)	85.8 (81.5–90.1)	87.5 (83.4–91.6)	80.8 (68.0–93.5)
35–39	1409 (11.5)	10.2 (8.3–12.1)	68.9 (60.3–77.5)	70.3 (61.8–78.9)	78.9 (65.9–91.9)
40–44	1047 (8.7)	12.5 (10.1–14.9)	66.8 (57.7–75.9)	70.7 (61.9–79.4)	72.3 (57.3–87.3)
45–49	1032 (8.3)	13.3 (10.9–15.6)	49.5 (39.4–59.7)	54.2 (44.3–64.1)	62.8 (49.2–76.4)
50–54	677 (5.6)	17.2 (13.9–20.5)	53.8 (43.9–63.7)	58.2 (48.1–68.3)	71.7 (57.4–85.9)
55–59	692 (5.7)	14.8 (11.8–17.7)	44.4 (33.2–55.5)	47.8 (36.5–59.2)	74.6 (62.0–87.2)
60–64	686 (5.6)	16.6 (13.4–19.6)	44.0 (33.8–54.3)	48.1 (37.8–58.4)	67.5 (54.2–80.9)
65+	1158 (9.4)	14.9 (12.4–17.4)	47.4 (39.1–55.7)	52.5 (43.9–61.0)	60.8 (48.7–72.9)
Education					
No education	2963 (25.3)	6.8 (5.5–8.1)	67.4 (61.6–73.2)	69.7 (63.9–75.4)	53.5 (45.9–61.2)
Primary	3674 (30.0)	9.4 (8.2–10.5)	69.3 (64.3–74.3)	72.5 (67.5–77.5)	67.8 (58.7–76.9)
Secondary	3515 (29.6)	11.4 (10.1–12.6)	51.1 (44.8–57.3)	55.8 (49.5–62.1)	83.7 (77.3–90.1)
Higher	1992 (14.9)	13.1 (10.9–15.1)	48.5 (41.9–55.2)	51.0 (44.2–57.8)	62.8 (51.6–74.1)
Gender					
Male	5241 (42.9)	9.1 (8.2–9.9)	58.6 (54.4–62.8)	61.8 (57.7–65.9)	72.1 (66.0–78.2)
Female	6903 (57.1)	9.3 (8.2–10.1)	65.4 (60.8–69.9)	68.8 (64.2–73.1)	72.7 (65.6–79.9)
Currently married					
No	1264 (9.7)	5.5 (2.0–9.0)	76.7 (75.4–77.9)	76.7 (75.4–77.9)	1
Yes	10,880 (90.2)	9.2 (8.5–9.9)	60.7 (57.5–63.9)	64.1 (61.1–67.2)	71.9 (67.2–76.7)
Currently working					
No	4728 (38.6)	11.8 (10.5–13.0)	59.3 (54.7–63.8)	62.2 (57.8–66.7)	74.9 (68.5–81.3)
Yes	7416 (61.3)	7.9 (7.2–8.6)	62.1 (57.9–66.4)	66.1 (61.9–70.2)	69.9 (63.1–76.7)
Living in a patriarchal household					
No	1377 (11.7)	9.6 (7.8–11.4)	56.9 (48.7–65.2)	63.6 (55.3–71.8)	80.9 (70.4–91.3)
Yes	10,767 (88.2)	9.1 (8.3–9.8)	62.2 (58.9–65.5)	65.0 (61.9–68.2)	71.3 (66.3–76.4)
Number of adult members[a]					
1–2	4286 (36.3)	8.8 (7.8–9.8)	62.8 (57.2–68.3)	65.6 (60.2–71.1)	61.6 (53.3–69.9)
3	2989 (24.6)	9.0 (7.7–10.3)	60.3 (54.7–65.9)	61.9 (56.4–67.50	72.6 (64.6–80.5)
≥4	4869 (38.9)	9.4 (8.3–10.5)	61.4 (56.7–66.1)	65.7 (61.2–70.2)	76.5 (68.5–84.6)
Family size[b]					
Small	7481 (62.8)	9.3 (8.5–10.2)	61.3 (57.4–65.1)	64.2 (60.5–67.9)	70.3 (64.2–76.4)
Large	4663 (37.1)	8.7 (7.6–9.8)	61.5 (56.4–66.6)	65.4 (60.7–70.2)	75.0 (68.5–81.5)
Place of residence					
Rural	7799 (73.4)	7.8 (7.0–8.6)	61.4 (57.2–65.7)	64.9 (60.8–68.9)	70.1 (64.2–76.1)
Urban	4345 (26.6)	12.7 (11.3–14.0)	61.1 (57.1–65.2)	63.7 (59.8–67.7)	74.9 (67.1–82.8)
BMI[c]					
Underweight	2080 (17.3)	5.8 (4.5–7.2)	78.9 (70.4–87.4)	78.9 (70.5–87.4)	55.3 (41.1–69.5)
Normal	7111 (58.6)	7.9 (7.2–8.7)	61.8 (57.7–65.9)	65.4 (61.5–69.4)	71.2 (64.6–77.8)
Overweight	2446 (19.9)	13.7 (12.2–15.3)	56.6 (51.2–61.9)	59.7 (54.4–64.9)	78.5 (70.7–86.2)
Obesity	507 (4.1)	18.8 (14.9–22.6)	48.5 (38.6–58.4)	55.6 (45.8–65.5)	74.6 (63.6–85.6)
SES					
Poor	4044 (33.9)	5.1 (4.3–5.9)	71.4 (65.1–77.8)	72.9 (66.7–79.2)	61.8 (48.7–74.9)
Middle	4048 (34.2)	7.9 (6.9–8.9)	64.6 (58.9–70.2)	68.1 (62.6–73.6)	70.2 (61.6–78.9)
Rich	4052 (31.8)	14.8 (13.5–16.2)	55.9 (51.7–60.2)	59.8 (55.7–63.9)	76.0 (69.8–82.3)
Prevalence		**9.1 (8.4–9.8)**	**61.4 (58.3–64.5)**	**64.7 (61.7–67.7)**	**72.1 (67.4–76.8)**

