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Review Paper

A systematic review of the nutritional status of adults experiencing homelessness

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ABSTRACT

Objectives: To identify, appraise, and describe studies focussing on the nutritional characteristics of people experiencing homelessness (PEH).
Study design: Systematic (narrative) review.
Methods: We identified full-text studies of any design and in the English language of adults (≥18 years) fulfilling the European Typology criteria for homelessness, based in community or hospital settings, and which report nutritional measures. Five electronic databases, 13 grey literature sources, reference lists, and forward citations were searched. Data on study characteristics and nutrition measures were collected and synthesised narratively. Risk of bias was assessed using relevant checklists for each study type.
Results: A total of 1130 studies were identified and retrieved. After screening, six studies were included for review: three cross-sectional studies; two case–control studies; and one randomised control trial, involving a total of 1561 participants from various settings including shelters, drop-in centres, hospitals, and hostels. All included studies were from high-income countries. Studies reported a range of nutrition measures including anthropometry (e.g., body mass index (BMI)), serum micronutrients and biomarkers, and dietary intake. Between 33.3% and 68.3% of participants were overweight or obese; 3.5%–17% were underweight; and low blood levels of iron, folate, vitamins C, D, and B12, and haemoglobin were prevalent. PEH consumed high amounts of dietary fats and alcohol, and low amounts of fruits and vegetables compared with national guidelines and housed individuals. There was moderate to high risk of selection and measurement bias and confounding in included studies.
Conclusions: A majority of PEH are within unhealthy BMI ranges and are deficient in serum micronutrients and nutritional biomarkers. Studies using large data sets that examine multiple aspects of nutrition are needed to describe the nutritional characteristics of PEH.
Registration: This systematic review is based on a prespecified protocol registered with the International Prospective Register of Systematic Reviews (PROSPERO CRD42021218900).

Background

Adult malnutrition is a major global health problem. Worldwide, it is estimated that 1.9 billion adults are overweight or obese and 462 million are underweight.[1] Diet is a significant contributor to the global burden of non-communicable disease (NCD) with 255 million disability-adjusted life years attributable to dietary factors.[2] Malnutrition is characterised by undernutrition (wasting, stunting, and underweight); micronutrient malnutrition (lack or excess of essential vitamins and minerals); and overweight, obesity, and diet-related NCDs such as cardiovascular disease, diabetes, and cancer.[3] Malnutrition increases vulnerability to illness and death via several mechanisms: by impairing the immune system, worsening infections and delaying recovery from illness; by reducing muscle strength and increasing fatigue, hindering activities of daily

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living (e.g., work, self-care); and by reducing psychosocial function.[4]

Malnutrition is spread unequally in populations and poverty heightens the risk of malnutrition. Those with low income and high food insecurity are more likely to consume energy-dense foods high in fat and sugar which, in high-income countries, are often cheaper and more readily available than healthier foods.[5] Conversely, nutrient-dense foods such as fruit, vegetables, low-fat milk, and wholemeal products tend to be less prevalent in the diets of those affected by poverty.[3,6,7] People experiencing homelessness (PEH) are particularly vulnerable to malnutrition because of a confluence of health and social factors. Homelessness can include several living conditions including a lack of shelter, sleeping rough, sleeping in temporary shelters, and having insecure or inadequate housing.[8] Compared with the general population, PEH are two to three times more likely to have chest, skin, and digestive problems, and are nearly twice as likely to have a diagnosed mental health problem.[9,10] A high proportion of PEH suffer from multimorbidity with an estimated median of six or seven long-term conditions, including physical and mental health problems and substance misuse.[11] This greater burden of poor health can deprioritise healthy eating, while poor nutrition exacerbates and contributes to the development of poor health.[6] The increased prevalence of health problems imposes greater nutritional requirements on PEH as energy and nutrient demands are higher during recovery from acute illness and whilst living with NCDs.[12] Drug and alcohol problems disproportionately affect PEH and pose further challenges to adequate nutrition, for instance, by impairing absorption of dietary nutrients and by reducing PEH's ability to engage with food services.[13] Moreover, a lack of fixed accommodation limits access to storage and cooking facilities and destitution leads to reliance on meals provided by shelters and soup kitchens, thereby limiting food choice.[6]

Despite widespread awareness of the challenging circumstances in which PEH live and the likely impact of inadequate nutrition, the literature assessing the nutritional status of this population remains sparse. To the best of our knowledge, there have been four literature reviews describing the nutritional characteristics of adult PEH.[13–16] Of these, two are systematic reviews focusing specifically on PEH with problem alcohol use; one of which describes nutritional deficiencies,[14] while the other examines interventions for preventing or treating malnutrition.[15] Although a large proportion of PEH are reported to have alcohol problems,[17] the focus on 'problem-drinkers' limits the generalisability of findings to the general adult population of PEH with associated over or underestimation of specific nutritional deficiencies. Of the remaining two reviews, one lacked a prespecified protocol,[16] the other lacked systematic and comprehensive searches,[13] and neither had transparent data synthesis. One of these reviews described the nutritional requirements and eating patterns of PEH in USA[13] and the other described the methods and limitations of previous research on the nutrition of adult PEH.[16] Both found inadequate nutritional intake in PEH, but the reported nutritional deficiencies varied between studies because of methodological heterogeneity and variations in endogenous diets, cultures, and food processing (e.g., flour fortification) across countries. However, vitamin C deficiency was a common finding and the overall importance of diet as a risk factor for acute and chronic disease was highlighted in both studies.[13,16] In addition, one review found that studies of PEH reporting measures of skin-fold thickness and muscle mass frequently identified 'wasting' but acknowledged that other studies reported higher proportions of PEH were overweight or obese than underweight.[16]

To the best of our knowledge, there are no previous systematic reviews of studies describing the nutritional characteristics of unselected adult PEH. We, therefore, aimed to systematically identify, appraise, and synthesise studies that describe the nutritional characteristics of the general adult population experiencing homelessness.

Methods

A prespecified protocol for this systematic review is registered with the International Prospective Register of Systematic Reviews (PROSPERO CRD42021218900).

Eligibility criteria

Inclusion criteria followed a 'Population, Exposure, Comparator, and Outcome' framework approach.[18] We included studies of adults (aged ≥18 years) experiencing homelessness from any setting, e.g., community or hospital. We used the European Typology of Homelessness and Housing Exclusion (ETHOS) criteria to define homelessness as the exposure: 'rooflessness (without a shelter of any kind, sleeping rough); houselessness (with a place to sleep but temporary in institutions or shelter); living in insecure housing (threatened with severe exclusion due to insecure tenancies, eviction, domestic violence); living in inadequate housing (in caravans on illegal campsites, in unfit housing, in extreme overcrowding)'.[8] We collected all available and relevant data for within-study comparators, e.g., normal reference ranges rather than applying a single comparator to all studies because reference ranges and dietary guidelines vary. Eligible outcomes were any objective or quantitative measure of nutrition, including but not limited to: levels of serum micronutrients or biomarkers (e.g., vitamins, iron, calcium, full blood count, haemoglobin, albumin); dietary intake (e.g., proteins, fats, carbohydrates, fruit and vegetables); and anthropometric data (e.g., body mass index (BMI)). We included studies of any quantitative design (e.g., descriptive studies, cross-sectional studies, and randomised controlled trials) conducted in any country. Searches were limited to the English language. For pragmatic reasons, we adapted our protocol to only include studies with a clear focus on nutritional characteristics and excluded literature reviews. To build on previous evidence and capture the most recent literature, the date limits for our search strategy were from the last review in 2014–2021.[16] Exclusion criteria comprised studies of incarcerated individuals and PEH due to extreme circumstances (e.g., earthquakes or tsunamis); and studies that examined nutritional content of meals offered to PEH rather than nutritional characteristics of PEH themselves.

Literature searches and study selection

Five electronic databases were searched from 1st January 2014 to 26th January 2021 (MEDLINE; Embase; PsycINFO; CINAHL; and Cochrane Central Register of Controlled Trials (CENTRAL)). The search strategy was adapted for each database and developed with input from a specialist librarian (CD) and a dietitian (MW). Table 1 shows the full search strategy for MEDLINE. Strategies for the remaining databases can be found in Supplementary Tables 1–4.

Thirteen grey literature sources were searched by a fourth reviewer (VP) in April 2021 using the following sources and strategies:

Table 1
MEDLINE Search Strategy 1st Jan 2014 to 1st Jan 2021.

Search Terms	
1. Homeless person*.ti.	35. (nutri* adj intake).tw.
2. Home?less*.ti.	36. (nutri* adj biomarker*).tw.
3. roof?less.ti.	37. (nutri* adj deficien*).tw.
4. House?less.ti.	38. (nutri* adj screening).tw.
5. (Home* adj2 lack).ti.	39. (nutri* adj characteristic*).tw.
6. (Home* adj2 no).ti.	40. body mass index/
7. (without adj2 home*).ti.	41. Anthropometry/
8. (lack adj2 hous*).ti.	42. anthropometric measurement*.tw.
9. (no adj2 hous*).ti.	43. calories.tw.
10. (without adj2 hous*).ti.	44. protein*.tw.
11. (lack adj2 roof*).ti.	45. (calor* adj intake).tw.
12. (no adj2 roof*).ti.	46. malnutrition/or deficiency diseases/or severe acute malnutrition/or starvation/
13. (without adj2 roof*).ti.	47. (disease adj related adj maln*).tw.
14. (inadequate* adj3 hous*).ti.	48. exp Nutrition Surveys/
15. (insecure* adj3 hous*).ti.	49. exp Blood Cell Count/
16. (insecure* adj3 tenan*).ti.	50. Full blood count.tw.
17. (unfit* adj2 hous*).ti.	51. folate.tw.
18. ((transition* or insecure or inadequate or substandard or sheltered or emergency or intermittent or transient or marginal* or problem*) adj (hous* or home* or accommodat*)).ti.	52. Vitamin B 12/
	53. Vitamin B 12 Deficiency/
	54. Vitamin D/or Vitamin D Deficiency/
19. (sheltered or unsheltered or shelters).ti.	55. Magnesium/or Magnesium Deficiency/
20. vagran*.ti.	56. Iron, Dietary/or Iron/or Anemia, Iron-Deficiency/
21. Destitute.ti.	57. C-Reactive Protein/
22. Skid?row.ti.	58. Calcium/or corrected calcium.tw.
23. (sleep* adj2 rough).ti.	59. hand grip test.tw.
24. ("street person" or "street people").ti.	60. 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59
25. unhoused.ti.	
26. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25	61. 26 and 60
27. nutrition assessment.tw.	62. limit 61 to (English language and humans)
28. (nutri* adj stat*).tw.	63. limit 62 to "all child (0–18 years)"
29. diet/or energy intake/or fasting/or food preferences/or exp hunger/or nutritional requirements/or nutritional status/or nutritive value/	64. 62 not 63
	65. limit 62 to "all adult (19 plus years)"
30. exp malnutrition/	66. 64 or 65
31. ?nourish*.tw.	
32. undernourish*.tw.	
33. malnourish*.tw.	
34. nutrients/or micronutrients/or trace elements/or vitamins/	

- KHP Pathway, Shelter Scotland, Crisis, Homeless Link, Revolving Doors Agency, and Lankelly Chase were searched using the term 'nutrition'.
- King's Fund, Grey Guide, GOV.UK, and Google Scholar were searched with the terms 'homeless; nutrition' — the first 100 outputs were screened for relevance.
- Open DOAR was explored but did not permit article searches.
- The British Dietetic Association and the American Dietetic Association were searched with the term 'homeless'.

Duplicates were removed and the remaining references were uploaded to DistillerSR software. All titles and abstracts and then selected and full texts were screened independently by two reviewers (HF and CH). Conflicts at title and abstract stage were resolved by discussion or full-text articles were screened if eligibility was unclear. Discrepancies at full-text stage were resolved by discussion or by involving a third reviewer (RL). During full-text screening, CH identified reviews with a focus on the nutritional status of PEH and searched the citations of reviews to identify additional articles.

Data extraction

Data extracted included: first author; publication year; location; study design; participant characteristics (age, sex, ethnicity); details of any comparators; definition of homelessness; and details of all nutritional characteristics reported and their results.

Risk of bias

Risk of bias (RoB) was assessed by CH using relevant tools for each study design: revised Cochrane risk of bias tool for randomised trials (RoB-2);[19] Critical Appraisal Skills Programme (CASP) case–control study checklist;[20] and the Joanna Briggs Institute (JBI) checklist for analytical cross-sectional studies.[21] Minor adaptations were made to the RoB tools to simplify their interpretation and provide overall scores (see Supplementary material). Studies that achieved 25–49%, 50–74%, and ≥75% of available points were classified as high, moderate, and low RoB, respectively.

Data synthesis

Studies were highly heterogeneous with respect to participants, methods, and outcomes. Therefore, meta-analysis was not appropriate and a narrative synthesis was conducted. Study findings were grouped and synthesised by type of nutritional data: anthropometric, micronutrient, and dietary intake.

Results

Study selection

The study selection process and reasons for exclusion at full-text level are shown in the PRISMA flowchart (Fig. 1). One thousand thirty studies were identified through electronic databases and 100 citations from grey literature. Six studies were included for review.

Study characteristics

Characteristics of included studies are listed in Table 2. There were two studies from UK,[22,23] two from South Korea,[24,25] one from Canada,[26] and one from USA.[27] Three were cross-sectional studies,[22,23,27] two were case-control studies,[24,25] and one was a randomised control trial (RCT).[26] Participants were recruited from a variety of settings and sample sizes ranged from 75 to 575 participants. Most participants were men (64–95%).

Risk of bias

Four studies included in this review had moderate RoB: three scored 50%[23,24,27] and one scored 60%.[26] One study had a high RoB (30%)[25] and one study had a low RoB (75%).[22] Sources of bias were similar across the studies with selection bias, measurement bias and potential effect of confounders being the primary contributors.

Study findings

Studies reported three broad categories of nutritional data: anthropometry, serum micronutrient levels, and dietary intake.

Anthropometry

Four studies[22,23,26,27] reported anthropometric data (Table 3). All four studies found high proportions of participants had an unhealthy BMI: 33.3–68.3% of participants were 'overweight or obese'

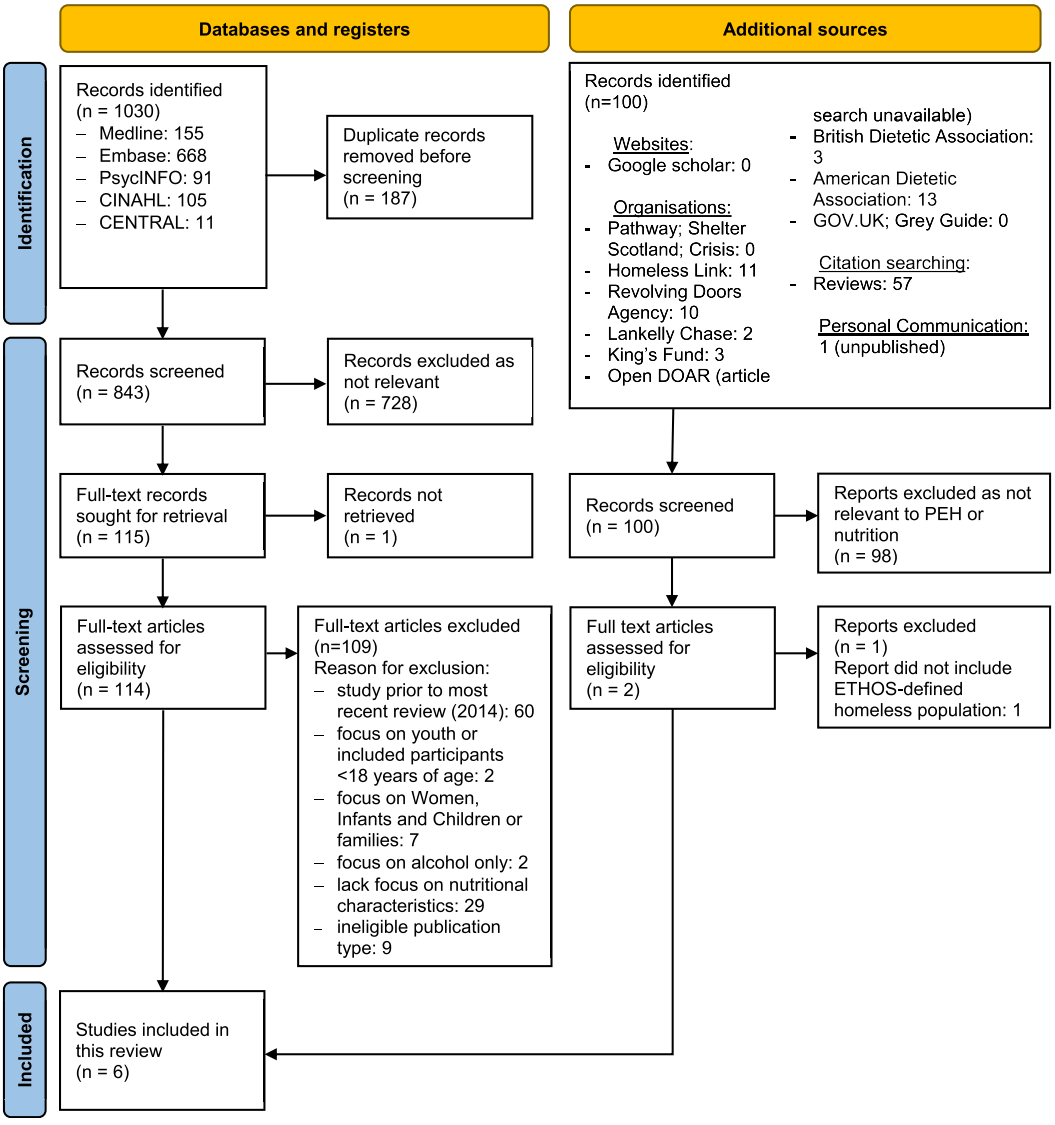

Fig. 1. PRISMA flowchart.

Table 2
Characteristics of included studies.

Study	Design	City, Country	Homelessness definition (study population)	Setting	*N*	Age, years	% Female	Ethnicity	Nutrition data reported
W-Melnik et al. 2015[26]	RCT	Toronto, Canada	Absolutely homeless[a] or precariously housed[b] (PEH with serious mental illness)	Shelters, drop-in centres, hospitals, outreach programs, mental health services, community centres	575	39.9[c] (11.8)	30.0	52.9% Minority ethnic groups 4.7% Aboriginal 42.4% White	BMI, Waist circumference
Hui Jai Lee et al. 2015[24]	Case-control	Seoul, South Korea	Not defined (PEH with acute alcohol intoxication)	Emergency room	217	51 (44.56)	4.1	Not reported	Serum biomarkers
Martins et al. 2015[27]	Cross-sectional	Rhode Island, USA	Not defined (PEH)	Local service for PEH	319	18–65[d]	36.0	47% White 20% African American 16% Hispanic, Latino 9% Mixed 5% Native American 1% Asian Pacific Islander 2% other	Weight, Height, BMI, Waist circumference
Fallaize et al. 2017[22]	Cross-sectional	Reading, UK	'Living rough' or in supported accommodation (PEH, and housed control group)	Drop-in centre or hostel	75 (+75 housed)	38 (11)	20.0	81% White 7% Black, African, Caribbean 3% Indian, Pakistani, Bangladeshi 9% Mixed	Food frequency questionnaire, BMI, Handgrip
Philipson et al. 2018[23]	Cross-sectional	Glasgow, UK	Registered with service for PEH (PEH)	Local service for PEH	196	40.8 ± 10.1	18.9	Not reported	Weight, BMI
Hui Jai Lee et al. 2019[25]	Case-control	Seoul, South Korea	Not defined (PEH and national survey data as control)	Emergency room	179	52 (47–58)	5.0	Not reported	Serum biomarkers

PEH, people experiencing homelessness; Age given in mean (±SD) or median (IQR); RCT, randomised control trial; BMI, body mass index.
[a] 'No fixed place to stay for at least the past seven nights with little likelihood of finding a place in the upcoming month'.
[b] 'Housed in single room occupancy, rooming house, or hotel/motel as a primary residence and in the past year have a history of two or more episodes of being absolutely homeless or one episode of being absolutely homeless of at least 4 weeks duration in the past year'.[28]
[c] Average of 'moderate' and 'high' care groups.
[d] Age range, average not reported.

Table 3
Anthropometric measures.

Study	Weight, kg	Height, m	BMI, kg/m^2	Waist circumference, cm	Handgrip, kg
W-Melnik et al. 2015[26]	–	–	26.4 ± 6.0[a]	93.0 ± 15.3[a]	–
Martins et al. 2015[27]	84.5 ± 23.3	1.70 ± 10.3	29.5 ± 7.8	97.5 ± 17.6	–
Fallaize et al. 2017[22]	73.3 ± 15.4	1.74 ± 9.0	24.5 ± 5.7	–	36.4 ± 8.4
Philipson et al. 2018[23]	71.4 ± 15.6	–	24.4 ± 5.1	–	–

[a] Baseline mean and SD for 'moderate and high need' groups were combined using Cochrane's formulae for combined mean and SD.[30] – not reported.

Table 4
Median (IQR) serum nutrient levels of PEH.

Study	Median serum nutrient levels (IQR)			
	Vitamins		Other	
Lee et al. 2015[24]	B1	145.8 nM/l (108.5–197.7) [a]Normal: 58–213 nM/l	Haemoglobin	14 g/dl (12.4–15.3)
	B6	34.2 nM/l (20.5–65.5) [a]Normal: 20–202 nM/l		
	B12	617 pg/ml (458–918) [a]Normal: 200–950 ng/l		
	C	11.6 μM/l (3.7–21.6) [a]Normal: 26.1–84.6 nM/l		
Lee et al. 2019[25]	B1	151 mmol/l (116–205)	Haemoglobin	13.8 g/dl (12.5–15.1)
	B6	34.1 mmol/l (22.1–53.3)	Albumin	4.0 g/dl (3.7–4.2)
	B12	572 pg/ml (392–804)	Calcium	8.7 mg/dl (8.4–9.1)
	C	4.1 μmol/l (1.5–12.7)		
	D	14.2 ng/ml (10.7–19.6) (Deficient <20 ng/ml)		

[a] Hospital laboratory reference ranges.

(BMI >25 kg/m^2) and 3.5–17% were underweight (BMI <18·5 kg/m^2). Waist circumference (WC) was reported in two studies.[26,27] In one study, 74 (30.9%) PEH participants were classified as 'overweight or obese' (≥102 cm for men or ≥88 cm for women) with a combined mean WC for both men and women of 93.0 (±15.3) cm.[26] The remaining study reported a mean WC of 97.5 cm (SD 17.6) in 313 PEH but the number of participants classified as overweight or obese by WC was not reported.[27]

In the only included RCT,[26] the authors examined the effect of a housing intervention on BMI and WC. At baseline, 121 of 245 (49%) and 74 of 239 (30%) of all participants were overweight/obese as measured by BMI and WC, respectively. Proportions of overweight/obese at 24 months follow-up were statistically significantly increased in both treatment and control groups: 137 of 245 (56%) and 88 of 239 (37%), respectively. However, there was no evidence of improvement in BMI or WC between the intervention and control group.

Handgrip strength, an anthropometric marker of nutritional status,[29] was reported in one study.[22] The results showed slightly lower mean handgrip strength in PEH (36.4 ± 8.4 kg) compared with housed participants (37.5 ± 9.2 kg).

Serum micronutrients and biomarkers

Three studies reported serum micronutrient and nutritional biomarker levels.[23–25] Data from 122 PEH registered with Glasgow's specialist Homelessness Health Service, showed 41 (33.6%) were anaemic, of whom 21 had additional blood tests to investigate the anaemia and the following were found to be deficient in eight participants: iron ($n = 1$), vitamin B12 ($n = 1$), and folate ($n = 6$).[23] A study from South Korea compared levels of vitamins B1, B6, B12, and C with hospital reference ranges in 217 PEH with acute alcohol intoxication (Table 4).[24] Median levels were within the normal ranges for all vitamins except vitamin C where 183 (84.3%) participants had low levels. Other abnormalities included five (2.3%), 51 (23.5%), and five (2.3%) participants with low levels of vitamins B1, B6, and B12, respectively. A retrospective chart review of 179 PEH from an emergency department in South Korea assessed vitamin D levels.[25] Using a nation-wide survey as a control, vitamin D deficiency was common generally, but PEH had lower vitamin D levels (15.7 ± 7.4 ng/ml vs 18.2 ± 5.5 ng/ml, $P < 0.001$) and higher proportions had severe vitamin D deficiency (18% vs 7.1%) (Table 4). Furthermore, vitamin D deficient participants had lower haemoglobin levels. Levels of vitamins B1, B6, B12, C, D, haemoglobin, albumin, and calcium were also reported but the absence of reference ranges precluded further comparisons.

Dietary intake

One study used a food frequency questionnaire to estimate daily intake of energy, macronutrients (carbohydrate, protein, and fat), key vitamins and minerals (vitamins A, B1, B2, B6, B12, C, D, E, iron, folate, calcium, iodine, zinc, and selenium), and food groups from PEH ($n = 75$) and a matched housed comparison group ($n = 75$).[22] A summary of these findings can be found in Supplementary Table 5. In general, the mean values for the intake of vitamins and minerals in PEH participants were similar to those of their housed counterparts except vitamin C intake, which was significantly lower in PEH (78.8 ± 58.9 mg vs 109.4 ± 62.5). However, compared to housed participants, salt, fat, and sugar intakes were significantly higher and carbohydrate and protein intake was significantly lower in PEH while there was limited evidence of any difference in total energy intake. There was greater variability across most nutrient levels in the PEH group, indicating greater variation in dietary intake in PEH compared with housed participants.

In the same study but examining main food groups, PEH consumed significantly higher amounts of alcohol (363 g (SD 593) vs 93.5 g (SD 185)), fats and oils (23.6 g (SD 20.5) vs 16.0 g (SD 11.2)),

meat (157 g (SD 109) vs 111 g (SD 54)), potatoes (94.0 g (SD 67.0) vs 66.3 (SD 50.3)); and significantly less fruit (96 g (SD 107) vs 260 g (SD 24)), nuts and seeds (3.4 g (SD 7.4) vs 9.9 g (SD 15.0)), and vegetables (205 g (SD 156) vs 244 g (SD 149)) than housed participants.

Similar results were found using 24-h dietary recall in a cross-sectional study of PEH ($n = 197$) in Rhode Island, USA.[27] PEH reported higher mean daily servings of grains (7.9 vs 6.0) and fats (74.0 vs 6.0); and lower mean daily servings of vegetables (2.8 vs 5.0), fruits (1.3 vs 4.0), dairy (1.1 vs 3.0), and meats and beans (2.2 vs 5.5) compared with national dietary recommendations.

Discussion

Summary of findings

Six studies met our inclusion criteria and described the nutritional characteristics of PEH. Their methods and quality varied and sample sizes were small. However, of studies that reported BMI, all consistently reported high proportions of PEH with unhealthy BMIs (overweight/obesity and underweight).[22,23,26,27] Vitamin C deficiency was highly prevalent in a group of PEH with acute alcohol intoxication.[24] While vitamin D deficiency appeared to be more prevalent in PEH attending hospital than in healthy controls.[25] Deficiencies in iron, folate, and vitamin B12 were also found in conjunction with low haemoglobin in PEH.[23] However, these micronutrient and vitamin deficiencies were seen in single studies only. PEH were found to consume higher amounts of dietary fats and lower amounts of fruits and vegetables when compared with both a housed comparator group[22] and national recommendations.[27]

Anthropometric characteristics reported in the Glasgow-based study[23] were comparable to those of another UK study[22] with similar proportions of participants found in overweight or obese BMI categories (33% and 37%), while studies carried out in North America[26,27] reported higher proportions of PEH in these categories (48% and 68%). The general shift in body composition from underweight to overweight/obese matches previous and more recent studies of PEH that did not meet our eligibility criteria.[7,31,32] However, the Glasgow-based study also reported a high proportion of individuals with an underweight BMI (17%), which could be related to high local rates of drug and alcohol misuse.[33,34]

Data on serum micronutrient levels were highly heterogeneous across studies making comparison difficult. Local reference ranges were not available for one study based in Seoul,[25] whereas another study, based in the same city, had reference ranges for only some micronutrients and identified deficiencies in vitamin C.[24] The third study with serum micronutrient data only reported proportions of participants with deficiencies in certain micronutrients such as iron, folate, and vitamin B12 rather than the micronutrient levels themselves and thus were not directly comparable.[23]

Comparison with previous reviews

Our findings suggest that unhealthy BMI (both overweight/obesity and underweight) could be more prevalent in PEH than previously thought.[16] A rise in overweight/obesity prevalence in PEH may be expected as part of the societal level obesity pandemic.[16] However, the suggestion of a concomitant rise in the prevalence of underweight is concerning and requires further investigation. Our finding of low vitamin C levels consolidates findings from previous reviews.[13,15,16] By way of possible explanation, previous literature described PEH's diets being high in dietary fats and alcohol, and low in fruit and vegetables.[13,16]

Implications of research in the wider context

The high rates of unhealthy BMI and vitamin C deficiency among PEH demonstrate the need for detailed nutritional assessments of this population involving multiple measures of nutrition rather than relying on single measures. For example, many PEH may have a BMI within the healthy or overweight/obese ranges yet have vitamin or nutrition deficiencies. Validated tools like the Malnutrition Universal Screening tool, which primarily uses anthropometry, could be used in conjunction with serum biomarker and vitamin levels for routine assessment of the nutritional status of PEH.[35] Furthermore, handgrip strength, a cheap and quick measure of malnutrition and physical function, could provide useful information if integrated into routine clinical services for PEH.[29] Interventions shown to be effective in increasing consumption of fruits and vegetables in PEH with problem alcohol use could be translated into practice to improve the nutritional status of PEH[12] alongside improved support for lifestyle changes including smoking cessation (cigarette smoking depletes vitamin C levels) and management of problem alcohol use.[36,37]

Evidence for the need to address malnutrition in the general population is strong. Meta-analyses show that early identification and management using oral nutritional supplements can reduce the risk of clinical complications of malnutrition by 70% and mortality by 40%.[38,39] Therefore, among PEH, where malnutrition rates are higher and more severe, identifying and addressing malnutrition could be expected to generate even greater benefits.

Strengths

To the best of our knowledge, there is no previous review of literature concerning the nutritional status of PEH with robust methodology involving a prespecified protocol, a comprehensive and systematic search strategy, transparent data synthesis, and quality appraisal. Therefore, this systematic review and its narrative synthesis provide a strong foundation for further research. The nutritional deficiencies observed in the included studies emphasise the need for the development of interventions to identify and treat nutritional deficiencies in PEH. This review identifies potential nutritional markers in PEH which could be targeted such as micronutrient supplementation and reduction of dietary fats and alcohol intake. Our review also highlights the dearth of literature that focusses on the nutrition of this vulnerable population. With only six studies included and with all studies being from high-income countries, more studies are required to understand the nutritional status of PEH from a wider range of settings and cultures.

