Transmission Dynamics of COVID-19 Outbreaks Associated with Child Care Facilities — Salt Lake City, Utah, April–July 2020

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Reports suggest that children aged ≥10 years can efficiently transmit SARS-CoV-2, the virus that causes coronavirus disease 2019 (COVID-19) (*1*,*2*). However, limited data are available on SARS-CoV-2 transmission from young children, particularly in child care settings (*3*). To better understand transmission from young children, contact tracing data collected from three COVID-19 outbreaks in child care facilities in Salt Lake County, Utah, during April 1–July 10, 2020, were retrospectively reviewed to explore attack rates and transmission patterns. A total of 184 persons, including 110 (60%) children had a known epidemiologic link to one of these three facilities. Among these persons, 31 confirmed COVID-19 cases occurred; 13 (42%) in children. Among pediatric patients with facility-associated confirmed COVID-19, all had mild or no symptoms. Twelve children acquired COVID-19 in child care facilities. Transmission was documented from these children to at least 12 (26%) of 46 nonfacility contacts (confirmed or probable cases). One parent was hospitalized. Transmission was observed from two of three children with confirmed, asymptomatic COVID-19. Detailed contact tracing data show that children can play a role in transmission from child care settings to household contacts. Having SARS-CoV-2 testing available, timely results, and testing of contacts of persons with COVID-19 in child care settings regardless of symptoms can help prevent transmission. CDC guidance for child care programs recommends the use of face masks, particularly among staff members, especially when children are too young to wear masks, along with hand hygiene, frequent cleaning and disinfecting of high-touch surfaces, and staying home when ill to reduce SARS-CoV-2 transmission (*4*).

Contact tracing* data collected during April 1–July 10, 2020 through Utah's National Electronic Disease Surveillance System (EpiTrax) were used to retrospectively construct transmission chains from reported COVID-19 child care facility outbreaks, defined as two or more laboratory-confirmed COVID-19 cases within 14 days among staff members or attendees at the same facility. EpiTrax maintains records of epidemiologic linkage between index patients and contacts (defined as anyone who was within 6 feet of a person with COVID-19 for at least 15 minutes ≤2 days before the patient's symptom onset) and captures data on demographic characteristics, symptoms, exposures, testing, and the monitoring/isolation period. A confirmed case was defined as receipt of a positive SARS-CoV-2 real-time reverse transcription–polymerase chain reaction (RT-PCR) test result. A probable case was an illness with COVID-19–compatible symptoms,† epidemiologically linked to the outbreak, but with no laboratory testing. For this report, the index case was defined as the first confirmed case identified in a person at the child care facility, and the primary case was defined as the earliest confirmed case linked to the outbreak. Pediatric patients were aged <18 years; adults were aged ≥18 years.

Persons with confirmed or probable child care facility–associated COVID-19 were required to isolate upon experiencing symptoms or receiving a positive SARS-CoV-2 test result. Contacts were required to quarantine for 14 days after contact with a person with a confirmed case. Facility attack rates were calculated by including patients with confirmed and probable facility-associated cases (including the index patient) in the numerator and all facility staff members and attendees in the denominator. Overall attack rates include facility-associated cases (including the index case) and nonfacility contact (household and nonhousehold) cases in the numerator and all facility staff members and attendees and nonfacility contacts in the denominator; the primary case and cases linked to the primary case are excluded.

During April 1–July 10, Salt Lake County identified 17 child care facilities (day care facilities and day camps for school-aged children; henceforth, facilities) with at least two confirmed COVID-19 cases within a 14-day period. This report describes outbreaks in three facilities that experienced possible transmission within the facility and had complete contact investigation information. A total of 184 persons, including 74 (40%) adults (median age = 30 years; range = 19–78 years) and 110 (60%)

* https://www.cdc.gov/coronavirus/2019-ncov/php/contact-tracing/contact-tracing-plan/contact-tracing.html.

† https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html.

children (median age = 7 years; range = 0.2–16 years), had a known epidemiologic link to one of these three facilities with an outbreak; 54% were female and 40% were male. Among these persons, 31 confirmed COVID-19 cases occurred (Table 1); 18 (58%) cases occurred in adults and 13 (42%) in children. Among all contacts, nine confirmed and seven probable cases occurred; the remaining 146 contacts had either negative test results (50; 27%), were asymptomatic and were not tested (94; 51%) or had unknown symptoms and testing information (2; 1%).

Among the 101 facility staff members and attendees, 22 (22%) confirmed COVID-19 cases (10 adult and 12 pediatric) were identified (Table 2), accounting for 71% of the 31 confirmed cases; the remaining nine (29%) cases occurred in contacts of staff members or attendees. Among the 12 facility-associated pediatric patients with confirmed COVID-19, nine had mild symptoms, and three were asymptomatic. Among 83 contacts of these 12 pediatric patients, 46 (55%) were nonfacility contacts, including 12 (26%) who had confirmed (seven) and probable (five) COVID-19. Six of these cases occurred in mothers and three in siblings of the pediatric patients. Overall, 94 (58%) of 162 contacts of persons with facility-associated cases had no symptoms of COVID-19 and were not tested. Staff members at two of the facilities had a household contact with confirmed or probable COVID-19 and went to work while their household contact was symptomatic. These household contacts represented the primary cases in their respective outbreaks.

Facility A Outbreak

Facility A, which had been deemed an essential business and had not closed before the outbreak occurred, required daily temperature and symptom screening for the 12 staff members and children and more frequent cleaning and disinfection; staff members were required to wear masks. Two COVID-19 cases in staff members were associated with facility A (Figure). The index case at facility A (patient A1) occurred in a staff member who reported symptom onset on April 2, self-isolated on April 3, and had a positive SARS-CoV-2 RT-PCR test result from a nasopharyngeal (NP) swab specimen obtained on April 6. Three days after patient A1's symptom onset, a second staff member (patient A2) experienced symptoms and had a positive SARS-CoV-2 test result 1 day later. Ten facility contacts (nine children aged 1–5 years and one staff member) remained asymptomatic during the monitoring period and were not tested. The last reported exposure at facility A was on April 3, when the facility closed. Among the 15 nonfacility contacts of patients A1 and A2 (including four children aged 1–13 years), 10 remained asymptomatic throughout their monitoring period and were not tested, and three received negative test results; the symptom and testing information for two nonfacility contacts was unknown. The primary patient, a household contact of the index patient, reported symptom onset 9 days before symptom onset in patient A1 and received a positive SARS-CoV-2 test result from an NP specimen collected on April 6. The facility attack rate (excluding the primary case) for facility A was 17% (two of 12) and was 7% overall (including contacts) (two of 27).

TABLE 1. Characteristics of all staff members, attendees, and their contacts associated with COVID-19 outbreaks at three child care facilities — Salt Lake County, Utah, April 1–July 10, 2020

	No. (% with available information)		
Characteristic	**Total***	**Adult***	**Pediatric***
Facility staff members, attendees, and contacts	184 (100)	74 (100)	110 (100)
Age, yrs, median (range)†	9 (0.2–78)	30 (19–78)	7 (0.2–16)
Sex			
Female	100 (54)	42 (57)	58 (53)
Male	74 (40)	31 (42)	43 (39)
Unavailable	10 (5)	1 (1)	9 (8)
Linkage to facility			
Facility staff member or attendee	101 (55)	18 (24)	83 (75)
Nonfacility contact§	83 (45)	56 (76)	27 (25)
Confirmed¶ COVID-19 cases			
Total	31 (17)	18 (24)	13 (12)
Symptomatic	24 (13)	15 (24)	9 (8)
Index case at facility	3 (2)	3 (4)	0 (–)
Asymptomatic	4 (2)	0 (–)	4 (4)
Probable¶ COVID-19 cases	7 (4)	5 (7)	2 (2)
Contacts§			
Total	146 (79)	51 (60)	95 (86)
Contacts with a negative test result	50 (27)	27 (36)	23 (21)
Asymptomatic contacts, not tested	94 (51)	22 (30)	72 (65)
Contacts with unknown symptoms and testing	2 (1)	2 (3)	0 (—)

Abbreviation: COVID-19 = coronavirus disease 2019.
* Does not include two persons with primary cases or their six contacts; two adult contacts had unknown symptom and testing information. Percent is calculated as a percentage of the total.
† Age data were missing for 11 contacts.
§ Includes pediatric and adult household and nonhousehold contacts.
¶ A confirmed case was defined as a positive SARS-CoV-2 reverse transcription–polymerase chain reaction test result. A probable case was an illness with symptoms consistent with COVID-19 and linked to the outbreak but without laboratory testing.

Facility B Outbreak

Facility B was closed during March 13–May 4. Upon reopening, temperatures of the five staff members and children were checked daily, and more frequent cleaning was conducted; only staff members were required to wear masks. Five COVID-19 cases in three staff members and two children were associated with facility B (Figure). The index case (B1) occurred in a staff member who was tested on May 31 while presymptomatic (because of a household contact with COVID-19) and received a SARS-CoV-2-positive test result; patient B1 experienced mild COVID-19 symptoms on June 3 and last worked on May 29. A second staff member (patient B2), experienced symptoms on June 8, was tested, and received a positive test result 2 days later. Patients B3 and B4, children aged 8 months

TABLE 2. Classification of contacts with known linkage to facility-associated confirmed adult and pediatric cases* at three child care facilities — Salt Lake County, Utah, April 1–July 10, 2020

Classification	No. (%)					
				Facility		
	Total†	Adult†	Pediatric	A	B	C
COVID-19 cases at facilities§	22	10	12	2	5	15
Contacts¶ linked to cases at facilities	162	79	83	25	28	109
Contacts¶ with confirmed COVID-19	9 (6)	2 (3)	7 (8)	0 (—)	4 (14)	5 (5)
Contacts¶ with probable COVID-19	7 (4)	2 (3)	5 (6)	0 (—)	3 (11)	4 (4)
Contacts¶ with negative test results	50 (31)	25 (32)	25 (30)	3 (12)	13 (46)	34 (31)
Asymptomatic contacts, not tested	94 (58)	48 (61)	46 (55)	20 (80)	8 (29)	66 (61)
Contacts with unknown symptoms and testing	2 (1)	2 (3)	0 (—)	2 (1)	0 (—)	0 (—)
Interval (days)						
Facility case onset to contact onset, median (range)**	4 (1–8)	6 (4–6)	3 (1–8)	1 (1–1)	4.5 (1–6)	4 (3–8)
Facility case onset to testing, median (range)††	2.5 (0–6)	1 (0–4)	4 (1–6)	2.5 (1–4)	1 (0–3)	2 (0–10)

Abbreviation: COVID-19 = coronavirus disease 2019.
* A confirmed case was defined as a positive SARS-CoV-2 reverse transcription–polymerase chain reaction test result. A probable case was an illness with symptoms consistent with COVID-19 and linked to the outbreak but without laboratory testing.
† A positive adult case linked to facility attendee from Facility B is included because they were a staff member.
§ Includes index cases.
¶ Includes pediatric and adult household and nonhousehold contacts.
** For cases in persons who were asymptomatic, onset for contact is date of receipt of positive test result.
†† Does not include three pediatric facility cases in persons who were asymptomatic who did not have symptom onset dates.

and 8 years, respectively, experienced mild signs and symptoms (fever, fatigue, runny nose) 7 and 8 days, respectively, after symptom onset in patient B2; both children were tested and received positive test results the day after their symptoms commenced. A third staff member, patient B5, experienced symptoms 9 days after symptoms occurred in patient B4, was tested, and received a positive test result 1 day later. The two children likely transmitted SARS-CoV-2 to their contacts including two confirmed cases (in one child's mother and father, both symptomatic 2 and 3 days, respectively, following the child's illness onset) and three probable cases (in two adults, including one mother and a child). The index patient (B1) was a household contact of the primary patient who had symptom onset May 26, was tested on May 29, and received a positive SARS-CoV-2 test result. The facility attack rate for facility B was 100% (five of five) and the overall attack rate was 36% (12 of 33).

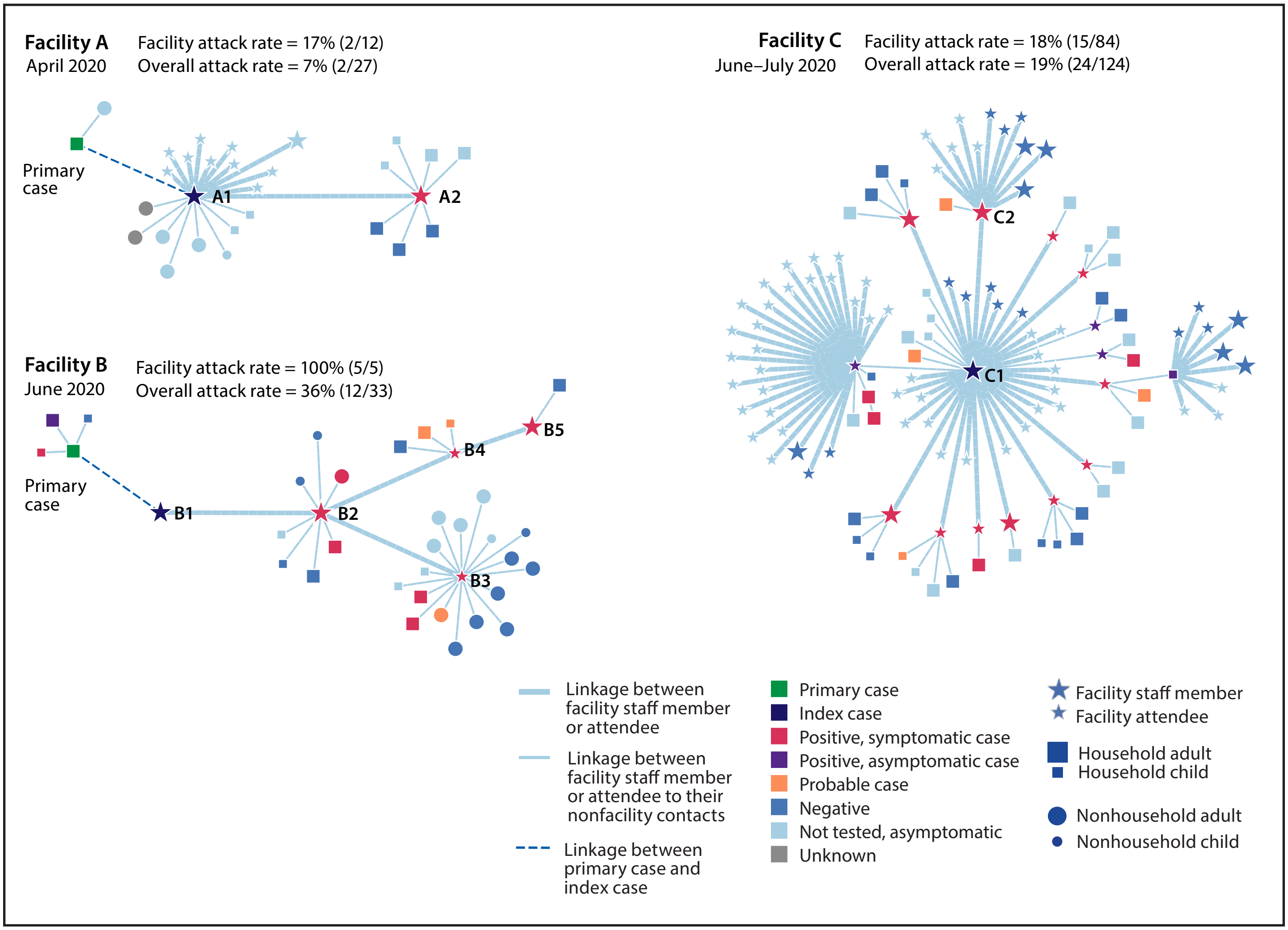
Facility C Outbreak

Facility C was closed during March 13–June 17. Upon reopening, the facility requested that 84 staff members and children check their temperature and monitor their symptoms daily; masks were not required for staff members or children. Fifteen COVID-19 cases (in five staff members and 10 children) were associated with facility C (Figure). Two staff members and two students reported symptoms on June 24 and self-isolated. The index case occurred in a staff member (patient C1), who had a positive test result from an NP specimen obtained on June 25. The second staff member, patient C2, was tested 2 days later and received a positive SARS-CoV-2 test result, and the two students (aged 7 and 8 years) were tested on June 28 and 29, respectively and received positive test results. Over the subsequent 8 days, an additional eight students (aged 6–10 years), three of whom were asymptomatic, and three staff members (all symptomatic) received positive SARS-CoV-2 test results. Pediatric patients at the facility likely transmitted SARS-CoV-2 to their contacts, including five confirmed cases in household contacts (three mothers, one aunt, and one child) and two probable household cases (one mother and one child). Symptoms developed 3 and 5 days following the child's illness onset when onset date was known. One mother who was presumably infected by her asymptomatic child was subsequently hospitalized. Among the seven cases in symptomatic children, fever was the most common sign, followed by symptoms of headache and sore throat. The source for this cluster was not identified. The facility attack rate for facility C was 18% (15 of 84) and the overall attack rate was 19% (24 of 124).