Note: CI = confidence interval.
[a] Number of family members 7 or over (based on mean number of members in a household).
[b] Number of adult members 18 years and older.
[c] The BMI categories were underweight (<18.5 kg/m^2), normal (18.5–24.9 kg/m^2), or overweight/obese (≥25 kg/m^2).

age-adjusted prevalence of total, undiagnosed, untreated, and uncontrolled DM in our sample study were 9.1%, 61.4%, 64.7%, and 72.1%, respectively.

The sociodemographic differences in total, undiagnosed, untreated, and uncontrolled DM are also shown in Table 1. The prevalence of DM was higher in the rich and middle SES groups (14.8% and 7.9%, respectively) than in the poor SES group (5.1%). However, in the case of undiagnosed DM, we saw the opposite situation: undiagnosed DM was higher in the poor and middle SES groups than in the rich SES group. The same thing happened with untreated DM: the poor and middle SES groups had more untreated DM (72.9% and 68.1%, respectively) than the rich SES group (59.8%). When compared to the middle and poor SES groups, 76% of the rich SES group had uncontrolled DM, which is greater than the middle and poor SES groups.

Multivariable analyses

Association between total, undiagnosed, untreated, uncontrolled DM with SES and other covariates

The AORs of the relationship between SES and the prevalence of total, undiagnosed, untreated, and uncontrolled DM in our study sample is shown in Table 2. When compared to people in the poor SES group, people in the rich and middle SES groups had 2.60 times (95% CI 2.05–3.29) and 1.47 times (95% CI 1.18–1.83) higher chance of developing DM. When compared to individuals in the poor SES group, those in the rich and middle SES groups were 0.50 times (95% CI 0.33–0.77) and 0.66 times (95% CI 0.43–0.99) less likely to have undiagnosed DM. When compared to individuals in the poor SES group, those in the rich SES group were 0.55 times (95% CI 0.36–0.85) less likely to have untreated DM.