Limitations

Our review focussed on the general adult homeless population to inform services and research into PEH more generally. Therefore, our exclusion criteria may have led to the omission of some relevant data (Excluded studies, Supplementary Material). For example, excluded studies of families or mother-child duos experiencing homelessness may contain relevant nutritional data. However, such studies do not always report adult and child data separately and, typically, specialist homelessness services exist to address the needs of these populations, including their nutritional needs (e.g., iron deficiency anaemia in women of childbearing age). Studies reporting the nutritional content of meals provided by shelters and NGOs may provide reasonable indications of nutrition intake in the absence of more direct measures of diet. However, these data were

excluded as they are insufficient to describe the nutritional status of PEH without additional associated nutritional data, e.g., the extent to which shelter meals contribute to overall dietary intake.

As with most research concerning PEH, included studies are limited by small sample sizes due to difficulties in recruitment of this transient and hard-to-reach population. Participants of studies in this review were recruited from settings such as shelters, drop-in centres, and hospitals. However, there are likely to be 'hidden' PEH who do not present at these settings for meals and have more extreme levels of malnutrition. The data reported in included studies were highly heterogeneous with BMI being the only standardised measure reported by some studies. Biochemical data alone is of limited value in the assessment of nutritional status and can change on a daily basis.[40] Two included studies, despite their focus on nutrition, only reported biochemical data, making their contribution to describing the nutritional characteristics of PEH more limited.[24,25] Finally, recruitment in these two studies was based on attendance at emergency departments and because acutely unwell patients are more likely have deranged micronutrient levels, data from these studies may not be representative of PEH more generally.

Conclusions

Unhealthy BMI (both underweight and overweight/obese) are more prevalent in PEH than in housed populations, as are high levels of vitamin C deficiency. Low levels of fruit and vegetable consumption are likely contributors to micronutrient deficiencies in PEH, alongside high levels of smoking and problem alcohol use. To the best of our knowledge, this is the first systematic review of the nutritional characteristics of adult PEH. However, extant studies are limited and heterogeneous, highlighting an evidence gap and the need for further research.

Author statements

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Ethical approval

This is a systematic review of literature and ethical approval is not required.

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Competing interests

All authors declare no competing interests.

Authors' contributions

RL conceived the idea for the project. CH, HF, and RL refined the research question and developed the study protocol. CH performed the database searches with supervision from HF, MW, and RL. CH and HF performed the study screening. VP performed the grey literature searches and screening. CH wrote the initial draft and HF, VP, MW, and RL made significant contributions to subsequent drafts. RL is the study guarantor.

Consent for publication

N/A

Availability of data and material

All data available is presented in the main manuscript and supplementary material.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.04.013.

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Developing a conceptual framework for flexible surge capacity based on complexity and collaborative theoretical frameworks

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ABSTRACT

Objectives: This study aims to develop a theoretical framework for the flexible surge capacity, inspired by existing surge capacity, complexity theory, and collaborative theoretical frameworks, and discuss its implementation and use in emergencies.
Study design: This was a descriptive study.
Methods: Theoretical frameworks for surge capacity, the complexity and resilience theory, and collaboration were reviewed and combined to develop a theoretical framework for the flexible surge capacity, incorporated with standard practical tools used in disaster and emergency management as interconnecting collaborative factors.
Results: The expanded number of disasters, public health emergencies, and the emergence of new risks and vulnerabilities indicate a complex situation and an apparent need to revisit the core of preparedness for unexpected incidents. Four crucial elements as parts of surge capacity, that is, staff, stuff, space, and systems, need to be considered in the planning and managing disasters and emergencies. Within the ordinary contingency plans, primary and secondary surges are planned and prepared. However, there are situations where those surges may not exist or are impossible to deliver. In such situations, available community resources should be used, described as flexible surge capacity. The flexible surge capacity framework incorporates a balanced and innovative process of integrating various resilience factors in complex incidents and collaboration among multiagency organizations.
Conclusions: The flexible surge capacity theoretical framework was developed. Nonetheless, further studies on the willingness of the medical and non-medical organizations to partake in the flexible surge capacity system are required.

Introduction

With an increasing number of disasters, public health emergencies, and armed conflicts, there has been a plethora of publications, which could have been categorized into several research topics, such as the 5Cs (command, control, communication, coordination, and collaboration), citizen participation, self-organization, risk perception, vulnerability, and the use of advanced technologies. These studies address the gaps and shortcomings of the management in all four phases of disaster management, that is, mitigation, preparation, response, and recovery.[1]

Such a broad change in disaster and emergency management demonstrates an obvious need to revisit the core of preparedness for unexpected incidents. In addition, global geopolitical changes, hybrid conflicts, climate change, and pandemics are new risks that create new vulnerabilities that influence the principles of disaster preparedness in a broad range of nations, from high-income to middle- and low-income countries. Moreover, one of the experiences gained in the current pandemic caused by COVID-19 was the need for a more comprehensive multiagency collaboration and the creation of diverse technical and practical innovations and measures.[2,3]

Two crucial factors need to be considered in the planning and managing disasters and emergencies that all constitute the four vital elements of surge capacity (SC). The first factor consists of the

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first three elements of SC, that is, elements that need to be scaled up or down during disaster management. These are staff, stuff, and space, often planned through contingency plans, using available resources within the organizations or facilities. The system is the second crucial factor and the fourth vital element of SC, that is, the guidelines and instructions that govern the quality and quantity of staff, stuff, and spaces. In most cases, the system is the contingency plan itself.[4] It describes how medical and non-medical management is organized to give staff a structural framework for working and prioritizing their activities. For years, emergency services in several countries, including Sweden and the United Kingdom, have implemented and used a joint framework, so-called the Joint Emergency Services Interoperability Principles, which were initially used by prehospital units but later used found to be useful even in hospital and clinical environments. These principles originate from MIMMS (Major Incident Medical Management and Supports) and are shortened as CSCATTT, which stands for command and control, safety, communication, assessment, triage, treatment, and transport. CSCATTT paradigm provides a systematic and structured approach for individuals and organizations involved in major incidents, both as a planning and evaluating tool.[5–7]

In practical terms, there is a primary capacity surge when disasters strike. According to the contingency plan (system), this surge targets the available staff, stuff, and spaces and is, in most cases, sufficient to overcome disaster challenges. However, with an extension of the process of the disaster or with simultaneous incidents elsewhere requiring central resources, a secondary surge is necessary. Both the primary and secondary surges should be seen as integrated parts of resilience. Still, the transition may create a complex situation when the process may happen simultaneously or in a random order.[8] This overwhelming situation can be understood with the help of complexity theory, which emphasizes interactions and the accompanying feedback loops that constantly change systems. Although it proposes that systems are unpredictable, they are also constrained by order-generating rules.[8] Such rules can enhance the interaction between diverse parts of the management system and the collaboration between organizations. Most healthcare systems are capable of a second surge based on their available but out-of-duty resources. Staff can be called into work and functional, but not used resources and spaces can be used.[4] Additional extension of an incident or a multidomain incident such as a terror attack, an armed conflict, or when the infrastructure necessary for delivering support is affected necessitates extra resources, which may not exist or be possible to deliver. Such a scenario should use the community resources and has been described as flexible SC (FSC).[7–9]

The idea of resource flexibility in disaster management is nothing novel and has been mentioned by several studies that have also targeted communities as a relevant resource.[10,11] However, the description of such a flexible system was first published in 2020, suggesting a partnership with diverse medical and non-medical institutions and facilities, led by public health authority.[9] There is a theoretical framework for SC, but a similar framework for FSC is missing. Such a theoretical framework should consider the multiagency involvement of several non-governmental and governmental organizations at the local level, which implicates a need for interaction and collaboration. Collaboration is a complex process that aims at building a relationship between two partners and typically encompasses factors such as trust, open communication, mutual respect, shared goals, and values among actively participating members to yield shared responsibility and decision-making.[12] A critical point in collaboration is to create interactivities using practical tools such as CSCATTT, which is widely used in emergency management.

This article aims to develop a conceptual, theoretical framework for FSC, inspired by the existing SC, complexity, and collaboration theoretical frameworks, and discuss its implementation and use in emergencies. A conceptual framework illustrates what can be expected through the research. It defines the relevant variables for the study and maps out how they might relate to each other. It also represents expected causes and the expected effects. These steps must be conducted before the details can be planned.[13]

Conceptual framework of SC

Inspired by the works of Hick et al.,[10,11] Bonnett et al. described the SC framework in 2006.[4] According to the authors and based on their review of published papers, there are several so-called surge-generating events. These events are either contained (geographically defined and the incident site is integral to the event, such as in bombings, tornadoes, flooding, etc.) or are population based (not defined geographically and can propagate throughout a population, such as pandemics, bioterrorism, etc.).[4] All these events cause a healthcare system to respond, expand, or scale up[9] in three broad areas: (1) public health SC aiming to increase the overall ability of the public health system to manage a significant incident, (2) facility-based, and (3) community-based surge capacities.

The latter highlights the significance of communities' off-site treatments facilities or as a unified area for command and control units to overview the multiagency operation and the work in healthcare facilities.[10,11] It also highlights the importance of a multilevel response to a disaster and that a response should be tiered, scalable, and flexible in treating many patients.[4,9]

It is not a secret that proper preparedness is built upon ordinary and daily activities and standards of care. With appropriate standards of care and daily operation, a facility can increase its volume with its available resources, and there is no need for modification in the system.[4] Disasters and emergencies influence the daily activities of health systems. A contained event requires immediate resources around the affected area and rapid transport of casualties to the hospitals, which may lead to overwhelming hospitals.[6] Such a situation requires extra resources, either being recruited from other hospitals or provided by evacuating non-disaster patients. Concern should be given to the event in which the hospital is a target itself. On this occasion, a total hospital evacuation is inevitable.[6] On the other hand, a population-based event requires proper isolation of infected or affected victims and selective transport to the hospitals. On such occasions, appropriate community care must be available to comfort patients and allow them to be tested and treated at home without seeking already affected hospitals.[14]

According to Bonnett et al.,[4] the surge starts as an intrinsic surge, including facilities and communities. A primary surge is a facility-based surge by activating disaster plans and implementing all steps and instructions. Operations will expand, but the situation will be contained within the hospital. In the second step, the community-based surge is activated when the situation expands. Off-site care centers and surge hospitals will start to work, overviewed, and supervised by municipal or regional coordination centers. The final step is when the community-based surge is not enough or available. This inadequacy indicates a need for extrinsic surge, which includes receiving assets from unaffected areas or evacuating victims to unaffected areas based on the type of event.[4]

Complexity and resilience framework

Using the vital elements of SC, Therrien et al.[8] expands the discussion on the needs of healthcare facilities to respond to an event by integrating the Hick et al. concept, which generates a model for health systems' readiness for and response to a wide

range of scenarios[15] to the strategies based on the four crucial elements of SC, that is, trained personnel (staff), supplies and equipment (stuff), rooms in which to treat patients (structure) and policies and procedures (systems),[16–18] and the concept of resilience, which from a crisis management perspective is the ability to "bounce back."[8,19] This response may indicate flexibility in the system (intrinsic) scale up and down and adjust its functioning before, during, or following changes and emergencies to sustain critical operations under expected and unexpected conditions.[20] It also means building capacity in crisis by reducing vulnerability and improving response planning. However, Therrien et al. noted that other organizational concerns in disaster and emergency management should also be addressed.

There is simply an interorganizational perspective that governs the connection between and dependency among organizations and influences the system's ability to respond to crises. Organizational resilience is thus partly dependent on the collaboration between various agencies' capacity to obtain accurate and recent information necessary equipment to jointly manage an influx of patients in each hospital and region based on previously negotiated coordination mechanisms and the power dynamics between organizations.[21,22] Complexity theory focuses on interaction dynamics, the unpredictable properties of interaction, and the relation between a system and its environment.[8]

Detailed and dynamic complexity is essential to manage such complexity as SC. The former is updated knowledge on the risk or etiology and management of scientific uncertainty, resources management, and internal decision-making and communication. The latter is the systematic management of stakeholders on municipal, regional, and national levels, the disparity, and inequity of the care between populations, and the risks presented by the public, policymakers, and professionals. To overcome these complexities and establish a robust network, common denominators found in 4S of SC can obtain interorganizational consistency. To develop and communicate various treatment or protective procedures to prevent early deaths or the spread of infection (system), to establish a unified triage system for assessment of patients (system), shared knowledge (staff), shared bed and equipment (stuff), are all examples of factors that can decrease the uncertainty, link diverse groups, facilitate resource coordination, and enhance the ability to respond.[23] Another essential tool that can be used in the event of disasters and emergencies to increase the compatibility of the multiagency management is the use of CSCATTT, which is part of MIMMS education in several countries.

Taking this conceptual theory into the World Health Organization's change of activity in disaster and emergency management from reactivity to proactivity,[9] the complexity of a crisis depends on the type of event, the presence of scientific uncertainty, and the speed at which it develops. Therefore, the response can be different if there is a pandemic or a terror attack.[8] In conclusion, Therrien et al. suggest a balanced and innovative process of integrating various resilience factors, building on a pragmatic approach based on complexity theory and the four "S" of SC.

Collaboration framework, incorporating CSCATTT

The collaborative framework aims at identifying and building those critical relationships that ease up and accommodate the process of achieving a goal. Fig. 1 shows the collaboration components. The words joint and shared are crucial to collaboration, which does initiate with cooperation, and coordination to end up with collaboration. From a theoretical perspective, two units start as separate entities, but they approach their final collaboration path, as they find mutual interests and contact points. Total collaboration is an

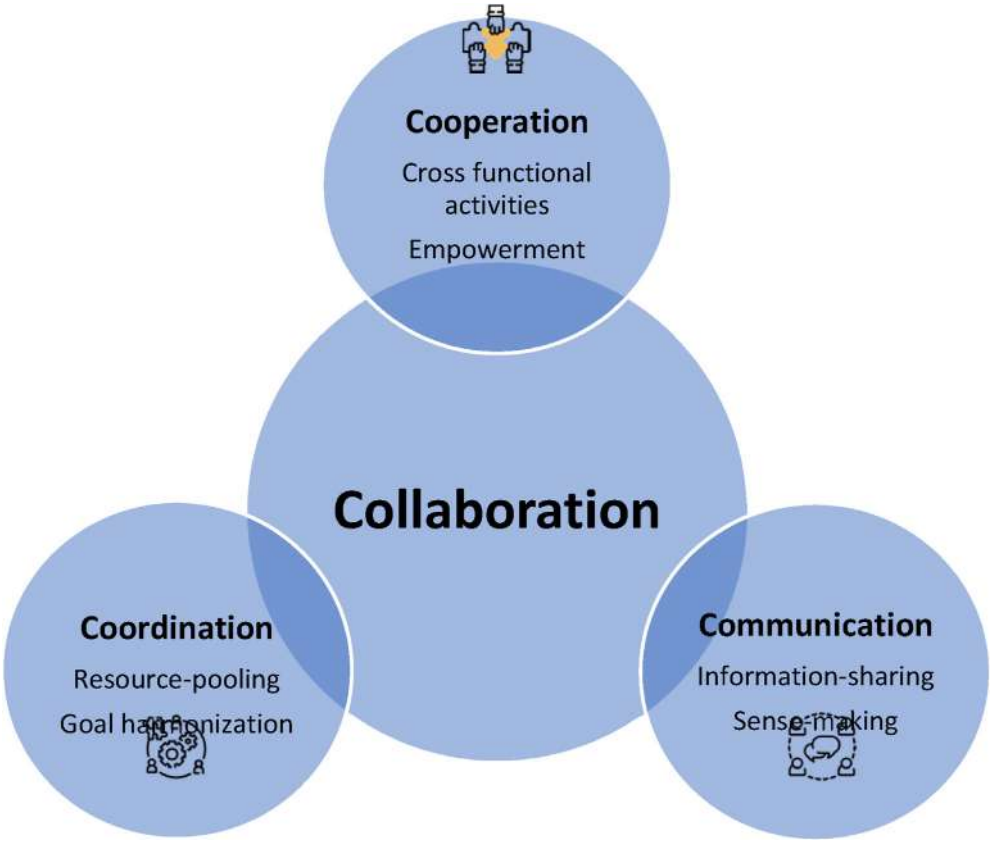

Fig. 1. Collaboration characteristics.[12,24,25]

integration process that lets units achieve a fusion. Fusion, however, is not a goal in disaster and emergency management because diversities are significant factors enabling the management of entire affected areas with diverse populations.[24,25]

Collaboration research emerges from several disciplines and professional fields. In their review, Patel et al.[24] found that the following are some essential factors for successful collaboration:

1. Context: This is the most critical factor determining the tasks and the types of individuals and teams working together. It also determines the kinds of support the collaboration needs.
2. Support: Appropriate support and resources can be decisive for the outcome of a collaboration. Well-designed teams with inadequate support are deemed to fail in their missions.
3. Tasks: Defining tasks is an essential factor in achieving the ultimate goals at all levels of response and engagement.
4. Interaction process: A collaborative approach requires an environment where collaborators engage in the interaction process, such as learning, coordination, communication, and decision-making.
5. Teams: These are individuals with shared tasks and common goals, a specified organizational function contributing to corporate objectives.
6. Individuals: These are people that interact to achieve collaboration. Individual performance (social and technical) is crucial to teams' performance.
7. Overarching factors: These are factors that are relevant to and interact with factors 1–6, such as trust, conflict, experience, goals, incentives, constraints, management, time, and performance. Trust is simply necessary for any collaboration, which may face disputes. A trustful relationship facilitates better communication, leadership, and the implementation of diverse security or medical measures. However, experienced people can overcome a conflict by having a clear goal and appropriate incentives. Constraints should enhance collaboration at its best, supported by decisive and trustful management, knowing that almost all factors inherent to collaboration and interactions will change over time and may influence the performance and outcome.

From disaster and emergency management perspectives, the context is the etiology of the incident, which needs support and teams that can work on the scene. Each team needs to have defined tasks performed by educated individuals. As disaster management is a multiagency performance, there must be an interactive process, that is, learning from each other, coordinating, communicating, and enhancing the mutual decision-making, which requires a mutual assessment of the situation. The communication and interaction between teams and organizations or the overarching factors can be expressed as CSCATTT, used as a planning and evaluation tool. Consequently, it can also be used as interaction points during interagency collaboration. It facilitates all necessary parts of collaboration, that is, cooperation, coordination, communication, information sharing, cross-functional activities, resource pooling, sense-making, empowerment, and goal-congruence. It also clarifies the benefits and challenges in collaboration.[25]

Conceptual framework of FSC

Having adopted SC theoretical framework adding the complexity and collaboration frameworks, Fig. 2 shows the FSC framework development. The concept is useful when the extrinsic surge has been initiated. In the Bonnett framework, after a hospital surge, the community resources are called in before going to extrinsic resource surge. Community resources in this model are medical facilities in the affected community. In contrast to Bonnett's model, the extrinsic surge in FSC starts directly after a failure in the facility-based surge. Then the first approach is to ask from other similar facility resources locally, regionally, and nationally. Suppose these resources are insufficient or cannot be delivered due to infrastructure disruption around the incident site. In that case, an FSC may initiate and use medical and non-medical facilities within the community.

Such surge results in two different approaches on the incident sites, depending on whether it is a contained event or a population-based event.[4] The resources could be recruited to the incident site or the affected area could be evacuated. In most scenarios, staff, stuff, and to some degree even space (field hospital) can be brought to the affected areas. However, this may not be possible with affected infrastructures, requiring community resources. In a population-based scenario, medical facilities cannot risk having infected individuals admitted to the hospital. Thus, community resources could be used to serve those remaining at home without overwhelming and threatening hospitals' capacity.[4,6,8,9]

Both scenarios require an FSC, including medical and non-medical resources. The FSC framework suggests medical resources be divided into certified and authorized primary and allied healthcare centers, including dental and veterinary clinics, physiotherapists, and pharmacists. The non-medical resources, according to an FSC framework, refer to all public and private facilities in the local area, such as schools, hotels, sports complexes, and similar facilities. Implementing such a system requires legal and individual willingness and a set of interactions points that enhance and facilitate collaboration between different units and agencies. Viewed from a theoretical perspective of complexity, FSC suggests a stepwise action of different levels of society to activate available local resources, but it may not follow a stepwise presumption.[9] Future investigations should investigate legal requirements for the implementation of FSC, but the willingness of individuals, both professional and lay people, should also be evaluated. Previous reports[26–29] have already shown that healthcare workers may not be willing to work under some circumstances, whereas laypersons seem eager to do more on the scene. These issues need to be discussed and clarified in future research.

Another critical point of discussion is the leadership of this community-based organization. Khorram-Manesh (FSC) proposed public health professionals as the ones who could carry this responsibility because of their broad experience in community work and knowledge of community health issues. However, using other specialists in different positions may also be needed. Irrespective of who will take part and how this system will be created, multiagency collaboration requires training in all interaction points, for example, as part of the collaboration, learn about Incident Command System, how command and control works, and how it can bind various organizations, horizontally, and own organization, vertically. A mutual understanding of leadership facilitates better communication in safety and management areas. In addition, it results in achieving a common situation assessment that further accommodates better management within the healthcare facility, the triage, treatment, and transport areas. The latter three needs are also considered multiagency tasks, particularly in mass casualty situations and in a case that requires other resources than the involved professional assets. These collaborations allow primary triage of victims and treatment of light injuries by allied healthcare workers and a new logistics line that may involve both allied healthcare workers and laypeople.

As disasters and emergencies needing an FSC are rare, table-top exercises and simulations should be used to understand FSC's usefulness better. Current pandemics and the Ukraine conflict present opportunities to test home isolation care and hospital evacuation as two scenarios that can engage the community's

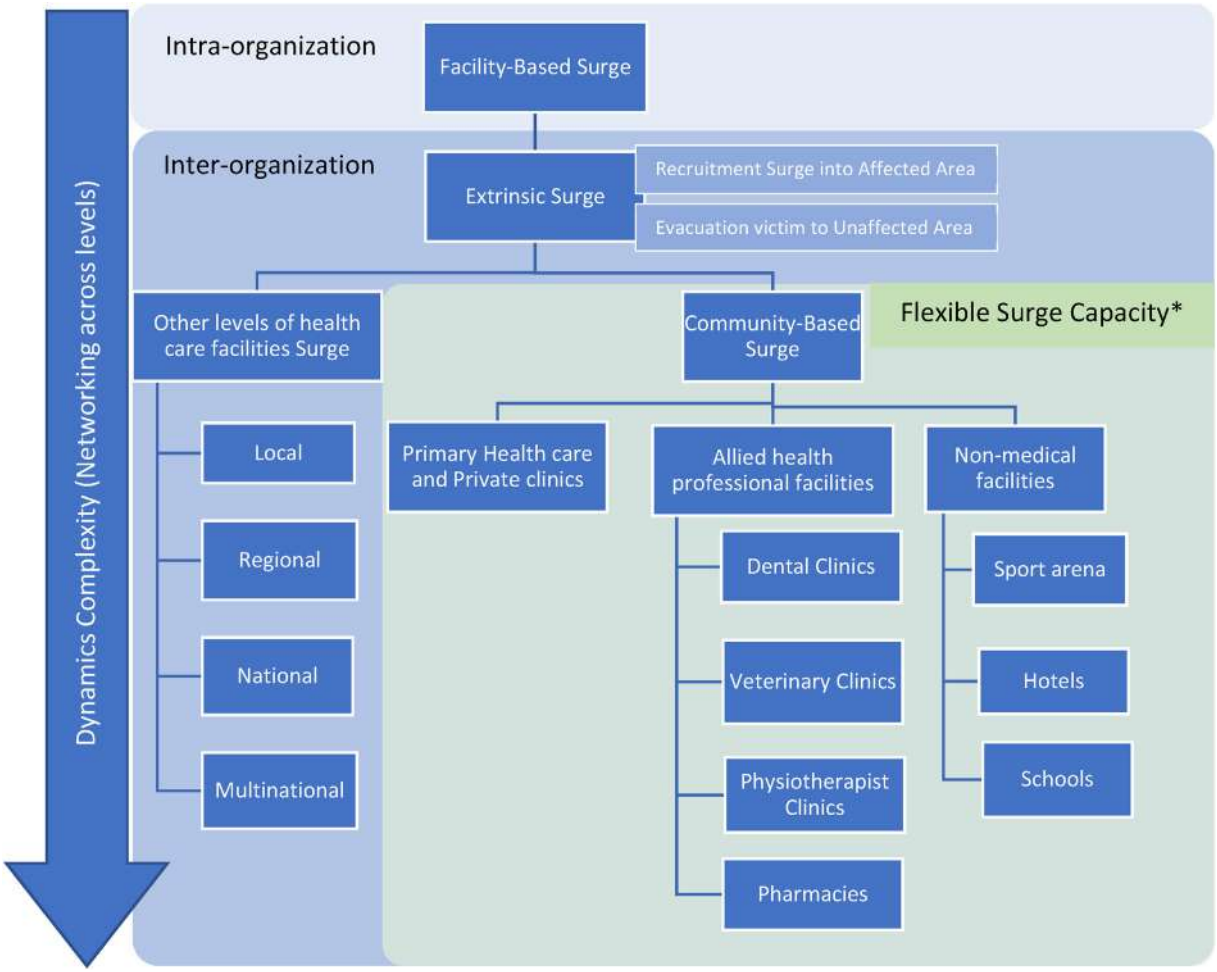

Fig. 2. Surge capacity framework incorporating the Flexible Surge Capacity. *This surge capacity will be recruited in case of failure in all other surge capacities.

resources. From an organizational perspective, the sustainability of collaboration depends on the factors, the benefits, and the challenges obtained from collaborating. These items can be trained and tested to help organizations understand and better collaborate to maximize benefits and the challenges curtailed.[30–32]

Conclusions

In conclusion, this paper has described the theoretical framework for the FSC, its use, and implementation. A conceptual, theoretical framework is necessary to understand the relevant variables for the need and use of FSC before the details at the local level can be planned. For years the topic of "surge capacity" has primarily been operating on a larger scale; the benefit of FSC is to bring the concept down to the individual, the family, and community level, where it truly belongs. FSC does not campaign for independent action of each facility. Still, a collaboration, allowing each facility to do what it is best to do, for example, hotels and restaurants can provide food services, and schools can take care of children and victims in need of shelter, etc., working throughout disasters and emergencies, and led by authorities such as public health with the knowledge in prevention and community-based healthcare management (e.g. infectious diseases). Future studies are needed to investigate the willingness of diverse medical and non-medical organizations in taking part in such a system to test and evaluate the system in an event when the population should not overwhelm a hospital, such as in the current coronavirus pandemic, and in a situation when the hospital needs community resources, such as in an incident, leading to hospital evacuation, for example, armed conflict.

Author statements

Ethical approval

Ethical approval for this study was waived because there was no human or animal in the methods and results of the study.

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Competing interests

None declared.

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Original Research

Ecological factors associated with areas of high tuberculosis diagnosis delay

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ABSTRACT

Objective: We aimed to identify areas of high tuberculosis (TB) diagnosis delay in mainland Portugal in 2017 and ecological factors associated with these areas.
Study design: This was an ecological study.
Methods: We considered all notified pulmonary TB cases from the Portuguese National Tuberculosis Surveillance System in mainland Portugal. Diagnostic delays were calculated at the municipality level. Demographic variables, proxies for TB awareness, health services capacity indicators, and socio-economic variables were included and extracted from official databases, such as Statistics Portugal, Ministeries, Foreigners and Border Services. We used spatial analysis to identify areas of high delay in 2017 and logistic generalised additive models to identify ecological factors associated with the identified cluster.
Results: We identified an area of high delay in 2017 in the South region of the country. Overall, municipalities with a smaller population density, smaller proportion of unemployed, fewer health centres and higher old-age dependency ratio, proportion of men, TB incidence, proportion of immigrants and high school dropout had a higher probability of belonging in a high delay area.
Conclusion: The role of primary health care in TB diagnosis should be further explored. Interventions should address factors interplaying at the local and individual levels. Policies influencing social and health conditions, leading to changes in individual behaviour, can lead to sustained improvements over time.

Introduction

Tuberculosis (TB) remains one of the most severe infectious diseases and a serious public health threat worldwide.[1] The World Health Organisation estimated that in 2018 10.0 million people fell ill with TB.[2] Portugal has made significant improvements over the past 15 years, reducing its incidence, per 100,000 inhabitants, from 28 in 2008 to 18 in 2019.[3] However, Portugal is still among the European countries with the highest TB incidence.[4]

Delays in diagnosing threaten TB control because they increase the likelihood of community transmission, untreated, undiagnosed or misdiagnosed individuals continue spreading to others. Delays in diagnosis might also lead to higher morbidity and mortality because the longer individuals remain untreated higher is the risk of chronicity and death.[2,5] Hence, reducing diagnostic delays, that is, the time from symptoms onset to diagnosis, is mandatory to control TB. Diagnostic delay can be further divided into patient and health services delay, time since symptoms onset and first contact with health services, and time since the first contact with health services and diagnosis, respectively. Both delays should be addressed to decrease diagnostic delay. Several studies identified factors associated with delays in TB diagnosis at the individual level, such as low disease awareness,[6,7] living in rural places,[6,7] gender,[6,7] number and

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type of health facilities visited,[8] comorbidity with HIV,[9] socio-economic status[10] and cultural barriers.[11] Although individual-level studies are critical to drawing healthcare and patient-level interventions, understanding the spatial disease distribution and factors associated with higher delays is crucial to propose local prevention and control strategies. Yet, we are not aware of studies regarding factors associated with delays at the local level. Thus, we aimed to identify areas of high delays in mainland Portugal in 2017 and ecological factors associated with these areas.

Methods

Study design, population and study period

We conducted an ecological study, considering all notified TB cases from the Portuguese National Tuberculosis Surveillance System in mainland Portugal between 1 January 2008 and 31 December 2017. We included pulmonary cases of TB who were identified through passive case finding (presenting symptoms). Diagnostic delay was defined as the time between symptoms onset and TB diagnosis. Patients reported the month and year in which they experienced symptoms. We imputed the first day of the month for each case, then calculated the diagnostic delay. Inconsistent dates, such as the negative number of days, patients with missing symptoms onset date, and diagnostic delay higher than 365 days or negative time, were excluded. The municipality of residence of each patient was also extracted. After selecting individuals, diagnostic delays were calculated at the municipality level and by year.

Variables

We extracted information at the municipality level from official databases, such as Statistics Portugal and Ministeries, Foreigners and Border Services. Variables were selected based on the literature and data availability. We included variables on several dimensions: (1) demographic, including population density, old-age dependency ratio and proportion of men per municipality; (2) TB and HIV incidence; (3) health services capacity, using the number of doctors and the number of public health care centres per municipality; and (4) socio-economic, which considered the proportion of immigrants, unemployed, the number of high school dropouts, the existence of prison establishment in the municipality and the incidence of social income beneficiaries. Table 1 displays information on the variables selected.

Statistical analysis

Our analysis followed a two-step approach: (1) identification of high delay areas and (2) analysis of ecological factors associated with these areas.

High delay areas

We calculated the mean number of days between symptoms onset and TB diagnosis for each municipality and year of diagnosis. Areas of high delay were then identified using SaTScan 9.6, which detects spatial, or space-time, clusters.[12] Using data from 2017, we conducted a spatial analysis to identify the most recent high delay areas. As a sensitivity analysis, we conducted a spatiotemporal analysis to understand whether the high delay areas identified in 2017 were similar to those identified over a decade between 2008 and 2017. The spatial unit used was the municipalities, considering only mainland Portugal ($n = 278$). We applied an elliptic spatial window with medium compactness and a maximum of 25% of the studied population. Each municipality will have a different number of cases and consequently different variances. Thus, we considered a normal distribution weighted by the number of cases in each municipality.[13] For the spatiotemporal analysis, the temporal unit was the year ($n = 10$); we considered a temporal window with 30% of the studied population. The significance level was set at 0.05.