Discussion

Analysis of contact tracing data in Salt Lake County, Utah, identified outbreaks of COVID-19 in three small to large child care facilities linked to index cases in adults and associated with transmission from children to household and nonhousehold contacts. In these three outbreaks, 54% of the cases linked to the facilities occurred in children. Transmission likely occurred from children with confirmed COVID-19 in a child care facility to 25% of their nonfacility contacts.

FIGURE. Transmission chains* and attack rates†,§ in three COVID-19 child care center outbreaks¶,,†† — Salt Lake County, Utah, April 1–July 10, 2020**



Abbreviation: COVID-19 = coronavirus disease 2019.

* Transmission chains developed using Microbe Trace software. https://www.biorxiv.org/content/10.1101/2020.07.22.216275v1.

† Facility attack rates include index cases and all facility staff members and attendees.

§ Overall attack rates include all facility staff members and attendees (including the index case) and nonfacility contacts (household and nonhousehold). It does not include the primary case or the cases linked to the primary case.

¶ A confirmed case was defined as a positive SARS-CoV-2 reverse transcription–polymerase chain reaction test result. A probable case was an illness with symptoms consistent with COVID-19 and linked to the outbreak but without laboratory testing.

** The index case was defined as the earliest confirmed case in a person at the child care facility.

†† A primary case was defined as the earliest confirmed case linked to the outbreak.

Mitigation strategies[§] could have helped limit SARS-CoV-2 transmission in these facilities. To help control the spread of COVID-19, the use of masks is recommended for persons aged ≥2 years.[¶] Although masks likely reduce the transmission risk (*5*), some children are too young to wear masks but can transmit SARS-CoV-2, as was seen in facility B when a child aged 8 months transmitted SARS-CoV-2 to both parents.

The findings in the report are subject to at least three limitations. First, guidance for contact tracing methodology changed during the pandemic and could have resulted in differences in data collected over time. Second, testing criteria initially included only persons with typical COVID-19 signs and symptoms of fever, cough, and shortness of breath, which

§ https://www.cdc.gov/coronavirus/2019-ncov/if-you-are-sick/isolation.html; https://www.cdc.gov/coronavirus/2019-ncov/if-you-are-sick/quarantine.html.

¶ https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/cloth-face-cover-guidance.html.

Summary

What is already known about this topic?

Children aged ≥10 years have been shown to transmit SARS-CoV-2 in school settings.

What is added by this report?

Twelve children acquired COVID-19 in child care facilities. Transmission was documented from these children to at least 12 (26%) of 46 nonfacility contacts (confirmed or probable cases). One parent was hospitalized. Transmission was observed from two of three children with confirmed, asymptomatic COVID-19.

What are the implications for public health practice?

SARS-CoV-2 Infections among young children acquired in child care settings were transmitted to their household members. Testing of contacts of laboratory-confirmed COVID-19 cases in child care settings, including children who might not have symptoms, could improve control of transmission from child care attendees to family members.

could have led to an underestimate of cases and transmission. Finally, because the source for the outbreak at facility C was unknown, it is possible that cases associated with facility C resulted from transmission outside the facility.

COVID-19 is less severe in children than it is in adults (*6*,*7*), but children can still play a role in transmission (*8*–*9*). The infected children exposed at these three facilities had mild to no symptoms. Two of three asymptomatic children likely transmitted SARS-CoV-2 to their parents and possibly to their teachers. Having SARS-CoV-2 testing available, timely results, and testing of contacts of patients in child care settings regardless of symptoms can help prevent transmission and provide a better understanding of the role played by children in transmission. Findings that staff members worked while their household contacts were ill with COVID-19–compatible symptoms support CDC guidance for child care programs recommendations that staff members and attendees quarantine and seek testing if household members are symptomatic (*4*). This guidance also recommends the use of face masks, particularly among staff members, especially when children are too young to wear masks, along with hand hygiene, frequent cleaning and disinfecting of high-touch surfaces, and staying home when ill to reduce SARS-CoV-2 transmission.

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REVIEW ARTICLE

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COVID-19 as an occupational disease

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Abstract

The impact of coronavirus disease 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 permeates all aspects of society worldwide. Initial medical reports and media coverage have increased awareness of the risk imposed on healthcare workers in particular, during this pandemic. However, the health implications of COVID-19 for the global workforce are multifaceted and complex, warranting careful reflection and consideration to mitigate the adverse effects on workers worldwide. Accordingly, our review offers a framework for considering this topic, highlighting key issues, with the aim to prompt and inform action, including research, to minimize the occupational hazards imposed by this ongoing challenge. We address respiratory disease as a primary concern, while recognizing the multisystem spectrum of COVID-19-related disease and how clinical aspects are interwoven with broader socioeconomic forces.

KEYWORDS
COVID-19, occupational, respiratory disease

1 | INTRODUCTION

The evolving coronavirus disease 2019 (COVID-19) pandemic continues to impose a major burden and toll on workers, even as vaccination efforts accelerate. The intersection of the pandemic with the workforce is a complex topic involving historic forces, issues of vulnerability and susceptibility, a dynamic understanding of transmission and related occupational hygiene, and multifaceted issues of testing for infection and related return-to-work challenges. To make that complexity digestible, this narrative review is intended for a general audience, and written to be easily accessible and applicable to an interdisciplinary range of perspectives, including those who may have little initial appreciation of the topic. In that vein, we are oriented therein to stimulating discussion and awareness, rather than to dissecting any particular aspect of this comple topic in great detail.

1.1 | History repeats: Disasters' toll on the workforce

Major epidemic and pandemic respiratory infections have historically brought devastation to the general population, often with a disproportionate impact on workers, that results in profound but frequently overlooked occupational morbidity and mortality.[1] Occupational health risks have, in recent history, been relatively unanticipated or dismissed during times of crisis, including the present COVID-19 pandemic,[2,3] previous influenza and coronavirus pandemics (such as the severe acute and Middle Eastern respiratory syndromes [SARS and MERS, respectively]), and 2001 US World Trade Center (WTC) bombing and subsequent recovery work.[4] A range of new and lingering pulmonary manifestations were reported after those public health crises, including reports of persistent reticular radiographic abnormalities and lung function deficits in patients infected with SARS and MERS and a range of pulmonary manifestations in WTC-exposed workers.[5-8] The current pandemic may, likewise, pose long-term risks for the respiratory health of workers, compounding the illnesses and deaths tallied each day.[9] In such catastrophes, badges of heroism affixed to responders may hide injuries inflicted if not outright deaths, some of which might have been preventable and could be prevented in future disasters.

It may be misleading to describe the present situation with COVID-19 as unprecedented. A century ago, the 1918–1919 influenza pandemic killed approximately 75 million people worldwide within the first 2 years of its onset.[10] There was a socioeconomic gradient, with higher mortality in the poorer sectors of the population, and those working in overcrowded conditions, such as naval seafarers, were at increased risk. The first described occupational group affected with COVID-19 was animal wholesale workers in Wuhan. The situation was similar to the earlier avian (H5N1) and H1N1 influenza, and SARS, where concerns about occupational infection arose among workers in healthcare and agriculture, those in crowded workplaces (e.g., cruise ships and meat packing plants), and those designated as "essential" workers, that is, workers deemed critical to societal infrastructure that were often not given the choice or the means to protect themselves. Meat packing is a prime example of where a constellation of problematic conditions elevate risk for the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[11]

The vigor and effectiveness of government intervention has varied widely,[12] as has the citizenry's willingness to conform to policy and guidance.[13] However, as noted further below, the range of workers affected by COVID-19 has grown quickly. As we continue to care for COVID survivors—many of whom have suffered acute respiratory distress syndrome and thrombotic complications, we are only beginning to learn what proportion of individuals are at increased risk for developing residual or progressive pulmonary fibrosis[5,14] and pulmonary vascular disease[15] as well as other fatigue and dyspnea-associated conditions such as myositis postinfection.[16] However, these complications appear to be disturbingly common[17] and thus may further diminish work capacity. As the pandemic progresses, there is concern for lingering or even chronic symptoms beyond the respiratory system and with major quality of life implications, based on recent data.[18] Lessons drawn from previous and current pandemics and disasters must be learned, and inform future responses to these inevitable events.

1.2 | Vulnerability and susceptibility at work in the context of COVID-19

Essential workers likely face the highest risk from exposure to SARS-CoV-2.[19] These include workers in healthcare, protective services (e.g., police officers, correctional officers, and firefighters), office and administrative support (e.g., couriers and messengers, and patient service representatives), social services (community health workers and some social workers), and maintenance workers (e.g., plumbers, septic tank installers, and elevator repair).[20,21] Accordingly, initial studies are reporting higher incidence rates of SARS-CoV-2 among healthcare workers (HCW).[2,22,23] Elevated incidence rates are likely, but less well documented for other essential workers. Some suggestive examples exist—a Swedish national study showed that taxi drivers and bus drivers—both with high degrees of social contacts, have been at increased risk.[24] Beyond simply exposure to virus-laden aerosols (VLA, wherein SARS-CoV-2 is suspended in air for prolonged periods of time), the COVID-19 pandemic has unmasked major socioeconomic factors that contribute to higher rates of infection, severity of illness, and risk of death. Disparities in illness and death among workers are linked to a number of interrelated factors, including the nature and hazards of the jobs performed as well as baseline health conditions and socioeconomic factors. These factors revolve around issues of vulnerability (increased likelihood of exposure) and susceptibility (increased likelihood of adverse clinical consequence; Table 1). While the influence of these factors has been most extensively documented in the United States, as discussed further below, these factors are very likely to operate internationally

TABLE 1 Worker vulnerability and susceptibility in the context of COVID-19

Vulnerable workers	Susceptible workers
Definition: Workers at higher risk for Covid-19 due to *greater likelihood of higher exposure*	*Definition*: Workers at *higher risk for COVID-19 (or worse outcomes)* at any level of exposure
Factors:	*Factors:*
Hazardous work characteristics:	Demographic characteristics:
• Exposure to infected aerosols (especially amongst essential workers or those unable to work from home)[26] • Lack of appropriate or properly fitted personal protective equipment (PPE), or occupational safety training • Densely populated, enclosed, or poorly ventilated workplaces[27]; difficulty distancing from VLAs • Prolonged face-to-face or physical contact or where social distancing cannot be practiced	• Elderly • Male sex Co-morbidities: Obesity, hypertension, diabetes mellitus, cardiovascular disease, kidney disease, cerebrovascular disease, COPD, and immunosuppression Co-exposures: • Smoking/environmental tobacco smoke exposure • Residence or work in high particulate air pollutant environments • Limited access to healthy foods and physical activity
Cross-cutting factors that may confer or compound both vulnerability and susceptibility	
Enhance Exposure to SARS-CoV-2:	
• Residence in densely populated neighborhoods • Residence in homes that are overcrowded, multigenerational or without access to running water • Dependence on mass or shared (crowded) transportation	
Predispose to poorer health outcomes:	
• Low socioeconomic status/underprivilege • Language and/or communication barriers • Limited access to paid sick leave and healthcare	

Note: These categories are not mutually exclusive (an individual may have both), and "cross-cutting" characteristics may contribute to both.

Abbreviations: COVID-19, coronavirus disease-2019; COPD, chronic obstructive pulmonary disease; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; VLAs, virus-laden aerosols.

and data are emerging to support their broad applicability in the context of COVID.[25]

Vulnerability is common among workers who face exposure to COVID-19 because they conduct operations and services considered essential. Even though many of these jobs place workers in close contact with infected co-workers and the public, enhancing their potential for exposure to SARS-CoV-2, the provision of minimally effective personal protective equipment (PPE) and adoption of other more effective preventive measures were delayed (in many regions) for many weeks after onset of the pandemic.

A report from New York City[28] confirmed that the mortality rate among African Americans and Latino patients (92.3 and 74.3 per 100,000 inhabitants, respectively) substantially exceeded that of Caucasian and Asian cases (45.4 and 25.3 per 100,000, respectively). As is often the case, ethnicity and race often conceal unmeasured or uninvestigated socioeconomic (including occupational), as opposed to biological, factors. Accordingly, the higher SARS-CoV-2 exposure risk incurred by people of color has recently been demonstrated in a recent study.[29] Low-income workers in the United States—who are disproportionately African American and Latino—are more likely to work in jobs with higher exposure and fewer opportunities for social distancing, and also bear a higher burden[30] of the susceptibility factors described in Table 1. Further, immigrants with multi-generation living arrangements and fewer opportunities for social distancing may be at increased risk for COVID-19. The disproportionate impact associated with ethnicity and race can be severe, with some groups experiencing up to nine-fold higher population-adjusted rates of COVID-19.[31] Disturbingly, Latinos markedly increased as a proportion of total COVID-associated deaths (16%–26%) in the United States from May to August 2020,[32] suggesting that early concerns of vulnerability and/or susceptibility amongst this group were not met with sufficient protective adjustments.

In particular, the severe impact of the pandemic upon the healthcare workforce (especially low income workers)[2,3,22] has become clear. In the United States, the largest number (around 1.3 million) of HCW are nurse assistants or home/personal care aides, with direct patient care.[20,33-35] Nearly a million more provide "essential" nondirect patient care services through work in housekeeping, laundry or food services where they also face substantial infection risk. Correctional facilities also provide health care in a particularly hazardous setting.[36] Close to a quarter of HCW at risk for exposure to SARS-CoV-2 have medical conditions that increase the probability of poor COVID-19 outcomes.[37] Nearly 1 in 10 low-wage workers in the United States report that they are in fair to poor health.[37]

It was only after the economic downturns became an undeniable reality, even in the richest countries of the world, that these disproportionate effects of the pandemic on higher risk occupational and socially disadvantaged groups began to receive some attention, mostly in editorials in several medical journals[23,38-40] and in news reports from the lay press.[41] Many workers entered the pandemic in low-wage jobs, and some experienced an additional loss of income, even if they remained employed, due to diminished work hours and hourly pay. Approximately 80% of low-income workers are paid hourly, and around 43% are employed in small firms with fewer than 25 people—with employers for whom survival during the crisis is likely most marginal.[42] The precarious financial circumstances of many workers decreases their ability to afford out-of-pocket healthcare costs. Notably, uninsured Americans are twice as likely to avoid seeking treatment for COVID-19 because of cost concerns.[37]

These findings underline the need for increased attention to reducing risk for these workers during the pandemic. Mitigation efforts include the following: improved administrative and engineering preventive controls (discussed below), ensuring access to Workers' Compensation benefits, adopting or expanding sick leave benefits, and providing occupational and general health insurance coverage (ideally low- or no-cost) for all workers. Many of these compensatory mechanisms may be unrealistic in low- and middle-income countries (LMICs) where resources are particularly scarce. However, it should be noted that some LMICs, including, for example, Thailand and Cuba, have done remarkably well during the pandemic perhaps in part due to strong implementation of public health measures in spite of limited resources.