Table 2
Adjusted odds ratio for the association between SES and other covariates with the prevalence of total, undiagnosed, untreated, and uncontrolled DM among individuals aged 18 years or older: 2017–2018, Bangladesh Demographic and Health Survey.

Measure	Adjusted odds ratio (95% CI)			
	DM (n = 12,144)	DM undiagnosed (n = 1173)	DM untreated (n = 1172)	DM uncontrolled (n = 440)
Age, yrs				
18–34	1.00	1.00	1.00	1.00
35–39	2.07 (1.61–2.65)[a]	0.39 (0.23–0.65)[a]	0.37 (0.22–0.63)[a]	0.79 (0.26–2.41)
40–44	2.76 (2.10–3.62)[a]	0.26 (0.15–0.44)[a]	0.27 (0.15–0.47)[a]	0.68 (0.22–2.12)
45–49	2.87 (2.19–3.76)[a]	0.16 (0.10–0.27)[a]	0.16 (0.09–27.1)[a]	0.55 (0.20–1.53)
50–54	4.31 (3.19–5.83)[a]	0.15 (0.09–0.28)[a]	0.15 (0.09–0.27)[a]	0.58 (0.20–1.69)
55–59	3.47 (2.59–4.65)[a]	0.10 (0.06–0.21)[a]	0.10 (0.06–0.18)[a]	0.49 (0.16–1.44)
60–64	4.25 (3.21–5.62)[a]	0.12 (0.07–0.21)[a]	0.11 (0.06–0.20)[a]	0.40 (0.13–1.16)
65+	3.54 (2.64–4.76)[a]	0.10 (0.06–0.16)[a]	0.10 (0.06–01.7)[a]	0.32 (0.12–0.88)[c]
Education				
No education	1.00	1.00	1.00	1.00
Primary	1.33 (1.10–1.61)[b]	1.08 (0.75–1.55)	1.13 (0.78–1.63)	0.78 (0.43–1.41)
Secondary	1.22 (0.99–1.52)	0.48 (0.32–0.71)[a]	0.50 (0.34–0.74)[b]	1.83 (0.94–3.52)
Higher	1.09 (0.83–1.45)	0.47 (0.29–0.77)[b]	0.48 (0.30–0.78)[b]	0.78 (0.37–1.64)
Gender				
Male	1.00	1.00	1.00	1.00
Female	1.27 (1.06–1.51)[c]	1.55 (1.10–2.19)[c]	1.61 (1.14–2.27)[b]	1.22 (0.69–2.16)
Currently married				
No	1.00	1.00	1.00	–
Yes	1.16 (0.81–1.67)	0.18 (0.04–0.79)[c]	0.22 (0.05–0.97)[c]	
Currently working				
No	1.00	1.00	1.00	1.00
Yes	0.69 (0.57–0.83)[a]	1.02 (0.74–1.39)	1.04 (0.75–1.43)	0.98 (0.58–1.65)
Living in a patriarchal household				
No	1.00	1.00	1.00	1.00
Yes	1.0 (0.78–1.27)	1.31 (0.86–2.00)	1.05 (0.69–1.60)	0.59 (0.29–1.20)
Number of adult members, 18+				
1–2	1.00	1.00	1.00	1.00
3	1.03 (0.85–1.25)	1.13 (0.79–1.62)	1.18 (0.82–1.69)	1.82 (1.0–3.31)
≥4	1.06 (0.85–1.33)	1.36 (0.91–2.04)	1.56 (1.04–2.35)[c]	2.14 (1.08–4.25)[c]
Family size				
Small	1.00	1.00	1.00	1.00
Large	0.84 (0.68–1.03)	0.76 (0.54–1.07)	0.70 (0.50–0.99)[c]	0.84 (0.47–1.50)
Place of residence				
Rural	1.00	1.00	1.00	1.00
Urban	1.12 (0.94–1.33)	1.21 (0.90–1.60)	1.16 (0.86–1.53)	1.02 (0.64–1.62)
BMI				
Normal	1.00	1.00	1.00	1.00
Underweight	1.33 (1.05–1.68)[c]	0.39 (0.23–0.67)[b]	0.47 (0.27–0.79)[b]	2.58 (1.0–6.67)[c]
Overweight	2.02 (1.55–2.63)[a]	0.42 (0.24–0.74)[b]	0.48 (0.27–0.85)[c]	3.28 (1.21–8.91)[c]
Obesity	2.45 (1.71–3.50)[a]	0.37 (0.19–0.74)[b]	0.49 (0.25–0.96)[c]	1.54 (0.48–4.90)
SES				
Poor	1.00	1.00	1.00	1.00
Middle	1.47 (1.18–1.83)[b]	0.66 (0.43–0.99)[c]	0.72 (0.47–1.09)	1.15 (0.56–2.38)
Rich	2.60 (2.05–3.29)[a]	0.50 (0.33–0.77)[b]	0.55 (0.36–0.85)[b]	1.22 (0.69–2.16)
Prevalence	**9.8 (9.1–10.2)**	**61.5 (56.4–62.0)**	**64.8 (59.6–65.2)**	**69.6 (63.6–72.4)**