Table 1
Description of the ecological variables included in the analysis.

Variable	Definition	Source
Demographics		
Population density	Logarithm of the number of inhabitants per square kilometre in the Portuguese municipalities	INE, 2017
Old-age ratio to maintain consistency with the rest of the terms	Number of residents with more than 64 years old divided by the number of residents between 15 and 64 years old, per 100 inhabitants	INE, 2017
Proportion of men	Number of male residents divided by the number of residents, per 100 inhabitants	INE, 2017
Incidence		
TB incidence	Number of pulmonary TB cases divided by the number of residents, per 100,000 inhabitants	SVIG-TB, 2017
HIV incidence	Number of HIV cases divided by the number of residents, per 100,000 inhabitants	INSA, 2017
Health services capacity indicators		
Doctors	Number of registered doctors per municipality per 1000 inhabitants	INE, 2017
Health centres	Number of public health care centres per 100,000 inhabitants	INE, 2012
Socio-economic factors		
Immigrants	Number of immigrants divided by the number of residents, per 100 inhabitants	SEF, 2017
Prison establishment	Categorical variable corresponding to the existence of at least one prison in the municipality	DGRSP, 2017
High school dropout	Number of individuals between 10-15 years old who dropped out without finishing high-school divided by the number of residents (10-15 years old), per 100 inhabitants	Census 2011 (INE)
Unemployment	Number of individuals registered as unemployed at the Portuguese public employment service divided by the number of residents (15–64 years old), per 100 inhabitants	IEFP/MTSSS-METD, 2017
Social income	Number of beneficiaries of social integration income (*Rendimento Mínimo Garantido e Rendimento Social de Inserção da Segurança Social*) divided by the number of residents, per 100,000 inhabitants	II/MTSSS, 2017

INE, Statistics Portugal; INSA, Doctor Ricardo Jorge National Health Institute; SEF, Foreigners and Borders Service; DGRSP, Directorate-General of Prison Services; IEFP/MTSSS-METD, Institute for Employment and Professional Training/Ministry of Labour, Solidarity and Social Security-Ministry of Economy and Digital Transition.

Ecological factors

We used the clusters defined in the spatial analysis to identify ecological factors associated with high delay areas (binary outcome – a municipality in a high delay cluster or not). Ecological variables were described using measures of central tendency and dispersion. As all but one of the variables assessed were continuous, we used generalised additive models (GAMs), which are more flexible than generalised linear models (e.g. logistic regression) because the relationship between dependent and independent variables can be linear or non-linear.[14] GAMs assume that the relationship between the outcome and the variables follow smooth patterns, defining a linear or non-linear shape. Thus, we fitted logistic GAMs with low-rank isotropic smoothers, estimated via restricted maximum likelihood.[15] We did not assume *apriori* distribution for any variables and let the model choose the most appropriate shape. We started by creating a baseline model, including population density, old-age dependency ratio (old-age ratio), the proportion of men, and pulmonary TB incidence. Then, we conducted a regression for each variable of interest, adjusting for the baseline model. Because of the possible non-linearity of the variables, there will not be a single coefficient to interpret but multiple coefficients. To facilitate the interpretation of smoother terms, we plotted the partial effects of smooths, in the probability scale, with a 95% Bayesian credible interval. Each partial effect plot can be interpreted as the probability of the outcome if all other variables were at their average value. The plots also give us an insight into the shape of the variable and its complexity. The only variable included in the model without a smooth term was prison, as it is a categorical variable, and we estimated the odds ratio (OR) with a 95% confidence interval (CI). Several diagnostics were performed for each model, such as evaluating the number of basis functions, residuals' distribution, and concurvity. The analyses were performed using R 4.0.2.[16]

Results

High delay areas

The time between symptoms onset and TB diagnosis increased in the past years in mainland Portugal. In 2008, the average diagnosis delay was 75.7 days (standard deviation [SD]: 59.1), and in 2017, 88.9 days (SD: 65.1). On the other hand, the number of TB cases notified over a decade decreased from 1838 in 2008 to 1221 in 2017. Supplementary Table 1 provides more descriptive information regarding the time between symptoms onset and TB diagnosis.

In 2017, one high delay cluster was identified in the South region of the country, including 21 municipalities (Fig. 1 and Supplementary Table 2). The weighted mean number of days between symptoms onset and TB diagnosis inside the high delay cluster was 137.7 days and outside the cluster 84.5 days.

A similar high delay cluster was identified in the spatiotemporal analysis. Between 2008 and 2017, the high delay cluster included 55 municipalities in the South region between 1 January 2016 and 31 December 2017. All the municipalities identified in 2017 were in this spatiotemporal cluster. The weighted mean number of days between symptoms onset and TB diagnosis inside the high delay cluster was 108.6 days, and outside, 80.1 days (Supplementary Fig. 1 and Supplementary Table 2).

Ecological factors

Descriptive statistics of the ecological factors by cluster are described in Table 2, and its geographical distribution is in Supplementary Figs. 2 and 3.

Fig. 1. Spatial distribution of the areas of high TB diagnosis delay in mainland Portugal. The dark area corresponds to the cluster identified in the spatial analysis.

In 2017, each municipality had a median population density (logarithm) of 4.2 inhabitants per kilometre,[2] a median old-age ratio of 58 and a median percentage of 47.5% men. Concerning health indicators, the median number of doctors per municipality was 1.85 per 1000 inhabitants and 6.8 health centres per 100,000 inhabitants. The median TB and HIV incidence rates were 6.9 and 4.2 per 100,000 inhabitants, respectively. Overall, mainland Portugal had 34 prison establishments and a median percentage of 1.87% immigrants, 6% unemployed and 1.5% high school dropout per municipality. In 2017, there was a median of 2208 social security beneficiaries per 100,000 inhabitants.

Then, we used GAMs to identify ecological factors with high delay areas. The baseline model included population density, EDI, the proportion of men and TB incidence, and each variable of interest was adjusted for the baseline model.

Fig. 2 presents the partial effects plot for the baseline model and HIV incidence. All the variables included in the baseline model

Table 2
Descriptive statistics of the ecological variables per municipality by cluster.

	Non-cluster N = 257	Cluster N = 21	Mainland Portugal N = 278
	Median (Q3; Q1)	Median (Q3; Q1)	Median (Q3; Q1)
Demographics			
Population density (log)	4.2 (3.2, 5.1)	3.3 (2.5, 4.5)	4.2 (3.1, 5.1)
Old-age dependency ratio (old-age ratio)	58.2 (52.6, 65.6)	60.6 (56.0, 65.1)	58.2 (52.8, 65.6)
Proportion of men	47.5 (47.0, 48.0)	48.5 (47.6, 48.7)	47.5 (47.1, 48.1)
Incidence			
TB incidence per 100,000 inhabitants	6.3 (0.0, 13.8)	14.5 (6.9, 26.7)	6.9 (0.0, 14.6)
HIV incidence per 100,000 inhabitants	4.1 (0.0, 11.0)	6.8 (0.0, 14.6)	4.2 (0.0, 11.8)
Health services capacity			
Number of doctors per 1000 inhabitants	1.8 (1.3, 2.8)	2.1 (1.3, 2.6)	1.8 (1.3, 2.8)
Number of health centres per 100,000 inhabitants	6.7 (2.97, 14.5)	7.3 (2.9, 14.2)	6.8 (2.9, 14.4)
Socio-economic factors			
Proportion of immigrants	1.6 (0.9, 3.1)	4.3 (3.1, 8.1)	1.8 (1.0, 3.3)
Prison establishment	30 (11.7%)	4 (19.0%)	34 (12.2%)
Proportion of high school dropout	1.5 (1.2, 2.0)	2.1 (1.6, 2.5)	1.5 (1.2, 2.0)
Number of beneficiaries of social insurance per 100,000 inhabitants	2201 (1460, 3283)	2281 (2015, 2812)	2208 (1484, 3229)
Proportion of unemployed	6.0 (4.8, 7.8)	5.8 (4.9, 6.5)	6.0 (4.8, 7.7)

Q3, third quartile; Q1, first quartile.

were statistically significantly associated with belonging in a high delay cluster. HIV incidence was non-significant and was the only variable with a linear behaviour.

The logarithm of population density was statistically significant and presented the most considerable effect on the probability of belonging in a high delay cluster, with municipalities with a logarithm population density of two presenting around 80% probability of being in a high delay cluster. However, the effect is uncertain for municipalities with high population density. Municipalities with a higher proportion of men also seem to have a higher probability of being in a high delay cluster. Nevertheless, the uncertainty is extensive, ranging from 0 to almost 100%, mainly because of the low number of observations with a higher proportion of men, representing a rare event. Municipalities with a higher old-age dependency ratio and higher TB incidence were also more likely to belong in a high delay cluster.

Health centres, immigrants, high school dropouts and unemployment were statistically significant (Fig. 3). Health centres presented a linear effect, with municipalities with less than five health centres per 100,000 inhabitants having a higher probability of being in a high delay cluster. The effect was smaller than for immigrants and high school dropouts. Immigrants had a non-linear effect, with more uncertainty for municipalities with a higher proportion of immigrants. Although the shape of the variable is unclear for a higher proportion of immigrants per municipality, a linear term would be unable to model the complexity of this variable. The probability of belonging in a high delay cluster was approximately 30% in municipalities with around 10 immigrants per 100 inhabitants. Municipalities with 4–5% high school dropout had approximately 20% probability of belonging in a high delay cluster. The proportion of unemployed presented a linear effect, with municipalities with less than 5% of unemployment having a higher probability of being in a high delay cluster.

In contrast, prison establishment, doctors and social income were non-significant (Fig. 3). As prison was a categorical variable, we estimated the OR and 95% CI. Municipalities with prison establishments had an odds of 1.17 belonging to a high delay cluster (95% CI: −1.67 to 1.97) than municipalities without prison establishments. The number of doctors and social income beneficiaries was non-linear, with high uncertainty regarding its effect's shape or direction. The effect on the probability of being in a high delay cluster for municipalities with more than 10 doctors per 1000 inhabitants and more than 6000 beneficiaries of social income per 100,000 inhabitants is unclear because of the small number of municipalities in these conditions.

Discussion

From 2008 until 2017, the time between symptoms onset and TB diagnosis has increased in mainland Portugal. We identified an area of high delay in 2017 in the South region of the country, with a higher average delay diagnosis than the rest of the country. Overall, municipalities with a smaller population density, smaller proportion of unemployed, fewer health centres and higher old-age dependency ratio, proportion of men, TB incidence, and proportion of immigrants and high school dropout had a higher probability of belonging in a high delay area.

Few studies have focused their analysis on the local level to the best of our knowledge. Our results are consistent with findings at the individual level. A study from the United Kingdom found a higher delay in areas of low TB incidence.[17] Although our study found that municipalities with higher TB incidence were more likely to belong in a high delay cluster, these regions had fewer inhabitants and cases, translating into a high incidence. For instance, Alcoutim and Aljustrel were two municipalities identified in the high delay cluster with a TB incidence of 42 and 47 per 100,000 inhabitants, respectively. However, these municipalities had respectively one and four cases of TB in 2017. We also found that municipalities with 8–20 immigrants per 100 inhabitants were more likely to belong in a high delay cluster. These results are in agreement with previous studies at the individual level that found that individuals who were not born in the country or lived <6 years had longer delays than native individuals.[18–20] Another Portuguese study found that individuals who lived further from a healthcare institution had longer healthcare delays.[21] These findings also agree with our results. Municipalities with fewer health centres had a higher probability of belonging in a high delay cluster. These findings combined with studies using individual data indicate the importance of primary healthcare in TB control. A study in Brasil found that patients diagnosed with TB in emergency facilities were younger and more socially vulnerable. The authors also found an association between TB diagnosis in emergency facilities and low primary care coverage at the municipality level.[22] Combined

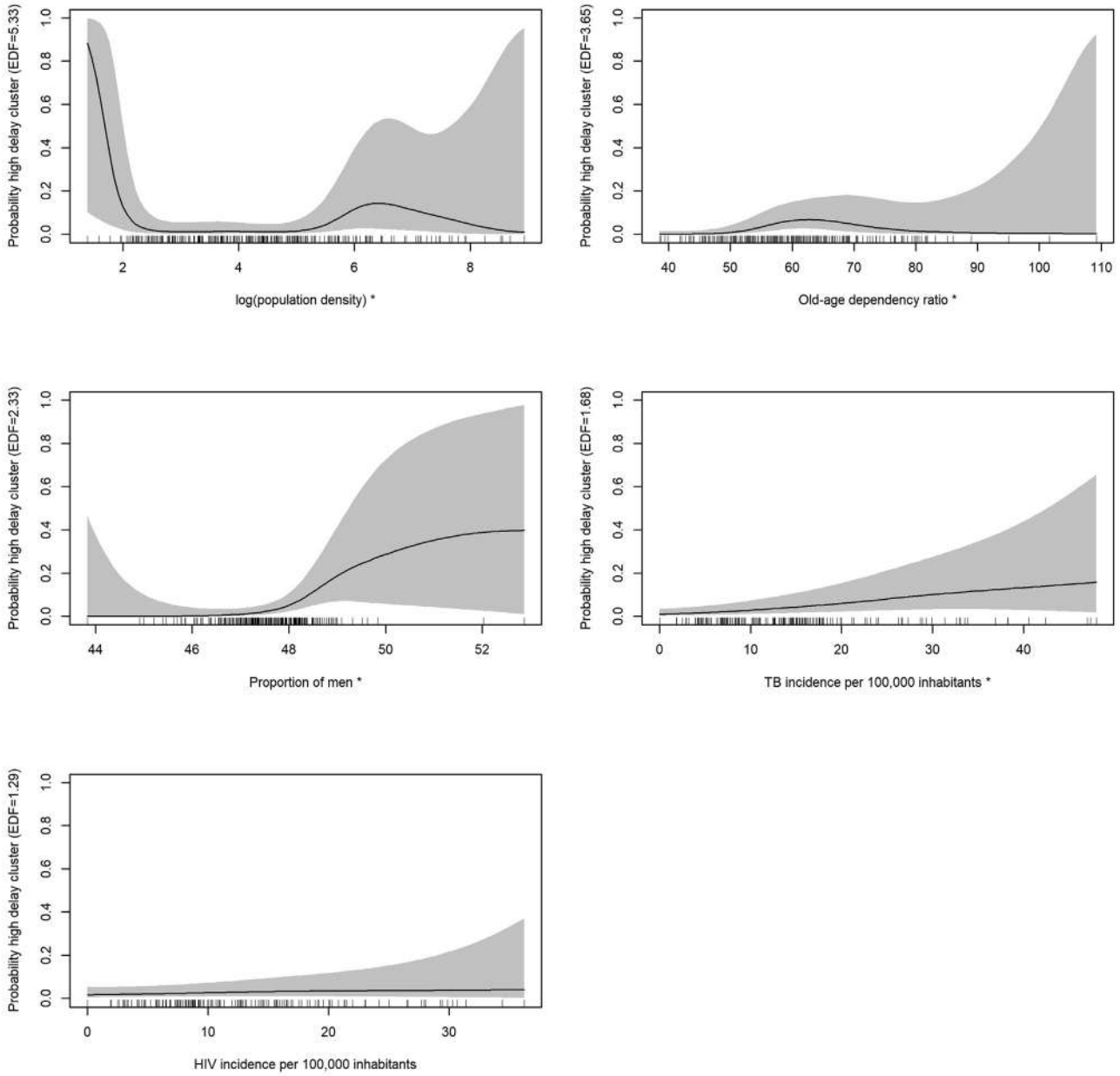

Fig. 2. Partial effects plot of the baseline model – population density, old-age dependency ratio, the proportion of men and TB incidence and HIV incidence. The label of the Y-axis displays the effective degree of freedom (EDF) of each variable. An EDF of 1 is equivalent to a straight line (linear), whereas an EDF of 2 is equivalent to a quadratic curve. As EDF increases, more complex is the term. The 'rug' underneath each figure corresponds to the location of each observation. The black line corresponds to the smooth term of the fitted GAM, and the grey shade corresponds to its 95% confidence interval. Significant variables are identified with an asterisk after the name of the variable on the X-axis.

with existing knowledge, these findings emphasise the importance of primary healthcare in TB control. Existing recommendations highlight the role of primary health care in TB primary prevention.[23] Our study further suggests the importance of primary health care for early diagnosis. In particular, attention should be paid to the liaison between general and public health practitioners, as well as community-based pulmonology clinics.

Our study found that municipalities with more than 48% men had a higher probability of belonging in a high delay cluster. In contrast, other studies found higher delays for women.[17,24,25] A previous imprisonment has also been associated with higher delay.[25] However, we did not find an association with municipalities that had prison establishments. Increased age was also associated with higher delays at the individual level.[20,24,25] We also did not find an association with the old-age dependency ratio, but the variable demonstrated a non-linear behaviour, suggesting a more complex relationship than previous studies have considered.

Delays in diagnosis result in increased infectivity in the community, facilitating transmission to other locals.[26,27] Several studies found an association between TB incidence and population density, rurality, considered a proxy for healthcare access, and low incidence migration.[28–30] We also found an association between these factors and high delay areas, which was also found in individual studies.[6,7,10,11] Thus, interventions aiming to address factors with interrelationships are most likely to be effective. Policies influencing social and health conditions, leading to changes in individual behaviour, can yield sustained improvements over time. Given the increase in TB diagnosis delay in the past years, it is

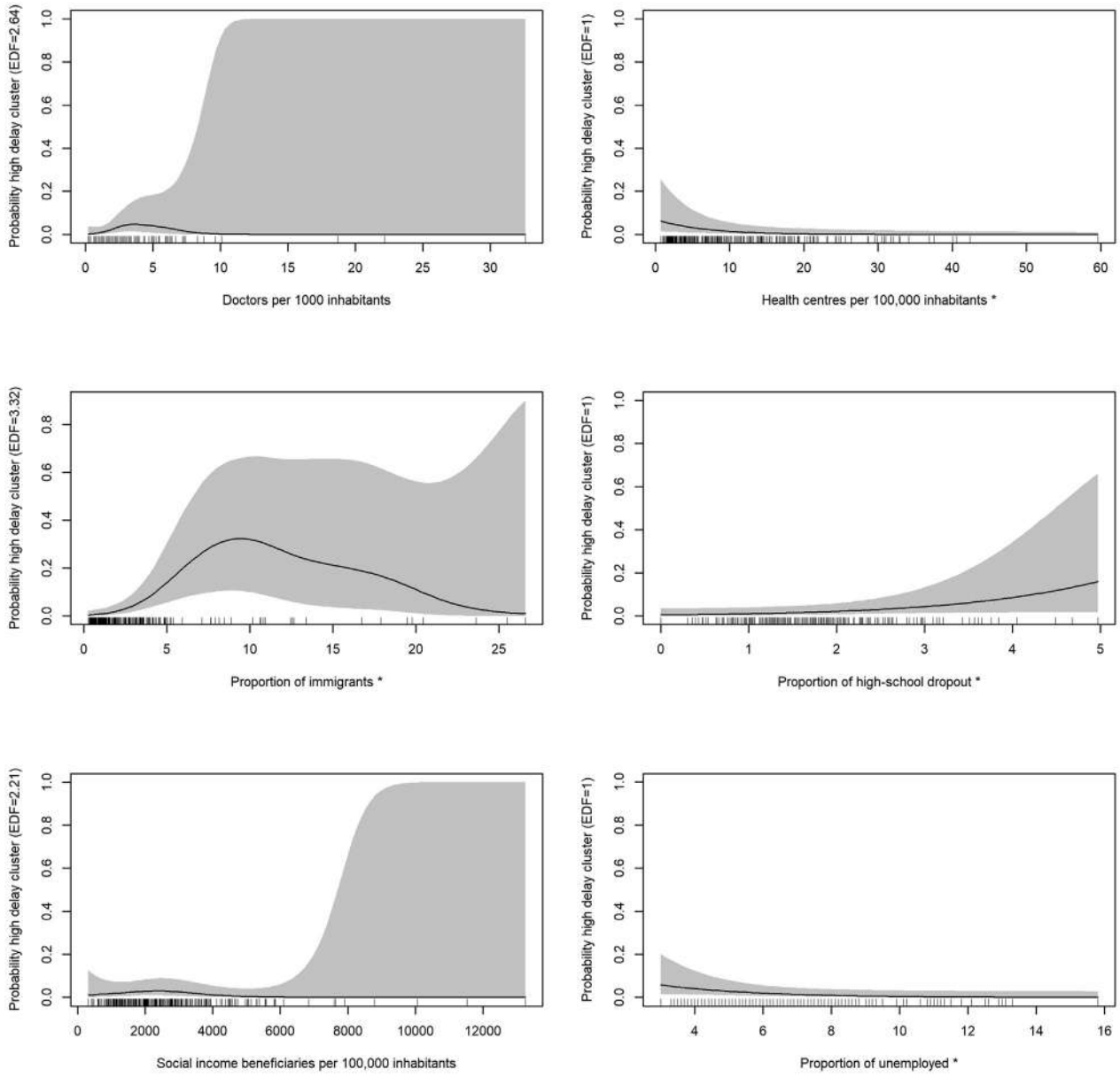

Fig. 3. Partial effects plot of the smooth terms for health services capacity indicators – number of doctors per 1000 inhabitants and number of health centres per 100,000 inhabitants, and socio-economic factors – proportion of immigrants, high school dropouts and unemployed, and number of social income beneficiaries per 100,000 inhabitants. The label of the Y-axis displays the effective degree of freedom (EDF) of each variable. An EDF of 1 is equivalent to a straight line (linear). As EDF increases, more complex is the term. The 'rug' underneath each figure corresponds to the location of each observation. The black line corresponds to the smooth term of the fitted GAM, and the grey shade to its 95% confidence interval. Significant variables are identified with an asterisk after the name of the variable, in the X-axis.

crucial to implement policies and programmes to improve areas of concern in high delay areas, targeting factors that influence local and individual. One of the Sustainable Development Goals targets is to end TB epidemics by 2030. However, TB diagnosis delay is a major threat to achieving this goal. Furthermore, the COVID-19 pandemic might have caused several setbacks in controlling TB. A recent study in Portugal interviewed coordinators of Outpatient Tuberculosis Centers; more than half of the interviewees mentioned delays in diagnosing TB during the first lockdown and a decrease in the use of health services.[31] Thus, TB control programmes should focus on critical areas of incidence and delay and target influencing factors. Improving access to health is vital, as municipalities with fewer health centres and less population density were more likely to belong in a high delay cluster. Primary health care has a major role in TB control. Thus, access and availability to those are of paramount importance.

Our study has some limitations. Our study was ecological and did not use individual data. Thus, the association observed in our study should not be interpreted as causal, and an association present at the municipality level might not be observed at an individual level – ecological fallacy. The percentage of missing data increased over the years. Almost one-quarter of the notified cases were unable to recall when the first symptoms appeared or registries had inconsistent dates, which led to the exclusion of these cases. This might have influenced the results, although it is challenging to clarify in which direction. The day on which the patient first experienced symptoms were also unavailable. We imputed the missing day to the first day of each month, which might have

overestimated the delay in some cases. The use of ecological information was also dependent on availability. The proportion of high school dropouts is from Census 2011 since data on education at the municipality level for 2021 were not yet available. We expect the proportion of high school dropouts to have decreased over the past decade. However, without geographical variation in this decrease, the results will still be unbiased. Similarly, some indicators are subject to recording patterns. For example, geographical variations in undocumented or illegal immigrants might lead to different behaviours concerning the probability of being in a high delay cluster. In addition, the number of doctors might not be the best representation of the availability of health services and could be influenced by the individual's mobility, as care could be sought in other municipalities. Future studies should consider other healthcare indicators, for instance, having a family doctor. It would also be interesting to consider the proportion of rural areas in each municipality and the role of overcrowding prisons.

Nevertheless, to the best of our knowledge, this is one of the first studies to study delays at the local level. Although an ecologic study in nature, which has limitations already discussed, our aim was to understand factors at the municipality level and not at the individual level. GAMs are commonly used in ecological studies[32–34] and have been used lately in studies investigating air pollution and TB.[35,36] This methodology should be considered in clinical studies interested to assess relationships with continuous variables. Analysing non-linear variables as linear or categorising them may lead to a loss of information and an inability to ascertain their true effect. We found that several of the factors analysed had non-linear, complex behaviours, which are usually not considered in the literature. For example, even using the logarithm of population density, the shape of the variable was complex. The probability of being in a high delay cluster had a clear non-linear behaviour: higher for municipalities with low population density, very low for municipalities nearing the average value, and slightly higher for municipalities with higher population density, although the uncertainty was larger.

Studies at the individual level identified several factors associated with TB diagnosis delay, such as low disease awareness,[6,7] living in rural places,[6,7] gender,[6,7] type of health facilities visited,[8] and socio-economic status.[10] Although these studies are crucial to designing interventions at the patient level, addressing the spatial distribution of the disease and the factors associated with high delay areas might help identify areas to act at the local level, improving individual and population health.

Author statements

Ethical approval

Ethical approval was obtained from the Ethics Committee of the Institute of Public Health of the University of Porto (CE19109) and the Ethics Committee of Regional Health Administration of Lisbon and Tagus Valley (3514/CES/2019).

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors made substantial contributions to the conception and design of the study, interpreted, and discussed the results, and all gave approval to the final article to be submitted. P.S. conducted the analysis. P.S., A.A. and A.L. drafted the manuscript. R.D. and C.N. contributed to data acquisition.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.04.010.

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Review Paper

Economic evaluations of interventions against viral pandemics: a scoping review

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ABSTRACT

Objectives: The COVID-19 pandemic has led to suggestions that cost-effectiveness analyses should adopt a broader perspective when estimating costs. This review aims to provide an overview of economic evaluations of interventions against viral pandemics in terms of the perspective taken, types of costs included, comparators, type of economic model, data sources and methods for estimating productivity costs.

Study design: Scoping literature review.

Methods: Publications were eligible if they conducted a cost-effectiveness analysis, cost-utility analysis, cost-benefit analysis or cost-minimisation analysis and evaluated interventions aimed at viral pandemics or for patients infected with viral pandemic disease. We searched PubMed, Embase and Scopus for relevant references and charted data from the selected full-text publications into a predefined spreadsheet based on research sub-questions, summary tables and figures.

Results: From 5410 references, 36 full-text publications fulfilled the inclusion criteria. The economic evaluations were mainly model based and included direct medical costs of hospital treatment. Around half of the studies included productivity costs and the proportion of total costs attributed to productivity costs ranged from 10% to 90%, depending on estimation methods, assumptions about valuation of time, type of intervention, severity of illness and degree of transmission.

Conclusions: Economic evaluations of interventions against viral pandemics differed in terms of estimation methods and reporting of productivity costs, even for similar interventions. Hence, the literature on economic evaluations for pandemic response would benefit from having standards for conducting and reporting economic evaluations, especially for productivity costs.

Introduction

Decision-makers involved in setting priorities for health care budgets need reliable evidence on the costs and effects of alternative interventions. This is often provided through cost-effectiveness analyses that compare the costs of two or more alternative interventions relative to their health effects.[1] To ensure that cost-effectiveness analyses are comparable and are based on the same type of information about resource use and effectiveness of health interventions, guidelines for conducting cost-effectiveness analyses have been produced.[2,3]

Reviews on guidelines for health economic evaluations have identified consensus on key methodological principles, such as the types of economic evaluation to be used, the time horizon for analysis, relevant health outcome measures and use of sensitivity analyses.[2,3] However, the reviews also identify aspects that lack a common understanding; for example, the study perspective, which costs are included, whether to account for indirect costs and how to do this, rates for discounting costs and effects, and methods for measuring health-related quality of life.[2,3]

Pandemic diseases present additional challenges for cost-effectiveness analyses because of their wide consequences for society as a whole. Pandemic diseases are highly contagious compared with other diseases and the measures for controlling them (such as lockdown or immunisation programmes) also impact people who are not infected with the disease, including the ability to work and study.[4–6] In addition, a country's limited ability

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to trade can have serious economic consequences.[6,7] The COVID-19 pandemic resulted in a real gross domestic product (GDP) growth rate in Q2 2020 of −9.49% in the US and −11.9% in the EU.[7–9]

In terms of the COVID-19 pandemic, some argue that a broader perspective should be adopted in economic evaluations as a new intervention against a viral pandemic is likely to impact not only the people becoming ill or receiving treatment but also the surrounding society.[10–12] A broader perspective would ensure that all costs and benefits of an intervention are included in the health economic evaluation and that decision-makers are fully informed about the costs and consequences.[11,12] Although the usual economic evaluation principles remain unchanged within the context of the COVID-19 pandemic, additional aspects to be considered include 'fear of contagion, severity of illness, insurance value, and innovation and its spill over effects'[14] as well as 'the broader benefits of restoring economic and social activity'.[10]

One of the implications of taking a broader perspective is the inclusion of productivity costs, which can be defined as 'the costs associated with lost or impaired ability to work or to engage in leisure activities due to morbidity and lost economic productivity due to death'.[1] The term 'indirect costs' has been used similarly as it 'can include temporary absence from work due to illness, reduced working capacity due to illness and disability, or lost productivity due to early death'.[13] There seems to be a lack of consensus in guidelines on whether productivity costs should be included and a lack of agreement in light of the pandemic on how to estimate these costs.[10,12]

Health economic aspects of pandemics have been described in systematic reviews of pharmaceutical interventions, such as vaccination[14,15] and antiviral treatment,[16] and of non-pharmaceutical interventions, such as lockdowns, closing borders or schools, screening, isolating symptomatic individuals and near contacts, and social distancing.[17] The aims of these studies were to summarise evidence and find cost-effective alternatives,[17] to provide an evidence base to inform economic evaluations and health technology assessments of COVID-19 treatments,[16] or to investigate the use of productivity costs in health economic evaluations of vaccine programmes and drugs.[15,18] Although not restricted to viral pandemic disease, vaccine and immunisation programmes often target viral disease and recent reviews have reported on the inclusion of productivity costs in economic analyses.[15,19] However, we have not been able to find reviews describing estimation of productivity costs or indirect costs in economic analyses of interventions against viral pandemics.

Therefore, the objective of this study was to provide an overview of economic evaluations of interventions against viral pandemics in terms of the perspective taken, types of costs included, comparators, type of economic model, data sources and methods for estimating productivity costs. This review provides researchers, policymakers and service providers with information about applied economic methods for evaluation of interventions against viral pandemics and suggests priorities for further research.

Methods

A scoping review was conducted to obtain an overview of existing economic evaluations of interventions against viral pandemics. A scoping review can assess a broad research question to identify and map the available evidence[20] and it can result in detailed descriptions of study methodologies.[21]

The specific subquestions in this scoping review were as follows:

- Which types of economic evaluations have been conducted for interventions against viral pandemics?
- Which types of interventions have been examined?
- Which perspectives have been used when measuring costs?
- Which types of study design have been used for estimation of costs?
- Which data sources have been used?
- Which types of costs have been included?
- How were productivity costs or indirect costs included?