Key research gaps in this area are (1) systematic observational studies, with socioeconomic indicators (beyond ethnicity/race alone) that include industry and occupation descriptors (see below); (2) occupation-specific exposure assessments and verification of effective safety measures (including but not limited to PPE); and (3) evidence-based prevention measures tailored to worksites according to level of risk for exposure to SARS-CoV-2.

1.3 | The role of occupational hygiene in reducing the risk of direct exposure to SARS-CoV-2

When countries loosen social distancing and other restrictions and there is increased potential for exposure in a multitude of industries and occupations, strengthening the fundamentals of occupational hygiene is critical.[43] There are four main techniques for preventing workplace exposures to SARS-CoV-2.[44] These include: (1) exposure elimination, (2) engineering controls, (3) administrative controls, and (4) PPE. Several national and international organizations have offered guidance in this regard.[45-49]

Reducing exposure is of course critical to reducing infection and the still unknown long-term lung sequelae of COVID-19.[5,15] These approaches must be informed by relevant laws and policies guarding against discrimination and being sensitive to disabilities. Recognizing that reasonable concerns for cost and burden to employers pose challenges that should be considered, protection of the worker remains paramount.[50] Unfortunately, the viability of worker protections varies widely across the globe. LMICs, and even more well resourced nations at times, may lack sufficient sanitizing supplies, PPE, and other administrative or engineering protections in health care facilities, and likely many workplaces,[51] and broader policies protecting workers with a holistic perspective are often quite weak.[52]

Regardless, occupational SARS-CoV2 exposure elimination fundamentally involves lowering community transmission and emerging vaccination efforts will greatly contribute to achieving this goal.[53] In parallel, preventing contagious workers from entering the workplace and increasing telecommunication and other options for work from home and otherwise maintain physical separation whenever possible. Pre-placement testing and screening individuals for symptoms and signs of COVID-19, excluding those screen-positive from contact with the uninfected, are important strategies. Unfortunately, these do not exclude infected individuals without signs or symptoms, who can only be identified by additional screening via medical testing; fortunately, rapid on-site screening is becoming more feasible and common, though false negatives remain a concern[54] (as discussed below).

Engineering controls are designed to be independent of behaviors and are generally more effective than PPE in protecting workers. Physical barriers, such as plastic barriers between workstations, can block some VLA and prevent direct person-to-person contamination. Ventilation, in the form of effective VLA removal or providing VLA-free air, can also prevent worker exposure, and its importance is increasingly appreciated.[55,56] Another example of an engineering control that may reduce exposure to VLA is ultraviolet germicidal irradiation (UVGI), though its effectiveness for SARS-CoV-2 has not been established. Further research into the efficacy of each of these controls for workplace VLA exposure is needed, especially given lingering controversy[57] amidst the emerging evidence that SARS-CoV-2 is spread by aerosol and not simply droplet.[58] As consensus around aerosol transmission consolidates and mitigation approaches are debated,[55,59,60] pitfalls of false reassurance from distance alone and/or barriers that do not block aerosols (which simply bypass barriers) need increased investigation via novel social and natural science collaborations. In doing so, portrayals of transmission risk as simply linked to droplet versus aerosol mode, itself part of a continuum of physicochemical properties linked to virus burden,[61] should be tempered and subject to careful science communication.

Administrative or work practice controls depend on high levels of adherence to be fully effective. Examples include social distancing, staggered staff schedules, requirements for facemasks and hand hygiene, protocols to decrease hazardous activities such as touching contaminated surfaces, and surface cleaning and disinfection (although the true propensity for surface transmission of SARS-CoV-2 has been much debated and needs ongoing investigation).[62] Proper infection control training and practice have been shown to decrease risk of SARS-CoV-2 infection.[2]

PPE, though most burdensome for the worker, and rightly placed at the bottom of the traditional exposure control effectiveness hierarchy, is still important to reduce risk of occupational infection and transmission of SARS-CoV-2.[2,23] Recent data show that proper PPE (together with proper training, and ongoing vigilance) can be very effective[63] but inconsistent or conflicting policies and poor training likely reduces its effectiveness, and can be a source of stress for workers.[64] Goggles or face shields, gloves, and gowns/aprons/suits, when properly applied, confer protection against droplet sprays and contaminated surfaces.

Respiratory protection to prevent inhalation of airborne respiratory droplets is also important. In well-ventilated low prevalence contexts, standard surgical masks offer reasonably adequate protection, but when there is significant concern for airborne exposure, N95 respirators are recommended. Earlier in the pandemic, the need for N95s was most associated with aerosol-generating procedures, but given the increased evidence around aerosol transmission more generally, N95 respirators are advisable when feasible given recent evidence that a high percentage of SARS-CoV-2 infection may occur in those healthcare workers wearing surgical masks[65] although a prior trial in the context of influenza surprisingly showed non-inferiority for surgical masks.[66] N95s are required to capture 95% of airborne particles. The KN95 designation in China is also defined as 95% filtration. In Europe, the equivalent is FF2, which are required to capture 94% of airborne particles. However, the testing standards for demonstrating these filtration percentages vary by jurisdiction. Most of the inhaled particles are from inward leakage around the edges of the respirator. Thus, at least annual fit testing is important, despite the temporary suspension of this requirement during the pandemic in some countries. Other types of respirators can also be used, such as elastomeric respirators and loose-fitting powered air purifying respirators (PAPRs). An advantage of PAPRs is that they do not require fit testing, and there is some evidence of greater protection.[67] The World Health Organization (WHO) has provided guidance in this regard,[68] which is updated periodically. Notably, there has been increasing attention to cloth-based masks and face covering, which from a practical perspective are attractive, widely used in nonoccupational public settings, and in many cases much more effective than previously believed.[69] However, given the variability and still modest evidence base, these have not widely been recommended in an occupational setting.

1.4 | Minimizing risk of airways disease from cleaning products

As noted above, attempts to control the spread of SARS-CoV-2 justifiably include use of cleaning and disinfecting products, which quickly escalated in not only health care but other workplaces (e.g., in retail and services), public settings, and homes. As with all occupational protective strategies, recommendations from health authorities for cleaning and disinfecting to eliminate SARS-CoV-2 from environmental surfaces should include direction to employers to provide workers' training on the proper use, and the hazards of cleaning chemicals.[70] These hazards include respiratory effects such as: (a) acute inhalation injuries (e.g., irritant-induced asthma) from accidental spills or inappropriate mixing of cleaning products; (b) occupational asthma from sensitization to agents such as enzymes or quaternary ammonium compounds that may be contained in all-purpose cleaners; and (c) exacerbation of airways disease (e.g., asthma or chronic obstructive pulmonary disease) or new cases of such disease, both of which can occur over time even with accident-free ("as directed") use of cleaning products.[71,72] Of concern is a 20% increase in calls to US poison control centers linked to cleaning and disinfecting products during January–March 2020 compared with the same period in 2019.[73] The largest reported increases were for inhalation incidents, cleaning products with bleach, and disinfecting nonalcohol products and hand sanitizers, particularly in early in March 2020 when stay-at-home orders began. Related respiratory concerns, as well as dermatological complaints, have manifested in diverse geographic regions across the globe.[74-76]

There is an ongoing need for government agencies, companies, and private organizations to communicate recommendations for safe and effective use of cleaning and disinfecting products to help achieve the dual goals of preventing both COVID-19 infection and secondary occupational airway diseases. As just one example, hazards due to cleaning products can be reduced with use of wiped instead of sprayed products; when possible, with use of robots; and with appropriate ventilation and education on these and other occupational hygiene practices. The magnitude of this pandemic points to an urgent need for research to improve understanding of the role of specific cleaning agents and procedures in causing and exacerbating both acute and chronic airway disease, and the control of such exposures. These data should be obtained in conjunction with studies of the effectiveness of cleaning products and procedures to eliminate infectious agents from environmental surfaces and aerosols. Such research will add to efforts, increasingly important as the COVID-19 pandemic endures, to distill the complexity surrounding the risk of cleaning and disinfection products on lung health.[65]

1.5 | Targeted testing of workers

It is clear that a large proportion of the workforce, across a variety of occupational sectors (especially essential workers), are at increased risk for COVID-19 (Table 1). Targeted SARS-CoV-2 testing should focus on these workers, using evidence-based screening algorithms to prioritize tests among the most exposed, vulnerable and susceptible workers (described above), as well as the symptomatic ones. The role of testing other asymptomatic but high-risk groups[77] remains uncertain. Testing may be reasonable in these groups, if prioritized by public health departments or clinicians, for reasons such as public health monitoring, sentinel surveillance, or screening of other asymptomatic individuals according to state and local plans.[78] The latter may, however, change frequently in response to rapidly changing local circumstances during the pandemic. Policy solutions are needed to eliminate financial barriers to testing uninsured or underinsured asymptomatic at-risk workers. Targeted testing needs to be used in conjunction with other exposure control measures, and with appropriate use of information technology. The WHO has provided additional perspective on this topic.[79]

That said, though a large number of SARS-CoV-2 tests are currently available, some are inadequately studied, with high rates of false-negative results early in the course of infection when the viral load in the upper respiratory tract is low.[80] Choosing the appropriate test and testing time window,[81] while acknowledging variable or uncertain diagnostic performance that is compounded by difference in population prevalence, is therefore crucial. A recent statistical model shows that effective molecular surveillance depends less on the analytical limits of detection, but largely on accessibility, frequency of tests, and speed of reporting.[82] Tests targeting nucleic acids or viral antigens in respiratory tract specimens are useful for diagnosing infection in workers. Serological tests may be useful for retrospective diagnosis of individual cases, in public health or workplace surveillance[83] but precise operating characteristics of these tests in this context remain uncertain. Most importantly, the potential of SARS CoV-2 antibodies to uniformly prevent related disease remains to be demonstrated.[84]

Workers may prefer sample collection venues outside the hospital, such as drive-throughs/booths, mobile laboratories, or systems catering to home or workplace, such as nucleic acid- or antigen-targeting self-test kits[85] or fingerstick blood samples for serologic tests. Smartphone-based devices[86] and rapid point of care serologic tests will likely soon be available.[87] With any of these, however, both specimen and test methodologic quality are variable, leading to significant risk for misleading information.

1.6 | Return-to-work strategies

As the aforementioned testing strategies improve and workplaces reopen, establishing practices that promote worker safety, maintain jobs and assure confidentiality are essential to protect all workers, including those most vulnerable to infection. Workplace return-to-work plans should: (1) assess the risk unique to specific workplaces and jobs[88]; (2) implement infection protection strategies (described above); and (3) develop evidence-based policies to identify and isolate individuals with suspected or confirmed infection, while allowing previously infected individuals to return to work after self-isolation.[89] Employers should consider applicable recommendations for workplace protections and relevant guidance on protecting workers' rights. External factors such as background community transmission, increasing vaccination rates, and healthcare system capacity influence governmental guidance on reopening. Workplaces should stay abreast of these local trends particularly as many regions have not yet experienced transmission rate reductions.

Return-to-work policies need to be stratified according to worker exposure risk levels,[88] which vary by industry and ability to distance and control exposure to infected individuals. They also need to take into account relevant up-to-date background disease prevalence and test performance characteristics. National and regional recommendation and policy (e.g., those of the Centers for Disease Control and Prevention, in the United States)[89] need be used as fundamental guidance. However, as with all such guidance, these are created as a practical balance between the strongest worker protection and the need for solutions that allow the workplace to operate at reasonable efficiency without prohibitive cost. Therefore, some tailoring to circumstance, while still being attentive to such high-level guidance, may be in the workers' best interest especially in countries or regions where guidance is outdated or where there are multiple guidelines that are in conflict. Workplaces with higher risk have a greater imperative to provide workers with more substantial administrative and engineering controls and PPE, and to facilitate routine symptom screening, testing for case identification, promptly isolating suspected new cases and close work contacts of infected workers and, increasingly, vaccination efforts. Lack of suitable accommodations may force the return of asymptomatic exposed essential workers, likely increasing the risk of infection for others. Of note, the true infectivity of an asymptomatic worker wearing appropriate PPE including a respirator is still unclear. Given the uncertainties, all workers with and without previous infection should be considered at risk and subject to universal workplace standards. Counseling patients in this regard is important,[90] but such frameworks may place disproportionate responsibility on the individual and should be adopted cautiously.

As was the case previously with SARS,[6] pulmonary sequelae of COVID-19 have begun to be reported.[5] Postinfection evaluation will be necessary for many individuals, and return-to-work issues will likely differ for workers with either related functional disability (whether temporary or permanent) or those with pre-existing chronic lung diseases. In doing so, sensitivity to psychological and neuropsychiatric consequences is also critical.[91] An evaluation of work capacity and ability to wear PPE will be necessary for some, and for those whose infection and resultant disability are assessed to be work-related, workers' compensation guidance should be established and supported. Importantly, the utility, cost-effectiveness, and sustainability of the different recommendations to protect workers[47,92-94] needs to be monitored.

1.7 | Incorporation of industrial and occupational data into public health surveillance and healthcare information systems

Given the importance of occupation as a COVID-19 risk factor, responding effectively to the epidemic requires industry and occupation (I/O) data on cases and contacts. Collecting I/O and employer data can help identify and control hotspots, provide information about patterns of disease, and inform intervention efforts to blunt future waves of disease; Italy has provided an informative model for consideration.[95] Benefits may include understanding seroprevalence of antibodies against SARS-CoV-2 among high-risk groups, which may be lower than anticipated[96] and thus counter overly optimistic predictions of herd immunity.

Despite initial delays in realizing the increased occupational risks of infection, the US Centers for Disease Control and Prevention (CDC) is now recommending collection of I/O data in confirmed or probable cases. The new case report form[97] captures structured information on HCW, including occupation and job setting (e.g., long-term care). I/O data can only be collected for potentially exposed (non-HCW) workers if the interviewee or interviewer considers the work setting "essential," which is not precisely defined and, despite available guidance,[98] substantial I/O data for COVID-19 cases continue to go uncollected. This problem is likely to be more severe in countries that lack effective public health infrastructure, and/or economic resources for adequate implementation.

Regrettably, the current pandemic follows a long tradition of incomplete occupational illness surveillance in most countries, including the US Data sources commonly used for occupational illness surveillance (e.g., national surveys, workers' compensation data) are deficient in multiple ways,[99-101] the most important of which, for COVID-19, are timeliness and both socioeconomic and geographic granularity. The extent to which electronic health record (EHR) data collection[102] has improved the situation remains suboptimal despite improvements in recent years.[103] A variety of systems, tools, big data platforms and apps[104,105] present opportunities to enhance occupational data collection, characterize, and address relationships between COVID-19 and work, and inform the response to the current and future pandemics, yet require substantial privacy controls and voluntary buy-in.[106,107]

When clinicians and public health officials collect data on industry, occupation, employer, and working conditions, they have the ability to (1) notify employers that an employee has tested positive, (2) help develop best practices for keeping workers safe, (3) share guidance on reducing workplace transmission,[47] (4) conduct contact tracing and detect workplace outbreaks, (5) reduce transmission from the workplace to the home, (6) inform workers who test positive of their rights, and (7) evaluate the impacts of varying social distancing guidelines. Enhanced data collection also requires policies and practices that protect workers' rights. A strong and equitable response will protect workers' privacy, financial well-being and health.

TABLE 2 Take-home points to enhance support and protection of workers in the context of COVID-19

1. Infectious pandemics such as COVID-19 have precedent for severe impact on workers, especially in terms of respiratory disease. Workers in general, and essential workers particularly, are more highly exposed to SARS-CoV-2 than the general population, and experience a greater risk of respiratory disease.
2. Factors conferring risk of exposure, vulnerability and susceptibility compound the impact of COVID-19 on workers, and these factors are strongly associated with socioeconomic status; essential workers being disproportionately low-income confers a significant disadvantage.
3. Some occupational interface with the virus is of course inevitable, and understanding the fundamentals of occupational hygiene is critical in the context of COVID-19.
4. There is an ongoing need to communicate recommendations for safe and effective use of cleaning and disinfecting products to help achieve the dual objective of preventing both COVID-19 and secondary occupational airway diseases.
5. Targeted SARS-CoV-2 testing should use evidence-based algorithms to prioritize tests amongst the most exposed, vulnerable and susceptible workers. Workplaces should establish a return-to-work plan that is tailored to specific workplaces and jobs, implements proper infection protection, and can efficiently identify and isolate individuals with likely infection.
6. Industrial and occupational data must be incorporated into public health surveillance and healthcare information systems.
7. Healthy workers should be afforded as much careful and appropriate protection as any others. More than accolades, workers want and deserve a safe environment in which to do their jobs, which is achievable by giving due attention to the key issues highlighted here. We must neither underestimate the risk of nor be unprepared for such catastrophic events.