Note: CI = confidence interval; AOR = adjusted odds ratio. Here a, b, and c indicate $P < 0.001$, $P < 0.01$, and $P < 0.05$, respectively.

The AORs of the association between other sociodemographic factors and the prevalence of total, undiagnosed, untreated, and uncontrolled DM are also shown in Table 2. Respondents aged 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, and 65+ years had significantly higher risks of getting DM but significantly poorer odds of undiagnosed and untreated DM than those aged 18–34 years. Respondents aged 65 years and older were also less likely to have uncontrolled DM than those aged 18 to 34 years. In comparison to the male population, females had a higher risk of developing DM, as well as having undiagnosed and untreated DM. In comparison to their counterparts, underweight and overweight respondents had a higher risk of acquiring DM and uncontrolled DM, as well as a decreased risk of undiagnosed and untreated DM.

Respondents with a secondary or higher education were less likely to have undiagnosed and untreated DM. Furthermore, those with a primary education had an increased risk of having DM.

The current working population was 0.69 times (95% CI 0.57–0.83) less likely than the non-working group to develop the disease. Non-married people were less likely to have undiagnosed and untreated DM than married people. A family with more than or equal to four adult members was linked to a higher risk of untreated and uncontrolled DM. Respondents with a large family size were 0.70 times (95% CI 0.50–0.99) less likely to have untreated DM than those with a small family size.

Summary measures of SES inequality

Table 3 shows summary measures of inequality. RII 1.53 indicates that a move from the bottom to the top of the SES distribution is associated with a 53% increase in the prevalence of DM. Whereas RII 0.92 and 0.93 indicates that a move from the bottom to the top of the SES distribution is associated with an 8% and 7% decrease in the prevalence of undiagnosed and untreated DM.

For DM prevalence, a value of 0.12 of SII indicates that the one-unit change from the bottom to the top of the SES group is associated with 0.12-unit decrease in the prevalence of DM. For undiagnosed and untreated DM, the value of −0.16 and −0.13 indicates

Table 3
Summary measure of SES inequality and the prevalence of total, undiagnosed, untreated, and uncontrolled DM among individuals aged 18 years or older: 2017–2018, Bangladesh Demographic and Health Survey.

Measure	Relative index of inequality (RII)	Slope index of inequality (SII)
	RR (95% CI)	β coefficient (95% CI)
DM	1.53 (1.38–1.70)[a]	0.12 (0.09–0.14)[a]
Undiagnosed DM	0.92 (0.85–0.98)[c]	−0.16 (−0.29, −0.03)[c]
Untreated DM	0.93 (0.87–0.99)[c]	−0.13 (−0.27, −0.04)[c]
Uncontrolled DM	1.04 (0.94–1.16)	0.09 (−0.13, 0.30)

Note: CI = confidence interval, RR = risk ratio. Here a, b, and c indicate $P < 0.001$, $P < 0.01$, and $P < 0.05$, respectively.

that one-unit change from the bottom to the top of the SES group is associated with 0.16- and 0.13-unit decrease in the prevalence of undiagnosed and untreated DM.