Protocol and registration

The current review followed the updated methodological guidance for conduct of scoping reviews by Peters et al.[21] and was reported in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist (see Supplementary file S1).[22] The scoping review was based on an *a priori* defined protocol, as recommended[21] and this can be accessed through the Open Science Framework (see link in Supplementary file S2).

Eligibility criteria

The Participants, Concept and Context (PCC) framework guided the eligibility criteria. The review included fully available publications in peer-reviewed journals. The year of publication was not limited as relevant papers from earlier pandemics were found. Primary research was preferred (i.e., not review articles or meta-analyses) and the analysis should be conducted with a health care or societal perspective. The study searched for articles with the following PCC criteria:

Participants: patients with emerging infectious virus causing outbreaks or pandemics (i.e., Ebola, Sika, SARS, MERS, H1N1, H5N1, or COVID 19) or a pandemic virus scenario.

Concept: cost-effectiveness analysis (CEA), where results were expressed in monetary units per case averted; cost-utility analysis (CUA), where results were expressed in monetary units per quality-adjusted life-years (QALYs) or disability-adjusted life-years (DALYs); cost-benefit analysis (CBA) or cost (minimisation) analysis, where results were expressed as an intervention's total saving or loss in monetary units.

Context: all contexts (i.e., all countries of origin) were included; however, the context should relate to health interventions and the perspective should be broader than the budget impact for a single hospital.

Information sources

The search was conducted in PubMed, EMBASE and Scopus,[23–25] which are databases that include articles describing medical and health economic outcomes research.

Search strategy

The search strategy was developed using two databases, and the final search was conducted in all three databases, in accordance with guidelines.[21] A preliminary search was conducted in PubMed and EMBASE using peer-reviewed clinical expert searches on relevant disease terms[26–28] and costs. The complete search strategy is provided in Supplementary file S3.

Selection of sources of evidence

Studies were selected in two steps following the inclusion and exclusion criteria listed in Table 1.

Two reviewers (MKR and IF) conducted the selection; MKR first screened titles and abstracts using the Covidence online platform[29] and IF mainly assisted in sorting full-text references and in extracting results. Full-text articles were then screened by both reviewers independently. This was performed in Endnote[30] as some of the full-text articles could not be uploaded to Covidence due to copyright regulations. Disagreements were solved by discussion.

Data charting process

Full-text articles that were deemed relevant were examined and their data were entered into a predefined charting form. The following data were extracted: author and year, country and type of intervention, type of economic evaluation, study population, outcome measures, structure of economic model if relevant, perspective taken, types of costs assessed, measurement of productivity costs or indirect costs, and sources of data. The data chart was analysed using frequency tables, bar graphs and/or narrative summaries according to the focus of the research subquestions.

Results

This study identified 5410 references and, after screening of titles, abstracts and full-text, 36 articles were included in the review (see Fig. 1). The 36 articles were published between 2008 and 2021, and their main characteristics are summarised in Table 2.

All continents were represented, but over half of the studies were from North America (28%) and Europe (31%). Participants were mainly patients with COVID-19 (50%) or H1N1 (31%). The full data chart is available in Supplementary file S4.

The following sections present results on the research subquestions.

Types of economic evaluations

Cost effectiveness was reported in 22 studies (61%),[31–55] four (11%) stated cost benefit,[55–59] two (4%) a cost utility,[53,55,60–62] three (8%) a cost-minimisation analysis[63–66] and five (14%) reported multiple analyses.[53–55,60,66]

Types of interventions

The interventions can be split into two groups according to World Health Organisation (WHO) objectives for epidemics:[67] (a) intervention strategies to supress transmission; and (b) interventions to optimise care for patients with confirmed epidemic disease. Twenty-three studies (64%) analysed interventions to supress transmission. These included use of face masks,[60,65] insectoid-threated nets,[48] increased access to contraception,[38,48] suppression policies,[52] lockdown,[44,57] mitigation and movement restriction policies,[53,55] hand hygiene,[60] school closure,[35,49,50,56,63] workplace non-attendance,[35,63] community contact reduction,[35,63] social distancing,[44,58] testing,[32,36,40] and isolation strategies.[44] Eight studies (22%) analysed interventions for patients with confirmed epidemic disease. These comprised changes in organisation of medical treatment[31,43,47,51] and treatment with specific pharmaceuticals.[37,46,61,68] Five studies (14%) examined interventions in both of the WHO defined groups.[35,39,45,63,66]

Perspective used when measuring costs

A societal perspective was stated in nine (25%) studies and a healthcare provider perspective in 12 (33%) studies. Four (11%) studies provided results from both perspectives. Nine studies did not state a perspective, but six (17%) included parameters referring to a societal perspective. A public payer perspective was used either alone or combined with private payer in two (6%) studies.

Study designs for cost estimation

Overall, 32 studies (89%) were model based, two studies were based on clinical studies[59,64] and two studies had no described study design. In 15 (42%) studies, expected values were derived from a transmission model (e.g., the SEIR [Susceptible, Exposed, Infected, Recovered] Model) and thereafter attached to costs. Decision trees were used in 10 (28%) studies; this was alongside either Markov or other simulation models in three (8%) studies.

Data sources

Nineteen studies included estimates acquired from published literature.[34–37,39,40,46–52,55–57,60–63,65,66] National or official statistical resources were used in 17 studies.[31,34,36,40,41,43–45,47,49,50,54,56–58,60,66] Five studies used aggregate or patient-level data from local hospital resources.[37,42,46,64,66] A few studies included prices from private insurance companies[38,43] or market prices,[42,60,64] questionnaires,[59] or interviews with individuals (e.g., patients, household and healthcare personnel).[59,64]

Types of costs

Costs were grouped into direct health care costs, (89%) intervention costs, (69%) productivity costs, (58%) direct costs to the patient (11%) and direct non-health care costs (14%). Fig. 2a–c presents the most common types of costs in more detail; all cost data are available in Supplementary file S5 (Tables S2d–e).

Productivity costs or indirect costs

Productivity costs were included in 21 (58%) studies, often measured as costs of lost labour incurred by the patient due to illness or premature death (25% and 11%), as absenteeism of

Table 1
Inclusion and Exclusion Criteria.

Inclusion criteria	Exclusion criteria
• Studies describing patients with an emerging infectious virus causing outbreaks or pandemics	• Literature reviews, letters, editorials, unpublished grey literature, guidelines, conference proceedings, case reports
• Studies conducting a cost-effectiveness analysis, cost-utility analysis, cost-benefit analysis or cost minimisation analysis	• Narrow perspective, e.g., single hospital
• The perspective of analysis should be health care, payer or societal	• Studies that did not adopt a comparator
• Full publication in peer-reviewed journal	• Not published in English
• Primary research	• Studies of vaccines
	• Cost of illness studies

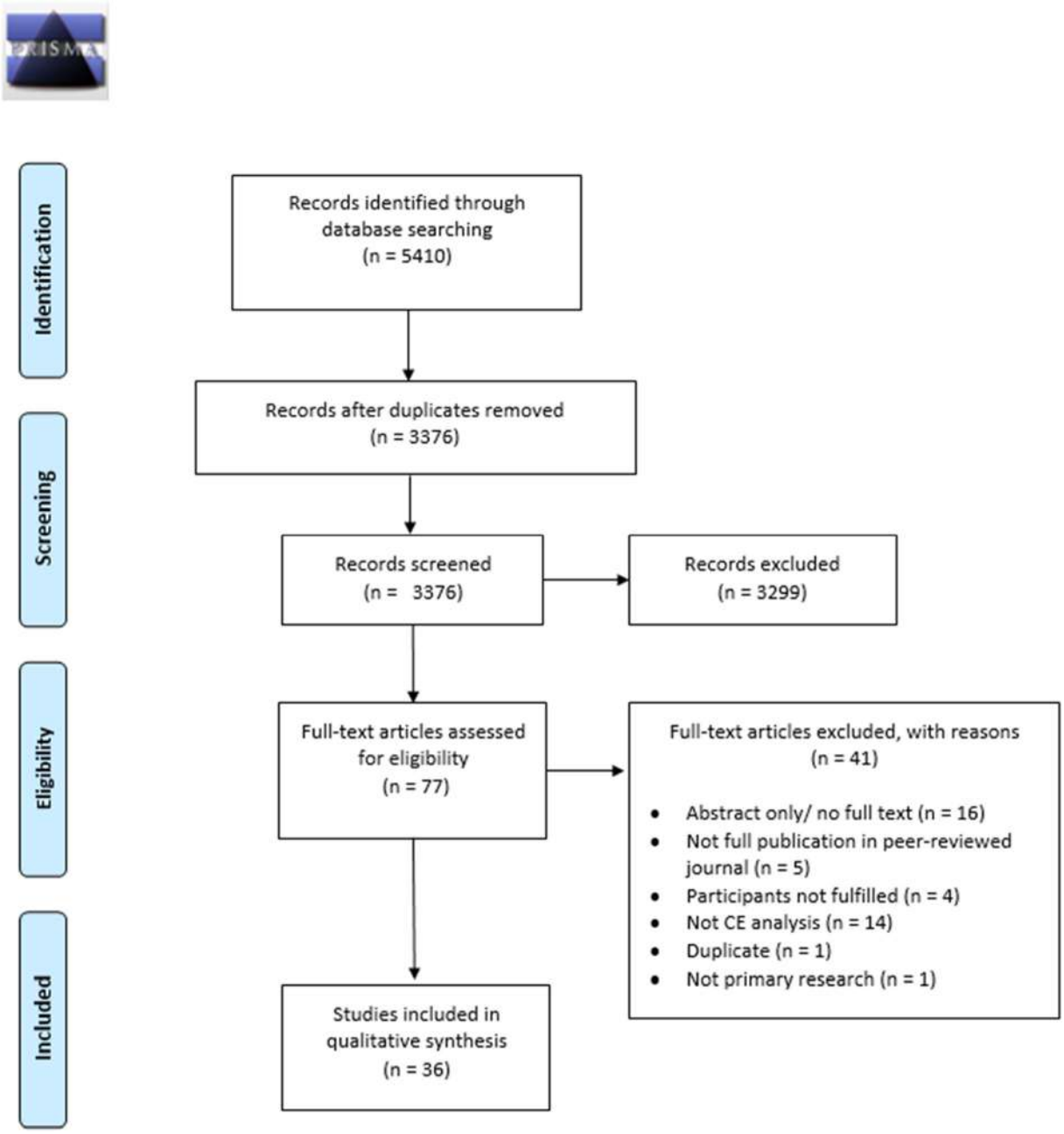

Fig. 1. Flow diagram of selection of sources of evidence.

relatives, close contacts and teachers (14%) but also, in some studies (11%), not explained further.

Six studies included daily wages of parents or relatives absent from work to take care of healthy or ill children.[35,49,50,56,63,65] Two studies analysed different testing strategies and included loss of salary for close contacts (e.g., during household quarantine).[32,55] One study included costs of work delay plus transportation for family members of sick individuals.[59]

Two studies included productivity costs for the health care sector as costs of quarantine and sick leave in terms of income for personnel in the hospital ward.[33,42]

Zala et al. modelled the cost effectiveness of suppression policies. These included productivity costs based on a macroeconomic model in which a pandemic influences GDP through (i) a reduced labour supply owing to death, illness (i.e., direct absenteeism), school closures and prophylactic absenteeism; (ii) consumption shocks owing to illness and precautionary avoidance; and (iii) modest investment deferment.[52]

Four studies (11%)[43,59,62,63] stated a specific approach to value productivity: the human capital approach. In this approach, income acts as a proxy for the production value of the individual.[1] Thirteen studies (36%) included productivity costs by multiplying days of absence due to illness, mortality or interventions by average income, GDP per capita/day or similar value per day. These studies did not state a specific approach, but their method of valuation was similar to the human capital approach.[32,33,35,40,42,44,49,50,52,56,61,64,65] Three studies (8%) did not explain their approach nor method of valuation.[39,54,58]

Different assumptions were applied when estimating productivity costs. Studies analysing school closure most often included productivity costs of at least one parent, but Brown et al. assumed that only parents of children aged 6–11 years would incur

Table 2
Characteristics of included studies.

Characteristic	No. of studies	%
Origin (Continent)		
Global	1	3%
Oceania	1	3%
South America	2	6%
Africa	4	11%
Asia	7	19%
North America	10	28%
Europe	11	31%
Disease		
Ebola	2	6%
Zika	2	6%
Pandemic Influenza scenario	3	8%
H1N1 (pandemic influenza A)	11	31%
COVID-19	18	50%
Study type		
Cost-minimisation & 'ACER'[a] cost-effectiveness	1	3%
Cost-effectiveness & cost-benefit	1	3%
Cost-effectiveness & return on investment-analysis	1	3%
Cost-utility & cost-effectiveness	2	6%
Cost-utility	2	6%
Cost-minimisation analysis	3	8%
Cost-benefit	4	11%
Cost-effectiveness	22	61%
Study design		
Patient simulation model (SEIR) with attached costs	15	42%
Decision tree	10	28%
Decision tree and Markov	2	6%
Decision tree and simulation model	1	3%
Simulation model, e.g., Monte Carlo simulation	4	11%
Others (survey, micro costing, not described)	4	11%
Perspective		
Societal perspective	9	25%
Healthcare provider perspective	12	33%
Health care and societal perspective	4	11%
Public payers' perspective	1	3%
Combined health sector perspective (public and private)	1	3%
Not explicitly given (societal perspective)	6	17%
Not explicitly given	3	8%

[a] Average cost-effectiveness ratio.

production loss due to absenteeism from work.[56] Neilan et al. assumed that a day in self-isolation would only halve productivity as some people would be able to work from home while moderately ill or taking care of an ill child.[40] Kelso et al. assumed costs to children as a school day lost would incur additional educational expense in the future.[63] Three studies assumed that seniors or persons aged over 65 years do not work and used a valuation of zero for time in this group.[40,50,65] In contrast, two studies referred to growing evidence that elderly individuals contribute to non-market productivity and thus included a value for all age groups over 18 years.[43,49] Four studies included productivity costs due to premature death, but only Kellerborg et al. assumed that life-years spent in poor health do not result in productivity gain.[62]

The proportion of total costs attributed to productivity costs ranged from 10% to 90% in the studies that included productivity costs. In studies with productivity costs around 90% of the total cost, the interventions included workplace or school closure, an unmitigated pandemic or high transmission scenarios. In studies with productivity costs around 10% of the total cost, the interventions included antiviral drugs or acute treatments for hospitalised patients, lower transmission scenarios or less severity of illness.[35,40,43,63]

Discussion

This scoping review identified 36 studies that included economic evaluations of interventions against viral pandemics. Most studies included costs of the intervention and economic consequences for the health care system. The costs to the health care system varied from costs of hospital resource use only to including GP visits, utensils or devices, pharmaceutical costs and costs of quarantine. Other studies reported consequences at a societal level, including productivity costs. Studies varied in reporting productivity costs, where the most common item was costs to the patient. Others included costs to relatives and to the health care sector.

Inclusion of productivity costs impacts the estimated total cost. Studies noted that the largest contribution to total cost was productivity losses, which arose from mortality at a young age or from widely applied interventions, such as lockdowns.[35,62] Severity of illness and degree of transmission were also contributing factors.[61]

The result of each cost-effectiveness analysis may be impacted by the approach used for measuring productivity costs. For example, placing a zero value on the time of older people implicitly gives a higher weight to interventions aimed at the working population who would incur productivity costs from illness while older people would not. Another example is deciding whose productivity costs should be measured. Some studies included productivity costs for the patient only or for the relatives. A few studies used the human capital approach for estimating productivity costs and although most other studies did something similar, they did not report a specific approach. The inconsistency in estimating costs, particularly productivity costs, is a challenge for decision-makers when selecting which interventions to implement. To improve consistency in methods and reporting of cost-effectiveness analyses, an updated guideline is needed specifically for interventions aimed at viral pandemics.

Study limitations

This review excluded studies of immunisation programmes as these were described in two recent systematic reviews.[15,19] Vaughan et al. reviewed 68 costing studies and found inconsistent practices in reporting on types of immunisation costs, and that vaccine and delivery cost details were frequently not reported. The authors also reported insufficient methodological detail on data analysis and provided a checklist with specific guidance on how to write up a costing study in the field of immunisation economics. Yuasa et al. reviewed 208 studies and found that most of the studies that included productivity costs only considered patients' absenteeism, while ignoring time lost by caregivers. The approach used to estimate productivity losses/gains was not commonly reported or not sufficiently detailed, but this may be partly due to varying country guidelines.[15] Similarly, the current scoping review found that the impact and method of calculation of productivity costs was sometimes unclear or not reported.

Cost of illness studies were not included because this review was limited to economic evaluations as defined by Drummond et al.;[13] thus, some relevant information might be omitted as a result.

Conclusions

The current scoping review showed that economic evaluations of interventions against viral pandemics may include productivity costs for both ill and non-ill individuals. In several studies, costs to parents or relatives were included, but also productivity losses within the health care sector and on a societal level were sometimes described. The estimation methods and reporting of productivity costs differed, even for similar interventions. The conclusion of a cost-effectiveness analysis can be greatly impacted by the approach used for measuring productivity costs, and this poses a challenge to decision-makers facing the choice of which

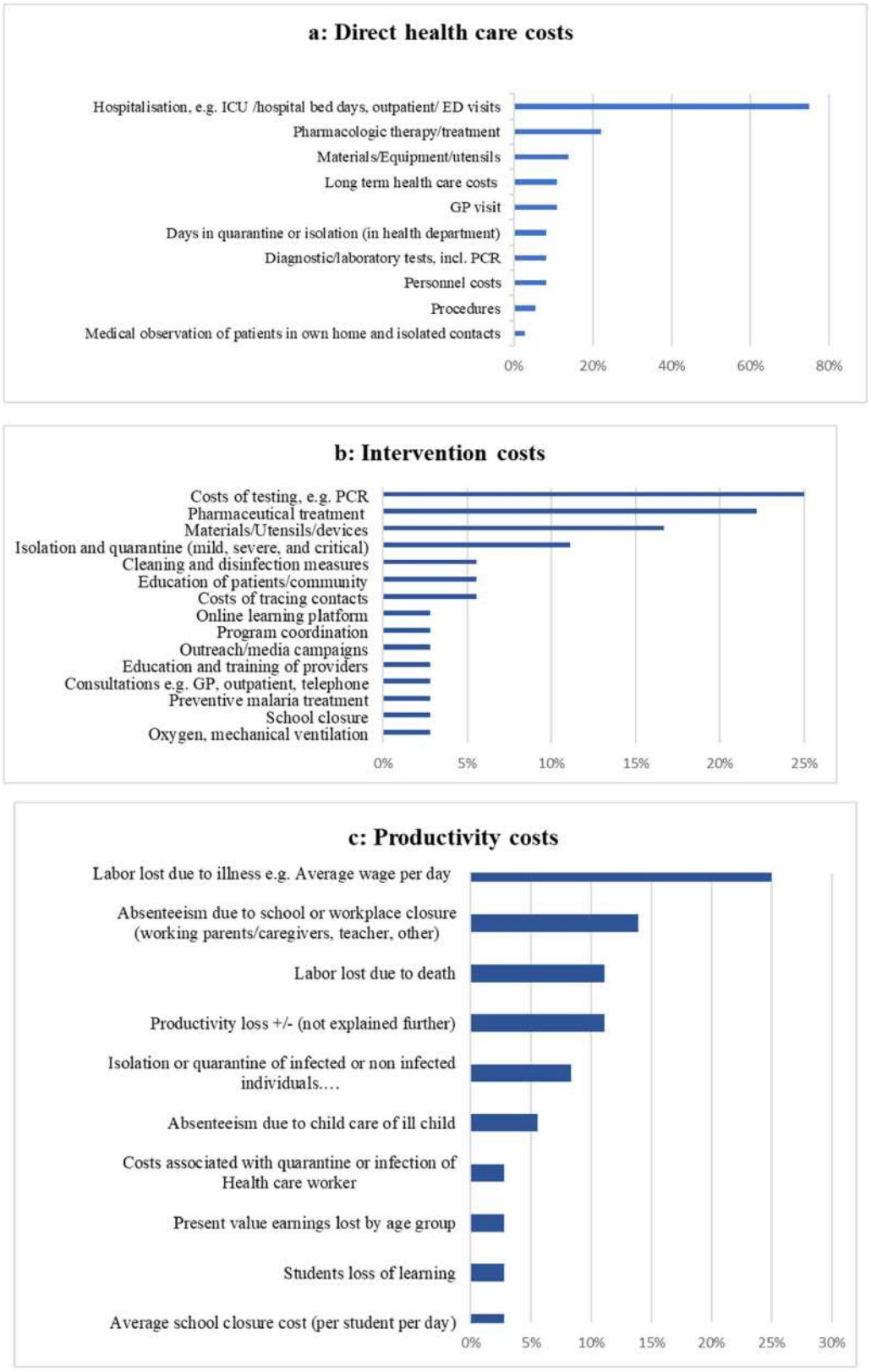

Fig. 2. a–c: Types of costs included in analyses.

interventions to implement. To improve consistency in the conduction and reporting of economic evaluations, an updated guideline is needed for interventions against viral pandemics.

Author statements

Ethical approval

None required.

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Competing interests

The authors declare 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.2022.05.001.

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Original Research

Effect of environmental factors on SARS-CoV-2 infectivity in northern hemisphere countries: a 2-year data analysis

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ABSTRACT

Objective: The COVID-19 pandemic that emerged in December 2019 brought human life to a standstill. With over 2-year since the pandemic originated from Wuhan, SARS-CoV-2 has caused more than 6 million deaths worldwide. With the emergence of mutant strains and COVID-19 surge waves, it becomes critically important to conduct epidemiological studies that allow us to understand the role of various environmental factors on SARS-CoV-2 infectivity. Our earlier study reported a strong negative correlation between temperature and COVID-19 incidence. This research is an extension of our previous study with an attempt to understand the global analysis of COVID-19 in northern hemisphere countries.
Study design: This research aims at achieving a better understanding of the correlation of environmental factors such as temperature, sunlight, and humidity with new cases of COVID-19 in northern hemisphere from March 2020 to February 2022.
Methods: To understand the relationship between the different environmental variants and COVID-19, a statistical approach was employed using Pearson, Spearman and Kendall analysis.
Results: Month-wise univariate analysis indicated a strong negative correlation of temperature and sunlight with SARS-CoV-2 infectivity, whereas inconsistencies were observed in correlation analysis in the case of humidity in winter months. Moreover, a strong negative correlation between average temperature of winter months and COVID-19 cases exists as evidenced by Pearson, Spearman, and Kendall analyses. In addition, correlation pattern between monthly temperature and COVID-19 cases of a country mimics to that of sunlight of a country.
Conclusion: This pilot study proposes that low temperatures and low sunlight might be additional risk factors for SARS-CoV-2 infectivity, mostly in northern hemisphere countries.

Introduction

The end of 2019 witnessed the emergence of a novel virus in Wuhan, China, which was later identified as severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2).[1] The spread of the virus accelerated to such an extent that the COVID-19 was declared as a pandemic on March 11 by the World Health Organization. Since then, governments all around the world have imposed major lockdowns and travel restrictions to contain the spread of the disease. As of May 2021, 161, 080, 581 confirmed cases have been identified, with more than 3,345,018 deaths worldwide. The SARS-CoV-2 is reported to develop pneumonia-like symptoms, such as sore throat, fever, cough, shortness of breath, loss of smell and taste, muscle ache, and dry mouth.[2,3] World Health Organization specifies six pandemic phases wherein previous pandemics such as influenza have reported—"waves of infection spread over months." [4] In a matter of the first year, COVID-19 reports a similar pattern with most countries experiencing a two-wave surge of COVID cases. The second wave has been observed in the winter season in most parts of the world, especially in the European countries, including Italy, Germany, Poland, Russia, and France, suggesting a possible link between temperature and COVID-19 incidence. Earlier outbreaks of other respiratory diseases, such as the influenza pandemic (1918), also reported a lethal second wave, which was responsible for the majority of deaths in the United States due to the pandemic.[5] To understand the role of environmental temperature in the SARS-CoV-2 infectivity, we published data at the beginning of the pandemic, which reported a strong negative correlation relationship between

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environmental temperature with SARS-CoV-2 infection rates in various countries worldwide.[6] Since then, several studies have been reported that support our findings, thus depicting high COVID-19 incidence, particularly in colder areas.[7–9] A study by Chen et al. reported a 5.4% decrease in COVID-19 cases with 1°C increase in temperature.[10] However, certain scattered did not observe positive or no correlation between temperature with COVID-19 cases.[11–13] Although some studies have focused on a single country, other studies have focused on a particular province incorporating such biasness in the analysis. A consequence of such limited data led to a low range of temperature being considered for each study. Also, migration of people was obstructed between the countries in the first place when international travel restriction was imposed. Having said that, it was post lockdown when migration within a country was limited, influencing the spread of infection of COVID-19. Thus, such studies could not find an association between temperature and COVID-19 cases. However, since the data at the time of our previous study was quite dynamic, we have validated our previous study by performing an extended global data analysis from March 2020 to February 2022. Owing to the discrepancies observed in understanding the role of temperature in SARS-CoV-2 infectivity, we have considered that temperature might not be an alone factor. The study has also considered additional environmental factors, such as sunlight and humidity. Our present study focuses on detecting the role of different environmental factors on COVID-19 incidence in northern hemisphere countries. Previously reported epidemics offer epidemiological studies that can help researchers to understand how COVID-19 might unravel with time. Such studies will allow local and global authorities to formalize optimized measures to curtail the frightening spread of this respiratory infection.

Methods

Data collection

The data for COVID-19 from March 2020 to February 2022 was collected from the http://ourworldindata.org/coronavirus website. In our study, we have considered new cases of COVID-19 as our variable of interest. The data for new cases for each country were calculated by deducting total cases per million of the previous month's data with later month data. As gathering data for environmental factors for every location of a single country was difficult, the data for the capital of each country were taken into consideration representing the data for the entire country. The data for the maximum and minimum temperature were retrieved from *climatestotravel* site, and the monthly average temperature was calculated for all the countries.[6] The data for sunlight were obtained in terms of insolation (kWh/m^2/day) for capital of each country from *giasma.com* site. The humidity data in terms of relative humidity of different countries were collected from *climate-data.org*. In this study, infectivity of SARS-CoV-2 has been studied in northern hemisphere countries alone, given the fact that the northern hemisphere countries experience winters in December and southern hemisphere countries experience it in the month of June. The data were divided into two sets—winter and summer. The data from November to February were considered for winter months, whereas the data from June to September were considered for summer months.

Statistical analysis

Univariate analysis was performed using Pearson, Spearman, and Kendall methods to determine the relationship between new cases of COVID-19 for each month and environmental factors, described previously.[6,14–17] The statistical analysis was considered significant for P-value <0.05. The univariate analysis for each factor was performed using the software GraphPad prism 6.0. The three-dimensional plot was generated using R Studio (Package ggplot2 of statistical software RStudio, version 1.4.1106).

Results

Association between new cases of COVID-19 and temperature and sunlight in northern hemisphere countries in the months of winter and summer

Our previous publication reported strong negative correlation between monthly average environmental temperature and COVID-19 cases. Following that, several studies have been performed to understand the role of temperature in SARS-CoV-2 infectivity and have also reported contradictory results in some cases. To understand the dependence of COVID-19 incidence on different seasons, we divided our data into two sets_winter and summer. The data from November to February were considered for winter months, whereas the data from June to September were considered for summer months. Also, the line of 0° latitude divides the Earth into the northern and southern hemispheres, each experiencing different temperatures at the same time of the year. We have considered only northern hemisphere countries for our analysis. We conducted univariate analysis using Pearson method between monthly average temperature and new cases of COVID-19 for summer and winter months of a country and observed strong negative correlation with statistical significance in winter months. To verify our findings, we further performed correlation using the Spearman univariate method as well as Kendall univariate method. Similar to the Pearson method, we observed a negative association between temperature and new cases of COVID-19 in winter months from November 2020 to February 2021 (Table 1). Hence, our findings suggested that cold temperature might influence SARS-CoV-2 infectivity. To validate our findings, we chose sunlight as another factor for our study. Univariate analysis using Pearson method for northern hemisphere countries depicted a strong negative correlation with statistical significance in winter months. Spearman and Kendall's statistical analyses also found a strong negative correlation in the winter months from November 2020 to February 2021 (Table 2 and Supplementary Fig. S1). Similar univariate analysis was conducted with summer and winter months' data for the year 2021 shown in Supplementary Tables S1 and S2. Thus, the elimination of southern hemisphere countries also reported a similar finding as mentioned earlier, indicating that cold temperature influences SARS-CoV-2 infectivity.

Month-wise univariate analysis to study the relationship between new cases of COVID-19 and different environmental factors in northern hemisphere countries

The general tendency of our data depicted a strong negative correlation between temperature and sunlight on SARS-CoV-2 infectivity in winter months and a slight negative correlation between humidity and new cases of COVID-19 in summer months. Hence, we performed month-wise univariate analysis of each factor to further understand the conjugative relationship between these factors and new cases of COVID-19. The univariate analysis between temperature with new cases of COVID-19 has been shown in Table 3. Pearson statistical analysis found a negative correlation between temperature and new cases of COVID-19 in March and April with statistical significance. However, from May to September, we observe that this relation is quite weak and not much significant. However, from October 2020 to April 2021, we reported strong negative correlation, thus supporting our previous finding. To further verify our findings, we performed correlation using the Spearman method as well as Kendall method and

Table 1
Relationship between average new cases of COVID-19 and average environment temperature in summer months and winter months of a country: northern hemisphere.

New cases of COVID-19 vs average environment temperature						
Characteristics	Pearson		Spearman		Kendall	
	Summer months	Winter months	Summer months	Winter months	Summer months	Winter months
Correlation coefficient	0.1393	−0.5307	−0.1361	−0.5858	−0.0967	−0.4125
P-value	0.0790	<0.0001	0.0861	<0.0001	0.0698	<0.0001
No. of countries	160	148	160	148	160	148

Table 2
Association between average new cases of COVID-19 and average sunlight in northern hemisphere countries in the months of winter and summer.

New cases of COVID-19 vs average sunlight						
Characteristics	Pearson		Spearman		Kendall	
	Summer months	Winter months	Summer months	Winter months	Summer months	Winter months
Correlation	0.2441	−0.6310	0.1614	−0.6737	0.1100	−0.4712
P-value	0.0013	<0.0001	0.0355	<0.0001	0.0332	<0.0001
No. of countries	170	158	170	158	170	158

Table 3
Month-wise univariate analysis to study the relationship between average new cases of COVID-19 and average monthly temperature in northern hemisphere countries.