Abbreviations: COVID-19, coronavirus disease-2019; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

2 | CONCLUSION

Workers in the global struggle against COVID-19 have been lauded as heroes, who appreciate this sign of respect. However, as has often been the case in past disasters, the designation as heroes can be associated with an unwanted passport to martyrdom. In addition to recognition for the contributions they make, workers want a safe work environment—a legal right in many countries. Rapidly emerging vaccines promise to attenuate the burden of COVID-19 on the workforce, but the timeframe and ultimate effectiveness of this welcome development remain uncertain, and broad vaccine availability in less well-resourced communities may be delayed for quite some time. Therfore, we urge attention to the key issues we have highlighted (Table 2), so that we can protect those whose work in the pandemic puts them at significant risk. In addition to our praise, respect in the form of optimized protective measures is what these workers want and deserve. And, as the current pandemic hopefully becomes better controlled, the world must prepare for subsequent disasters such that the occupational safety of frontline responders becomes a priority.

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High rate of symptomless COVID-19 infection among grocery store workers

Those in customer-facing roles five times as likely to test positive as their colleagues

Date: October 30, 2020

Source: BMJ

Summary: Grocery store employees are likely to be at heightened risk of COVID-19 infection, with those in customer-facing roles 5 times as likely to test positive as their colleagues in other positions, a new study suggests.

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FULL STORY

Grocery store employees are likely to be at heightened risk of COVID-19 infection, with those in customer-facing roles 5 times as likely to test positive as their colleagues in other positions, suggests the first study of its kind, published in the journal *Occupational & Environmental Medicine*.

What's more, among those testing positive, three out of four had no symptoms, suggesting these key workers could be an important reservoir of infection, say the researchers.

Published research focusing on essential/key workers has largely focused on healthcare workers. To try and plug this knowledge gap and find out how COVID-19 has affected the health and wellbeing of other key workers, the researchers studied 104 employees of one grocery store in Boston, Massachusetts.

Each employee was tested for SARS-CoV-2, the virus responsible for COVID-19 infection, in May this year as part of a mandatory testing policy across Boston.

But before doing so, they completed detailed questionnaires on: their lifestyle; medical history; employment history; working patterns and role at the store; commuting to and from work; and the protective measures they were able to take against infection at work.

They were also asked to provide information on COVID-19, including any symptoms and exposure to anyone with confirmed SARS-CoV-2 over the past 14 days. Information on mental health was gleaned from two validated questionnaires for depression and anxiety: PHQ-9 and GAD-7.

One in five (21 out of 104) workers tested positive for SARS-CoV-2, indicating a prevalence of 20% at that point in time. This was significantly higher than the prevalence of the infection in the local community at the time: 0.9-1.3%.

Three out of four of those testing positive (76%) had no symptoms. And of those testing positive, most (91%) had a customer facing role compared with 59% of those testing negative.

Workers in customer facing roles were five times more likely to test positive than their colleagues in other types of role, after accounting for potentially influential factors, such as the prevalence of SARS-CoV-2 where they lived. Those in supervisory roles were six times more likely to do so.

Ninety-nine employees filled in the mental health questionnaires: 24 workers reported at least mild anxiety. Only half (46%) of them said they were able to practice social distancing consistently at work, whereas most (76%) of those who weren't anxious were able to do so.

Eight employees were deemed to be mildly depressed from their questionnaire answers. They were less likely to practice social distancing consistently at work and more likely to travel to and from work on public transport or shared rides compared with those who weren't depressed.

Those able to commute on foot, by bike or in their own car were 90% less likely to report depressive symptoms.

This is a small observational study of workers in one store in one city at one point in time, which relied on subjective reports, and as such, can't establish cause, caution the researchers.

Nevertheless they say: "This is the first study to demonstrate the significant asymptomatic infection rate, exposure risks, and associated psychological distress of grocery retail essential workers during the pandemic."

And they point out: "Once essential workers are infected with SARS-CoV-2, they may become a significant transmission source for the community they serve."

They believe their findings support: "the policy recommendations that employers and government officials should take actions on implementing preventive strategies and administrative arrangements, such as methods to reduce interpersonal contact, repeat and routine SARS-CoV-2 employee testing, to ensure the health and safety of essential workers."

And they add: "Our significant mental health finding calls for action in providing comprehensive employee assistance services to help essential workers cope with the psychological distress during the COVID-19 pandemic."

Story Source:

Materials provided by **BMJ**. *Note: Content may be edited for style and length.*

Journal Reference:

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Covid-19: risks to healthcare workers and their families

Mistakes made in the first wave must not be repeated in the second

Ulf Karlsson, Carl-Johan Fraenkel

Since the beginning of the coronavirus 2019 (covid-19) pandemic, healthcare workers have shown a remarkable resilience and professional dedication despite a fear of becoming infected and infecting others.[1] In a linked paper (doi:10.1136/bmj.m3582), Shah and colleagues now report robust and concerning findings regarding the risks of covid-19 among health workers and their households.[2]

In a large register based cohort study, comprising the entire Scottish healthcare workforce, the authors compared the risk of covid-19 related hospital admission between patient facing and non-patient facing workers, their household members, and the general population. Absolute risks were low, but during the first three months of the pandemic patient facing healthcare workers were three times more likely to be admitted with covid-19 than non-patient facing healthcare workers. Risk was doubled among household members of front facing workers, in analyses adjusted for sex, age, ethnicity, socioeconomic status, and comorbidity.

Previous work reported similar risks for covid-19 among healthcare workers,[3 4] but the new study provides the most comprehensive estimate to date of the risk of more serious disease, and it is the first to report risk to household members. The reasons for the observed increase in risk—likely multifactorial—need to be explored to help to guide safety improvements in healthcare settings.

During lockdowns, most essential workers are unable to protect themselves by working from home. Furthermore, insufficient physical distancing is a leading contributor to any work related covid-19 outbreak.[5] Consequently, workers in sectors such as transport and social care are also at increased risk of covid-19, although healthcare workers have been shown repeatedly to be at highest risk.[5 6]

During the first wave of the pandemic, overstretched healthcare systems left health workers in hard hit countries struggling with long working hours, fatigue, and extreme psychological stress. Rapidly vanishing supplies, national lockdowns, and a feeding frenzy on the open market for personal protective equipment (PPE) led to shortages.[7] Healthcare workers often had to care for patients with suspected or confirmed covid-19 infection without proper training or adequate PPE. This contributed to an increased risk to healthcare workers during the initial phase of the pandemic.[3 8 9]

Superspreading events, a hallmark of previous coronavirus outbreaks, contribute substantially to community transmission of covid-19 and to work related clusters.[5] Most countries struggled with insufficient testing capacity in the first months of the pandemic, which hampered early detection of emerging outbreaks and implementation of infection control measures. Increasing experience now suggests that every suspected healthcare associated infection should trigger a bundle of immediate infection control measures, including extensive screening for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), quarantining of all patients on the affected ward, physical distancing between personnel, and use of reinforced PPE during all contact with patients on the affected ward, in order to prevent larger outbreaks.[10-12]

Most, but not all, studies report increased risks for health workers caring for patients with covid-19.[3 13 14] Working in intensive care units is not associated with an increased risk of infection, possibly owing to the protection afforded by high level PPE or to the decrease in infectivity that occurs in the later stages of the illness, even among critically ill patients.[13 15] The greatest risk to healthcare workers may be their own colleagues or patients in the early stages of unsuspected infections when viral loads are high.[12]

Most studies to date, including Shah and colleagues' study, have evaluated risks to healthcare workers during the early phases of the pandemic. Advances since then may have reduced the risks, although further confirmatory studies are needed. Such advances include greater knowledge of transmission dynamics and the impact of asymptomatic and pre-symptomatic infections,[16] better access to effective PPE, improved testing capabilities, optimised triage systems, implementation of new infection control measures such as continuous mask use in hospitals,[17 18] and faster outbreak alerts and responses.

High quality prospective studies evaluating new prevention and control practices will be important to guide improvements in our approach to protecting healthcare workers and their families,[19] including those from ethnic minority communities who have the highest risks of infection and poor outcomes, widening workplace inequality.[3] The international community must support efforts by the World Health Organization to secure adequate supplies of PPE and covid-19 tests for low and middle income countries. An effective vaccine, if and when available, must be distributed fairly and healthcare workers must be prioritised globally. In accordance with United Nations Sustainable Development Goals, we must ensure the protection and security of all health workers in all settings.[20]

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How Many Teachers Are at Risk of Serious Illness If Infected with Coronavirus?

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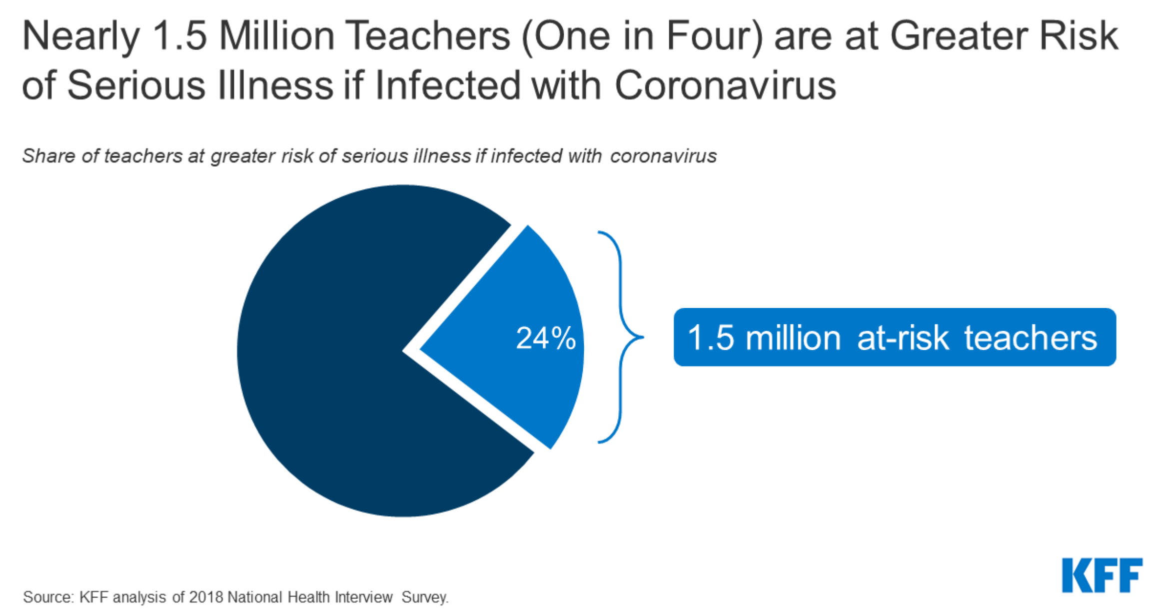
As the nation continues to struggle to contain the spread of coronavirus, there is considerable debate about when and how to reopen schools. Education is primarily a state and local concern, and although they have received mixed guidance from federal officials, the decisions over reopening will be made at the state and local level.

One of the myriad of issues these officials will face will be how to keep school employees safe at work, particularly those who are at increased risk of serious illness if they become infected with coronavirus. The Centers for Disease Control have identified a number of factors that put individuals at increased risk of serious illness if infected; these include several health conditions, including having diabetes, chronic obstructive pulmonary disease (COPD), heart disease, moderate or severe asthma, having a body mass index (BMI) of greater than 40, or having a compromised immune system, which for example, may occur during cancer treatment. Being age 65 and older also is considered to be a risk factor. In a previous study (https://www.kff.org/coronavirus-covid-19/issue-brief/almost-one-in-four-adult-workers-is-vulnerable-to-severe-illness-from-covid-19/), we reported that almost one in four workers are at higher risk of severe illness if they were to become infected. While children are at less risk for serious illness from coronavirus than adults and often have mild or no symptoms when infected, the teachers and other adult staff in schools face higher risk. We used a similar approach to look at teachers and other instructors, and we find that one in four teachers (24%, or about 1.47 million people), have a condition that puts them at higher risk of serious illness from coronavirus (**Figure)**. This percentage is the same as the one we found for workers overall; the challenge for school systems and for teachers in particular is the sheer volume of traffic and tight quarters in many school environments, which may make social distancing a significant challenge in many settings. For higher-risk teachers, failure to achieve safe working conditions could have very serious results.



Nearly 1.5 Million Teachers (One in Four) are at Greater Risk of Serious Illness if Infected with Coronavirus

Given the difficulty of maintaining social distancing in a crowded school environment, these at-risk teachers may be reluctant to return to their schools until infection rates fall to much lower levels. At the same time, teaching is not a particularly high-paying profession, so many teachers may feel economically compelled to return to their schools if they reopen, even if those teachers do not feel safe. How state and local officials balance the desire to reopen schools and other facilities with the need to assure the safety of students, parents, and school personnel will have significant health and economic consequences for both people and the communities they live in. Assuring the safety of teachers and others at higher risk of serious illness from coronavirus is a crucial part of the calculation around reopening.

METHODS

This analysis uses data from the 2018 National Health Interview Survey (NHIS) to look at the share of workers who would be at increased risk of becoming seriously ill if they become infected with coronavirus. The risk factors we were able to analyze were having diabetes, chronic obstructive pulmonary disease (COPD), heart disease, a body mass index (BMI) above 40, and a functional limitation due to cancer. As we previously discussed we included 62% of those with asthma none of the other risk factors, as at risk. In addition, the CDC criteria consider all people over age 65 to be at increased risk. We define teachers as individuals whose occupation is “primary, secondary, and special education school teachers” or “other teachers and instructors,” and are employed in the “Education Services Industries” industry. Only teachers who are currently working, looking for work or on a temporary absence such as a planned vacation, maternity leave or temporary medical leave were included.

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COVID-19: Workers' Compensation

12/9/2020 Josh Cunningham

The COVID-19 pandemic has created countless challenges for state policymakers across the country. Among those is the role that workers' compensation insurance plays in helping workers infected with the disease. Every state has its own unique workers' compensation policy landscape. States apply varying coverage requirements and standards based on industry, occupation, and the size and structure of a business. Workers' compensation is designed to benefit both employees and employers by providing reliable insurance coverage with predictable, timely payments and reduced legal costs. Beyond providing medical treatment at no cost to the employee, workers' compensation also provides wage replacement benefits for lost wages resulting from time away from work. If a worker dies due to a qualifying condition, the worker's family could be eligible for financial death benefits. Most states have a dedicated workers' compensation court system where judges make the final decision on claims and benefits awarded.

Does Workers' Compensation Cover COVID-19?

The answer is complicated. Generally, workers' compensation does not cover routine community-spread illnesses like a cold or the flu because they usually cannot be directly tied to the workplace. Some states have made exceptions for certain workers who develop chronic illnesses, like cancer, resulting from repeated exposure to harmful materials and environments. According to the National Council on Compensation Insurance, prior to the COVID-19, at least 19 states had policies stating that when firefighters and other first responders develop lung and respiratory illnesses, those conditions are presumed to be work-related and covered under workers' compensation. It is unclear if those existing policies would include COVID-19 illnesses.

The COVID-19 pandemic presents a unique circumstance where the many jobs that are not typically considered hazardous have suddenly become very dangerous for the workers. Workers deemed essential including health care workers, mass transit operators and grocery store workers are at a high risk of exposure to the virus while at work. But the more hazardous working conditions do not guarantee that a COVID-19 infection would be covered under workers' compensation in most states.