Association between total, undiagnosed, untreated, and uncontrolled DM with SES by gender

Table 4 shows the AOR for the association between total, undiagnosed, untreated, and uncontrolled DM with SES by gender. Male and female people in the rich SES group have a higher chance of having DM than their poorer SES counterparts. Respondents in the rich bands of wealth were less likely to be undiagnosed with DM than those in the poor bands, regardless of male or female. Respondents with a rich SES and who were female were less likely to have untreated DM (AOR 0.48, 95% CI 0.28–0.83) than those with a poor SES and who were female. Male respondents from the rich socio-economic strata were more likely than male respondents from the poorer socio-economic strata to report uncontrolled DM (AOR 6.34, 95% CI 1.43–28.1).

Discussion

This is the first study to show whether the association between SES and undiagnosed, untreated, and uncontrolled DM differs by gender in Bangladesh. The following are the five most important findings: 1) there was a considerable age-adjusted prevalence of DM (9.8%). Undiagnosed, untreated, and uncontrolled DM prevalence was 61.4%, 64.7%, and 72.1%, respectively; 2) females had a higher prevalence of DM and undiagnosed, untreated, and uncontrolled DM than males; 3) SES is important in a) predicting the likelihood of an individual developing DM, b) influencing an individual's undiagnosed DM, and c) influencing a patient's decision to take antidiabetic medication, according to the findings. 4) While SES had an independently detrimental effect on untreated DM, gender moderated the association; females from poor SES were more likely to receive treatment than females from rich SES; and 5) the association between DM control and rich SES was only evident in men.

The obtained age-adjusted DM prevalence (9.1%) was greater than that reported in other small-scale investigations in Bangladesh (crude prevalence 3%–7.9%).[13,14,40] Our findings are consistent with DM prevalence estimates from research conducted in adjacent South Asian countries such as India (11.1%),[41] Nepal (11.7%),[42] China,[43] Pakistan (11.1%),[44] and Sri Lanka (10.3%).[45] This alarmingly high prevalence of DM in Bangladesh is regarded as a warning indication of the disease's rapid spread. We should keep in mind that our age groups, study populations, measuring methodologies, and DM diagnostic criteria and definitions all have an impact on prevalence estimates. As a result, comparisons of our findings to data from earlier surveys should be made with caution.

According to the findings, 61.4% of diabetic patients were unaware of their disease, and only 35.3% were taking treatment. This is in accordance with a recent analysis from the International DM Federation, which found that more than half of diabetic patients in South Asia were uninformed of their disease.[46] Only 27.9% of persons with DM who were using anti-diabetic medication had normal fasting plasma glucose levels. This figure is significantly poorer than in wealthy countries.[47,48] Our findings, on the other hand, are similar to those reported in studies from other developing countries, such as China,[49] Nepal,[44] India,[50] and Kazakhstan.[51] In light of these circumstances, Bangladesh has to raise DM awareness among the general public, as well as provide appropriate education and follow-up for diabetic patients. Furthermore, given the poor control rate, rigorous interventions and greater clinical attention should be implemented as soon as possible among diabetic patients in order to lower blood sugar levels.

Gender and the prevalence of DM yielded varied results, with geographic location emerging as a crucial driver. Females were found to have a higher prevalence of DM than males in several developing countries, including India,[52] Indonesia,[53] Bangladesh,[54] China,[48] Nepal,[42] Nigeria,[55] and Tanzania,[56] in contrast to developed countries in the European region[57] and the USA,[58] where males were more likely to have DM. Although the exact mechanism for this finding is unknown, it is thought that multifactorial biological and environmental variables such as genetic risk, epigenetic factors, poor dietary quality, insufficient physical activity, and a higher prevalence of overweight/obesity influence the higher likelihood of DM in females.[59,60] In addition, an additional analysis was conducted in our study to corroborate this hypothesis, and it was found that the prevalence of overweight/obesity was higher among females than males.