	New cases of COVID-19 vs average environment temperature						
Characteristics	Pearson		Spearman		Kendall		Number of countries
	r	*P*-value	rho	*P*-value	tau	*P*-value	
2020							
March	−0.2536	0.0013	−0.5381	<0.0001	−0.3699	<0.0001	159
April	−0.3395	<0.0001	−0.4782	<0.0001	−0.3349	<0.0001	160
May	0.1537	0.0524	−0.2044	0.0095	−0.1420	0.0085	160
June	0.2622	0.0008	−0.0425	0.5934	−0.0296	0.5847	160
July	0.1716	0.0300	−0.1042	0.1897	−0.0717	0.1861	160
August	0.0807	0.3107	−0.1099	0.1664	−0.0766	0.1574	160
September	0.0298	0.7085	−0.1836	0.0202	−0.1333	0.0136	160
October	−0.3272	<0.0001	−0.4576	<0.0001	−0.3096	<0.0001	160
November	−0.4333	<0.0001	−0.5388	<0.0001	−0.3813	<0.0001	160
December	−0.5470	<0.0001	−0.6222	<0.0001	−0.4441	<0.0001	148
2021							
January	−0.3850	<0.0001	−0.5017	<0.0001	−0.3333	<0.0001	148
February	−0.3717	<0.0001	−0.4568	<0.0001	−0.3073	<0.0001	148
March	−0.3267	<0.0001	−0.4836	<0.0001	−0.3348	<0.0001	162
April	−0.4243	<0.0001	−0.4461	<0.0001	−0.3105	<0.0001	157
May	−0.2536	0.0013	−0.5381	0.0000	−0.3699	0.0000	159
June	−0.3395	0.0000	−0.4782	0.0000	−0.3349	0.0000	160
July	0.1537	0.0524	−0.2044	0.0095	−0.1420	0.0085	160
August	0.2622	0.0008	−0.0425	0.5934	−0.0296	0.5847	160
September	0.1716	0.0300	−0.1042	0.1897	−0.0717	0.1861	160
October	0.0807	0.3107	−0.1099	0.1664	−0.0766	0.1574	160
November	0.0298	0.7085	−0.1836	0.0202	−0.1333	0.0136	160
December	−0.3272	0.0000	−0.4576	0.0000	−0.3096	0.0000	160
2022							
January	−0.4333	0.0000	−0.5388	0.0000	−0.3813	0.0000	160
February	−0.5470	0.0000	−0.6222	0.0000	−0.4441	0.0000	148

observed similar results with strong negative correlation mostly in the winter months. We had further performed month-wise univariate analysis between sunlight and new cases of COVID-19. Pearson, Spearman, and Kendall statistical analyses observed strong negative correlation in the month of March and April. The univariate analysis between sunlight with new cases of COVID-19 has been shown in Table 4. We observed that sunlight follows a similar pattern such as temperature with strong negative correlation from October 2020 to April 2021. Similar to this, we observed strong negative correlation in the months of December 2021 to February 2022. Our findings with both temperature and sunlight indicated that cold temperatures escalate SARS-CoV-2 infection rates. To visualize our data more constructively, we squared the values of correlation coefficient of temperature and sunlight obtained from Pearson method and plotted against the months. Squaring of the values was done to eliminate the negative values of the correlation coefficient. Graph of square of correlation coefficient against months has been shown in Fig. 1 and Supplementary Fig. S2. The graphical pattern of correlation coefficient of average temperature mimics to the pattern of average sunlight with new average COVID-19 cases in each month. These findings suggest that the sunlight and environment temperature may have similar influence on estimator COVID-19 cases. Humidity was another variable included in our study. As the air temperature changes, relative humidity also changes, which is why month-wise correlation analysis was performed. The month-wise analysis of humidity and

Table 4
Month-wise univariate analysis to study the relationship between average new cases of COVID-19 and average monthly sunlight in northern hemisphere countries.

	New cases of COVID-19 vs average sunlight						
Characteristics	Pearson		Spearman		Kendall		No. of countries
	r	*P*-value	rho	*P*-value	tau	*P*-value	
2020							
March	−0.3113	0.0001	−0.5638	0.0000	−0.3902	<0.0001	159
April	−0.3345	<0.0001	−0.4001	0.0000	−0.2663	<0.0001	170
May	0.1272	0.0984	−0.0566	0.4632	−0.0362	0.4851	170
June	0.2134	0.0052	0.1278	0.0969	0.0847	0.1021	170
July	0.1562	0.0420	0.1521	0.0477	0.1070	0.0388	170
August	0.2359	0.0020	0.2026	0.0081	0.1425	0.0059	170
September	0.1144	0.1374	−0.0541	0.4836	−0.0430	0.4057	170
October	−0.3260	<0.0001	−0.4360	<0.0001	−0.2948	<0.0001	170
November	−0.4825	<0.0001	−0.5761	<0.0001	−0.4067	<0.0001	170
December	−0.6352	<0.0001	−0.7238	<0.0001	−0.5152	<0.0001	158
2021							
January	−0.5011	<0.0001	−0.6072	<0.0001	−0.4254	<0.0001	158
February	−0.4450	<0.0001	−0.5327	<0.0001	−0.3663	<0.0001	158
March	−0.3268	<0.0001	−0.4549	<0.0001	−0.3233	<0.0001	168
April	−0.3507	<0.0001	−0.4087	<0.0001	−0.2828	<0.0001	169
May	−0.3113	0.0001	−0.5638	0.0000	−0.3902	0.0000	159
June	−0.3345	0.0000	−0.4001	0.0000	−0.2663	0.0000	170
July	0.1272	0.0984	−0.0566	0.4632	−0.0362	0.4851	170
August	0.2134	0.0052	0.1278	0.0969	0.0847	0.1021	170
September	0.1562	0.0420	0.1521	0.0477	0.1070	0.0388	170
October	0.2359	0.0020	0.2026	0.0081	0.1425	0.0059	170
November	0.1144	0.1374	−0.0541	0.4836	−0.0430	0.4057	170
December	−0.3260	0.0000	−0.4360	0.0000	−0.2948	0.0000	170
2022							
January	−0.4825	0.0000	−0.5761	0.0000	−0.4067	0.0000	170
February	−0.6352	0.0000	−0.7238	0.0000	−0.5152	0.0000	158

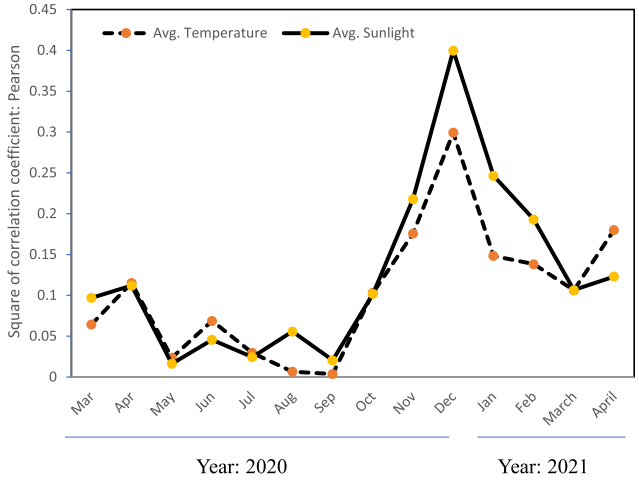

Fig. 1. Pattern of correlation coefficients of COVID-19 cases with monthly average sunlight and monthly average temperature of country in the month March 2020–April 2021 in northern hemisphere countries: Pearson analysis.

new cases of COVID-19 using Pearson, Spearman and Kendall method reported certain inconsistencies with positive value of R^2 in some months, whereas negative value in others. The univariate analysis between humidity with new cases of COVID-19 from March 2020 to April 2021 has been shown in Table 5.

Discussion

The world is in a pandemic mode for more than 2 years now and the novel SARS-CoV-2 continues to spread at an alarming rate. With the emergence of more contagious mutant strains, infection rates all over the world have been reported to increase rapidly. Despite various attempts by governments all over the world to limit the spread of SARS-CoV-2 through several precautionary measures such as social distancing, wearing masks, restricting gatherings, imposing night curfew, performing vaccinations, and practicing hand hygiene, the infectivity of this virus continues to be irrepressible. With most countries currently preparing to encounter the third wave of the deadly SARS-CoV-2, it becomes important to understand the seasonality of the virus to be able to predict infection waves beforehand and ensure rigorous public health mitigation strategies. Former studies that focused on major infectious outbreaks examined various factors that could influence the infectivity of viruses. Respiratory viruses such as influenza viruses and other coronaviruses (SARS and MERS-CoV) have been reported to depend upon environmental factors such as temperature.[18–20] Several studies conducted on influenza and SARS coronavirus reported high sensitivity of these viruses to increased temperatures. A study conducted in 2006 reported significant decrease in SARS-CoV infectivity, as the rise in temperature from 15°C to 29°C was observed. Considering such findings, we conducted a study to understand the link between temperature and COVID-19 incidence at the beginning of the pandemic. Our study observed higher COVID-19 cases in countries that were located in the higher latitudes of the globe. Thus, we performed a detailed correlation study that suggested a strong negative correlation between temperature and COVID-19 cases in March and April 2020. Since then, several studies were reported, which were in agreement with our findings,[21] and negative influence of temperature on COVID-19 cases was observed. A study conducted by Sobral et al. reported that 1°F increase in temperature led to a decrease of 6.4 cases per day.[22] However, some studies claimed positive correlation between temperature and COVID-19 cases.[11,12,23] Also, research conducted in 127 countries by Yuan et al. reported unclear link between COVID-19 incidence and humidity >70%.[13] Another study reveals insignificant relationship between relative humidity and spread of COVID-19.[24]

Table 5
Month-wise univariate analysis to study the relationship between average new cases of COVID-19 and average humidity in northern hemisphere countries.

Characteristics	New cases of COVID-19 vs average humidity						
	Pearson		Spearman		Kendall		Number of countries
	r	*P*-value	rho	*P*-value	tau	*P*-value	
2020							
March	0.1925	0.0141	0.4706	0.0000	0.3249	0.0000	162
April	0.2041	0.0076	0.3877	0.0000	0.2650	0.0000	170
May	−0.0565	0.4643	0.0744	0.3350	0.0533	0.3097	170
June	−0.1547	0.0439	−0.1481	0.0540	−0.1059	0.0436	170
July	−0.1622	0.0346	−0.1874	0.0144	−0.1329	0.0110	170
August	−0.0396	0.6078	−0.1817	0.0177	−0.1291	0.0134	170
September	−0.0681	0.3776	−0.2776	0.0002	−0.1902	0.0003	170
October	−0.2089	0.0062	−0.4016	<0.0001	−0.2650	<0.0001	170
November	−0.0233	0.7630	−0.3356	<0.0001	−0.2228	<0.0001	170
December	0.1171	0.1442	−0.1211	0.1308	−0.0654	0.2311	157
2021							
January	0.2075	0.0091	0.2732	0.0005	0.1888	0.0005	157
February	−0.0477	0.5527	0.3264	0.0000	0.2181	0.0001	157
March	0.2701	0.0004	0.2975	0.0001	0.2023	0.0001	170
April	0.2359	0.0021	0.1744	0.0242	0.1278	0.0160	167

Hence, in this study, we conducted a global 2-year analysis to identify the association of temperature and humidity with SARS-CoV-2 infectivity. To verify our finding that cold temperature augments COVID-19 infection, we performed correlation analysis for winter and summer months separately and observed negative correlation in winter month. Our present study has majorly focused on COVID-19 incidence in northern hemisphere countries. To further reconfirm that low-temperature influences SARS-CoV-2 infectivity, we included sunlight as another factor and performed univariate statistical analysis. Similar negative relationship between sunlight and new cases of COVID-19 was detected, with value of correlation coefficient near to 0.7 in the month of December. All these observations strongly suggested that cold temperature aggravates COVID-19 incidence. Three-dimensional representation of relationship between temperature, sunlight, and new cases of COVID-19 is depicted in Fig. 2. Various studies have reported several hypotheses that explain this relationship between air temperature and viral seasonality. Warmer temperature possibly affects the ordering of phospholipids, thus decreasing the stability of enveloped viruses such as SARS-CoV-2.[25] Seasonal fluctuations in temperature have also been reported to influence the airway defense at diverse levels. Low temperature can promote dry breathing that immobilizes the cilia, allowing the virus to elude mucous layer and attack the host cell easily.[26] Temperature is also known to suppress immune responses allowing the virus to replicate in host cells faster at low temperature.[27] The second finding of our study indicated that humidity is weakly associated with SARS-CoV-2 infectivity, and major inconsistencies were observed in the correlation analysis between the two factors.

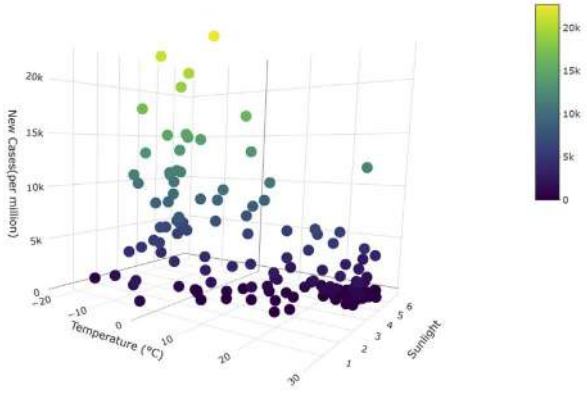

Fig. 2. Three-dimensional representation of relationship between average COVID-19 cases, average temperature, and average sunlight in winter months from November 2020 to February 2021.

The end of 2020 and beginning of 2021 witnessed many countries such as the United States, France, Russia, the United Kingdom, Italy, and Spain experiencing the second wave of COVID-19 pandemic, thus supporting the fact that cold temperature augments SARS-CoV-2 infectivity. Ours is the first global study that has focused on 2-year data from March 2020 to February 2022 and has taken into account all countries affected by COVID-19. With the uncertainties associated with novel mutant strains and upcoming third COVID wave, understanding the role of different environmental factors in the infectivity of this virus will help formulate optimized public health measures. Despite the novelty of SARS-CoV-2 virus, it is highly anticipated that this virus would possibly follow infectivity pattern similar to other respiratory viruses such as influenza virus and other coronaviruses.

Our study indicates a negative correlation between temperature, sunlight, and the number of COVID-19 cases, specifically in the northern hemisphere countries. However, the plausibility of this infectious virus also depends on age, sex, and ethnicity, the prevalence of different diseases in the population, as well as the prevalent antibodies in an individual (naturally or artificially acquired). Also, our findings take into account the atmospheric temperature on COVID-19 cases; how indoor temperature might affect infection rate remains unclear. Our study takes into account a comprehensive approach in understanding the role of temperature and sunlight in infection rates of the virus and takes into account the fluctuations observed in a single country. Moreover, with the emergence of SARS-CoV-2 mutant strains, the future trail of SARS-CoV in affecting the infection rate remains dubious. Although the pattern of infection by the virus may differ in the near future due to our growing knowledge of treatment and an improved understanding of the SARS-CoV-2 virus infectivity, a holistic approach on understanding how environmental factors affect the rate of infectivity will help formulate possible public measures to curb the infection rate in near future. Our study does not implicate those warm temperatures will be enough to curb the spread of the virus but rather emphasizes that more vigilant quarantine measures should be taken to avoid the dramatic spread of SARS-CoV-2. Our recent study has also suggested a combinatorial influence of environment temperature and other metabolic diseases such as obesity and high cholesterol on SARS-CoV-2 infectivity.[28] Future studies should also focus on

other factors such as public health policies, healthcare structures, and healthcare quality to understand the upsurge in COVID-19 cases in some countries compared with others.

Our 2-year data analysis further proposes that cold temperature could aggravate COVID-19 incidence, especially in the northern hemisphere countries. This research provides important pattern of COVID-19 infectivity and suggests that warmer temperature could limit the COVID-19 infection if the other precautionary measures are vigilantly followed.

Author statements

Author contribution

V.T. collected information, prepared tables and figures, and drafted the article. R.B. analyzed data and participates in writing the article. C.C.M. formulated study and written article.

Ethical approval

Not required.

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Competing interests

All authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.04.011.

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Short Communication

Efficacy of COVID-19 vaccines by race and ethnicity

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ABSTRACT

Objectives: Vaccine uptake amongst ethnic minority populations has been persistently lower, which may be because of socio-economic factors such as health literacy and health insurance status. This review aimed to assess to what extent COVID-19 clinical trials have considered the impact of race and ethnicity on COVID-19 vaccine safety and efficacy.
Study design: This was a systematic review.
Methods: Data regarding ethnicity in COVID-19 vaccine clinical trials were systematically reviewed according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines in this systematic review, which ran from inception until June 2021. Three international databases, PubMed, Scopus and Web of Science, were used to conduct systematic article searches. Only two studies reported vaccine efficacy among ethnic minority groups.
Results: The efficacy of the mRNA-1273 vaccine was confirmed to be 95% in Caucasians and 97.5% in 'people of colour' in a study by Baden et al. In another study by Polack et al., BNT162b2 mRNA vaccine efficacy was reported to be 95.2% in Caucasians, 100% in Afro-Caribbean or African Americans, 94.2% in Hispanic or Latinx and 95.4% in non-Hispanic, non-Latinx people.
Conclusions: Given the highly differing effect of COVID-19 on the Afro-Caribbean, Hispanic and South Asian populations, it is imperative for COVID-19 vaccine clinical trials to thoroughly assess the safety and efficacy of vaccines in different ethnicities and, if necessary, develop ethnicity-specific protocols, which can minimise the disproportionate effect of COVID-19 on ethnic minority populations.

Introduction

Globally, it is well established that ethnic minority populations, such as Afro-Caribbeans, South Asians and Hispanics, have been identified as carrying a higher risk of mortality from COVID-19.[1] However, despite this, vaccine uptake amongst ethnic minority populations has been persistently lower, which may be because of socio-economic factors, such as health literacy and health insurance status, mobility and social marginalisation.[2,3]

Addressing injustice and inequality in the impact of the vaccine on different ethnic groups requires a multifaceted approach that focuses on the needs of marginalised groups and ethnic groups.[4]

Distrust of science and treatment, as well as vaccination, is rooted in a history of mistrust resulting from immoral research, especially on African American, Latino, and Asian American populations.[4,5] Racism is an important factor in creating inequality in the face of disease, morbidity and mortality, especially vaccination against various diseases, and the same is true for COVID-19.[4–6] Policies that are designed to benefit many and to the detriment of others so that some races and ethnicities have unequal access to care and health care and even educational and employment opportunities.[4–6]

Given the complex interplay between ethnicity and COVID-19 disease and considering that the effect of race and ethnicity on the safety and efficacy of COVID-19 vaccine has not been studied in

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general, and its aspects are still unknown. This systematic review study was conducted to investigate the effect of different races, the effect of racial issues and racism on clinical trials of the effect of the COVID-19 vaccine to reveal all aspects of this effect.

Methods

The research protocol was registered in the PROSPERO (CRD42021261961). Data regarding ethnicity in COVID-19 vaccine clinical trials were systematically reviewed according to Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines in this systematic review, which ran from January 2020 until June 2021. Three international databases, PubMed, Scopus and Web of Science, were used to conduct systematic article searches. In addition, the Google Scholar search engine was examined. A survey was then performed to collect grey literature from libraries. In accordance with PECO (Population, Exposure, Comparator, and Outcomes) guidelines, the keywords used for the search in this study were chosen based on published preliminary studies and Medical Subject Headings (MeSH terms; in the reviewed database), as well as a thorough analysis of the study questions. Keywords used in this report included combinations of COVID-19, SARS-CoV-2 infection, 2019-nCoV infection, mRNA COVID-19 vaccine, vaccine, COVID-19 vaccine, ncov-19 vaccine, RNA vaccine and RNA-based COVID-19 vaccine. Of a total of 356 identified studies, 11 were included after considering both inclusion and exclusion criteria. The inclusion criteria were (1) randomised clinical trials experiments, (2) studies evaluating the effectiveness of COVID-19 vaccines, (3) studies with full text available, (4) studies of high and medium quality (score 16 and above), and (5) studies that have been released until the implementation of the systematic review process in this report (January 2020 until June 2021). The exclusion criteria were (1) cohort and control case studies, (2) case series, (3) case reports, (4) review studies, (5) studies without full text, (6) letter to the editor and (7) and (8) low-quality studies with a quality score of less than 16.

The quality of confirmatory studies was assessed with the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) checklist. The checks in this checklist were performed using 32 different items (scores between 0 and 32). In this study, studies that received a score of 16 or higher from the authors were selected and selected as mediocre and good-quality articles. Studies that received a score below 16 were considered poor quality and were excluded from the study. In these studies, none of the articles were deleted due to poor quality.

Table 1
Information on studies entered in the systematic review.

First author	Vaccine	Type of study	Total enrolled (detail) (n)	Caucasian/ethnic minorities (%)
Baden, L. R.[3]	mRNA-1273	Phase 3 randomised, stratified, observer-blinded, placebo-controlled trial	30,351 (Caucasian: 24,024, Asian: 1382, Afro-Caribbean or African American: 3090, American, Indian or Alaska Native: 233, Native Hawaiian or Other Pacific Islander: 67, multiracial: 634, other: 637, not reported and unknown: 282)	79.2/20.9%
Anderson, E. J.[7]	mRNA-1273	Phase 1, dose-escalation, open-label clinical trial	40 (Asian: 1, Caucasian: 39, Hispanic or Latino: 1)	98/2%
Folegatti, P. M.[8]	ChAdOx1 nCoV-19 vaccine (intervention) – MenACWY vaccine (control)	Phase 1/2, participant-blinded, multicentre, randomised controlled trial	1077 (not mentioned)	79.2/20.9%
Jackson, L. A.[9]	mRNA-1273 vaccine candidate, encodes the S-2P antigen	Phase 1, dose-escalation, open-label trial	45 (American, Indian or Alaska Native: 1, Asia: 1, Afro-Caribbean: 2, Caucasian: 40, Unknown: 1, Hispanic or Latino: 6)	89/11%
Keech, C.[10]	NVX-CoV2373 rSARS-CoV-2	Phase 1–2 Trial open-label	131 (American Indian or Alaska Native: 7, Asian: 17, Afro-Caribbean or African American: 2, multiracial: 1, Native Hawaiian or Other Pacific Islander: 1, not reported: 0, Caucasian:,103, Hispanic or Latino: 19)	78.6/21.4%
Logunov, D. Y.[11]	Gam-COVID-Vac combined vector	Phase 3 randomised controlled trial	19,866 (Caucasian: 19,571, Asian:286, Other:9)	98.5/1.48%
Mulligan, M. J.[12]	RNA vaccine BNT162b1	Phase 1/2 placebo-controlled, observer-blinded dose-escalation study	45 (Caucasian: 37, Afro-Caribbean or African American: 1, Asian: 7)	82.2/17.8%
Polack, F. P.[13]	BNT162b2 mRNA	Phase 2/3 placebo-controlled, observer-blinded, pivotal efficacy trial	37,706 (Caucasian: 31,266, Afro-Caribbean or African American: 3492, Asian: 1608, Native American or Alaska Native: 201, Native Hawaiian or Other Pacific Islander: 76, multiracial: 855, not reported: 208, Hispanic or Latinx: 10,543)	82.9/17.1%
Ramasamy, M. N.[14]	ChAdOx1 nCoV-19 vaccine	Phase 2/3 single-blind, randomised, controlled	552 (Caucasian: 524, Afro-Caribbean or Afro-Caribbean British: 1, Asian or Asian British: 19, mixed race or ethnicity: 4, other race or ethnicity: 4)	95/5%
Richmond, P.[15]	SCB-2019 vaccine	Phase 1, randomised, double-blind, placebo-controlled trial	151 (race: Asian: 16, Afro-Caribbean: 1, Caucasian: 132, Other: 2/ethnicity: Hispanic or Latino: 10, not Hispanic or Latino: 141)	87.4/12.6%
Stone, J. H.[16]	NVX-CoV2373	Phase 1/2 randomised, placebo-controlled trial	131 (American Indian or Alaska native: 7, Asian:17, Afro-Caribbean or African American: 2, multiracial: 1, native Hawaiian or other pacific: 1, Caucasian: 103, Hispanic or Latino: 19)	78.6/21.4%

Results

The studies, as shown in Table 1, included phase 1, 2 and 3 trials, as well as different vaccines. The total population included in the 11 studies was 90,095, of which 85% were of Caucasian ethnicity. Only two studies reported vaccine efficacy among ethnic minority groups. The efficacy of the mRNA-1273 vaccine was confirmed to be 95% in Caucasians and 97.5% in 'people of colour' in a study by Baden et al.[13] In another study by Polack et al., BNT162b2 mRNA vaccine efficacy was reported to be 95.2% in Caucasians, 100% in Afro-Caribbean or African Americans, 94.2% in Hispanic or Latinx and 95.4% in non-Hispanic, non-Latinx people.[17] The remaining studies did not look at the efficacy or effects of vaccines based on ethnicity or race.

Discussion

Overall, our results indicate that ethnic minority populations are often excluded or under-represented in clinical trials. Various reasons have been postulated to account for this phenomenon, such as language barriers, health illiteracy, mistrust of research, stigma, cultural factors and loss of earnings in deprived populations.[2,18] In addition to reduced clinical research participation by ethnic minority groups, many clinical trials also often do not report ethnicity despite its clinical relevance.[19]

In conclusion, it is evident that several COVID-19 vaccine clinical trials have not considered the impact of ethnicity on the safety and efficacy of COVID-19 vaccines in concordance with the surrounding literature.[19]

Various studies have raised various debates about racism as a key factor, which may cast doubt on the effectiveness of the vaccine among different ethnic groups. Bagasra et al. reported in their study that a significant difference in the level of trust in the government's response to the COVID-19 pandemic, with Indian/Alaskan Natives reporting lower trust compared with Whites, Blacks and Asians.[6]

The study by Hussain-Gambles et al. also reports that ethics committees can address racial and ethnic inequalities by providing guidance to researchers and more rigorously reviewing clinical trial protocols.[20]

The study by Kahn et al. also reports that the scientific community must systematically collect accurate data on race and ethnicity to eliminate ethnic inequalities in clinical settings and provide appropriate feedback at the individual and create social.[21]

Given the highly differing effect of COVID-19 upon the Afro-Caribbean, Hispanic and South Asian populations, it is imperative for COVID-19 vaccine clinical trials to thoroughly assess the safety and efficacy of vaccines in different ethnicities and, if necessary, develop ethnicity-specific protocols, which can minimise the disproportionate effect of COVID-19 on ethnic minority populations.

Author statements

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Ethics approval

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Competing interests

The authors declare that they have no conflict of interest.

Authors' contributions

N.S., M.M. and A.V. contributed to the design. M.M., N.D. and H.G.H. participated in most of the study steps. A.D., M.M., N.D., H.G.H. and K.K. prepared the article. All authors have read and approved the content of the article.

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Original Research

Projected all-cause deaths attributable to COVID-19–related unemployment in Croatia in 2020

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ABSTRACT

Objectives: In 2020, Croatia reported the first increase in the unemployment rate after six consecutive years of reduction in the number of unemployed persons. Unemployment is associated with an increase in morbidity and mortality among unemployed persons. We estimated the number of potential excess deaths that could be associated with an increase in unemployment seen after the beginning of the COVID-19 pandemic in 2020.
Study design: This was a cross-sectional analytic study.
Methods: We used previously published meta-analyzed hazard ratios for the unemployment–mortality association and unemployment and mortality data from the Croatian Bureau of Statistics to estimate 1-year age-standardized deaths potentially attributable to COVID-19–related unemployment for persons aged 20–64 in Croatia.
Results: In January 2021, we observed a 19% increase in unemployment among persons aged 20–64 years compared with February 2020 (prepandemic). This increase in unemployment could lead to 23 excess deaths among newly unemployed persons. This would constitute a 42% increase in the number of deaths and 29% of all deaths among this group. Deaths were disproportionately higher among men and those aged >40 years.
Conclusions: To mitigate the negative impact of COVID-19–related unemployment on population health, interventions that will reduce the further spread of SARS-CoV-2 and policies that will ensure economic recovery and reduction of unemployment are needed. Job skills training and provision of legal and welfare advice programs for unemployed persons should be integrated with health interventions.

Introduction

COVID-19 is caused by a novel SARS-CoV-2 that emerged in late 2019 in Wuhan, China.[1] On January 30, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a public health emergency of international concern, the international spread accelerated from late February 2020, and on March 11, 2020, a pandemic was declared.[2] Croatia is a high-income country and a European Union (EU) member with a population of 4.1 million.[3] The first case of COVID-19 was reported in Croatia on February 25, 2020,[4] and as of June 2021, Croatia had 358,379 confirmed cases and 8123 deaths attributed to COVID-19.[5] In addition to the substantial impact on mortality and morbidity, the COVID-19 pandemic had a negative impact on the Croatian economy, and it had led to the 8% drop in the gross domestic product (GDP) in 2020 compared with 2019.[6]

The Croatian government implemented a set of regulations and restrictions to try to control the transmission of SARS-CoV-2.[7] The first set of regulations was introduced on March 19, 2020, and they focused on limiting travel of Croatian citizens across the national borders and limiting economic activity to only the most essential services (e.g. emergency medical services, food industry, gas stations, and grocery shops). The first increase in the number of unemployed persons was recorded in March 2020, and by January 2021, the unemployment increased by 17% compared with January 2020.[8] This increase came after six consecutive years of reduction in the number of unemployed persons, and this was the largest increase in unemployment since 2010 (Supplementary Fig. 1).[8]

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The right to work is a basic human right and a key part of economic stability in the concept of social determinants of health.[9] Job insecurity and unemployment have detrimental consequences for a person's health and well-being.[10] A person is considered unemployed if they are of working age and without work and if they are seeking work and currently available for work.[11] Unemployment is associated with excess mortality because of an increase in suicide, alcohol, and drug misuse[12–14] and an increase in heart disease and stroke mortality.[15] Negative health consequences of unemployment are often the most prominent in the first months or a year since losing the job, but an increase in the rate of unemployment can have a long-lasting impact on population health.[15]

In this article, we aim to estimate the number of potential excess deaths that could be associated with the increase in unemployment that we observed after the lockdown measures for mitigating the impacts of COVID-19 were implemented in 2020 (COVID-19–related unemployment).

Methods

To calculate excess deaths due to COVID-19–related unemployment, we used a method for determining the population attributable fraction (PAF).[16] This method was used by Matthay et al. to estimate the excess deaths that could be associated with COVID-19–related unemployment in the United States of America.[17] To estimate the increase in mortality due to unemployment, we used previously published meta-analyzed hazard ratios (HRs) for the unemployment–mortality association stratified by age and gender.[14] To estimate the impact of the COVID-19 pandemic on unemployment in Croatia, we used monthly unemployment data published by the Croatian Employment Service.[8] We calculated the difference in the number of unemployed persons in February 2020 (prepandemic period) and 12 months later in January of 2021 for persons who were aged 20–64 years. We used the estimated number of persons who are aged 20–64 years and who lived in Croatia in 2020 to calculate the percentage of unemployed persons in February 2020 and January 2021 and the increase in unemployment for this period.[18] We used the 2019 annual report on the number of deaths in Croatia to estimate prepandemic mortality rates stratified by age and gender.[19]

Results

Among persons aged 20–64 years, 25,302 more people were unemployed in January 2021 compared with February 2020. This was a 1.05% point increase in the unemployment rate (from 5.52% to 6.57%) or a relative increase of 19%.