State Response to COVID-19

States are taking action to extend workers' compensation coverage to include first responders and health care workers impacted by COVID-19. A common approach is to amend state policy so that COVID-19 infections in certain workers are presumed to be work-related and covered under workers' compensation. This presumption places the burden on the employer and insurer to prove that the infection was not work-related making it easier for those workers to file successful claims. Some employers and insurers have raised concerns that these presumption policies will increase insurance costs for employers at a time when businesses are already facing significant financial challenges.

In total, 17 states and Puerto Rico have take action to extend workers compensation coverage to include COVID-19 as a work-related illness. Nine states have enacted legislation creating a presumption of coverage for various types of workers. Minnesota, Utah and Wisconsin limit the coverage to first responders and health care workers. Illinois, New Jersey and Vermont cover all essential workers while California and Wyoming cover all workers. Four states have used executive branch authority to implement presumption policies for first responders and health care workers in response to COVID-19. Another four states including California and Kentucky have taken executive action to provide coverage to other essential workers like grocery store employees.

State Spotlight

In March, Washington state's Department of Labor and Industries announced that health care workers and first responders will receive wage-replacement benefits and have all related health care expenses covered under the state's workers' compensation program when quarantined by a physician. Washington has a single publicly-managed insurance option that employers can purchase giving the state more control over the coverage offered to workers. Other essential workers in Washington who test positive for COVID-19 will be considered on a case-by-case basis. The state has established three criteria for evaluating these COVID-19 claims:

- Was there an increased risk or greater likelihood of contracting the condition due to the worker's occupation (such as a first responder or health care worker)?
- If not for their job, would the worker have been exposed to the virus or contracted the condition?
- Can the worker identify a specific source or event during the performance of his or her employment that resulted in exposure to the new coronavirus (examples include a first responder or health care worker who has actually treated a patient with the virus)?

State Actions

NCSL is tracking legislation, executive orders and other administrative policy changes that directly address workers' compensation coverage of COVID-19.

State	Status	Type of Worker With Presumption of Occupational Disease	Bill or Order Number

Alaska	Enacted (program expired)	▪ First reponders ▪ Health care workers	SB 241
Arkansas	Executive Order	▪ All workers whose jobs make exposure to COVID-19 possible or likely. ▪ The order does not give a presumption of coverage, but defines COVID-19 as an occupational disease making it coverable by workers compensation under the regular process of filing a claim.	EO 20-35
Arkansas	Executive Order	▪ Any worker who can establish that they contracted COVID-19 as a result of their job	EO 20-35
California	Executive Order	▪ All workers who test positive for COVID-19 and who are not exclusively working from home	EO N-62-20
California	Enacted	▪ All workers exposed to COVID-19 resulting from a hazardous workplace	AB 685
California	Failed	▪ First responders ▪ Health care workers	AB 664
California	Failed	▪ All essential workers	AB 196
California	Enacted	▪ Workers employed to combat the spread of COVID-19	SB 1159
California	Failed	▪ Hospital workers	SB 893
Colorado	Failed	▪ All essential workers	SB 216
Connecticut	Executive Order	▪ All essential workers who contracted COVID-19 between March 10, 2020 and May 20, 2020	EO 7JJJ
Florida	Admin. Policy Change	▪ First responders ▪ Child safety investigators ▪ Corrections officers ▪ National Guard service members responding to COVID-19 ▪ State-employed health care workers	CFO Directive 2020-05
Florida	Informational Memorandum	▪ Reinforces the administrative policy change and informs insurance carriers that existing Florida law defines and covers occupational diseases.	OIR-20-05M
Illinois	Enacted	▪ All essential workers	HB 2455
Kansas	Failed	▪ All workers who work in close proximity with the public or coworkers	HB 2007 (special session)
Kansas	Failed	▪ All workers who work in close proximity with the public or coworkers	HB 2018 (special session)
Kansas	Failed	▪ All workers who work in close proximity with the public or coworkers	SB 1 (special session)
Kentucky	Executive Order	▪ First responders ▪ Health care workers ▪ Military and National Guard ▪ Domestic violence shelter workers ▪ Child advocacy workers ▪ Rape crisis center staff ▪ Grocery store workers ▪ Postal workers ▪ Child care workers	EO 2020-277

Louisiana	Failed	▪ All essential workers	SB 475
Massachusetts	Pending	▪ Paramedics ▪ Emergency and urgent care health care workers	HD 4949
Massachusetts	Pending	▪ Emergency room and urgent care health workers	HB 4749
Massachusetts	Pending	▪ All public employees working outside of their home	SB 2732
MIchigan	Pending	▪ All essential workers	HB 5758
Michigan	Pending	▪ First responders ▪ Health care workers ▪ Corrections officers	SB 906
Michigan	Pending	▪ All essential workers	SB 928
MIchigan	Executive Order	▪ First responders ▪ Health care workers	EO 2020-125
Michigan	Pending	▪ Workers who contract COVID-19 would be ineligible for workers' compensation if their employer was in compliance with public health requirements and guidelines	SB 1019
Michigan	Pending	▪ All workers who are required by their employer to work outside their home	HB 6040
Minnesota	Enacted	▪ First responders ▪ Health care workers	HF 4537
Minnesota	Failed	▪ School and higher education workers	HF 9 e
Minnesota	Failed	▪ School and higher education workers	SF 16 f
New Hampshire	Executive Order	▪ First responders	Emergency Order #36
New Jersey	Pending	▪ All essential workers	AB 3998
New Jersey	Enacted	▪ All essential workers	AB 3999
New Jersey	Pending	▪ Would prohibit payment of workers compensation benefits for COVID-19 unless the employer committed gross negligence	AB 4496
New Jersey	Pending	▪ Workers in warehouses and distribution centers	AB 4784
New Mexico	Executive Order	▪ Certain state workers and volunteers	EO 2020-025
New York	Pending	▪ First responders	SB 8117A
New York	Pending	▪ All workers who have contact with others	SB 8266
New York	Pending	▪ All workers at risk of exposure as part of their job	AB 10401
North Carolina	Failed	▪ First responders ▪ Corrections officers	HB 1056

Northa Carolina	Failed	▪ All essential workers	HB 1057
North Dakota	Executive Order	▪ First responders ▪ Health care workers ▪ Providers of treatment, care, programs or services to individuals with intellectual or developmental disabilities ▪ Employees of the Life Skills and Transition Center ▪ *Benefits limited to temporary wage replacement while in quarantine and health care treatments	EO 2020-12.2
Ohio	Pending	▪ First responders	HB 571
Ohio	Pending	▪ All essential workers	HB 573
Ohio	Pending	▪ Grocery store workers ▪ Food processing workers	HB 605
Ohio	Pending	▪ Health care workers	HB 633
Ohio	Pending	▪ Corrections officers	HB 667
Ohio	Pending	▪ First responders	HB 668
Pennsylvania	Failed	▪ Workers employed by a life-sustaining business or occupation	HB 2396
Puerto Rico	Enacted	▪ All workers infected while performing authorized services	SB 1540
Rhode Island	Pending	▪ All essential workers	HB 8066
South Carolina	Failed	▪ First responders ▪ Health care workers ▪ Corrections officers	HB 5482
Tennessee	Failed	▪ Essential workers ▪ Any infected worker if 9 or more other workers at the same location have also become infected	SB 8007b
Texas	Pre-filed	▪ Nurses	HB 396
Utah	Enacted	▪ First responders ▪ Health care workers	SB 3007
Vermont	Enacted	▪ First responders ▪ Health care workers ▪ Corrections officers ▪ Long-term care staff ▪ Child care providers ▪ Employees of pharmacies or grocery stores ▪ Other workers with high risk of exposure	SB 342
Virgina	Failed	▪ First responders ▪ Health care workers ▪ School employees	HB 5028a
Virgina	Failed	▪ First responders	SB 5022a

Virginia	Failed	▪ First responders ▪ Health care workers	SB 5097a
Virginia	Failed	▪ First responders ▪ Health care workers	SB 5104a
Virginia	Failed	▪ First responders ▪ Health care workers ▪ Corrections officers	SB 5066a
Virgina	Failed	▪ First responders ▪ Health care workers ▪ School employees	HB 5028 a
Washington	Admin. Policy Change	▪ First responders ▪ Health care workers	Press Release
Wisconsin	Enacted	▪ First responders	AB 1038
Wyoming	Enacted	▪ All workers otherwise covered under workers' compensation	SB 1002 (special session)

PLOS ONE

RESEARCH ARTICLE

Estimating the burden of United States workers exposed to infection or disease: A key factor in containing risk of COVID-19 infection

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Data Availability Statement: The data underlying the results presented in the study are available from the United States Bureau of Labor Statistics at: https://www.bls.gov/oes/home.htm and https://www.onetonline.org/find/descriptor/result/4.C.2.c.1.b. These merged data sets are available at: https://github.com/bakermarissa/exposedtodisease.

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Abstract

Introduction

With the global spread of COVID-19, there is a compelling public health interest in quantifying who is at increased risk of contracting disease. Occupational characteristics, such as interfacing with the public and being in close quarters with other workers, not only put workers at high risk for disease, but also make them a nexus of disease transmission to the community. This can further be exacerbated through presenteeism, the term used to describe the act of coming to work despite being symptomatic for disease. Quantifying the number of workers who are frequently exposed to infection and disease in the workplace, and understanding which occupational groups they represent, can help to prompt public health risk response and management for COVID-19 in the workplace, and subsequent infectious disease outbreaks.

Methods

To estimate the number of United States workers frequently exposed to infection and disease in the workplace, national employment data (by Standard Occupational Classification) maintained by the Bureau of Labor Statistics (BLS) was merged with a BLS O*NET survey measure reporting how frequently workers in each occupation are exposed to infection or disease at work. This allowed us to estimate the number of United States workers, across all occupations, exposed to disease or infection at work more than once a month.

Results

Based on our analyses, approximately 10% (14.4 M) of United States workers are employed in occupations where exposure to disease or infection occurs at least once per week. Approximately 18.4% (26.7 M) of all United States workers are employed in occupations where exposure to disease or infection occurs at least once per month. While the majority of exposed workers are employed in healthcare sectors, other occupational sectors also have high proportions of exposed workers. These include protective service occupations (e.g. police officers, correctional officers, firefighters), office and administrative support

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occupations (e.g. couriers and messengers, patient service representatives), education occupations (e.g. preschool and daycare teachers), community and social services occupations (community health workers, social workers, counselors), and even construction and extraction occupations (e.g. plumbers, septic tank installers, elevator repair).

Conclusions

The large number of persons employed in occupations with frequent exposure to infection and disease underscore the importance of all workplaces developing risk response plans for COVID-19. Given the proportion of the United States workforce exposed to disease or infection at work, this analysis also serves as an important reminder that the workplace is a key locus for public health interventions, which could protect both workers and the communities they serve.

Introduction

As COVID-19 spreads globally, there is public health importance in characterizing the role of the workplace in disease transmission, given the variety of work tasks that could promote the spread of infectious disease (e.g., interfacing with customers, patients, and co-workers; preparing food), and the role of the workplace in spreading previous epidemics or pandemics [1,2].

It is known that those working in healthcare settings face increased exposure to agents causing infectious diseases such as SARS-CoV-2, but may also have better infectious disease protection plans and policies than other occupational settings, potentially limiting the transmission of disease to community members [3]. While important, these measures may be inadequate for the effective prevention of infection for such high risk occupations, especially when they are working with inadequate PPE stockpiles, and the hospitals are overwhelmed due to heavy patient loads [4]. Nearly 4% of confirmed COVID-19 cases in Wuhan, China (as of February 11, 2020) were in healthcare workers, indicating the workplace is a potential location of transmission even among workers who are trained to protect themselves from biological hazards [5].

However, other occupational groups which may have more sporadic exposure to infectious or disease-causing agents may not have the same level of planning, or even think that an infection disease control plan is warranted for their workplace. Of the first 25 COVID-19 cases confirmed in Singapore, 17 had probable relation to occupational exposure, including workers in retail stores and casinos, domestic workers, a tour guide, taxi and private hire car drivers, security guards, and workers at the same construction site, further exemplifying the role of the workplace in transmitting disease [6].

Understanding the burden of occupational exposure to infection and disease, including how many workers are potentially exposed and what occupations they work in, allows for upstream prevention measures, both at the workplace (e.g. developing appropriate infectious disease response plans, integrating infectious disease trainings into other workplace trainings, developing workplace policies that can support a workforce potentially exposed to SARS-CoV-2) and regulatory levels (e.g. increased access to paid sick leave, hazard pay for those exposed during a pandemic, etc.). These workplace and regulatory policies will be valuable in helping reduce the transmission of infectious disease from and within the workplace, and their importance may be realized with burden estimates

Previously, state-level employment data were utilized to estimate the number of workers exposed to a host of occupational exposures in United States Federal Region X (Washington, Oregon, Idaho, Alaska), spanning chemical, physical, ergonomic, and psychosocial hazards [7]. Here, utilizing the same data analysis methods as previously detailed in Doubleday et al., the number of workers across the United States exposed to disease or infection at work more than once a month is estimated. Despite some of the inherent limitations in using these existing data sources, we believe this analysis is valuable for informing risk assessments and prompting protective actions that occupational sectors and regulatory agencies can take during infectious disease outbreaks, such as COVID-19.

Methods

Two sources of data were utilized for this analysis, and are detailed below.

United States employment data was obtained from the Bureau of Labor Statistics (BLS) Occupational Employment Statistics database [8]. The most current employment data at the time of analysis was from May 2018, and is organized by 2010 Standard Occupational Classification codes (2010 SOC). SOC codes are hierarchical, ranging from two-digits (Major Group Code) to six digits (Detailed Occupation Code), with the six-digit codes being the most detailed [9].

To estimate exposure to disease and infection in the workplace, we used data within the O*NET database. O*NET is a job characterization tool, generated from survey data, with rich information on tasks performed, skills needed, and job characteristics for different occupations, in order to inform job seekers or researchers [10]. As nearly 600 six-digit SOC occupations are updated each year, the entire O*NET database is completely refreshed every few years [11]. Between 2001 and 2011, nearly 160,000 employees from 125,000 workplaces had responded to O*NET questionnaires. O*NET uses a deliberate survey sampling scheme, to ensure representation of workers from across the United States, across organizations of different size, and from both government and private workers. For small SOCs where it may be hard to find respondents, and to complement data from job incumbents, O-NET also relies on occupational analysts and occupational experts to answer questionnaires. O*NET does not collect data from military occupations; thus, SOC codes beginning with 55 "Military Specific Occupations" are not included in O*NET data. Similarly, employment numbers for "Military Specific Occupations" is not reported in the BLS Occupational Employment Statistics Database. No other SOC codes are excluded from the O*NET database, but two SOC codes were not included in the measure utilized for this analysis, which were for the occupations of "Rock Splitters, Quarry" and "Timing Device Assemblers and Adjusters" employing 4,870 and 780 persons in the United States, respectively [12].

To characterize frequency of workplace exposure to infectious disease, we used the following O*NET question: "How often does your current job require you be exposed to diseases or infections?" Respondents, who take the survey online or on paper, could select from the following frequencies of exposure: Never; Once a year or more but not every month; Once a month or more but not every week; Once a week or more but not every day; Every day [13]. Respondents are given little context when completing the survey, with interpretation of the question up to the respondent. Within O*NET, these data are converted to a 0–100 score, representing weighted-average frequency of the metric for each SOC code. For this analysis, occupations were retained that had a score of 50–100, representing exposure to disease/infection more than once a month. SOC codes were merged with the national employment data to calculate the total number of workers employed in the occupations with exposure to disease/infection at more than once a month.

All data analysis was conducted using the statistical software package R version 3.6.3.

Table 1. Number and percent of workers exposed to infection or disease more than one time per month, and more than one time per week, by major (2-digit) Standard Occupational Classification code (SOC).