According to numerous studies, men and women seek health care in various ways.[61,62] This study also discovered a significant difference in undiagnosed and untreated DM between male and female respondents, with females having a larger proportion of undiagnosed and untreated DM than males. The richer rate among women is likely due to the fact that in a patriarchal culture like Bangladesh,[29] men have a crucial role in determining a woman's health needs. Because men are the decision makers and have unlimited control over all resources, they decide when and where women should seek medical treatment. As a result, when a woman is sick, she is less likely to seek medical attention than a man. Furthermore, males had a richer rate of controlled DM. Discrepancies in treatment rates between men and women could explain some of the differences in control rates.

Table 4
Adjusted odds ratio for the association between total, undiagnosed, untreated, and uncontrolled DM with SES by gender among individuals aged 18 years or older: 2017–2018, Bangladesh Demographic and Health Survey.

Measure	Male[1] (AOR, 95% CI)				Female[1] (AOR, 95% CI)			
	DM	Undiagnosed DM	Untreated DM	Uncontrolled DM	DM	Undiagnosed DM	Untreated DM	Uncontrolled DM
SES								
Poor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Middle	1.87 (1.36–2.56)[a]	0.53 (0.25–1.11)	0.50 (0.23–1.06)	2.03 (0.48–8.61)	1.25 (0.94–1.64)	0.80 (0.48–1.34)	0.88 (0.52–1.48)	1.17 (0.47–2.92)
Rich	4.01 (2.85–5.65)[a]	0.45 (0.21–0.94)[c]	0.60 (0.27–1.30)	6.34 (1.43–28.1)[c]	1.91 (1.44–2.54)[a]	0.45 (0.26–0.79)[b]	0.48 (0.28–0.83)[b]	0.76 (0.30–1.92)

[1] Models were adjusted by age, education, marital status, working status, living in a patriarchal household, number of adult members in the household, family size, BMI, place of residence, and SES. Here a, b, and c indicate $P < 0.001$, $P < 0.01$, and $P < 0.05$, respectively.

This analysis revealed interesting links between SES and DM prevalence. The findings of nationally representative data from Bangladesh revealed that DM was more common among those of richer SES than among those of poorer SES. This is in contrast to the situation in Western countries,[23,24] where DM is more prevalent among those with poor SES. The food security and energy expenditure patterns among people in poor SES in the South Asian region should be considered when interpreting this contrast: food scarcity, poorer consumption of refined foods, and patterns of high energy expenditure due to moderate or strenuous physical activity at work.[18]

This study found that diabetic patients with a poor SES were less likely to be aware of their DM and were also less likely to be taking anti-diabetic medication. These findings are consistent with earlier research undertaken in both developed[19,20] and developing countries.[63,64] It is probable that the poorer percentage of undiagnosed and untreated DM among Bangladesh's poorer socio-economic groups is due to the high cost of DM care for those in poorer socio-economic groups. Families in Bangladesh with a monthly income of less than 4500 Taka (equal to 57 USD) are deemed poor,[65] according to one study, while the average yearly cost of DM care in Bangladesh is USD 314.[66] Another important finding was that the poor SES group showed a poorer probability of having normal fasting plasma glucose levels under treatment. Plausible explanations for the poor rate of control in the poor SES group are the poor level of awareness and treatment for the disease, lack of knowledge of the sequel of uncontrolled DM, and differing values with respect to the importance of the future.

The data also revealed that whether a patient was a woman or a man, rich SES had a detrimental effect on their likelihood of developing DM. The results suggest that gender was not a moderator in the association between having a rich SES and developing DM, and that this association was independent of gender. Both males and females who came from wealthy families were at a disadvantage in terms of their chance of developing DM. The findings also revealed that belonging to the rich SES group boosts the reduced risk of undiagnosed DM in both males and females, implying that it is poor SES per se for both males and females that disadvantages individuals with undiagnosed DM, rather than either male or female belonging to the poor SES group.