The unemployment increase in 2020 was higher among women than men (1.18% vs 0.92% points, respectively; Table 1). Half of the population aged 20–64 years were women, but they made up 55% of all unemployed persons and 56% of newly unemployed persons in 2020. Persons aged 20–29 years constituted 20% of the population, but they made 26% of all unemployed persons and 36% of newly unemployed persons in 2020. When compared with the proportion of the population, the excess deaths due to the COVID-19–related unemployment were disproportionately higher among those aged 40–64 years, men aged 40–49 years, and women aged 20–49 years (Fig. 1). In 2020, men constituted 50% of the population aged 20–64 years and 44% of newly unemployed persons, but they made up 83% of all excess deaths due to COVID-19 unemployment.

A 1.05% points increase in unemployment due to the COVID-19 pandemic could lead to 23 excess deaths in this age group. This would constitute a 42% increase in the number of deaths among

Table 1
Unemployment related risk ratios, COVID-19–related unemployment increase stratified by age and gender, estimated number of excess deaths due to COVID-19–related unemployment by age and gender, Croatia, February 2020 to January 2021.

	All					Female by age					Male by age					Female all	Male all
	20–29	30–39	40–49	50–64	Total	20–29	30–39	40–49	50–64	Total	20–29	30–39	40–49	50–64	Total		
Unemployment–mortality risk ratio (RR)	1.73	1.73	1.77	1.25	–	1.73	1.73	1.34	0.9[a]	–	1.95	1.95	1.86	1.17	–		
COVID-19–related unemployment increase in percentage points, February 2020 to January 2021	1.91	1.18	1.01	0.53	1.05	2.15	1.38	1.08	0.62	1.18	1.69	0.98	0.94	0.43	0.92	1.18	0.92
Deaths attributable to COVID-19–related unemployment	3	3	8	9	23	1	1	1	0	3	3	3	6	3	15	3	15
Percentage of all attributable deaths	13%	13%	35%	39%	100%	33%	33%	33%	0%	100%	20%	20%	40%	20%	100%	17%	83%
Percentage of total population	20%	22%	23%	35%	100%	19%	22%	22%	37%	100%	20%	23%	23%	34%	100%	50%	50%

Risk ratios calculated based on the hazard ratios presented in Roelfs et al.[14]
RR for women 50-64 was 0.94 with 95% confidence interval including 1, and this is why we treated this age group as not having an additional risk of death due to unemployment.

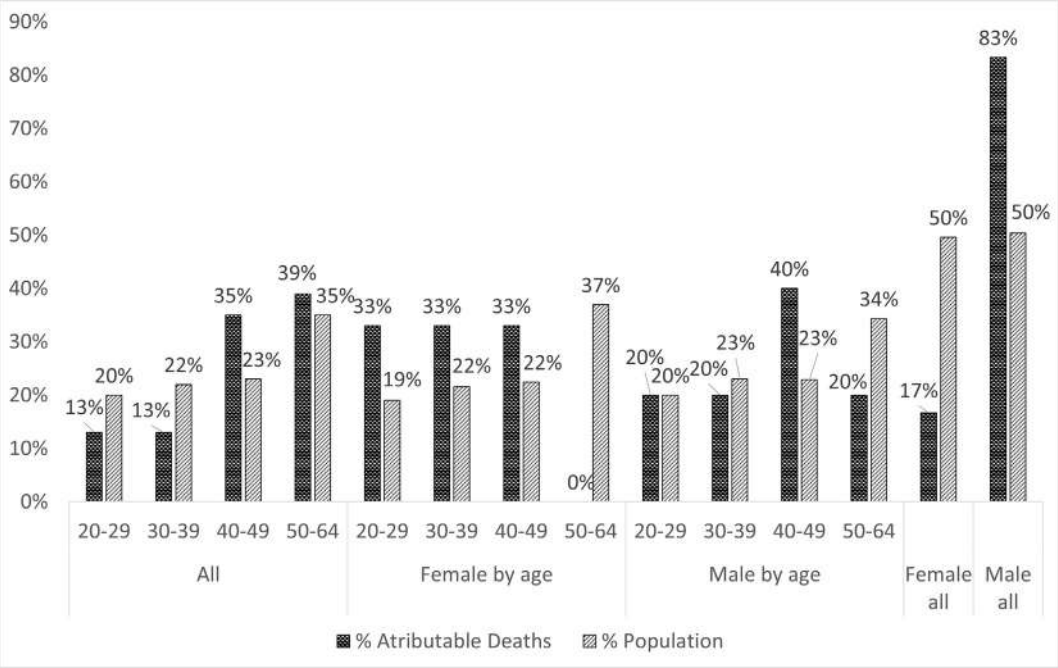

Fig. 1. Estimated 1-year age-standardized death count attributable to COVID-19 -related unemployment for the Croatian population aged 20 -64 years stratified by age and gender, Croatia, Feb 2020 -Jan 2021. Values indicate the attributable death count due to COVID-19 related unemployment, percentage of attributable deaths, and percentage of population in each group.

newly unemployed persons and 29% of all deaths among newly unemployed (Fig. 2).

We explored scenarios where COVID-19–related unemployment increases were five times (5.25 percentage points) and 10 times (10.5 percentage points), the observed level of increase in unemployment (Table 2). Excess deaths attributable to COVID-19–related unemployment in these two potential scenarios would be 114 and 222, respectively.

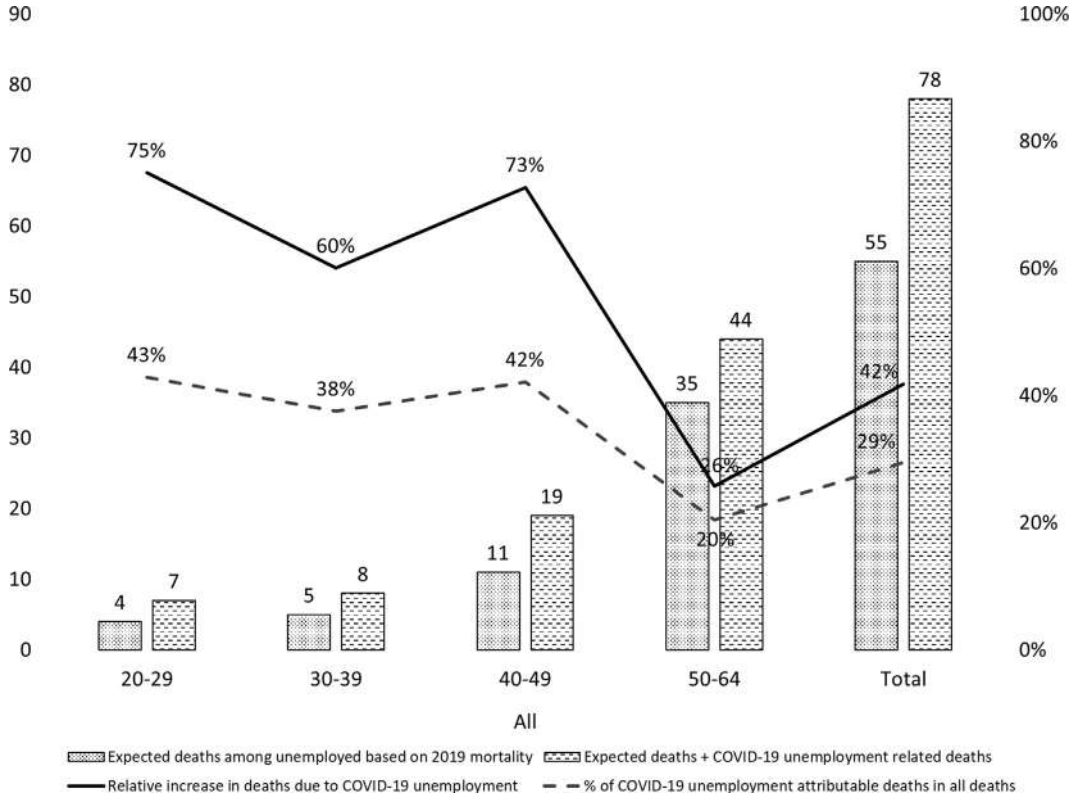

Fig. 2. Estimated deaths among unemployed persons, relative increase and percentage of excess deaths due to COVID-19 related unemployment stratified by age, Croatia, Feb 2020 -Jan 2021.

Table 2
Estimated number of COVID-19 attributable deaths if the COVID-19–related unemployment in 2020 increased by 5.25 percentage points (5× of official estimates) or 10.5 percentage points (10× official estimates), Croatia, February 2020 to January 2021.

Increase in COVID-19 related unemployment	20–29	30–39	40–49	50–64	Total	% of total deaths among 20 to 64 in 2019 (n = 8411)	% of estimated total COVID-related deaths as of February 2021 (n = 5011)
Unemployed persons on January 2021 (at 5.25 percentage points increase)	45,170	31,235	27,505	22,600	126,510		
Deaths attributable to COVID-19 unemployment	14	17	40	43	114	1.36%	2.28%
Unemployed persons on January 2021 (at 10.5 percentage points increase)	90,340	62,470	55,010	45,200	253,020		
Deaths attributable to COVID-19 unemployment	25	34	77	86	222	2.64%	4.44%

Discussion

Our analysis suggests that an increase in unemployment that happened after the start of the COVID-19 pandemic could result in 23 excess deaths among the working-age population in Croatia. The excess deaths will be disproportionally higher among those aged >40 years of age and men. To put this estimate into context, as of February 2021, a total of 5011 deaths attributable to COVID-19 were recorded,[20] whereas a total number of deaths among persons aged 20–64 years in 2019 was 8411.[19]

A similar analysis that was done for the United States showed that estimated excess deaths due to COVID-19–related unemployment were approximately 8% of the total number of COVID-19–related deaths in 2020.[17] The much smaller excess deaths in Croatia (<1% of all COVID-19–related deaths) could be partially explained by the much lower increase in COVID-19–related unemployment in Croatia compared with the United States (1 vs 10 percentage points increase), by lower mortality rates in working-class population in Croatia and by a larger increase in unemployment among the older working-age population in the United States compared with Croatia.

The non-pharmaceutical interventions (e.g. physical distancing, face coverings mandates, banning of large in-person gatherings, school and workplace closures, etc.) implemented to mitigate the impact of the COVID-19 pandemic on population health resulted in a significant reduction in transmission, hospitalization, and deaths related to COVID-19 across the world.[21] The evaluation of the implementation of non-pharmaceutical interventions in Organization for Economic Co-operation and Development countries showed faster economic recovery when implemented early enough in the pandemic.[22] However, these interventions can also lead to a reduction in economic activity and an increase in unemployment, which can have a negative impact on the population health.[14,15]

Before the COVID-19 pandemic Croatian GDP growth was accelerating, with a growth rate of 2.9% in 2019.[6] In 2020, the GDP growth turned negative and contracted sharply by 8.0% driven mainly by a fall in the tourism sector, domestic consumption, and difficulties in exports. Among the 27 EU member states, only Spain (10.8%), Italy (8.9%), and Greece (8.2%) experienced more severe GDP contractions in 2020.[6] The pandemic also had a negative impact on public finance. The public debt in Croatia reached 88.7% of GDP in 2020, a 15.9% points rise from 2019.[23] Croatia still has to catch up with the rest of the EU: the country's GDP per capita stands at 64% of the EU average in 2020 and labor participation remains low at 51.7%.[6]

In an attempt to mitigate the severe consequences of the COVID-19 pandemic on both companies and employees, the Croatian State Aid Model to microcompanies and small- and medium-sized enterprises affected by the COVID-19 pandemic was developed, amounting to a total of 653.3 million EUR between April 2020 and April 2021. It aimed to ensure that companies that are experiencing cash difficulties due to the pandemic have the liquidity to maintain their activities during and after the pandemic. For example, as of February 2021, more than 32,000 employers were receiving government subsidies to sustain 127,278 persons employed during the pandemic.[24] This number is similar to the estimated 126,510 unemployed persons if the increase in unemployment was five times the observed one (5.25 percentage points). In this scenario, the estimated excess deaths due to COVID-19 unemployment would be 114, and this would make 1.4% of total deaths in the 20–64 years age group in 2019. Therefore, while the rise in unemployment due to the COVID-19 pandemic in Croatia seems much smaller compared with the one in the United States, for now, it seems that a more drastic increase was mitigated by the government programs designed to assist employers to keep their workers employed during the pandemic. Additional research to explore the health benefits of government programs that provided basic support for workers during the pandemic should be done, and it should include EU countries with a diverse set of support programs to estimate the economic and health impact of different approaches.

Research findings analyzing data from the past 30 years found that fiscal consolidation equal to 1% of GDP, typically reduces GDP by about 0.5% within 2 years and raises the unemployment rate by about 0.3 percentage points.[25] The impact on long-term unemployment is apparent, and it hurts wage-earners disproportionately more than profit- and rent-earners, hindering the recovery and worsening job prospects.[25] The potential benefits of fiscal consolidation should be balanced against the short- and medium-run adverse impacts on growth and jobs.

Deaths related to the COVID-19 unemployment will disproportionally burden men and persons who are aged 40–49 years (23% of population and 35% of excess deaths) and 50–64 years (35% of population and 39% of excess deaths). The main reason for the disproportional number of excess deaths in men and persons >40 years is much higher baseline mortality compared with women and persons <40 years (Supplementary Table 2). While men constitute 50% of the population and 44% of newly unemployed in 2020, more than 80% of all excess deaths due to COVID-19 unemployment were among men. We observed higher COVID-19–related unemployment among women than among men, but the excess deaths due to the COVID-19 unemployment among women constituted only 17% of all the excess deaths. A similar pattern was reported in the US analysis where 21% of excess deaths due to COVID-19–related unemployment were among women while they made 50% of the working population.[17] This discrepancy in the excess deaths among women can be explained by lower unemployment–mortality association for women in each age group [14] and by substantially lower mortality rates among 20- to 64-year-old women compared with men (Supplementary Table 2). For example, in Croatia in 2019, women constituted 50% of the population aged 20–64 years, and only 31% of all deaths in this age group.[19]

The immediate excess deaths due to unemployment are attributed to an increase in the risk of suicide[13,26] and an increase in

alcohol and drug misuse that leads to an increase in morbidity and mortality.[12] In the recent analysis of trends in the number of suicides in the early months of the COVID-19 pandemic, Croatia seems to have a higher number of suicide deaths compared with the same time in 2019.[27] To mitigate these risks, it will be essential to address mental health challenges of the economic crisis by producing good access to mental health and primary health care services for unemployed persons and their families, with the adequate capacity to early recognize mental health problems, suicidal ideas, and heavy drinking or drug use (e.g. using hotlines for mental health counseling, raising awareness of the importance of mental health in the time of economic downturn, public health campaigns for reducing stigma around mental health).[13,26] In addition to access to mental health services, it has been shown that participation in group job skills training reduced the symptoms of depression and enhanced the emotional functioning of unemployed persons.[28] Provision of legal and welfare advice co-located with primary health care can improve mental health outcomes for unemployed persons.[29] Therefore, making sure that unemployed persons, especially the ones aged >40 years, have easy access to mental health services that are integrated with referrals to job skills training and access to legal and welfare advice could help reduce the negative impact of unemployment on health.

Loss of income and isolation exacerbated the risk of family violence during the COVID-19 pandemic in many settings.[30] Among the interventions for mitigating the impact of family violence are specific funding for measures to prevent and respond to violence, ensuring that the public, in particular women and children, are aware of the resources and types of services available by broadcasting violence hotline numbers via mass media, including social media platforms, and maintenance and expansion of hotlines and shelters. According to the United Nations recommendation, services for victims of violence and support to civil society and women's rights organizations should be included in the national COVID-19 preparedness, response, and recovery plan.[31]

In addition to more immediate effects on mortality, the increase in the rate of unemployment was associated with increased cardiovascular and cerebrovascular mortality up to 5 years after the unemployment increase.[15] To mitigate the longer-term effects of unemployment on cardio and cerebrovascular health, unemployed persons should have access to interventions that reduce high systolic blood pressure, improve smoking cessation, increase physical activity, promote a healthy diet (e.g. reduction of sodium intake), and improve stress management.[32]

Limitations

Our analysis has several limitations. First, the mortality HRs for unemployment were extracted from the meta-analysis that reported the median follow-up of 8 years. Therefore, by estimating the annual excess of deaths due to unemployment, we may have overestimated the number of excess deaths in first year because some causes required a longer duration to lead to death.[17] However, this and other analyses have shown that the highest increase in mortality was observed in the first few years since the unemployment.[15,26] Second, our estimates reflect 1-year attributable mortality among persons who lost their job due to the COVID-19 pandemic, but the long-term impacts of the recession on the Croatian and world economy and employment levels are still unclear, and they may last far longer, compounding the negative impact on the population health. Third, Croatian Employment Service reports the number of unemployed persons by month, but they do not provide monthly estimates of the active labor force stratified by age and gender that is needed to calculate the exact unemployment rate. Therefore, to calculate the unemployment rate stratified by age and gender, we used the 2020 population estimates reported by the Croatian Bureau of Statistics. Given that the entire population is not included in the official unemployment rate calculations, our estimates of the unemployment rate were lower in comparison to the official national estimates that use only the active labor force as the denominator (e.g. for February 2020, official unemployment rate was 8.2%, and our estimate was 5.5%). However, for estimating PAF due to unemployment, we used the difference in prepandemic and pandemic unemployment rate; and the difference between the prepandemic and pandemic unemployment rates for both approaches were almost identical (1.1% vs 1.05%). Forth, while we observed the increase in the unemployment after the first lockdown measures for limiting economic activity were implemented, we cannot know if all newly unemployed persons since March 2020 were unemployed because of the impact of the COVID-19 pandemic or some other reason. However, given the change in the rate and the absolute number of unemployed persons that happened right after the start of the COVID-19 pandemic, we believe that majority of unemployment could be attributed to the impact of COVID-19. Fifth, it is unclear how the pandemic impacted the health risk of persons who are not employed but are not in active pursuit of a job. Finally, the majority of newly unemployed persons in 2020 had a high school education (68%), 22% had an education level higher than high school, and 10% had an education level lower than high school,[8] but we were not able to estimate excess deaths due to unemployment stratified by level of education because we did not have access to the necessary unemployment data stratified by education level and age. This estimate would be important for better understanding the distribution of excess deaths and targeting prevention interventions based on education level.

Conclusions

A relatively modest increase in unemployment due to the COVID-19 pandemic in Croatia resulted in a small number of excess deaths related to unemployment. In situations of a larger increase in unemployment, deaths attributable to unemployment could add to deaths directly associated with the COVID-19 and will disproportionately burden men and those who are aged 40–64 years. A combination of non-pharmaceutical interventions and vaccination is needed to reduce the further spread of SARS-CoV-2 and reduce the burden of COVID-19 on the population. To mitigate the negative impacts of unemployment on population health, policies that will ensure economic recovery and aim to reduce unemployment to prepandemic levels are needed. Interventions aimed at preventing health conditions responsible for the majority of the negative health consequences associated with unemployment (e.g. suicide, alcohol, and drug use, mental health disorders, cardio and cerebrovascular diseases) should be accessible and integrated with the job skills training and provision of legal and welfare advice programs for unemployed persons.

Author statements

Ethical approval

This study was based entirely on publicly available secondary data and was therefore exempt from institutional review board review.

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Competing interests

The authors have no conflicts of interest to report.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.04.004.

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Original Research

Relationship between the housing coldness/warmth evaluation by CASBEE Housing Health Checklist and psychological distress based on TMM Community-Based Cohort Study: a cross-sectional analysis

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ABSTRACT

Objectives: Previous studies have reported the relationship between housing environment and health, although due to cost and effort, it was difficult to conduct housing condition surveys on a large scale. The CASBEE Housing Health Checklist (the Checklist) made it possible to easily evaluate the housing condition from the resident's perspective. This study examined the relationship between housing coldness/warmth evaluation using the Checklist and psychological distress in a large-scale general Japanese population.
Study design: A cross-sectional study.
Methods: We analysed data from 29,380 people aged ≥20 years who lived in Miyagi Prefecture, Japan. As an assessment of housing coldness/warmth, we used the Checklist. We classified participants' total scores on the Checklist related to coldness/warmth into quartiles. The Kessler 6 scale was used as an indicator of psychological distress. Multivariable logistic regression models were used to estimate the adjusted odds ratio (OR) and 95% confidence intervals (CIs). Adjusted OR and *P*-values for linear trends were calculated using the quartiles of the Checklists' score.
Results: Among participants in Q1 (i.e., poorer subjective house condition), the percentage of people with psychological distress was high. Compared to the highest quartile, Q1 showed poorer evaluation of housing coldness/warmth, and higher OR for psychological distress. The OR (95% CI) of psychological distress for Q3, Q2, and Q1 compared with Q4 were 1.93 (1.74–2.14), 2.82 (2.55–3.12), and 5.78 (5.25–6.35), respectively.
Conclusions: Housing coldness/warmth evaluation was significantly related to psychological distress. This finding suggests that maintaining a comfortable thermal environment at home could be important for residents' mental health.

Introduction

Housing environments are known to be important factors for health. The World Health Organization (WHO) stated that housing environment factors such as low indoor temperatures and insulation, high indoor temperatures, injury hazards, and housing accessibility affect the health of residents.[1,2] The WHO Housing and health guidelines state that indoor temperatures should be high enough to protect residents from the negative health effects of cold.[2] This recommendation level is strong. Thus, indoor thermal environment is an important target among housing environment factors. Actually, several countries have set guidelines for using heating to keep the indoor temperature comfortable.[3,4]

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Previous studies have reported the relationship between indoor thermal environment and health. Some studies reported that home heating and insulation improved asthma symptoms and self-reported health condition.[5,6] Another study reported that home heating decreased the morning blood pressure surge in winter.[7] These findings suggest that the indoor thermal environment is important for physical health outcomes. However, the relationship between indoor thermal environment and mental health remains unclear as was concluded by a systematic review.[8] Smart Wellness Housing Project in Japan has been implemented since 2014, and projects on health and housing environment are being conducted. A previous study reported that housing quality affected quality of life in the Japanese population. Among the results, the assessment of indoor thermal environment was significantly associated with the mental health score that was assessed by the Short Form-8 questionnaire.[9] Further research is needed to understand the relationship between indoor thermal environment and mental health.

Humans can maintain a constant state regardless of changes in external environmental factors, and this property is called 'homeostasis.' When the external environment changes excessively, it affects the physiological aspect as an excessive stress response to the stressor, and causes adverse effects on the autonomic nervous system, endocrine system, and immune system. In addition, psychological responses such as depression and anxiety occur to stressors.[10–12] From this perspective, we hypothesized that indoor thermal environment is associated with psychological distress. Measuring the indoor temperature is the best way to directly assess the housing coldness/warmth, but they are cost and effort intensive. To the best of our knowledge, no large-scale research has been conducted because there has never been a simple standard survey to assess the housing environment effectively.

The Comprehensive Assessment System for Building Environment Efficiency (CASBEE) is a tool to evaluate the environmental performance of buildings. CASBEE has residential and urban development evaluation tools, which are collectively referred to as the 'CASBEE family.'[13] The Japan Sustainable Building Consortium issued the CASBEE Housing Health Checklist (the Checklist) as one of the CASBEE family.[14–17] The Checklist is a tool for assessing housing health-related performance from a resident's perspective. With this checklist, we can easily score our housing health-related performance such as housing coldness/warmth, noise, brightness, cleanliness, safety, and security. The advantage of the Checklist is that it does not require specialized knowledge or equipment. By using this checklist, we conducted a large-scale study on housing environment and health.

In this study, we aimed to investigate the cross-sectional relationship between the housing coldness/warmth evaluation by the Checklist and psychological distress in the general Japanese population.

Methods

Participants

We conducted a cross-sectional study using follow-up data from the Tohoku Medical Megabank Project Community-Based Cohort Study (TMM CommCohort Study).[18] The detailed design has been previously reported.[19] Briefly, the TMM CommCohort study aimed to assess and address the physical and psychological impacts of the Great East Japan Earthquake (GEJE). This study completed a baseline survey between May 2013 and March 2016, and informed consent was obtained from 54,952 participants in Miyagi Prefecture. People who participated in the baseline survey received a follow-up survey by mail. The schedule of sending the follow-up questionnaire was dependent on the time of the baseline participation. We performed a housing survey by the Checklist during the follow-up phase. We conducted a follow-up survey for the baseline survey participants and used the data from 32,484 respondents from January 17, 2016, to November 21, 2018. However, 3104 participants were excluded for the following reasons: (1) no data of psychological distress ($n = 1009$), and (2) no data on the housing coldness/warmth evaluation ($n = 2095$). Finally, we analysed data from 29,380 participants.

Assessment of psychological distress

We used the Kessler 6 scale (K6) as an indicator of psychological distress. K6 is based on modern psychometric theory and is widely used as an indicator of psychological distress.[20–24] Participants were asked to respond to the following question: 'Over the last month, how often have you felt the following: nervous, hopeless, restless or fidgety, so sad that nothing could cheer you up, that everything was an effort, or worthless?' The possible responses were as follows: 'all of the time' (4 points), 'most of the time' (3 points), 'some of the time' (2 points), 'little of the time' (1 points), and 'none of the time' (0 points). The total K6 score ranged from 0 to 24. The Japanese version of the K6 was developed using the standard back-translation method, which has been validated previously.[25] Following previous studies, we focused on the moderate or higher level of psychological distress as a score $\geq$5 of 24 points.[26–29]

Assessment of housing coldness/warmth

As an assessment of housing coldness/warmth, we used the Checklist.[14] The Checklist was developed in Japan as a tool for assessing the health-related performance of housing. Previous studies have reported validation of the Checklist for housing only in Japanese samples. Takayanagi et al. conducted a Web-based survey of 4793 residents of detached houses to investigate the association between the housing warmth evaluation by the Checklist and the insulation performance level. Housing with poor insulation performance had a lower evaluation of warmth on the Checklist.[15] Kawakubo et al. conducted a Web-based survey on detached houses (5497 households) in Japan to investigate the relationship between the evaluation of houses by the Checklist and the prevalence of various diseases by self-report. The results showed that the odds ratio (OR) of having no disease was significantly higher in the better group compared to the poorer group in terms of housing evaluation.[16]

Participants were asked to answer questions about their satisfaction with their home. The Checklist comprises 50 questions, of which 12 are related to coldness/warmth assessment. The question was as shown in Table 1. The possible responses were as follows: 'often' (0 points), 'sometimes' (1 points), 'rarely' (2 points), and 'never' (3 points). The total score for the 12 questions ranged from 0 to 36.

Covariates

We included the following variables as covariates: age, sex, working status (full-time employee, self-employed or temporary work or part-time, seeking work, unemployed, or unknown), educational background (below high school, vocational school or junior college or technical college, university or graduate school, others, unknown), family composition (alone, household, unknown), and season at the time of the survey (summer, winter, others). For the classification of seasons, the average temperature of Sendai City from 2016 to 2018 was used as a representative of Miyagi Prefecture, and it was divided into three seasons in

Table 1
The CASBEE Housing Health Checklist related to coldness/warmth.

Questions of the CASBEE Housing Health Checklist related to coldness/warmth		Often (0 points)	Sometimes (1 points)	Rarely (2 points)	Never (3 points)
		Proportion of subjects with psychological distress[a] (%)			
CASBEE 1	How often do you close the living room and spend time without using an air conditioner or fan in summer? (Living room)	274/1056 (25.9)	697/2375 (29.3)	1773/6598 (26.8)	3912/19,351 (20.2)
CASBEE 2	How often do you feel hot in the living room due to the ineffectiveness of the air conditioner during summer? (Living room)	1378/5224 (26.3)	2171/8169 (26.6)	1433/6396 (22.4)	1674/9591 (17.5)
CASBEE 3	How often do you feel cold during heating the living room? (Living room)	1806/6053 (29.8)	2457/8976 (27.4)	1343/6408 (21.0)	1150/7943 (14.5)
CASBEE 4	How often do you have trouble sleeping because of the summer heat? (Bedroom)	829/1766 (46.9)	3348/12,069 (27.7)	1759/9427 (18.7)	720/6118 (11.8)
CASBEE 5	How often do you have trouble sleeping due to the humidity in the summer or in the rainy season? (Bedroom)	458/823 (55.7)	2336/6881 (33.9)	2507/11,187 (22.4)	1355/10,489 (12.9)
CASBEE 6	How often do you close your bedroom and sleep without using an air conditioner or fan in summer? (Bedroom)	902/3409 (26.5)	1362/4999 (27.2)	1897/7494 (25.3)	2495/13,478 (18.5)
CASBEE 7	How often do you have trouble sleeping because of coldness in winter? (Bedroom)	373/692 (53.9)	1864/4902 (38.0)	2446/9885 (24.7)	1953/13,901 (14.0)
CASBEE 8	How often do you have dry nose and throat when you wake up in winter? (Bedroom)	1249/3068 (40.7)	3269/12,775 (25.6)	1402/7090 (19.8)	736/6447 (11.4)
CASBEE 9	How often do you feel cold in the undressing room in winter? (Sanitary space)	2293/6606 (34.7)	2828/12,312 (23.0)	969/5612 (17.3)	566/4850 (11.7)
CASBEE 10	How often do you feel cold in the bathroom in winter? (Sanitary space)	1970/5317 (37.1)	2737/10,988 (24.9)	1259/7017 (17.9)	690/6058 (11.4)
CASBEE 11	How often do you feel cold in the toilet in winter? (Toilet)	2126/5997 (35.5)	2711/11,359 (23.9)	1145/6453 (17.7)	674/5571 (12.1)
CASBEE 12	How often do you feel cold when you get out of heating room in winter? (Corridor/ stairs)	2499/7595 (32.9)	3008/13,771 (21.8)	739/4577 (16.1)	410/3437 (11.9)

CASBEE, Comprehensive Assessment System for Building Environment Efficiency; K6, the Kessler 6 scale.
[a] Psychological distress was defined as K6 score $\geq$ 5.

descending order of monthly average temperature. We defined June, July, August, and September as summer, December, January, February, and March as winter, and the other months as other seasons. In addition, we added information about house destruction during the disaster (totally damaged or large-scale damage, small-scale damage, no damage or outside disaster area, and unknown) as covariates because this study was conducted in the area affected by the GEJE. Age was defined as the time of responding to the follow-up survey. Information about educational background and family composition was at the time of the baseline survey because we did not collect these data during the follow-up phase.

Statistical analyses

The data are presented as mean (standard deviation) for continuous variables or numbers (percentages) for categorical variables. We classified participants' summary score on the Checklist related to coldness/warmth into quartiles. The characteristics of participants across the quartiles were compared using the Chi-squared test for categorical variables and analysis of variance for continuous variables. Multiple logistic regression was used to assess the relationship between summary score of the Checklist and psychological distress. We calculated the OR and 95% CIs. Adjusted OR and *P*-values for linear trends were calculated using

the quartiles of the Checklists' summary score. Three multivariable-adjusted models were applied. First, covariates included age and sex (Model 1). Second, additional covariates included working status, educational background, family composition, season at the time of survey, and house destruction during the disaster were included (Model 2). Third, we also adjusted the Athens Insomnia Scale (AIS) score because the Checklist included questions related to sleeping habits (CASBEE 4–8) (Model 3).[30,31] Following previous studies, we defined total of less than 4 points as 'no problem,' 4–5 points as 'warrants consultation with a doctor if possible (insomnia possible),' and 6 or more points as 'warrants consultation with a doctor (insomnia suspected).'[32,33] Moreover, analysis was further stratified according to season at the time of survey because we were concerned that the assessment of housing coldness/warmth would differ depending on the season at the time of survey. As the Checklist consists of five question items about housing conditions in summer (CASBEE 1, 2, 4–6) and seven question items about housing conditions in winter (CASBEE 3, 7–12), we also examined the relationship between summer score and psychological distress and winter score and psychological distress separately. We defined the sum of five question items about summer housing conditions as summer score and seven question items about winter housing conditions as winter score, respectively. Finally, multiple logistic regression was used to assess the relationship between each question items of the Checklist and psychological distress. All analyses were performed using the Statistical Analysis System Software, version 9.4 for Windows (SAS Inc., Cary, NC, USA). Two-tailed *P*-values <0.05 were considered to be statistically significant.