			Exposed > 1 time/month		Exposed > 1 time/week	
	2-digit SOC	total in SOC	#	%	#	%
31	Healthcare Support	4,117,450	3,958,560	96.1%	3,160,890	76.8%
29	Healthcare Practitioners and Technical	8,646,730	7,911,430	91.5%	6,728,420	77.8%
33	Protective Services	3,437,410	1,789,490	52.1%	1,026,660	29.9%
39	Personal Care and Service	5,451,330	2,841,730	52.1%	29,810	0.5%
21	Community and Social Services	2,171,820	704,280	32.4%	168,190	7.7%
25	Education, Training, and Library	8,779,780	2,048,070	23.3%	--	--
37	Building and Grounds Cleaning and Maintenance	4,421,980	924,290	20.9%	--	--
43	Office and Administrative Support	21,828,990	3,532,530	16.2%	2,871,400	13.2%
19	Life, Physical, and Social Science	1,171,910	159,970	13.7%	20,030	1.7%
15	Computer and Mathematical	4,384,300	587,970	13.4%	--	--
53	Transportation and Material Moving	10,244,260	930,930	9.1%	118,770	1.2%
47	Construction and Extraction	5,962,640	491,990	8.3%	--	--
51	Production	9,115,530	371,480	4.1%	--	--
13	Business and Financial Operations	7,721,300	300,900	3.9%	300,900	3.9%
27	Arts, Design, Entertainment, Sports, and Media	1,951,170	57,140	2.9%	--	--
11	Management	7,616,650	59,050	0.8%	--	--
17	Architecture and Engineering	2,556,220	--	--	--	--
23	Legal	1,127,900	--	--	--	--
35	Food Preparation and Serving Related	13,374,620	--	--	--	--
41	Sales and Related	14,542,290	--	--	--	--
45	Farming, Fishing, and Forestry	480,130	--	--	--	--
49	Installation, Maintenance, and Repair	5,628,880	--	--	--	--
	All SOCs	**144,944,620**	**26,669,810**	**18.4%**	**14,425,070**	**10.0%**

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Results

As of May 2018, there were a total of 144.7 million persons employed in the United States in employer-employee arrangements counted by BLS. Of these 144.7 million workers, an estimated 18.4% (26,669,810) were employed in occupations where exposure to disease or infection occurs more than once a month. As of May 2018, 10% (14,425,070) of the United States workforce was employed in occupations where exposure to disease or infection occurs at least once a week. Table 1 summarizes the number and proportion of workers exposed more than once a week and more than once a month by major occupational sectors (two-digit SOC). Both Healthcare Practitioner and Technical Occupations, and Healthcare Support Occupations have more than 90% of workers exposed more than once a month, and more than 75% of workers exposed more than once a week. Other notable major occupation groups with high proportion of exposure are Protective Service Occupations (52% exposed more than once a month, including police officers, firefighters, transportation security screeners), Personal Care and Service Occupations (52% exposed more than once a month, including childcare workers, nannies, personal care aides), and Community and Social Services Occupations (32.4% exposed more than once a month, including probation officers, community health workers, and social and human health assistants).

The 16% of office and administrative support occupations with exposure to disease or infection more than once a month are patient representatives, couriers and messengers, and medical secretaries. The nearly 4% of workers exposed in business and financial operation occupations are compliance specialists, which includes environmental compliance specialists and coroners. The full O*NET dataset, ranking the frequency of exposure for each SOC is publicly accessible online [14], as is employment and wage data [8]. As these databases are periodically updated, they should be referenced for information on frequency of exposure for a specific occupation.

Discussion

During an infectious disease outbreak, the workplace can play an important role in both spreading the disease [15,16] and helping to stop the spread of disease through workplace practices and policies [1,17]. Understanding the wide range of occupations that could be exposed to infection or disease due to work activities is important for planning risk management and communication to workers, in addition to prioritizing workplace response plans. This analysis estimates that the number of workers who face frequent exposure to an infection or disease at work; estimates of the number of workers who fall ill due to such exposures are not possible in this analysis. However, a primary goal of public health, especially in the face of a global pandemic, is to prevent the spread of disease. Therefore, understanding how many workers are frequently exposed, and what occupations they represent, is an important first step in being able to prompt and enact risk reduction strategies prior to disease transmission occurring, and illness manifesting. Thus, the results reported here have important public health implications.

Several limitations must be emphasized. Exposure to disease or infection in the workplace, and resultant transmission into the community, is dependent on many factors which were not able to be investigated in this analysis. This includes number of contacts that worker has with the public, workplace emphasis on and access to handwashing, number of interactions with bodily fluids, existing hygiene and cleaning practices in the workplace, availability of appropriate personal protective equipment (PPE) etc. While certainly this could vary between occupations, many of these factors would also vary within occupations, and none of these data were captured with the O*NET data. Presenteeism, reporting to work despite being symptomatic for disease, is common in the workplace, and is another contributor to the transmission of infectious disease, and potentially to the spread of epidemics or pandemics [2,18]. One analysis examined the role of workplace transmission in the 2009 H1N1 pandemic, estimating that about 8 million employees in the United States worked while infected, and that these workers may have caused the infection of as many as 7 million of their co-workers [19].

Access to paid leave, which could ameliorate the financial burden of staying home while sick, varies substantially by occupation, industry, employer, location, and worker sociodemographic profile (e.g., race/ethnicity) [20,21]. Workers without access to paid leave have higher rates of presenteeism, and are less likely to receive preventative health services such as getting flu shots [22]. Occupational sector also influences rates of presenteeism, with studies from various countries showing higher rates of presenteeism among workers in healthcare, public service, and educational sectors, as these essential services often do not have substitute workers available [23–25]. Indeed, a recent systematic review identified occupation type as one of the strongest predictors of presenteeism [2]. As many of these sectors are already exposed to disease due to work activities, it is important that disease response plans for these sectors include not only control methods to reduce exposures at work, but also contingency plans to ensure sick workers do not come back to work with disease. This could be accomplished through cross-training, providing extra paid sick leave during this time, ensuring flexible working conditions, and ensuring substitute workers are identified to fill in if essential workers fall ill.

Importantly, O*NET data are also subject to misclassification and undercounting. O*NET data were generated from self-reported subjective questionnaires and therefore are subject to bias and misclassification. Respondents may not realize they are exposed to infection or disease at work unless they are in a workplace where these hazards are communicated to them and protective equipment is provided (e.g., healthcare sectors) leading to potential differential misclassification across occupational groups. Workers could also be reporting expose to disease or infection that occurs while commuting to work (particularly by public transportation), leading to additional misclassification. Additionally, information from the O*NET database is applied at the occupation-level, and therefore does not account for within-job exposure variation [26]. Many workers are not included in the O*NET and BLS data sources, including independent contractors (which includes "gig economy" workers), domestic workers, self-employed, undocumented, and continent workers. These workers may be uniquely susceptible to exposure at work due to limited ability to take time off if they or a family member is ill [27]. In Sweden and Norway, higher rates of presenteeism (coming to work when sick) were found among low-income and immigrant workers [28]. This further emphasizes the importance of continuing to develop occupational surveillance systems that capture exposures and outcomes experienced by these undercounted groups, as well as ensure worker protections extend to protect these undercounted workers.

In conclusion, our analysis shows that a large proportion of the United States workforce, across a variety of occupational sectors, are exposed to disease or infection at work more than once a month. These are workers that public health should consider especially at risk for COVID-19, due to frequent exposure to disease and infectious agents. However, it should be noted that there are many other workers that could also be exposed to SARS-CoV-2, or encourage the spread of COVID-19, such as workers who are not given access to flexible working, workers who do not feel they can take sick time if they or a family member is sick, workers who do not have access to paid sick leave, or workers that perform essential services and do not have access to substitute workers. Work presented here underscores the importance of all workplaces developing sector-specific response plans to keep employees safe, halt the transmission of disease in the workplace, and ensure sick workers do not have to come to work. It also serves as a reminder that the workplace is an important locus for public health interventions, as many workers are frequently exposed to disease and infection at work, and their exposures can Increase disease incidence both in worker and community groups.

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The plight of essential workers during the COVID-19 pandemic

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The COVID-19 pandemic has vividly highlighted how much society depends upon essential workers. Praise for the heroic work being done by health-care workers to save lives worldwide in dangerous, exhausting conditions is everywhere. But those same workers are often left unprotected by governments and systems that have failed to supply them with enough personal protective equipment (PPE), supplies, and resources to do their jobs. In April alone, there were an estimated 27 COVID-19-related health worker deaths in the USA, 106 in the UK, and 180 in Russia, with tens of thousands of infections. The actual numbers are probably much higher.

But essential work extends beyond health care. Although some people have been able to shift their jobs to their homes, millions of workers have jobs that cannot be done at home—not only custodial staff and orderlies in hospitals, but also teachers and child-care workers, grocery clerks and supermarket workers, delivery people, factory and farm workers, and restaurant staff, often without adequate PPE. These people leave their homes to help maintain a semblance of normality for others, at great risk to themselves and their families.

What constitutes an essential worker in the USA varies by state, but black and Latino Americans make up a large part of the essential workforce and have been disproportionately affected by COVID-19. In New York City, over 60% of COVID-19 deaths have been in black and Latino populations. Meat processing plants have become hotspots for transmission, with 700 new cases at a Texas plant on May 16. 81 employees at a Walmart in Massachusetts tested positive for COVID-19 on May 2. Those who would rather quit their jobs than be exposed to a dangerous work situation face a daunting prospect in the USA. 36 million people have filed for unemployment in the past 2 months and quitting a job (even one that is unsafe) would disqualify workers from unemployment insurance benefits. In the UK, 33% (10·6 million people) of the total workforce are deemed key workers according to the Office for National Statistics. Despite a government plan to pay furloughed workers 80% of their salary, many low-wage workers such as cleaners, migrant and seasonal workers, and student labourers might not be eligible.

Transport staff have been particularly hard hit. In New York City, 120 employees of the Metropolitan Transportation Authority (MTA) have died due to COVID-19, and nearly 4000 have tested positive. The MTA changed guidance to advise wearing face masks before the US Centers for Disease Control and Prevention (CDC) and WHO shifted their guidance, but being exposed to the public, even with adequate PPE, presents dangers. At least 28 London bus drivers have died due to COVID-19, and a UK railway worker, Belly Mujinga, died after being spat on by a passenger who claimed to have COVID-19, leaving behind an 11-year-old daughter.

The International Labour Organization has reported that 2·7 billion people—81% of the world's workforce—had been affected by lockdown measures. 61% of workers are from the informal sector, 90% of whom are in low-income and middle-income countries, and social protection measures are often inadequate, with a lack of access to health-care support and economic protections. Informal and migrant workers are likely to fall through the cracks and ensuring their safety must be a priority.

Some US states are considering reopening restaurants, bars, gyms, and swimming pools, without a viable system in place to test, trace, and isolate people, and a CDC draft plan to lift the lockdown has been watered down by the Trump administration. In Germany, infection rates rose as lockdown restrictions began to ease and in the UK Boris Johnson's vague, amorphous plan to end lockdown has caused confusion and angered many. Gifted with a 2-month lockdown and a chance to lay the groundwork for a staged, successful reopening, many western leaders have instead prevaricated, shifted blame, and appear not to grasp the dangers of lifting lockdown without robust testing and mitigation strategies in place. The rush towards a premature, ill-advised end to the lockdown risks a second wave of infections that could surpass the first, and essential workers who never got a chance to isolate and consider their health during the first wave will face the greatest risk to their lives.

When this pandemic has ended, we cannot allow a return to the status quo ante. We must ensure that essential workers can do their jobs safely, and that they have adequate health care and paid sick leave to safeguard their health beyond extraordinary pandemics. Essential workers are just that—essential—and by protecting their health, we protect the health and wellbeing of us all. ■ *The Lancet*

For more on the **effects of COVID-19 in racial and ethnic minority groups** see https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/racial-ethnic-minorities.html

For the **International Labour Organization report** see https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_741358/lang--en/index.htm

For more on the **COVID-19 crisis and informal and migrant workers** see https://oecd-development-matters.org/2020/04/22/the-covid-19-crisis-income-support-to-informal-workers-is-necessary-and-possible/

Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study

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Summary

Background Data for front-line health-care workers and risk of COVID-19 are limited. We sought to assess risk of COVID-19 among front-line health-care workers compared with the general community and the effect of personal protective equipment (PPE) on risk.

Methods We did a prospective, observational cohort study in the UK and the USA of the general community, including front-line health-care workers, using self-reported data from the COVID Symptom Study smartphone application (app) from March 24 (UK) and March 29 (USA) to April 23, 2020. Participants were voluntary users of the app and at first use provided information on demographic factors (including age, sex, race or ethnic background, height and weight, and occupation) and medical history, and subsequently reported any COVID-19 symptoms. We used Cox proportional hazards modelling to estimate multivariate-adjusted hazard ratios (HRs) of our primary outcome, which was a positive COVID-19 test. The COVID Symptom Study app is registered with ClinicalTrials.gov, NCT04331509.

Findings Among 2 035 395 community individuals and 99 795 front-line health-care workers, we recorded 5545 incident reports of a positive COVID-19 test over 34 435 272 person-days. Compared with the general community, front-line health-care workers were at increased risk for reporting a positive COVID-19 test (adjusted HR 11·61, 95% CI 10·93–12·33). To account for differences in testing frequency between front-line health-care workers and the general community and possible selection bias, an inverse probability-weighted model was used to adjust for the likelihood of receiving a COVID-19 test (adjusted HR 3·40, 95% CI 3·37–3·43). Secondary and post-hoc analyses suggested adequacy of PPE, clinical setting, and ethnic background were also important factors.

Interpretation In the UK and the USA, risk of reporting a positive test for COVID-19 was increased among front-line health-care workers. Health-care systems should ensure adequate availability of PPE and develop additional strategies to protect health-care workers from COVID-19, particularly those from Black, Asian, and minority ethnic backgrounds. Additional follow-up of these observational findings is needed.

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Introduction

Since its emergence, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes COVID-19, has become a global health threat.[1] As of July 22, 2020, more than 15 million cases of COVID-19 have been documented worldwide, with nearly 618 000 deaths.[2] In the UK and the USA, Black, Asian, and minority ethnic communities have been disproportionately affected.[3,4] With ongoing community transmission from asymptomatic individuals, disease burden is expected to rise. As a result, there will be an ongoing need for front-line health-care workers in patient-facing roles. Because this work requires close personal exposure to patients with SARS-CoV-2, front-line health-care workers are at high risk of infection, contributing to further spread.[5] Initial estimates suggest that front-line health-care workers could account for 10–20% of all diagnoses,[6,7] with some early evidence that people from Black, Asian, and minority ethnic backgrounds are at higher risk.[3]

Based on experience with other respiratory viruses, consistent use of personal protective equipment (PPE) is important to reduce nosocomial transmission.[8] Guidelines from the UK and the USA recommend mask use for health-care workers caring for people with COVID-19.[9,10] However, global shortages of masks, respirators, face shields, and gowns, caused by surging demand and supply chain disruptions, have led to efforts to conserve PPE through extended use or reuse, and

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See Online for appendix

Research in context

Evidence before this study

We searched PubMed for articles published between Jan 1 and June 30, 2020, with the terms "covid-19", "healthcare workers", and "personal protective equipment". We did not restrict our search by language or type of publication. The prolonged course of the COVID-19 pandemic, coupled with sustained challenges supplying adequate personal protective equipment (PPE) for front-line health-care workers, have strained global health-care systems in an unprecedented fashion. Despite growing awareness of this problem, there are few studies to inform policy makers on the risk of COVID-19 among health-care workers and the effect of PPE on disease burden. Previous reports of infections in health-care workers are based on cross-sectional data with limited information on individual-level risk factors. Our PubMed search yielded no population-scale investigations.

Added value of this study

We did a prospective observational study of 2 135 190 individuals, comprised of front-line health-care workers and the general community who were voluntary users of the COVID Symptom Study smartphone application (app). From self-reported data obtained via this app, we found that front-line health-care workers had at least a threefold increased risk of COVID-19. Compared with front-line health-care workers who reported adequate availability of PPE, those with inadequate PPE had an increase in risk. However, adequate availability of PPE did not seem to completely reduce risk among health-care workers caring for patients with COVID-19. We also found that Black, Asian, and minority ethnic health-care workers might be disproportionately affected.