Another interesting finding was that gender moderated the association between untreated DM and poor SES; females from poor SES were more likely to have untreated DM than females from rich SES. The findings imply that having a poor SES has a detrimental influence only on the likelihood of untreated DM in women. This is due to the fact that impoverished women are more likely to live in areas of concentrated poverty, where they have limited access to quality education, career prospects, sufficient housing, sanitation, and food security.[67] Furthermore, research has shown that poorer living conditions, higher levels of food stress, and a lack of means to cope with hardship led to higher rates of non-use of health services.[68] As a result, women from poor socio-economic backgrounds were doubly victimized, as they were less likely to obtain treatment than women from richer socio-economic backgrounds.

Although there is no independent association between SES and uncontrolled DM, the study revealed that there was a link between uncontrolled DM and rich SES that only appeared in males. Males with a richer SES were more likely to have uncontrolled DM than males with a poorer SES. The apparent explanation is that in Bangladesh, wealthier males are more likely to be overweight/obese and live in sedentary lifestyles with less physical labor.[69] As a result, despite obtaining anti-diabetic medicine was richer among rich male SES groups, control rates were poorer.

Age was determined to be an important risk factor for the development of DM in several earlier studies,[70,71] and the prevalence of DM rose with age. In line with the findings of earlier investigations, our findings revealed similar evidence. This could be attributed to a lack of insulin secretion as a result of aging pancreatic function. Furthermore, the demand for insulin in the human body may increase in certain circumstances, or the body's insulin use may be inappropriate in the elderly.[72] Furthermore, increasing age has been shown to predict poorer daily physical activity levels,[73] with older persons having higher rates of insufficient physical activity, increased inactive time, and decreased physical activity.[73]

Undiagnosed and untreated DM was significantly associated with age in our investigation, with older people being more diagnosed and significantly and favorably associated with antidiabetic drug treatment. Other research in LMICs, such as Bangladesh,[16] India,[52] Nepal,[44] and China,[49] as well as developed countries,[74,75] have shown similar results. One argument is that as people get older, they are more likely to get DM, be aware of it, and have the financial means to get proper treatment. People aged 65 years and older were similarly less likely to have uncontrolled DM, albeit this could be explained in part by disease duration and a higher incidence of treatment in this group.

Education was found to be favorably associated with DM awareness and treatment, which is in line with earlier research.[15,16] Higher education may lead to more understanding about preventative health care and awareness of health services, as one possible explanation.[15] This study also discovered that having a large family was linked to a poorer probability of having untreated DM. Family members may pay attention to and support one another, which could be one of the explanations. Within the family, there is a learning and peer impact, making it easier to communicate with one another, share health-related knowledge, and improve health literacy to boost the usage of health services.[21]

Marriage is the most important factor of healthcare consumption, according to several previous studies.[76,77] In line with previous studies, we noticed that married people were less likely to have undiagnosed and untreated DM. Marriage may increase the use of DM health services by producing changes in lifestyle, health/illness awareness, and also by facilitating postponed/hidden illnesses due to social stigmatization.

Adult overweight or obesity is a well-established risk factor for DM,[54] and this study added to that knowledge. This study also provided evidence of the link between underweight and the development of DM, which is consistent with some of the paucity of research investigations.[54,78] Patients who are underweight are more likely to be older at the time of diagnosis, have an immunological component, and have a proclivity for specific pathophysiological characteristics, such as reduced insulin resistance and poorer insulin secretory capability.[54] Furthermore, nonobese people's risk of DM is impacted by heredity. Being under and overweight was also found to be more likely associated with to be undiagnosed, untreated, and uncontrolled DM.