Results

Baseline characteristics according to the Checklist score related to coldness/warmth are shown in Table 2. We analysed data from 29,380 participants (10,221 men and 19,159 women). The mean age of participants was 61.7 years (SD, 11.5), and 6656 participants (22.7%) had psychological distress. Subjects in Q1 (i.e.,

Table 2
Participants' baseline characteristics according to the CASBEE Housing Health Checklist score related to coldness/warmth ($n = 29,380$).

	Total	Score of the CASBEE Housing Health Checklist related to coldness/warmth				*P*-value[a]
		Q1 (≤16) (Poorer)	Q2 (17–20)	Q3 (21–25)	Q4 (≥26) (Better)	
Number	29,380	8111	6896	7499	6874	
Sex, *n* (%)						
Men	10,221 (34.8)	2707 (33.4)	2467 (35.8)	2632 (35.1)	2415 (35.1)	0.013
Women	19,159 (65.2)	5404 (66.6)	4429 (64.2)	4867 (64.9)	4459 (64.9)	
Age, years	61.7 (11.5)	59.5 (12.7)	61.1 (11.5)	62.3 (10.9)	64.3 (9.7)	<0.0001
K6 score, *n* (%)						
<5	22,724 (77.3)	4958 (61.1)	5298 (76.8)	6231 (83.1)	6237 (90.7)	<0.0001
≥5	6656 (22.7)	3153 (38.9)	1598 (23.2)	1268 (16.9)	637 (9.3)	
Working status, *n* (%)						
Full-time employee	2016 (6.9)	666 (8.2)	529 (7.7)	478 (6.4)	343 (5.0)	<0.0001
Self-employed or temporary work or part-time	10,927 (37.2)	3240 (40.0)	2678 (38.8)	2746 (36.6)	2263 (32.9)	
Seeking work	205 (0.7)	87 (1.1)	42 (0.6)	49 (0.7)	27 (0.4)	
Unemployed	15,008 (51.1)	3784 (46.7)	3389 (49.1)	3904 (52.1)	3931 (57.2)	
Unknown	1224 (4.2)	334 (4.1)	258 (3.7)	322 (4.3)	310 (4.5)	
Educational background, *n* (%)						
Below high school	18,057 (61.5)	5042 (62.2)	4160 (60.3)	4557 (60.8)	4298 (62.5)	0.0005
Vocational school or junior college or technical college	7072 (24.1)	1977 (24.2)	1704 (24.7)	1810 (24.1)	1581 (23.0)	
University or graduate school	3756 (12.8)	950 (11.7)	909 (13.2)	1031 (13.8)	866 (12.6)	
Others	192 (0.7)	62 (0.8)	44 (0.6)	44 (0.6)	42 (0.6)	
Unknown	303 (1.0)	80 (1.0)	79 (1.2)	57 (0.8)	87 (1.3)	
House destruction during the disaster, *n* (%)						
Totally damaged or large-scale damage	3171 (10.8)	818 (10.1)	683 (9.9)	775 (10.3)	895 (13.0)	<0.0001
Small-scale damage	16,414 (55.9)	4651 (57.3)	3927 (57.0)	4224 (56.3)	3612 (52.6)	
No damage or outside disaster area	8653 (29.5)	2337 (28.8)	2017 (29.3)	2219 (29.6)	2080 (30.3)	
Unknown	1142 (3.9)	305 (3.8)	269 (3.9)	281 (3.8)	287 (4.2)	
Family composition, *n* (%)						
Alone	2078 (7.1)	606 (7.5)	487 (7.1)	517 (6.9)	468 (6.8)	0.0601
Household	26,686 (90.8)	7316 (90.2)	6289 (91.2)	6835 (91.2)	6246 (90.9)	
Unknown	616 (2.1)	189 (2.3)	120 (1.7)	147 (2.0)	160 (2.3)	
Season at the time of survey, *n* (%)						
Summer respondents	9318 (31.7)	2319 (28.6)	2209 (32.0)	2430 (32.4)	2360 (34.3)	<0.0001
Winter respondents	13,474 (45.9)	3922 (48.4)	3100 (45.0)	3454 (46.1)	2998 (43.6)	
Other season respondents	6588 (22.4)	1870 (23.1)	1587 (23.0)	1615 (21.5)	1516 (22.1)	
AIS score, *n* (%)						
<4 points	17,395 (59.2)	3660 (21.0)	3954 (22.7)	4809 (27.7)	4972 (28.6)	<0.0001
4–5 points	5352 (18.2)	1701 (31.8)	1361 (25.4)	1350 (25.2)	940 (17.6)	
6 or more points	6323 (21.5)	2673 (42.3)	1508 (23.9)	1272 (20.1)	870 (13.8)	
Unknown	310 (1.1)	77 (24.8)	73 (23.6)	68 (21.9)	92 (29.7)	

The values in the table are presented as the means (standard deviations) for continuous variables or numbers (percentages) for categorical variables.
AIS, the Athens Insomnia Scale; CASBEE, Comprehensive Assessment System for Building Environment Efficiency; K6, the Kessler 6 scale.
[a] *P*-value obtained from Chi-squared test or analysis of variance for the quartiles.

poorer subjective house condition) were the youngest, and the percentage of people with psychological distress (K6 ≥5) and sleeping difficulties (AIS ≥6) was high. As the quartile increased, the proportion of unemployed increased. This seems counterintuitive, but most of the unemployed subjects were retired elderly people. There was no significant difference in family composition. Except for age difference (66.2 vs 61.7), no other marked differences were observed between the analysed subjects and those excluded.

Table 3 shows the relationship between the assessment of housing coldness/warmth based on the summary score and psychological distress. In both the crude and age-sex adjusted models, the assessment of housing coldness/warmth was significantly related to psychological distress. Further adjustment for working status, educational background, house destruction during the disaster, family composition, and season at the time of survey did not change the findings (Model 2). The OR (95% CI) of psychological distress for Q3, Q2, and Q1 compared with Q4 were 1.93 (1.74–2.14), 2.82 (2.55–3.12), and 5.78 (5.25–6.35), respectively. Even still statistically significance remains, there is an attenuation in the OR for psychological distress in the 'poorer' housing group was obtained when we added the AIS score as a covariate (Model 3). Adding smoking status and drinking status as covariates did not change the results (data not shown). In addition, when we performed stratified analysis by season at the time of survey, our results were essentially unchanged (eTable 1).

Fig. 1 shows the relationship between each question item of the Checklist and psychological distress. All question items were significantly related to psychological distress. Compared with the answer of 'Never,' the OR of having psychological distress for the 'Rarely,' 'Sometimes,' and 'Often' answers was higher (*P* for linear trend <0.0001). The OR for psychological distress for the subjects with 'sometimes' and 'often' categories were much higher for three of the CASBEE variables (CASBEE 4, 5, and 7) related with sleeping difficulties.

We performed a similar analysis for summer score (CASBEE 1, 2, 4–6) and winter score (CASBEE 3, 7–12). In both season score, the assessment of housing coldness/warmth was significantly related to psychological distress (eTable 2). In addition, when we stratified our analysis by the season at the time of survey, the result was similar for all seasons (data not shown).

Discussion

We examined the relationship between the assessment of housing coldness/warmth and psychological distress. In summary score, the assessment of housing coldness/warmth by the Checklist was significantly related to psychological distress. All question items about housing coldness/warmth in the Checklist were significantly related to psychological distress. In addition, in summer score and winter score, the assessment of housing coldness/warmth by the Checklist was significantly related to psychological distress. When we performed stratified analysis by season at the time of survey, this relationship was consistent across all season subgroups.

Previous studies have reported that home heating and insulation improved asthma symptoms and self-reported health.[5,6] Another study in Japan reported that increased use of heating raised indoor temperatures and decreased the morning blood pressure surge in winter.[7] These reports are consistent with our findings showing the importance of indoor thermal environments. This study showed that housing coldness/warmth evaluation is related to psychological distress. Our results suggested that housing environment is important for residents' health, even if it is a simple assessment from the residents' perspective without any actual measurements.

Some studies using the Checklist have reported that the residential environment is related to the prevalence of asthma, allergies, and other illnesses.[34,35] However, there have been no reports showing the relationship between housing evaluation and psychological distress using the Checklist. This study is the first to show that the assessment of housing coldness/warmth by the Checklist was related to psychological distress in the general Japanese population. Our findings suggest that maintaining a comfortable thermal environment could be important for mental health.

In our study, both summer and winter scores were related to psychological distress. Previous studies of indoor thermal environments were limited to investigating the relationship between winter cold and health.[5–7,36,37] However, our results have shown that not only the coldness of winter but also the heat of summer at home is related to psychological distress. Our findings indicated that preventive measures should be taken against not only winter coldness but also summer heat to maintain the mental health of residents. Our results indicated that the risk was higher for winter than summer. This suggests that mental health is impacted more by cold than by heat or humidity in this region of Japan.

Previous study reported that the ORs of insomnia is significantly higher in those with depression than in those without depression.[38] In addition, insomnia is a risk factor for depression.[39,40] Thus, in this study, we considered the effect of AIS on relationship between the assessment of housing coldness/warmth and psychological distress because some of the questions mentioned the sleeping habit. Although the relation was somewhat attenuated, the relation was unchanged. Furthermore, we calculated the OR for psychological distress using the Checklist's score with and without three question items (CASBEE 4, 5, and 7) to see if that would make any difference. The results did not

Table 3
Relationship between the assessment of housing coldness/warmth by summary score and psychological distress.

Summary score of the CASBEE Housing Health Checklist related to coldness/warmth	Q1 (≤16) (Poorer)	Q2 (17–20)	Q3 (21–25)	Q4 (≥26) (Better)	*P* for linear trend
Number of subjects	8111	6896	7599	6874	
Number of subjects with psychological distress[a]	3153	1598	1268	637	
Crude OR (95% CI)	6.22 (5.67–6.83)	2.95 (2.67–3.26)	1.99 (1.80–2.20)	1.00 (ref.)	<0.0001
Age-sex adjusted OR (95% CI)	5.66 (5.16–6.22)	2.77 (2.50–3.06)	1.91 (1.72–2.11)	1.00 (ref.)	<0.0001
Multiple adjusted OR (95% CI)[b]	5.78 (5.25–6.35)	2.82 (2.55–3.12)	1.93 (1.74–2.14)	1.00 (ref.)	<0.0001
Multiple adjusted OR (95% CI)[c]	4.39 (3.98–4.84)	2.42 (2.18–2.68)	1.78 (1.61–1.98)	1.00 (ref.)	<0.0001

AIS, the Athens Insomnia Scale; CASBEE, Comprehensive Assessment System for Building Environment Efficiency; CI, confidence interval; K6, the Kessler 6 scale; OR, odds ratio.

[a] Psychological distress was defined as K6 score ≥ 5.

[b] Adjustment items were age, sex, working status, educational background, house destruction during the disaster, family composition, and season at the time of survey.

[c] Adjustment items were age, sex, working status, educational background, house destruction during the disaster, family composition, season at the time of survey, and AIS score.

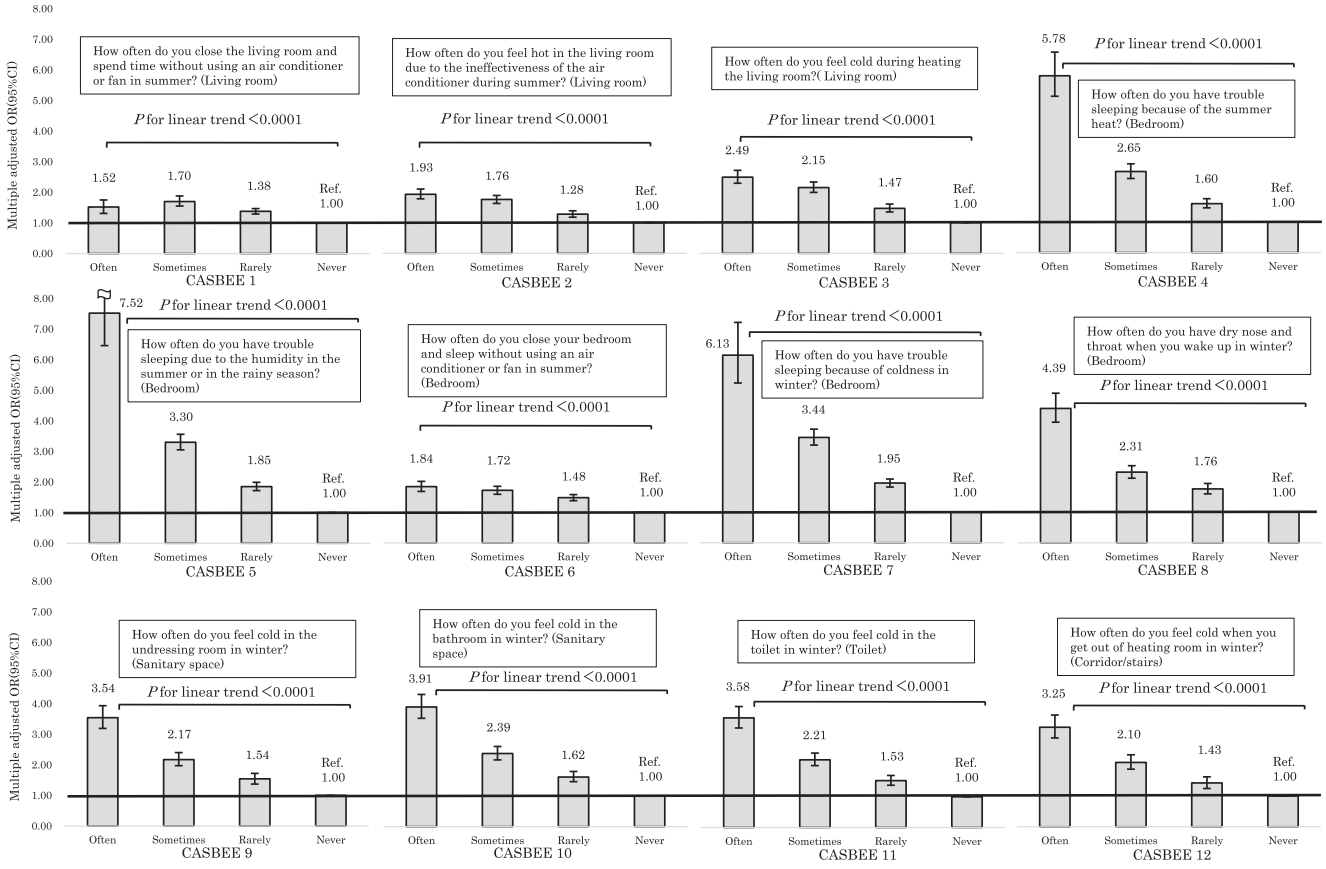

Fig. 1. Relationship between each question item of the CASBEE Housing Health Checklist and psychological distress. CASBEE, Comprehensive Assessment System for Building Environment Efficiency. Adjustment items were age, sex, working status, educational background, house destruction during the disaster, family composition, and season at the time of survey. *P*-values for linear trends were derived from multiple logistic regression analysis. Error bars represent 95% confidence intervals.

change. Therefore, we believe that the relationship between assessment of housing coldness/warmth and psychological distress is independent of AIS. We also considered that socio-economic status is an important confounding factor, so we adjusted for working status, educational background, house destruction during disaster, family composition, and season at the time of survey. However, due to lack of information, we could not adjust for income data in this study.

This study has strength. This study covers a large population of about 30,000 people. In previous studies,[5–8] it was difficult to collect many samples because these studies involved home renovations and actual room temperature measurements. By using the checklist, we were able to conduct a large-scale and precise survey of housing environment and health. Although this checklist was a subjective evaluation of residents, all question items of the Checklist related to housing coldness/warmth were significantly related to psychological distress. Our findings showed that housing dissatisfaction is related to psychological distress, even with a simple assessment from a resident's perspective.

Our study also has some limitations. First, we did not adjust for income data due to lack of information. However, considering the best alternative, we included working status and educational background as covariates in our analysis, even though they are only rough proxies. Second, all variables used in the analysis were based on self-administered questionnaires. The evaluation of the housing environment by the Checklist was a subjective evaluation by the resident. Therefore, participants who feel psychological distress may have poorly evaluated the housing environment. This might overestimate the relationship between assessment of housing coldness/warmth and psychological distress. Thirdly, the evaluation of housing coldness/warmth by the Checklist may not always match the actual room temperature. Although a previous study has reported the relationship between housing warmth evaluation using the Checklist and the insulation performance level of the house,[11] further research might be required to confirm the validity of the Checklist. In future, we will investigate the relationship between the indoor thermal environment and psychological distress by combining actual indoor temperature and subjective evaluations. Fourth, we did not collect information about relocation after the GEJE during the follow-up survey, and this could not be included in the analysis. The post-earthquake relocation might have affected the participant's housing environment, and the results of this study may show a stronger association than current results. Finally, in this study, all information on educational background and family composition was based on the baseline survey because we did not collect these data during the follow-up phase. Therefore, we could not know the change of those variables which might also change our results.

In conclusion, the assessment of housing coldness/warmth was significantly related to psychological distress. This relationship was consistent after adjusting for confounding factors. We suggest that maintaining a comfortable thermal environment at home could be important for residents' mental health.

Author statements

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Ethical approval

This study was approved by the Institutional Review Board of the Tohoku Medical Megabank Organization (approval number of the Ethical Review Board: 2021-4-028).

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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.2022.05.003.

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Short Communication

Self-reported health behaviors and risk perceptions following the COVID-19 vaccination rollout in the USA: an online survey study

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ABSTRACT

Objectives: Concerns have been raised that mass vaccination campaigns might lead to reduced engagement with other recommended health behaviors. We assessed self-reported behaviors and risk perceptions following the COVID-19 vaccine rollout in the USA.
Study design: Between December 2, 2020, and March 23, 2021, we conducted three online survey studies with US adult respondents.
Methods: Respondents self-reported their COVID-19 vaccination status, their frequency of engaging in risk-increasing behaviors and wearing a mask when in public places, and their COVID-19 risk perceptions (i.e., perceived likelihood of getting COVID-19 and of being hospitalized if they got COVID-19).
Results: Our analytical sample included 832 respondents who had completed the first and final surveys and had received either 0 or 2 doses of a COVID-19 vaccine. Most respondents were non-Hispanic White (75%), male (77%), and US Veterans (64%), with the median age between 55 and 74 years. Overall, respondents reported frequently wearing masks when in public and rarely engaging in risk-increasing behaviors. Regardless of vaccination status, respondents reported more frequently engaging in risk-increasing behaviors and lower risk perceptions in March 2021 than in December 2020. Mask wearing did not change over the study period, with vaccinated respondents consistently reporting more frequent mask wearing than unvaccinated respondents.
Conclusions: Taken together, our findings indicate that the COVID-19 vaccine rollout in the USA did not result in the rapid abandonment of protective behaviors or dramatic uptake of risk-increasing behaviors. Additional studies are needed to monitor how mass vaccination might impact public behaviors and risk perceptions as coverage widens.

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Introduction

Efforts to limit the impact of the COVID-19 pandemic have relied heavily on people making substantive changes to the way they live and interact with one another. Most people have been diligent in adopting and adhering to recommended health behaviors despite the high costs and difficulty of doing so.[1] However, signs of decreasing engagement, particularly to less habitual and more burdensome health behaviors (e.g., physical distancing), have emerged during the pandemic.[2,3]

Concerns have been raised that the rollout of COVID-19 vaccines would exacerbate decreasing public engagement to health behaviors.[4,5] Misconceptions about the protection offered by vaccines among those fully or partially vaccinated[6] and overconfidence in the protection of people who are vaccinated among unvaccinated people[4] have been noted as potential drivers of increased complacency toward health behaviors, which could undermine the public health impact of the COVID-19 vaccines. However, current evidence on the impact of the COVID-19 vaccine rollout on public engagement with other health behaviors remains limited and inconclusive,[7,8] particularly in the USA.

The aim of this study was to better understand the impact of the COVID-19 vaccine rollout on reported frequency of engaging in risk-increasing behaviors, wearing a mask when in public, and

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risk perceptions across the early vaccine rollout period in the USA (December 2020 to March 2021). To identify potential differences in the reported behaviors and perceptions of vaccinated and unvaccinated respondents, we compared respondents based on their COVID-19 vaccination status (0 doses vs 2 doses) as of March 2021.

Methods

Study population and recruitment

Respondents in this IRB-approved study were US adults recruited and compensated by Qualtrics for an online longitudinal study about the experiences of US Veterans and non-Veterans during the COVID-19 pandemic. Three surveys were conducted between December 2020 and March 2021 (December 2 to December 27, 2020 (n = 2085), January 21 to February 6, 2021 (n = 1257), and March 8 to March 23, 2021 (n = 1075)).

Procedure

Respondents answered a series of questions about their current behaviors, well-being, healthcare experiences, and attitudes regarding the COVID-19 pandemic. Although not relevant to the present findings, it is worth noting that at the start of the March 2021 survey, respondents were randomly assigned to a control group or to view one of two messages about COVID-19 vaccines as part of a separate experiment about communications regarding COVID-19 vaccine development and safety.[9] As the messages had no effect on respondents' vaccine intentions, safety perceptions, or worries about side-effects, we report data across all respondents.

Measures

Vaccination status (measured March 2021): 'Have you received the COVID-19 vaccine?' with responses 'No,' 'Yes, 1 dose,' and 'Yes, 2 doses.' As we could not differentiate between those vaccinated with a 1-dose vaccine (Johnson & Johnson) and those who received the first of a 2-dose vaccine (e.g., Pfizer or Moderna), respondents who answered 'Yes, 1 dose' were not included in these analyses. However, analyses including these respondents are available in the Appendix.

Risk-increasing behavior (measured December 2020 and March 2021): How frequently, if at all, respondents were doing five risk-increasing behaviors ('Going to gatherings of 10 or more people'; 'Going on optional shopping trips'; 'Going on optional travel'; 'Having optional social visits'; 'Eating inside restaurants, bars, and food courts'). These items demonstrated good reliability (Cronbach's alpha [α] = 0.84 for December 2020; α = .87 for March 2021) and were averaged for analyses.

Mask wearing (measured December 2020 and March 2021): How frequently, if at all, respondents were 'Wearing a mask over your nose and mouth when you are in a public place (e.g., a store).' The risk-increasing behavior and mask-wearing questions were answered using a six-point scale (1 = 'Never,' 2 = 'Very rarely,' 3 = 'Rarely,' 4 = 'Occasionally,' 5 = 'Frequently,' and 6 = 'Very frequently').

Risk perceptions (measured December 2020 and March 2021): Two questions ('In your opinion, how likely is it that you will get COVID-19 during the next month?,' and 'If you were to get COVID-19, how likely do you think it is that you would need to be hospitalized?') answered using a five-point scale (1 = 'Not at all likely' to 5 = 'Very likely').

Statistical analyses

Analyses were conducted using RStudio Version 1.4.1106. We conducted linear mixed-effects models with lme4 for each outcome measure with survey time (December 2020; March 2021) as the within-subjects factor and vaccination status as the between-subjects factor. For follow-up comparisons, we used rstatix to conduct Welch's independent t-tests and paired-samples t-tests. These analyses were not preregistered. Although we preregistered the research question, we realized the proposed analyses were not the most appropriate for answering the research question. Thus, we present the preregistered analyses in the Appendix.

Results

A total of 1075 respondents completed the December 2020 and March 2021 surveys (completion rate = 52%). Our analytic sample included 832 respondents who reported having received either 0 doses (361, 34%) or 2 doses (471, 43%) of a COVID-19 vaccine in the March 2021 survey. Most respondents were non-Hispanic White (621, 75%), male (641, 77%), and US Veterans (529, 64%), with a median age between 55 and 74 years (Appendix Table 1a).

On average, respondents reported very rarely engaging in risk-increasing behaviors both before and after the COVID-19 vaccine rollout (Fig. 1 and Appendix: Table 2). In December 2020, unvaccinated (0 doses) respondents reported more frequently engaging in risk-increasing behaviors as compared to vaccinated (2 doses) respondents (mean difference estimate, 0.39 [95% CI, 0.25 to 0.53]). Regardless of vaccination status, respondents reported more frequently engaging in risk-increasing behaviors over time, with the steeper increase observed among vaccinated respondents (0-dose group difference, −0.20 [95%CI, −0.29 to −0.12]; 2-dose group difference, −0.43 [95% CI, −0.49 to −0.36]). By March 2021, vaccinated and unvaccinated respondents did not differ (difference, 0.17 [95% CI, 0.00 to 0.33]), with both groups reporting very rarely engaging in risk-increasing behaviors following the vaccine rollout.

Most respondents reported frequently-to-very frequently wearing a mask when in public both before (December 2020: 99% of vaccinated respondents vs 87% unvaccinated respondents) and after the COVID-19 vaccine rollout (March 2021: 98% of vaccinated respondents vs 85% unvaccinated respondents). There were no observed changes regarding the reported frequency of mask wearing over the study period within groups; however, unvaccinated respondents consistently reported less frequently wearing masks as compared to vaccinated respondents (December 2020 difference; −0.44 [95% CI, −0.57 to −0.31]; March 2021 difference; −0.44 [95% CI, −0.58 to −0.31]).

All respondents, even those who were unvaccinated, reported that it was less likely they would get COVID-19 (0-dose group difference, 0.13 [95% CI, 0.02 to 0.23]; 2-dose group difference, 0.67 [95% CI, 0.59 to 0.75]) or be hospitalized if they did get COVID-19 (0-dose group difference, 0.19 [95% CI, 0.08 to 0.29]; 2-dose group difference, 0.76 [95% CI, 0.66 to 0.87]) in March 2021 as compared to December 2020, with the greatest reductions observed among respondents who were vaccinated by March 2021.

Discussion

Taken together, our findings indicate that the COVID-19 vaccine rollout in the USA did not result in the rapid abandonment of protective behaviors or dramatic uptake of risk-increasing behaviors. Overall, respondents reported very rarely engaging in risk-increasing behaviors both before and after the vaccine rollout. Thus, despite respondents engaging slightly more frequently in risk-increasing behaviors after the vaccine rollout, with a steeper

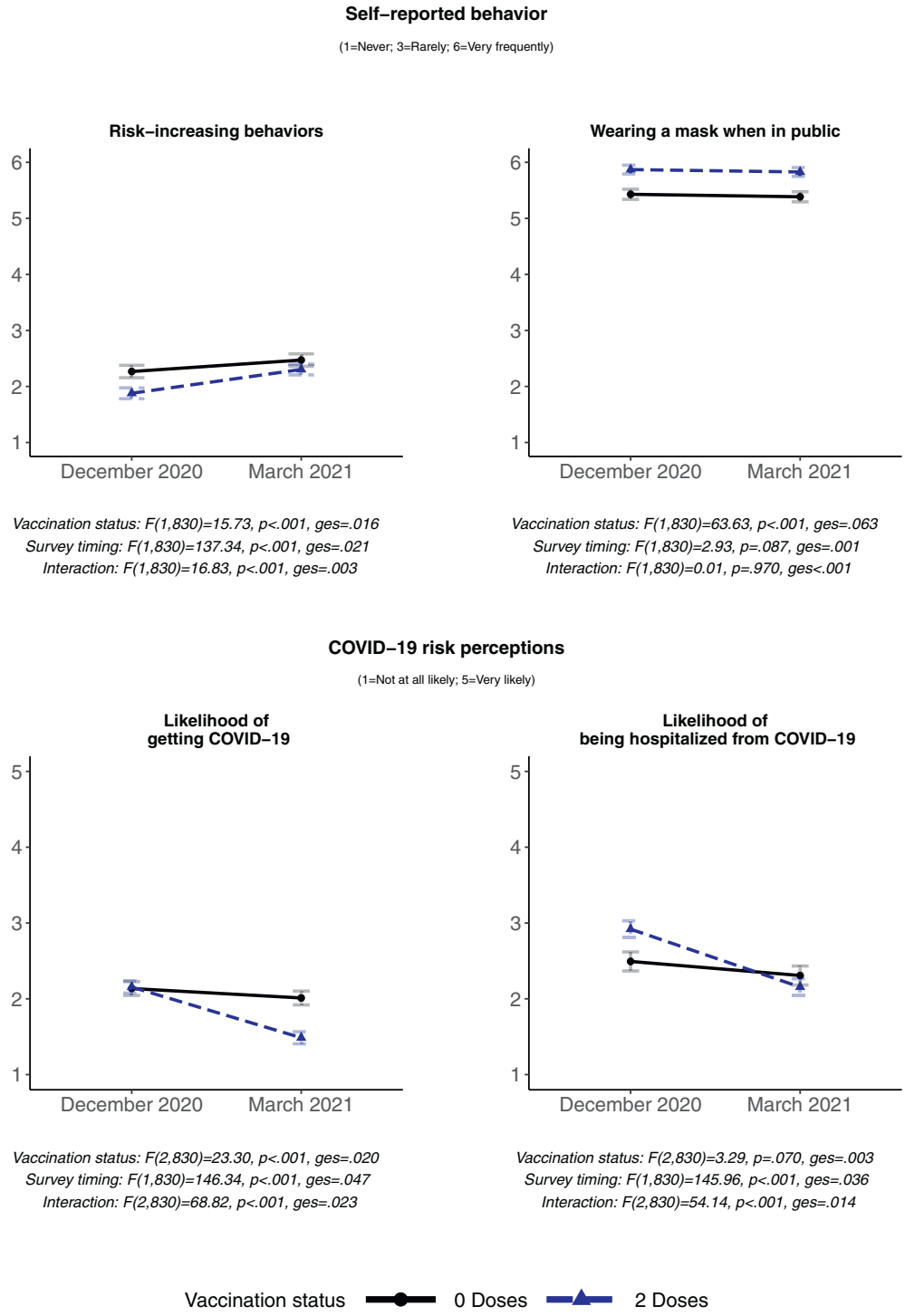

Fig. 1. Respondents' self-reported behaviors and risk perceptions from the December 2020 and March 2021 surveys according to their self-reported vaccination status as of March 2021. Results of mixed-effects models' main effects and interactions shown in each panel.

change among vaccinated respondents, both vaccinated and unvaccinated respondents continued to predominantly avoid engaging in risky behaviors and situations. Engagement with protective health behaviors also remained high following the COVID-19 vaccine rollout with the vast majority of respondents in our sample consistently reporting that they frequently-to-very frequently wore masks when in public. Notably, vaccinated respondents reported more frequent mask wearing than unvaccinated respondents, which further highlights the scope for promoting mask use by unvaccinated individuals. Although engagement with risk-increasing behaviors and mask wearing did not change dramatically, risk perceptions did vary with vaccinated respondents in particular thinking it was less likely they would get COVID-19 or be hospitalized if they did get COVID-19 following the COVID-19 vaccine rollout.