Implications of all the available evidence

Front-line health-care workers, particularly those who are from Black, Asian, and minority ethnic backgrounds, could be at substantially greater risk of COVID-19. Health-care systems should ensure adequate availability of PPE and develop additional strategies to protect health-care workers from COVID-19.

disinfection protocols have been developed, for which scientific consensus on best practice is scarce.[11–13]

Although addressing the needs of front-line health-care workers during the COVID-19 pandemic is a high priority,[6,14] data to inform such efforts are scarce, and particularly so among Black, Asian, and minority ethnic communities. Thus, we did a prospective population-based study using data from a smartphone-based application (app) to investigate the risk of testing positive for COVID-19, the risk of developing symptoms associated with SARS-CoV-2 infection, or both, among individuals in the UK and the USA.

Methods

Study design and participants

COVID Symptom Study (previously known as COVID Symptom Tracker) is a free smartphone app developed by Zoe Global (London, UK) in collaboration with Massachusetts General Hospital (Boston, MA, USA) and King's College London (London, UK). It offers participants a guided interface to report baseline demographic information and comorbidities, daily information on symptoms, and COVID-19 testing. Participants are encouraged to log daily, even when asymptomatic, for longitudinal collection of incident symptoms and COVID-19 testing results. The app was launched in the UK on March 24, 2020, and the USA on March 29, 2020.

We did a prospective, observational cohort study using the COVID Symptom Study app. Participants were recruited through social media outreach and invitations from the investigators of long-running cohort studies to their volunteers (appendix p 3). At enrolment, participants consented to use of information for research and agreed to applicable privacy policies and terms of use. Our study was approved by the Partners Human Research Committee (protocol 2020P000909) and King's College London ethics committee (REMAS ID 18210, LRS-19/20-18210).

Procedures

Information obtained through the COVID Symptom Study app has been described in detail.[15] Briefly, on first use, participants were asked to provide demographic factors and were questioned separately about a series of COVID-19 risk factors (appendix pp 4–8). At enrolment and with daily reminders, participants were asked if they felt physically normal, and if they reported not feeling well they were asked about their symptoms (appendix p 11). Participants were also asked if they had been tested for COVID-19 and the results (none, negative, pending, or positive). Our primary outcome was a report of a positive COVID-19 test. Follow-up started when participants first reported on the COVID Symptom Study app and continued until a report of a positive COVID-19 test or the time of last data entry, whichever occurred first.

Participants were also asked if they worked in health care and, if yes, whether they had direct patient contact. For our primary analysis, we defined front-line health-care workers as participants who reported direct patient contact. Prespecified secondary analyses among front-line health-care workers investigated PPE availability and contact with patients with COVID-19, as well as the primary site of clinical practice. A post-hoc analysis among front-line health-care workers assessed the effect of race and ethnicity. Beginning March 29, 2020, in an updated version of the app used by 84% of participating health-care workers, we included mandatory questions about availability of PPE for participants who identified as a front-line health-care worker. Among these individuals, we asked whether they cared for patients with suspected or documented SARS-CoV-2 infection and the frequency with which they used PPE (always, sometimes, or never). We asked if they had enough PPE when needed, if they had to reuse PPE, or if they did not have enough because of shortages. We classified PPE as adequate if they never required PPE or if they reported always having the PPE they needed. We classified PPE as inadequate if they reported they did not have enough PPE or if it was not available. We also asked health-care workers to report the site of their patient care (inpatient, nursing home, outpatient, home health, ambulatory clinic, or other).

Statistical analysis

We used standard calculations to determine the minimum detectable hazard ratio (HR) for our primary categorical exposure (health-care worker status) and risk of reporting a positive COVID-19 test with 80% power.[16]

We used Cox proportional hazards modelling stratified by age, date, and country to estimate multivariable-adjusted HRs and 95% CIs. Covariates were selected a priori based on putative risk factors, including sex (male or female), race or ethnic origin (non-Hispanic white, Hispanic or Latinx, Black, Asian, or more than one or other), history of diabetes (yes or no), heart disease (yes or no), lung disease (yes or no), kidney disease (yes or no), current smoking status (yes or no), and body-mass index (17·0–19·9 kg/m², 20·0–24·9 kg/m², 25·0–29·9 kg/m², and ≥30·0 kg/m²). Data imputation replaced no more than 5% of missing values for a given metadatum, with numerical values replaced with the median and categorical variables imputed using the mode.

Because our primary outcome (positive COVID-19 test) required a participant to receive a test, we did several prespecified secondary analyses. First, we tested a symptom-based classifier predictive of positive COVID-19 testing.[17] Briefly, using logistic regression and symptoms preceding testing, we have previously described that loss of smell or taste, fatigue, persistent cough, and loss of appetite predicted COVID-19 positivity with high specificity (appendix p 2). Second, to account for country-specific predictors of obtaining testing, we did separate inverse probability weighting in the UK and the USA as a function of demographic and clinical factors, followed by inverse probability-weighted Cox proportional hazards modelling stratified by age and date with additional adjustment for the covariates used in previous models (appendix p 2). To assess factors associated with PPE adequacy, work in especially high-risk clinical settings, or greater exposure to patients with COVID-19 (including a post-hoc analysis of race and ethnicity), we used multivariable logistic regression models to estimate adjusted odds ratios (ORs) and 95% CIs. Two-sided p values less than 0·05 were considered statistically significant. All analyses were done using *R* version 3.6.1.

For more on ***R*** see https://r-project.org

The COVID Symptom Study app is registered with ClinicalTrials.gov, NCT04331509.

Role of the funding source

Zoe Global developed the app for data collection. The funders had no role in study design, data analysis, data interpretation, or writing of the report. LHN, DAD, MSG, SO, CJS, and ATC had access to raw data. The corresponding author had full access to all data in the study and had final responsibility for the decision to submit for publication.

Results

Between March 24 and April 23, 2020, we enrolled 2 810 103 consecutive users of the COVID Symptom Study app to our study. 2 627 695 participants in the UK and 182 408 in the USA provided baseline information about feeling physically normal or having symptoms (appendix p 14). 134 885 (4·8%) participants reported being a front-line health-care worker. The prevalence of COVID-19 was 2747 cases per 100 000 front-line health-care workers compared with 242 cases per 100 000 people in the general community (figure). The highest infection rates were reported in the US states New York, New Jersey, and Louisiana and in areas around London and the Midlands in the UK.

After excluding 670 298 participants with less than 24 h of follow-up and 4615 individuals who reported a positive COVID-19 test at baseline, we included 2 135 190 participants in our prospective inception cohort, of whom 99 795 (4·7%) identified as front-line health-care workers (appendix p 14). Based on this cohort, we had 80% power to detect a minimum HR of 1·16 for risk of reporting a positive COVID-19 test between health-care workers and the general community. In this cohort, we recorded 24·4 million entries, or 11·5 logs per participant, with median follow-up of 18·9 days (IQR 5·1–26·1). Median age was 44 years (IQR 32–57). Compared with the general community, front-line health-care workers were more frequently female, had a slightly higher prevalence of body-mass index 30·0 kg/m² or higher, were slightly more likely to smoke (particularly in the UK), and were more likely to use non-steroidal anti-inflammatory drugs (table 1; appendix pp 9–10). At baseline, 20·2% of front-line health-care workers reported at least one symptom associated with SARS-CoV-2 infection compared with 14·4% of the general population; fatigue, loss of smell or taste, and hoarse voice were especially frequent (appendix p 11). When comparing health-care workers who were asked about PPE use with those who were not asked, no difference was noted in baseline factors including age (median 45 years *vs* 40 years), female sex (81% *vs* 82%), or body-mass index (median 25·9 kg/m² *vs* 25·7 kg/m²).

We recorded 5545 incident reports of positive COVID-19 testing over 34 435 272 person-days. In the UK, 1·1% of

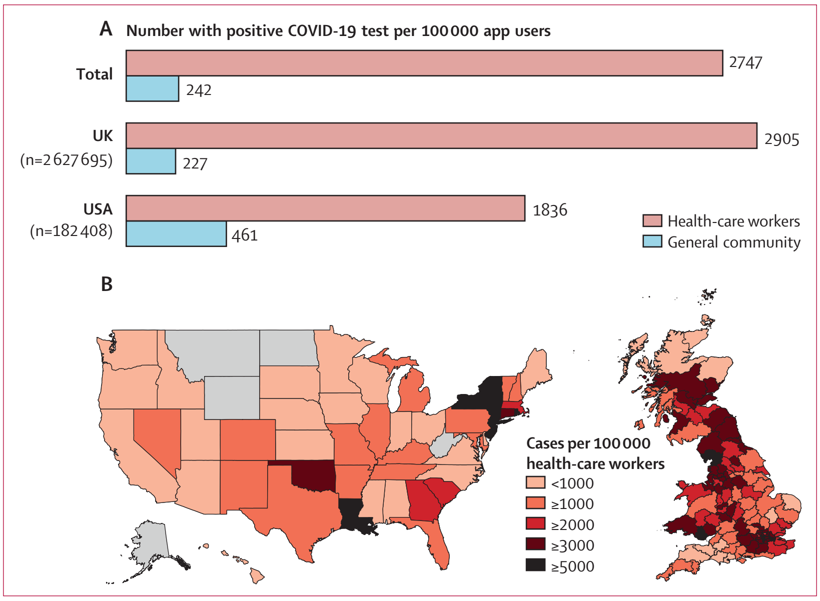

***Figure:* Risk of testing positive for COVID-19 among front-line health-care workers**
(A) Between March 24 and April 23, 2020, considerable disparities were noted in prevalence of a positive COVID-19 test among front-line health-care workers compared with the general community, in both the UK and the USA. (B) Prevalence of a positive COVID-19 test reported by front-line health-care workers in the UK and the USA. Regions in grey did not have sufficient data for analysis. app=COVID-19 Symptom Study smartphone application.

	Front-line health-care workers (n=99 795)	General community (n=2 035 395)
Country		
UK	85·4%	93·9%
USA	14·6%	6·1%
Age, years	42 (33–53)	44 (33–56)
<25	4·5%	4·7%
25–34	24·7%	19·2%
35–44	25·1%	21·5%
45–54	23·6%	19·5%
55–64	17·5%	16·2%
≥65	3·9%	13·1%
Missing data for age	1·1%	5·7%
Sex		
Male	17·0%	37·0%
Female	83·0%	63·0%
Race or ethnic origin*		
Non-Hispanic white	88·2%	92·5%
Hispanic or Latinx	1·1%	0·5%
Black	1·2%	0·6%
Asian	4·4%	2·2%
More than one or other	2·4%	2·9%
Missing data for race or ethnic origin, or prefer not to say	2·7%	1·3%

(Table 1 continues in next column)

	Front-line health-care workers (n=99 795)	General community (n=2 035 395)
(Continued from previous column)		
Body-mass index (kg/m²)	25·8 (22·8–30·2)	25·3 (22·5–29·1)
17·0–19·9	5·8%	8·3%
20·0–24·9	38·1%	39·2%
25·0–29·9	30·1%	31·5%
≥30·0	25·9%	21·1%
Missing data for body-mass index	0·5%	0·5%
Comorbidities		
Diabetes	2·5%	3·1%
Heart disease	1·6%	2·4%
Lung disease	13·1%	12·2%
Kidney disease	0·6%	0·7%
Cancer	0·5%	1·3%
Missing data for cancer	0·3%	0·3%
Pregnant (% of females)	0·9%	1·0%
Medication use		
Non-steroidal anti-inflammatory drugs	8·2%	6·1%
Immunosuppressants	2·5%	3·2%
Chemotherapy or immunotherapy	0·1%	0·3%
Angiotensin-converting enzyme inhibitor	5·0%	4·9%
Missing data for angiotensin-converting enzyme inhibitor	10·1%	4·3%
Current smoking		
Yes	10·2%	8·5%
Missing data for smoking status	0·2%	0·1%

Data are % or median (IQR). % are calculated based on the total number of participants with available data. Polytomous variables might not add up to 100% because of rounding. Questions about history of cancer, angiotensin-converting enzyme inhibitor use, and smoking status have been asked since launch in the USA and March 29, 2020, in the UK; questions about race and ethnic origin were asked since April 17, 2020, in both the UK and the USA. Percentages within each category are based on the total population responding when the question was first asked. *Non-Hispanic white defined as UK White, US White, and no designation of other race or ethnic origin. Hispanic or Latinx designated as Hispanic and Latino. Black defined as UK Black, Black British, US Black, and African American. White defined as UK White and US White. Asian defined as UK Asian, Asian British, UK Chinese, Chinese British, US Asian, and US Native Hawaiian or other Pacific Islander. More than one or other defined as UK mixed race White and Black or Black British UK, mixed race other, UK Middle Eastern or Middle Eastern British, US American Indian or Alaska Native, other, and denoted more than one race.

***Table 1:* Baseline characteristics of front-line health-care workers compared with the general community**

health-care workers reported being tested compared with 0·2% of the general community (health-care workers to community testing ratio 5·5), whereas 4·1% of US health-care workers were tested versus 1·1% of the general community (testing ratio 3·7). Compared with the general community, front-line health-care workers had a twelve-fold increase in risk of a positive test after multivariable

	Event/person-days	Incidence (30-day)	Age-adjusted hazard ratio (95% CI)	Multivariate-adjusted hazard ratio (95% CI)	Inverse probability-weighted hazard ratio (95% CI)
Overall (primary analysis)					
General community	3623/32 980 571	0·33%	1 (ref)	1 (ref)	1 (ref)
Front-line health-care worker	1922/1 454 701	3·96%	11·68 (10·99–12·40)	11·61 (10·93–12·33)	3·40 (3·37–3·43)
According to race or ethnic origin (post-hoc analysis)					
Non-Hispanic white, general community	1498/23 941 092	0·19%	1 (ref)	1 (ref)	1 (ref)
Black, Asian, and minority ethnic, general community	227/1 362 956	0·50%	2·49 (2·16–2·86)	2·51 (2·18–2·89)	1·74 (1·71–1·77)
Non-Hispanic white, front-line health-care worker	726/935 860	2·33%	12·47 (11·33–13·72)	12·58 (11·42–13·86)	3·52 (3·48–3·56)
Black, Asian, and minority ethnic, front-line health-care worker	98/72 556	4·05%	21·68 (17·61–26·68)	21·88 (17·78–26·94)	4·88 (4·76–5·01)

All models were stratified by 5-year age group, calendar date at study entry, and country. Multivariate risk factor models were adjusted for sex (male or female), history of diabetes (yes or no), heart disease (yes or no), lung disease (yes or no), kidney disease (yes or no), current smoking (yes or no), and body-mass index (17·0–19·9 kg/m², 20·0–24·9 kg/m², 25·0–29·9 kg/m², and ≥30 kg/m²). Black, Asian, and minority ethnic was defined among individuals who had race or ethnicity information and did not identify as non-Hispanic white.

Table 2: **Risk of reporting a positive test for COVID-19 among front-line health-care workers compared with the general community**

adjustment (adjusted HR 11·61, 95% CI 10·93–12·33; table 2; appendix p 15). The association seemed stronger in the UK (adjusted HR 12·52, 95% CI 11·77–13·31) compared with the USA (2·80, 2·09–3·75; $p_{difference}$<0·0001; appendix p 12).

We considered the possibility that noted differences could be related to testing eligibility. A multivariable-adjusted Cox proportional hazards model with inverse probability weighting for predictors of testing also showed a higher risk of infection among front-line health-care workers (adjusted HR 3·40, 95% CI 3·37–3·43; table 2), which was higher in the UK (3·43, 3·18–3·69) than in the USA (1·97, 1·36–2·85; $p_{difference}$<0·0001; appendix p 12). In a prespecified secondary analysis, a validated model was used based on a combination of symptoms predictive of COVID-19 infection.[16] Compared with the general community, health-care workers initially free of symptoms had an increased risk of predicted COVID-19 (adjusted HR 2·05, 95% CI 1·99–2·10), which was higher in the UK (2·09, 2·02–2·15) than in the USA (1·31, 1·14–1·51; $p_{difference}$<0·0001).