Some of the study's strengths are as follows: i) in the study, it was discovered that DM is more prevailing in Bangladeshi males and females in the rich socio-economic group than in the poor socio-economic group, which contradicts findings from industrialized countries; ii) because this study used data from a nationally representative sample of adults aged 18 years and older from both rural and urban areas and a large number of subjects ($n = 12{,}144$), the results are representative of the entire adult population of Bangladesh; iii) the subjects were assessed by interviewers and biomarker professionals (health technicians or nurses), who went to the subjects' homes and questioned them and collected data. According to a manual created for this survey, biomarker staff and interviewers received training (classroom training and practical experience). Building rapport with a respondent, conducting a

successful interview, anthropometry measurements, HemoCue 201+ blood glucose testing, and hazardous waste disposal were all covered in the training; and iv) a rich participation rate (98%) was achieved through rigorous field staff training and close supervision of the fieldwork, giving the study good statistical power.

The following are the study's drawbacks: i) because the patients were a large number of people in communities, clinical record data such as history of DM and other diseases, and types of DM, were not investigated. Some of the people had never been to a hospital in their lives. However, this is not a significant constraint in terms of information on different types of DM, given type 2 DM affects approximately 95% of diabetic patients in Bangladesh; ii) the study only gathered minimal information about the individuals' lifestyles. It contained BMI-related characteristics, but not food habits or physical activity. Because healthy lifestyle choices, such as healthy eating and physical activity, can reduce the risk of obesity and the development of DM, we included overweight/obesity status in our analyses. Furthermore, because the proven connections between DM and SES were so strong, it is doubtful that including other lifestyle variables in the model would result in a non-significant link between predicting the likelihood of having DM and SES; iii) instead of serum glycated hemoglobin (HbA1c), the blood glucose level was assessed using the HemoCue 201+ blood glucose analyzer in whole blood taken by finger prick from the capillaries in the middle or ring finger following an overnight fast. The HemoCue 201+ is a well-known portable analyzer that is commonly used in community surveys, even in distant communities where maintaining a 'cold chain' in the field is impossible; and iv) only FBG levels were assessed in all subjects as markers of DM, the omission of impaired glucose tolerance testing and glycated hemoglobin level assessments could have led to an underestimation of the prevalence of DM.

Conclusions

This study found a relatively high prevalence of undiagnosed, untreated, and uncontrolled DM in the study area. Rich SES groups in Bangladesh were more likely to have DM than poor SES groups, whereas poor SES groups with DM were less likely to know they have it and less likely to get treatment than rich SES groups. The government and other concerned parties are urged by this study to pay more attention to developing suitable policy measures to reduce the risk of DM, particularly among rich SES groups, as well as targeted efforts to screen for and diagnose DM in socioeconomically disadvantaged groups. However, future longitudinal studies are needed to investigate the influence of potential mechanisms mediating the relationship between undiagnosed, untreated, and uncontrolled DM and SES.

Author statements

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Ethical approval

The data collection techniques for the BDHS were authorized by the ORC macro institutional review board. The National Ethics Review Committee of Bangladesh's Ministry of Health and Family Welfare examined and approved the survey protocol. Individual respondents' informed consent was sought before the interview began, followed by an oral explanation by the interviewers, as per the BDHS guidelines. Before the investigations, respondents were briefed and instructed about the relevance of fasting states. This study was exempted from full review as it was based on public usage of a secondary data collection that was anonymous and had no identifying information about the survey respondents. All study protocols were carried out in accordance with the principles of the Declaration of Helsinki as revised in 2013.

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None.

Competing interests

The authors state that the work was carried out in the absence of any commercial or financial relationships.

Data availability

The data sets used and analyzed during the present study are available from the Measure DHs website: https://dhsprogram.com/data/available-datasets.cfm.

Authors' contribution

MMK and MR were the ones who came up with the idea for the study, performed the key statistical analyses, and wrote the first draft of the manuscript. SEH, MJI, IFA, NHCD, PS, and NH provided feedback on the statistical analyses as well as the draft manuscript. MRI supervises the study. The final study was read and approved by all contributors.

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