Limitations of the present study include reliance on the accuracy of self-reported vaccination status and behavior. Self-report data provide valuable public health insights, given the high

correspondence with actual health behaviors[10,11] and medical records (e.g., for vaccination status).[12] However, it is important to consider that there are many reasons why respondent's answers may have been inaccurate or inconsistent (e.g., social desirability). Observational data for the same period would therefore provide greater confidence in the present findings. In addition, our sample is not representative of the general population. Nonetheless, these findings provide important insights into the behaviors and perceptions of US adults, some of whom were eligible and received COVID-19 vaccines in the early stages of the rollout.

Continued assessment of public behavior remains important, given changing recommendations (e.g., revised CDC guidance for fully-vaccinated individuals announced in April and May-2021),[13] easing of public health measures, and the emergence of variants of concern (e.g., Delta/Omicron).

The present findings do not support concerns that the COVID-19 vaccine rollout resulted in complacency toward other health behaviors by either vaccinated or unvaccinated individuals. Conversely, vaccinated respondents continued to avoid risk-increasing behaviors and very frequently wore masks when in public even in light of their reduced risk following vaccination, which these respondents acknowledged in updating their risk perceptions. Unvaccinated respondents also continued to refrain from risk-increasing behaviors, frequently wore masks in public, and reported only moderate changes in their risk perceptions. These findings suggest that, at least in this study, the COVID-19 vaccine rollout did not appear to result in widespread complacency toward other health behaviors.

Author statements

Acknowledgments

The views expressed in this paper are those of the authors and do not necessarily represent the position or policy of the U.S. Department of Veterans Affairs or the United States Government. References are limited by space.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contributions

Thorpe, Scherer, and Fagerlin, concept and design; Thorpe, Scherer, Shoemaker, and Fagerlin, acquisition, analysis, or interpretation of data; Thorpe, drafting of the manuscript and statistical analysis; Scherer and Fagerlin, supervision; all authors, critical revision of the manuscript for important intellectual content.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2022.05.007.

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Original Research

Teachers' emotional well-being during the SARS-CoV-2 pandemic with long school closures: a large-scale cross-sectional survey in Northern Italy

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ABSTRACT

Objectives: This study aimed to evaluate the magnitude of emotional burden on teaching staff during the SARS-CoV-2 pandemic in a significantly impacted region. In addition, the correlates of emotional burden were analysed to enable the design of targeted interventions.
Study design: This study was a cross-sectional survey.
Methods: An electronic survey was administered to the teaching staff at public schools and kindergartens in a specific geographical area. Cross-sectional assessments of pandemic-specific variables were performed using the Pandemic Fatigue Scale, the Depression Anxiety Stress Scale (DASS)-21, the Satisfaction with Life Scale, and the Resilient Coping Scale. DASS-21 results were compared with results from a parallel survey that was representative of the local general population.
Results: In total, 3251 teaching staff members participated in the survey. Teachers showed a higher emotional burden for depression, anxiety and stress than the general population during the pandemic. According to a linear regression model, this burden is correlated with the language in which the questionnaires were answered, mistrust towards institutions, specific SARS-CoV-2 anxiety, past infection with SARS-CoV-2, avoidance of information about the pandemic and pandemic fatigue; emotional burden was negatively correlated with measures for life satisfaction, resilience and team atmosphere. Some independent variables were shown to contribute differentially to the variance of depression, anxiety or stress.
Conclusions: Emotional distress during the pandemic among teachers is higher than in the general population and correlates with variables that could, at least in principle, be targeted for specific interventions.

Introduction

South Tyrol is a province in Northern Italy where native Italian, German and bilingual speakers live together but have a heterogeneous sociocultural background. South Tyrol was severely impacted by the SARS-CoV-2 pandemic. Accordingly, several different restrictive lockdowns were imposed: kindergartens (children aged 3–6 years) and primary schools (children aged 6–11 years) were closed or switched to distant learning between March 2020 and April 2021 for about one-third of the regular operating time. For middle schools (children aged 12-14), high schools (children aged 15-19 years) the duration of school closures was longer, and for high schools and professional schools (children aged 15-19 years), distance learning and school closures accounted for over half of the regular teaching time. Even before the SARS-CoV-2 pandemic, there was evidence that the teaching profession is often associated with increased stress[1] and that teachers generally have higher levels of depression than the general population.[2,3] During the pandemic, many teachers may have been faced with additional, more specific burdens, including an increased risk of infection while teaching, a feeling of responsibility for the health of the students, significant changes in the daily work routine (online lessons, hygiene routines, increased potential for conflict with parents, students, colleagues, and directors) and a feeling of low self-efficacy.

As the emotional well-being of teachers directly impacts the quality of teaching and the emotional state of the students,[4,5] a survey of the emotional burden on teachers during the pandemic is

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of central importance. To date, in addition to studies on the psychological well-being of teachers during the SARS-CoV-2 pandemic, studies on other population groups have been published, including health workers,[6,7] patients with chronic diseases,[8] college students,[9] undergraduate students,[10] dentists and dental students[11] and the general population.[12–14] These studies show a high level of emotional stress during the SARS-CoV-2 pandemic.

However, the results of previous publications on the extent of depression, anxiety and stress in teachers are inconsistent.[15] An online survey of depression among teachers in China, using a snowball sampling method, showed depression in 57.6% of 871 female teachers and 54.2% of 225 male teachers.[16] According to this survey, younger teachers and those with lower resilience are more vulnerable. In September 2020, a methodologically similar survey of 1633 teachers in the Basque region,[17,18] using the Spanish version of the Depression Anxiety Stress Scale (DASS)-21,[19] showed symptoms of depression in 32.2% of teachers, and an increased level of anxiety and stress was reported in 49.3% and 50.4%, respectively. In addition, this study reported that a greater proportion of female than male teachers experienced depression, anxiety and stress. The study also showed that older teachers had a higher level of emotional burden, which is in contrast to Zhou et al.[16] The divergent results could be because of differences in the selection bias, timing of the survey, implementation of different protective measures in individual countries,[20] perceived social support and autonomy of the teachers,[21] different types of teachers (kindergarten, different school types and university) and/or the questionnaires used.

As a result of these inconsistencies, the present study performed a survey to determine the emotional state (and its correlates) of the teaching staff of the South Tyrolean schools and kindergartens at the end of the 2020/21 school year. The present study used the same instruments to measure the emotional burden as in the Basque region study.[17,18] Further online surveys using the same instruments in the same geographical region (South Tyrol) for the general population took place at approximately the same time; thus, the present study was able to compare results with a local control group.

The main purpose of this study was to estimate the point prevalence of emotional burden during the pandemic, to compare it with the local general population and to determine correlates of emotional distress to enable the implementation of targeted preventive measures. According to prior research, high levels of emotional distress during the pandemic among school and kindergarten teachers were expected compared with the general population. In addition, it was predicted that there would be a significant correlation of depression, anxiety and stress with various endogenous and exogenous variables, such as mistrust towards institutions, chronic disease, coping style, resilience, satisfaction with life, pandemic fatigue, coronavirus anxiety, perceived team atmosphere, function at school, size of the institution, sex, age, sociocultural background, feeling prepared for online teaching, quarantine of their own class, prior infection with SARS-CoV-2 and years of teaching service.

Methods

Participants and procedures

All educational staff members (approximately 10,000) at South Tyrolean German, Italian and Ladin kindergartens and schools were invited by email (sent via the local school management) to participate in the online survey. Interested teachers completed the online survey (SosciSurvey) via an electronic link, which was active during the first 2 weeks of June 2021.

The link was accessed 4032 times, of which 3568 participants gave their informed consent and started answering the questionnaire. A total of 3253 participants completed the questionnaire. Two participants were excluded from further data analysis because they were likely answered without reading the questions; therefore, the final statistical analysis refers to 3251 participants, which corresponds to a final response rate of 32.5%.

The local general population control group consisted of a subsample from a larger sample that was selected as a representative local sample from the public statistic institute (ASTAT) in a 2020 survey and who agreed to answer a further questionnaire in June 2021. Complete DASS-21 values were available from 278 participants (mean age = 51.39 years [SD = 15.82], women 55.5%, return rate 43%).

To compare conspiracy and general distrust towards institutions, answers to the same questions from another larger local survey by the public statistics institute ASTAT in May 2021 are available as a control group (N = 1360, mean age = 52.2 years [SD = 17.78], women 53%, return rate 31%; for details, refer to a study by Lombardo and Gaertner[22]).

Instruments

In addition to demographic, personal and workplace variables, information about the quarantine of the teacher's own class/group (yes/no), the perceived quality of communication with students, the perceived working climate (5-point Likert scale) and the perceived preparation for online teaching were recorded (4-point Likert scale). To ensure anonymity as much as possible, the age, years of service and size of the institution were recorded in an aggregated form. The items on resilience, specific SARS-CoV-2 fear and conspiracy thinking were taken from the Covid-19 Snapshot Monitoring (COSMO) survey.[23] Conspiracy was split into two factors according to the results of a principal component factor analysis (mistrust towards institutions vs conspiracy thinking). The two factors explained 64.17% of the variance.

Teachers' emotional burden was assessed using the DASS-21 in the German[24] and Italian[25] versions. The questionnaire shows good psychometric properties.[25,26] The classification into different degrees of severity was based on the cut-off values of Lovibond and Lovibond.[27] Pandemic fatigue was measured with the six items from the Pandemic Fatigue Scale (PFS).[28] Life satisfaction was measured using the Satisfaction with Life Scale (SWLS),[29] available in a validated form for the German and Italian languages.[30,31] Coping strategies were recorded with the 4-item Brief Resilient Coping Scale (BRCS),[32] which records the adaptive handling of stressful situations and has been used in various surveys during this pandemic.[9,33] It is important to note that although BRCS is often used in different languages, to our knowledge, it is currently only available in a published and validated form in English. Therefore, the four items were translated by native Italian- and German-speaking colleagues into their respective languages and back-translated on the basis of the colleagues' certified English language skills. The procedure involved a subsequent discussion on the choice of the appropriate terminology for both languages by five members of the Psychological Service Department in Health District Bressanone/Brixen, Italy.

Data analysis

Prior research suggests that depression, anxiety, and stress might correlate to some extent with exogenous variables, such as age, sex and sociocultural background; thus, the present study included these variables in a linear regression model, so that any eventually confounding contribution of these exogenous variables

was statistically controlled. The variables in the regression model were selected based on prior research showing a correlation with emotional burden and on the assumption that they could be a proxy for targeted prevention programmes. In addition, the ETA coefficients were computed for plausible exogenous and endogenous variables, confirming relatively high correlations for endogenous variables with emotional burden and low correlations for the exogenous variables (for details, see ETA coefficients in Table S10 in the Supplementary material). For statistical comparison with the control group, the one-sample *t*-test was used when the raw data were unavailable; otherwise, the independent sample *t*-test was computed. Linear regression analysis was used to calculate the correlates of emotional burden. Statistical comparisons of single Likert-scale items were performed using the Wilcoxon test. All statistical analyses were performed using SPSS Version 23. Because of the large sample size, parametric test procedures were used if possible, even when data were not normally distributed. To avoid a β error, the significance level was set at 0.01. A significance level between 0.01 and 0.05 is interpreted as weakly significant.

Results

Table 1 shows the sociodemographic characteristics of the study participants. In this study, Cronbach's alpha for the DASS-21 scores were as follows: 0.945 (total), 0.901 (depression), 0.826 (anxiety) and 0.901 (stress).

The prevalence of high DASS-21 scores for depression, anxiety and stress among teachers and comparison with the local general population control group is shown in Table 2. The differences between the means of the two groups on the DASS-21 were statistically significant (independent sample *t*-test) for all variables, showing a higher emotional burden for teachers compared with the local general population control group.

Descriptive statistics and comparison with other groups for life satisfaction, pandemic fatigue, specific coronavirus anxiety, conspiracy and coping style

The mean score for teachers on the SWLS was 26.95 (SD = 5.06), which corresponds to a relatively high level of life satisfaction.[30] For teachers, the BRCS total scores were <14 (indicating low resilience coping) in 39.6%, 14–16 in 38.2% (medium resilience coping) and 17–20 (high resilience coping) in 22.3%. Compared with a large German survey,[34] the results from the present study correspond to an overall low level of resilience to handling stress.

The mean value for the PFS is 3.50 (SD = 1.1567). This is lower than the mean value of 3.97 that was reported in the German COSMO survey, dated 1 June 2021[28,35] (one-sample *t*-test: t = −22.927, df = 3250, $P < 0.001$, 95% confidence interval [CI] −0.5048 to −0.425). In addition, according to 33.4% of teachers, coronavirus triggers their anxiety, and 42.0% reported that they often or permanently think about coronavirus.

Compared with the local general population control group, teachers showed an increased general distrust towards the institutions; teachers more frequently believe that important things happen that they are never informed about (Wilcoxon z = −3.8398, $P < 0.001$), that politicians keep the true motivation of their decisions secret (Wilcoxon z = −2.954, $P = 0.0032$) and that citizens are closely monitored by government institutions (Wilcoxon z = −4.237, $P < 0.001$). In contrast, teachers less frequently believe that secret organisations have a major impact on political decision-makers (Wilcoxon z = 4.237, $P < 0.001$). With regard to the statement that COVID-19 was deliberately introduced into the world, there was a statistical trend for lower ratings with teachers compared with the general population (Wilcoxon z = 1.5483, $P = 0.01216$).

Correlates of emotional burden

To determine the contribution of various predictor variables to explain the overall DASS-21 score and the relative variance in subscores, a linear regression analysis was performed. As a result of some different independent variables for teachers and kindergarten teachers (e.g. perceived communication quality with students, perceived preparation for online teaching, prior experience with online teaching and differences in function profiles at school/kindergarten), an additional separate regression analysis was performed for the two subgroups ($N = 2533$ and $N = 718$, respectively). The variables entered into the regression model, and the results for the total sample are listed in Table 3. The results of the linear regression model for the two subgroups can be found in the Supplementary material.

According to the regression model, participants with higher scores on the SWLS showed a lower level of overall emotional stress, defined as the DASS-21 total score. The same in true for participants who answered the questionnaire in German (vs Italian), who perceived the team atmosphere as good, showed high resilience, low pandemic fatigue, little fear of SARS-CoV-2, lower mistrust towards institutions and reported no past SARS-CoV-2 infection.

In contrast, no significant contribution was found for the type of employment, years of service, resilient coping style or the type of school. A tendency towards a higher total emotional burden was found for women (significant for the dependent variable stress), younger age (significant for stress), chronically ill teachers (significant for anxiety) and those who reported quarantine of their own class. The same variables that explain the DASS-21 total score variance were also significant for the dependent variable depression. A separate data analysis for school and kindergarten teachers shows comparable β values and significant effects for both groups (for details, see the Supplementary material).

A further linear regression analysis, including school-specific variables, showed no significant contributions for involvement in online teaching (β = −0.012, t = −0.686, $P = 0.493$), the subjective feeling of preparedness for online teaching (β = −0.003, t = −0.192, $P = 0.848$) nor for the perceived quality of communication with students (β = −0.016, t = −0.919, $P = 0.358$) on the variance of the DASS-21 total score. Involvement in online teaching was specifically associated with increased depressive symptoms (β = −0.047, t = −0.2.613, $P = 0.009$); however, online teaching had no impact on stress and anxiety symptoms (β = −0.008, t = −0.4713, $P = 0.638$ and β = −0.031, t = −0.1.594, $P = 0.111$, respectively). The size of the institution and the specific function at school/kindergarten did not impact the emotional burden on teachers in either schools or kindergartens. The results for the separate regression analysis for teachers and kindergarten staff can be found in the Supplementary material.

Discussion

There is broad agreement that the SARS-CoV-2 pandemic increases the risk of emotional distress.[33,36,37] The present study confirms high DASS-21 total scores as well as elevated scores for the subscales (depression, anxiety and stress) among kindergarten and school teachers. These results are in line with those of previous studies[3,16,17] but are somewhat more moderate. This could be due to the different recruitment methods and the associated differences in non-response bias. In addition, compared with the study from the Basque region, the different timing of the survey may also

Table 1
Sociodemographic characteristics of study participants.

Variable		*n* (%)
Age ($N = 3251$)	<31	318 (9.8)
	31–40	622 (19.1)
	41–50	1113 (34.2)
	51–60	1015 (31.2)
	>60	183 (5.6)
Sex ($N = 3251$)	Female	2707 (83.3)
	Male	537 (16.5)
	Other	7 (.2)
Language ($N = 3251$)	German	2579 (79.3)
	Italian	672 (20.7)
School ($N = 3251$)	Kindergarten: 3-5	704 (21.7)
	Primary school 6-11	902 (27.7)
	Middle school 12-14	552 (17.0)
	Professional school 15-19	383 (11.8)
	High School 15-19	696 (21.4)
	Other	14 (.4)
Function at kindergarten ($n = 704$)	Kindergarten teacher	314 (44.6)
	Pedagogic collaborator	235 (33.4)
	Collaborator for integration	15 (2.1)
	Kindergarten teacher for integration	23 (3.3)
	Kindergarten teacher with additional responsibilities (coordination)	107 (15.2)
	Other	10 (1.4)
Number of collaborators at kindergarten ($n = 704$)	2	79 (11.2)
	3–4	140 (19.9)
	>4	485 (68.9)
Quarantine of the own kindergarten group	Yes	411 (58.4)
	No	293 (41.6)
Function at school ($n = 2533$)	Teacher	1906 (75.2)
	Collaborator for integration	88 (3.5)
	Teacher for integration	150 (5.9)
	Teacher with additional responsibilities (coordination)	358 (14.1)
	Other	31 (1.2)
Number of collaborators at school ($n = 2533$)	1–9	227 (9.0)
	10–19	383 (15.1)
	20–50	673 (26.6)
	51–79	449 (17.7)
	>79	801 (31.6)
Quarantine of the own school class	No	1281 (50.3)
	Yes	1266 (49.7)
Years of service ($n = 3249$)[a]	<5	624 (19.2)
	5–15	835 (25.7)
	>15	1790 (55.1)
	Missing	2 (0.1)
Employment type ($N = 3251$)	Full time	2171 (66.8)
	Part time	1080 (30.2)
Chronic disease ($N = 3251$)	Yes	416 (12.8)
	No	2835 (87.2)
Infection with SARS-CoV-2 ($N = 3251$)	Yes (mild 49.7%; middle 38.5%; severe 11.8%)	636 (19.6)
	No	2615 (80.4)

[a] Missing values for two subjects.

contribute to the differences: in contrast to Santamaria et al.,[17] our survey was carried out at the end of the school year before the long summer holidays. In addition, during the survey period of the present study, the pandemic wave subsided, and vaccination was available.

This cross-sectional survey confirms a significantly higher emotional burden among teachers compared with the general population. A high level of distress correlates significantly with a previous SARS-CoV-2 infection, higher levels of distrust towards institutions, Italian (compared with German) employees, coronavirus fatigue, lower resilience and lower life satisfaction. Teachers with a chronic disease showed higher levels of anxiety, whereas female teachers were prone to higher stress levels.

Table 2
Mean scores for the Depression Anxiety Stress Scale (DASS)-21 total, depression, stress and anxiety scores, and the proportion of participants with elevated scores above the respective cut-offs for the teaching staff and the local general population control group.

Category	DASS-21 score (mean ± SD)				Percentage above cut-off score			
	Teaching staff ($n = 3251$)	General population control group ($n = 278$)	*t*	Sig. (2-tailed)	Teaching staff ($n = 3251$)	General population control group ($n = 278$)	Exact Chi-square	Sig. (2-tailed)
Total score	21.68 ± 20.74	10.72 ± 15.85	10.77	<.001*	N/A	N/A		
Depression	6.41 ± 7.69	3.33 ± 6.39	7.57	<.001*	26.4	12.2	27.1	<.001*
Anxiety	4.31 ± 6.16	2.39 ± 4.41	6.72	<.001*	21.4	11.9	14.14	<.001*
Stress	10.97 ± 9.01	5.0 ± 6.79	13.65	<.001*	34.3	9.6	40.4	<.001*

N/A for not available, * means significant at P < .01.

Table 3
Linear regression model for the dependent variable Depression Anxiety Stress Scale (DASS)-21 total score, DASS-21 depression, DASS-21 anxiety and DASS-21 stress.

DASS21 total score		$R^2_{adj.}$		s_{yx}	F	P
		0.431		15.64	145.929	0.000*
		B	SE	β	t	P
Predictor	(Constant)	100.808	3.927		25.668	0.000*
	Language	5.986	0.717	0.117	8.345	0.000*
	Sex	−1.826	0.782	−0.034	−2.336	0.020
	Age	−0.686	0.342	−0.035	−2.005	0.045
	Type of school	0.321	0.213	0.023	1.511	0.131
	Employment type	0.053	0.599	0.001	0.089	0.929
	Years of service	−0.225	0.451	−0.009	−0.500	0.617
	Team atmosphere	−1.926	0.364	−0.073	−5.286	0.000*
	Chronic illness	−1.766	0.843	−0.028	−2.095	0.036
	Infection with SARS-CoV-2	−1.981	0.700	−0.038	−2.828	0.01*
	Quarantine	−1.207	0.555	−0.029	−2.173	0.030
	Mistrust towards institutions	0.182	0.066	0.045	2.781	0.005*
	Conspiracy thinking	−0.189	0.135	−0.023	−1.401	0.161
	Live satisfaction	−0.940	0.060	−0.230	−15.592	0.000*
	Resilience	−2.341	0.097	−0.370	−24.049	0.000*
	BRCS coping style	−0.091	0.118	−0.012	−0.775	0.44
	Pandemic fatigue (PFS)	0.361	0.046	0.121	7.813	0.000*
	Coronavirus anxiety (high values corresponds to low levels of anxiety)	−0.744	0.060	−0.178	−12.434	0.000*
DASS21—depression		$R^2_{adj.}$		s_{yx}	F	P
		0.387		6.03	121.818	0.000*
		B	SE	β	t	P
Predictor	(constant)	35.120	1.513		23.219	0.000*
	Language	1.071	0.276	0.056	3.876	0.000*
	Sex	−0.292	0.301	−0.014	−0.969	0.332
	Age	−0.053	0.132	−0.007	−0.406	0.685
	Type of school	0.154	0.082	0.029	1.884	0.060
	Employment type	−0.036	0.231	−0.002	−0.156	0.876
	Years of service	−0.274	0.174	−0.028	−1.577	0.115
	Team atmosphere	−0.605	0.140	−0.062	−4.314	0.000*
	Chronic illness	−0.414	0.325	−0.018	−1.274	0.203
	Infection with SARS-CoV-2	−0.596	0.270	−0.031	−2.210	0.027
	Quarantine	−0.528	0.214	−0.034	−2.468	0.014
	Mistrust towards institutions	0.051	0.025	0.034	2.012	0.044
	Complottism	−0.088	0.052	−0.029	−1.698	0.090
	Life satisfaction	−0.452	0.023	−0.298	−19.493	0.000*
	Resilienz	−0.728	0.037	−0.310	−19.409	0.000*
	BRCS coping style	−0.059	0.045	−0.020	−1.303	0.193
	Pandemic fatigue (PFS)	0.159	0.018	0.143	8.917	0.000*
	Coronavirus anxiety (high values corresponds to low levels of anxiety)	−0.211	0.023	−0.137	−9.183	0.000*
DASS21—stress		$R^2_{adj.}$		s_{yx}	F	P
		0.408		6.94	132.555	0.000*
		B	SE	β	t	P
Predictor	(Constant)	41.234	1.742		23.669	0.000*
	Language	3.564	0.318	0.160	11.202	0.000*
	Sex	−1.259	0.347	−0.053	−3.632	0.000*
	Age	−0.549	0.152	−0.064	−3.616	0.000*
	Type of school	0.146	0.094	0.024	1.553	0.120
	Employment type	0.235	0.266	0.012	0.883	0.377
	Years of service	0.057	0.200	0.005	0.285	0.776
	Team atmosphere	−0.926	0.162	−0.080	−5.728	0.000*
	Chronic illness	−0.467	0.374	−0.017	−1.248	0.212
	Infection with SARS-CoV-2	−0.409	0.311	−0.018	−1.316	0.188
	Quarantine	−0.482	0.246	−0.027	−1.956	0.050
	Mistrust towards institutions	0.016	0.029	0.009	0.547	0.584
	Complottism	−0.019	0.060	−0.005	−0.314	0.754
	Life satisfaction	−0.306	0.027	−0.172	−11.450	0.000*
	Resilience	−1.070	0.043	−0.389	−24.777	0.000*
	BRCS coping style	−0.004	0.052	−0.001	−0.076	0.939
	Pandemic fatigue (PFS)	0.147	0.020	0.113	7.166	0.000*
	Coronavirus anxiety (high values corresponds to low levels of anxiety)	−0.318	0.027	−0.175	−11.983	0.000*

(*continued on next page*)

Table 3 (*continued*)

DASS21—anxiety		$R^2_{adj.}$		s_{yx}	F	P
		0.273		5.25	72.833	0.000*
		B	SE	β	t	P
Predictor	(Constant)	24.455	1.319		18.534	0.000
	Language	1.351	0.241	0.089	5.607	0.000*
	Sex	−0.275	0.263	−0.017	−1.047	0.295
	Age	−0.084	0.115	−0.014	−0.728	0.467
	Type of school	0.021	0.071	0.005	0.287	0.774
	Employment type	−0.146	0.201	−0.011	−0.724	0.469
	Years of service	−0.009	0.151	−0.001	−0.056	0.955
	Team climate	−0.395	0.122	−0.050	−3.226	0.001*
	Chronic illness	−0.885	0.283	−0.048	−3.127	0.002*
	Infection with SARS-CoV-2	−0.976	0.235	−0.063	−4.147	0.000*
	Quarantine	−0.197	0.187	−0.016	−1.055	0.291
	Mistrust towards institutions	0.116	0.022	0.095	5.250	0.000*
	Complottism	−0.082	0.045	−0.033	−1.810	0.070
	Live satisfaction	−0.181	0.020	−0.149	−8.946	0.000*
	Resilience	−0.543	0.033	−0.289	−16.620	0.000*
	BRCS coping style	−0.028	0.040	−0.012	−0.711	0.477
	Pandemic fatigue (PFS)	0.055	0.016	0.062	3.573	0.000*
	Coronavirus anxiety (high values corresponds to low levels of anxiety)	−0.214	0.020	−0.173	−10.663	0.000*

*Significant at <.01.

The elevated emotional burden among employees with a previous SARS-CoV-2 infection has also been confirmed in other populations.[38] As a consequence, the higher rate of infection with SARS-CoV-2 among school staff compared with the general population (19.6% vs 14%) may also contribute to their higher emotional distress. In addition, teachers also seemed to distrust the institutions more frequently than the local general population control group, which, in turn, is associated with increased emotional stress. It is possible that the pandemic has increased distrust in institutions, especially among those teachers who already felt high emotional stress before the pandemic.

In this study, the sociocultural background, defined as the language in which the questionnaire was answered, is an independent correlate of emotional stress, at least during this pandemic phase. As there are no such sociocultural differences in the local general population control group and Italian as well as German teachers are working and living in the same geographical area, this is likely to be a school/kindergarten-specific peculiarity. In South Tyrol, schools are organised relatively autonomously according to the main teaching language, and most teachers work in a school that corresponds to their first language. Because the impact of the language on emotional distress remains significant after important, potentially confounding, variables (see Table 3) were statistically controlled for, additional, not addressed, variables must be considered in a follow-up investigation. Examples could be differences in class size, organisational models, additional work duties and socioeconomic background of the students.

Avoidance of information about the pandemic is associated with an increased risk of high emotional distress. However, in contrast to other studies,[9,33,39–41] the general coping style does not contribute to the variance in emotional distress. This pandemic probably confronts teachers with specific challenges that cannot be adequately addressed with a general style of coping. On the other hand, those with a high level of resilience feel less depressed, anxious and stressed, which has also been confirmed in other populations.[9,42,43]

As expected and shown in other studies,[44,45] there is a significant negative correlation between life satisfaction and depression, anxiety and stress, whereas people with chronic physical disease show an elevated level of anxiety[8,14] and deserve special attention. The fact that women have higher stress (but not depression or anxiety) levels can best be explained by the double burden of working from home for (younger) women with school-aged children during the pandemic. The large negative impact of the pandemic on younger age groups has also been shown in other studies during the coronavirus crisis.[46–49] This could be due to a differential negative impact of social distancing and/or a different use of new online media by older and younger study participants.[14] The higher levels of depression in teachers with quarantine experience could be attributed to a greater feeling of responsibility for the spread of the infection in their classes. Another explanation could be that the prolonged social isolation associated with quarantine results in an increased feeling of low self-efficacy during quarantine. Because quarantine was rare in kindergarten, this study only observed the effect of quarantine in school teachers.

The perceived team atmosphere contributes to predicting general emotional stress, while we didn't find any significant effect for the quality of communication with the students. or self-rated preparation for online lessons. This result underlines the importance of the team atmosphere as a resilience factor in the workplace.

The size of the facility, type of employment (full time vs part time) and years of service do not predict the emotional burden. The fact that years of service did not impact emotional burden is in line with prior studies before the pandemic that showed no correlation between burnout and years of service.[50] In contrast to our study, another study showed a higher rate of burnout among part-time employees in prepandemic years.[51] Although burnout cannot be equated with an overall emotional burden as measured in our survey, this divergence could also be compatible with our hypothesis, that educational work is particularly difficult during the pandemic and outweighs the advantage of full-time employment. These results allow the implementation of targeted preventive measures and better preparation for a possible future pandemic.

Limitations

The cross-sectional design of the present study and a lack of longitudinal data does not allow for conclusions on the quantitative direct effects of the pandemic on teaching staff members. The generalisability of the study results in such surveys is always limited because of a potential non-response bias and the resulting concerns about the representativeness of the results. In addition, differences in timing may have a varying impact, especially during a pandemic. These results are a snapshot, and the recording of

changes over time would require a longitudinal study. Nevertheless, this survey confirms, even if interpreted with caution, a high emotional burden on teachers in this particular situation and shows some significant correlates of these burdens.

Conclusions

This single assessment, cross-sectional study confirms an increased level of emotional stress in teachers compared with the general population and provides important data for the planning and implementation of prevention programmes, especially during a pandemic. Strategies should be targeted towards teachers with a prior infection with SARS-CoV-2, chronically ill teachers, younger and female teachers, and those with quarantine experience. Lower resilience, lower life satisfaction, higher levels of specific coronavirus anxiety, avoidance of information about the pandemic, higher levels of mistrust towards the institutions, and lower ratings for team atmosphere at school are warning signals and population groups with these characteristics should receive special attention for preventive interventions. In the educational system, the sociodemographic background (here defined as Italian vs German) has to be considered as a significant moderator variable with respect to pandemic-specific emotional impact.

Owing to the importance of the emotional well-being of educators for their teaching success, especially during the pandemic, monitoring, psychological prevention measures and support should be implemented and evaluated. This study helps in targeting such procedures to particularly vulnerable subgroups. In the future, longitudinal studies should be performed to provide further valuable information on the predictors and course of emotional stress in teachers.

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Ethical approval

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Competing interests

The authors have no competing interests to declare.

Appendix A. Supplementary data

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