In a post-hoc analysis, compared with individuals in the general community from a non-Hispanic white ethnic background, the risk for a positive COVID-19 test was increased for individuals from Black, Asian, and minority ethnic backgrounds in the general community (adjusted HR 2·51, 95% CI 2·18–2·89), for Black, Asian, and minority ethnic health-care workers (21·88, 17·78–26·94), and for non-Hispanic white health-care workers (12·58, 11·42–13·86; table 2). In post-hoc analyses, the association of race and health-care worker status with risk of COVID-19 was assessed. Black, Asian, and minority ethnic health-care workers had an increased risk of COVID-19 (adjusted HR 1·81, 95% CI 1·45–2·24) compared with non-Hispanic white health-care workers.

	Adequate PPE	Reused PPE	Inadequate PPE
Overall			
Event/person-days	592/332 901	146/80 728	157/60 916
Unadjusted hazard ratio (95% CI)	1 (ref)	1·46 (1·21–1·76)	1·32 (1·10–1·57)
Multivariate-adjusted hazard ratio (95% CI)	1 (ref)	1·46 (1·21–1·76)	1·31 (1·10–1·56)
No exposure to patients with COVID-19			
Event/person-days	186/227 654	19/37 599	48/35 159
Unadjusted hazard ratio (95% CI)	1 (ref)	0·96 (0·60–1·55)	1·53 (1·11–2·11)
Multivariate-adjusted hazard ratio (95% CI)	1 (ref)	0·95 (0·59–1·54)	1·52 (1·10–2·09)
Exposure to patients with suspected COVID-19			
Event/person-days	126/54 676	36/19 378	26/14 083
Unadjusted hazard ratio (95% CI)	2·40 (1·91–3·02)	3·23 (2·24–4·66)	1·87 (1·24–2·83)
Multivariate-adjusted hazard ratio (95% CI)	2·39 (1·90–3·00)	3·20 (2·22–4·61)	1·83 (1·21–2·78)
Exposure to patients with documented COVID-19			
Event/person-days	280/50 571	91/23 751	83/11 675
Unadjusted hazard ratio (95% CI)	4·93 (4·07–5·97)	5·12 (3·94–6·64)	5·95 (4·57–7·76)
Multivariate-adjusted hazard ratio (95% CI)	4·83 (3·99–5·85)	5·06 (3·90–6·57)	5·91 (4·53–7·71)

All models were stratified by 5-year age group, calendar date at study entry, and country. Multivariate risk factor models were adjusted for sex (male or female), history of diabetes (yes or no), heart disease (yes or no), lung disease (yes or no), kidney disease (yes or no), current smoking (yes or no), and body-mass index (17·0–19·9 kg/m², 20·0–24·9 kg/m², 25·0–29·9 kg/m², and ≥30·0 kg/m²). PPE=personal protective equipment.

Table 3: **Risk of reporting a positive test for COVID-19, according to availability of PPE and exposure to patients with COVID-19 among front-line health-care workers (prespecified secondary analysis)**

Risk estimates were similar among male (adjusted HR 14·02, 95% CI 12·38–15·82) compared with female (11·27, 10·53–12·14) front-line health-care workers.

Among front-line health-care workers, availability and use of PPE, COVID-19 patient exposures, and subsequent risk for testing positive were assessed in prespecified analyses. Compared with health-care workers who reported adequate PPE, front-line health-care workers reporting PPE reuse had an increased risk of a positive COVID-19 test (adjusted HR 1·46, 95% CI 1·21–1·76), with inadequate PPE associated with a comparable increase in risk after multivariable adjustment (1·31, 1·10–1·56; table 3).

In a prespecified secondary analysis, front-line health-care workers with inadequate PPE caring for patients with documented COVID-19 had an increased risk for COVID-19 after multivariable adjustment (adjusted HR 5·91, 95% CI 4·53–7·71) compared with those with adequate PPE not caring for patients with suspected or documented COVID-19 (table 3). Risk for front-line health-care workers reusing PPE and exposed to patients with documented COVID-19 was also increased (adjusted HR 5·06, 95% CI 3·90–6·57). Notably, even among front-line health-care workers reporting adequate PPE, the risk for COVID-19 was increased for those caring for patients with suspected COVID-19 (adjusted HR 2·39, 95% CI 1·90–3·00) and for those caring for patients with documented COVID-19 (4·83, 3·99–5·85), compared with health-care workers who did not care for either group (table 3).

In a post-hoc analysis, differences were noted in PPE adequacy according to race and ethnicity, with non-white health-care workers more frequently reporting reuse of or inadequate access to PPE, even after adjusting for exposure to patients with COVID-19 (adjusted OR 1·49, 95% CI 1·36–1·63; table 4).

In a prespecified secondary analysis, risk of COVID-19 by practice location was assessed. Compared with risk for the general community, risk for front-line health-care workers was increased in all health-care settings, but was highest for those working in inpatient settings (adjusted HR 24·30, 95% CI 21·83–27·06) and nursing homes (16·24, 13·39–19·70; table 5). Notably, health-care workers in nursing homes most frequently (16·9%) reported inadequate PPE, whereas inpatient providers reported reuse of PPE most often (23·7%; table 5). In a post-hoc analysis, compared with non-Hispanic white health-care workers, Black, Asian, and minority ethnic health-care workers were more likely to work in higher risk clinical settings, including inpatient hospital or nursing homes (adjusted OR 1·13, 95% CI 1·03–1·23) and to care for patients with suspected or documented COVID-19 (1·20, 1·09–1·30). These noted differences were most pronounced among Black health-care workers (appendix p 13).

	Health-care workers reporting reuse of or inadequate PPE	Multivariate-adjusted odds ratio (95% CI)
Overall		
Non-Hispanic white, front-line health-care worker	27·7%	1 (ref)
Black, Asian, and minority ethnic, front-line health-care worker	36·7%	1·49 (1·36–1·63)
According to racial or ethnic subgroup*		
Non-Hispanic white`	27·7%	1 (ref)
Hispanic or Latinx	49·6%	2·64 (2·03–3·45)
Black	33·5%	1·30 (1·02–1·65)
Asian	35·6%	1·42 (1·24–1·63)
More than one race or other race	34·7%	1·33 (1·12–1·57)

Multivariate risk factor models were adjusted for 5-year age group, sex, and exposure to patients with COVID-19 (none, suspected, and documented). Black, Asian, and minority ethnic was defined among individuals who had race or ethnicity information and did not identify as non-Hispanic white. PPE=personal protective equipment. *Non-Hispanic white defined as UK White, US White, and no designation of other race or ethnic origin. Hispanic or Latinx designated as Hispanic and Latino. Black defined as UK Black, Black British, US Black, and African American. White defined as UK White and US White. Asian defined as UK Asian, Asian British, UK Chinese, Chinese British, US Asian, and US Native Hawaiian or other Pacific Islander. More than one or other defined as UK mixed race White and Black or Black British UK, mixed race other, UK Middle Eastern or Middle Eastern British, US American Indian or Alaska Native, other, and denoted more than one race.

Table 4: **Risk of reporting PPE inadequacy or reuse among front-line health-care workers, according to race or ethnic origin (post-hoc analysis)**

Discussion

Among 2 135 190 people in the UK and USA using the COVID-19 Symptom Study app between March 24 and April 23, 2020, we noted that front-line health-care workers had at least a threefold increased risk of reporting a positive COVID-19 test and predicted COVID-19 infection, compared with the general community, even after

	Event/ person-days	Incidence (30-day)	Age-adjusted hazard ratio (95% CI)	Multivariate-adjusted hazard ratio (95% CI)	Health-care workers reporting reuse of PPE	Health-care workers reporting inadequate PPE
General community	3623/32 980 571	0·33%	1 (ref)	1 (ref)	..	..
Front-line health-care worker						
Inpatient	564/184 293	9·18%	23·58 (21·20–26·25)	24·30 (21·83–27·06)	23·7%	11·9%
Nursing homes	118/52 901	6·69%	16·48 (13·60–19·97)	16·24 (13·39–19·70)	15·4%	16·9%
Outpatient hospital clinics	51/45 217	3·38%	10·75 (8·10–14·27)	11·21 (8·44–14·89)	16·3%	12·2%
Home health sites	36/38 642	2·79%	7·79 (5·58–10·87)	7·86 (5·63–10·98)	14·7%	15·9%
Ambulatory clinics	44/66 408	1·99%	6·64 (4·90–9·01)	6·94 (5·12–9·41)	19·3%	11·8%
Other	73/64 310	3·41%	9·42 (7·42–11·96)	9·52 (7·49–12·08)	12·0%	13·8%

Model was stratified by 5-year age group, calendar date at study entry, and country and adjusted for sex (male or female), history of diabetes (yes or no), heart disease (yes or no), lung disease (yes or no), kidney disease (yes or no), current smoking (yes or no), and body-mass index (17·0–19·9 kg/m², 20·0–24·9 kg/m², 25·0–29·9 kg/m², and ≥30·0 kg/m²). Ambulatory clinics include free-standing (non-hospital) primary care or specialty clinics and school-based clinics. PPE=personal protective equipment.

Table 5: **Front-line health-care workers and risk of testing positive for COVID-19, by site of care delivery (prespecified secondary analysis)**

accounting for other risk factors. Post-hoc analyses showed that Black, Asian, and minority ethnic health-care workers are at especially high risk of SARS-CoV-2 infection, with at least a fivefold increased risk of COVID-19 compared with the non-Hispanic white general community. Among front-line health-care workers, reuse of PPE or inadequate PPE were each associated with a subsequent increased risk of COVID-19. Although health-care workers caring for patients with COVID-19 who reported inadequate PPE had the highest risk of SARS-CoV-2 infection, increased susceptibility to infection was evident even among those reporting adequate PPE. Front-line health-care workers who worked in inpatient settings (where providers most frequently reported PPE reuse) and nursing homes (where providers most frequently reported inadequate PPE) had the greatest risk. Non-white health-care workers were disproportionately affected by scant PPE adequacy and more likely to work in clinical settings with greater exposure to patients with COVID-19.

Our findings could help provide greater context for previous cross-sectional reports from public health authorities suggesting 10–20% of SARS-CoV-2 infections occur among health-care workers.[6,7] Our results offer individual-level data additionally accounting for workplace risk factors that complement these limited reports by providing a more precise assessment of the magnitude of increased risk among health-care workers during the initial phases of the COVID-19 pandemic. Taken in the context of the requirement for testing to establish a COVID-19 diagnosis, our range of results based on either reporting a positive test for COVID-19 or symptoms predictive of COVID-19 offer several complementary estimates for risk among front-line health-care workers.

We also provide evidence that sufficient availability of PPE, quality of PPE, or both reduce the risk of COVID-19, but reuse of PPE or inadequate PPE might confer comparably increased risk, which is compatible with findings from one of the first studies to specifically investigate PPE reuse.[18] The greater risk associated with PPE reuse could be related to either self-contamination during repeated application and removal of PPE or breakdown of materials from extended wear. Of note, during the period of this study, disinfection protocols before PPE reuse were not widely available.[11–13] Thus, results should be not extended to reflect risk of PPE reuse after such disinfection, which has now been implemented in various settings. An assessment of the PPE supply chain and equitable access to PPE should be a part of the deliberate and informed decision making about resource allocation.

However, even with adequate PPE, health-care workers who cared for patients with COVID-19 remained at increased risk, highlighting the importance of not only ensuring PPE quality and availability but also other aspects of appropriate use, including correct application and removal of PPE and clinical situation (practice location). Moreover, these data underscore the possibility for health-care workers to perpetuate infections or contribute to community spread, particularly when asymptomatic or mildly symptomatic, and justify calls to increase testing to reduce hospital-based transmission.[5]

Notably, we recorded a significant difference in risk for health-care workers in the UK compared with the USA. This discrepancy could be attributable to country-specific or region-specific variation in population density, socio-economic deprivation, overall availability or quality of PPE, and type of health-care settings, and these findings require further investigation. Our results might also reflect differences in access to testing among health-care workers compared with the general community in the UK compared with the USA. However, in secondary analyses using inverse probability-weighted Cox modelling adjusting for the probability of receiving a test, we also found that health-care workers in the UK were at higher risk of reporting a positive test. Furthermore, health-care workers were at greater risk of developing symptoms predictive of eventual COVID-19, which does not reflect access to testing. Thus, the higher risk noted in the UK could reflect a higher infection rate because of differences in the quality and appropriate use of PPE across practice settings[19] or country-specific differences in PPE recommendations for health-care workers or the general public (eg, cloth face coverings).[20,21] Ideally, we would assess risk within a population that has undergone uniform screening. However, the current shortage of PCR-based testing kits does not make such an approach feasible but could justify targeted screening of front-line health-care workers.[5,22] Future studies using serological testing to ascertain SARS-CoV-2 infection will require assessments of test performance and the ability to distinguish recent or active infection from past exposure.

Our results are supported by historical data during similar infectious disease outbreaks. Ebola virus has a basic reproduction number (ie, the number of new cases generated from one individual) comparable with that for SARS-CoV-2. During the Ebola virus disease crisis, health-care workers comprised 3·9% of all cases, 21–32-times greater than the general public.[23] During the severe acute respiratory syndrome epidemic, health-care workers comprised 20–40% of cases,[24–26] and inadequate PPE was associated with increased risk.[26] The experience with influenza A virus subtype H1N1 reaffirmed the importance of PPE,[27] with much higher infection rates among health-care workers in dedicated containment units.[28]

Our study has several strengths. First, we used a smartphone app to rapidly obtain prospective data from a large multinational cohort in real time, offering actionable risk estimates to inform the public health response to an ongoing pandemic.[29] By recruiting participants through existing cohorts,[30] our results provide proof of concept of the feasibility of leveraging existing infrastructure and engaged participants to address a key knowledge gap. Second, we obtained information from participants who did not have a positive COVID-19 test, which offered an opportunity to prospectively assess risk factors with minimal recall bias. Third, our study design recorded initial onset of symptoms, which minimises biases related to capturing only severe cases through hospitalisation records or death reports. Finally, we gathered information on a wide range of known or suspected risk factors for COVID-19 generally not available in existing registries or population-scale surveillance efforts.

We acknowledge several limitations. First, details for some exposures were shortened to ensure our survey was brief. For example, we did not ask about specific occupations, experience level, type of PPE used (eg, masks, respirators, or powered air-purifying respirators), receipt of PPE training (eg, mask fit-testing or application and removal of PPE), and frequency of exposure to patients with SARS-CoV-2 infection or aerosolising procedures. We are pursuing additional questionnaires to more deeply investigate these topics in a subset of participants. Second, our findings are based on self-report. However, alternative exposure measures, such as PPE supply, or assessment of additional outcomes would have been difficult to obtain within the context of a fast-moving pandemic. In future studies, linkage to other sources (eg, electronic health records) might be possible. Third, our cohort is not a random sampling of the population. Although this limitation is inherent to any study requiring voluntary provision of information, we acknowledge that data collection through smartphone adoption has comparatively lower penetrance among some socioeconomic groups and adults older than age 65 years, despite smartphone use by 81% of US adults.[31] This limitation could have resulted in selection bias, although our primary conclusions were robust to several sensitivity and secondary analyses. In future studies, we plan greater targeted outreach of under-represented populations. Our primary outcome was based on the report of a positive COVID-19 test. During the study period, this outcome would generally reflect a positive PCR-based swab, which should be moderately specific, compared with antibody testing, which was not widely available. However, any misclassification of positive testing should be non-differential according to occupation.

In conclusion, we reported increased risk for SARS-CoV-2 infection among front-line health-care workers compared with the general community, using either self-reported data on COVID-19 testing positivity or a symptom-based predictor of positive infection status. This risk was especially high among Black, Asian, and minority ethnic health-care workers and individuals in direct contact with patients with COVID-19 who reported inadequate PPE availability or were required to reuse PPE. Ensuring the adequate allocation of PPE is important to alleviate structural inequities in COVID-19 risk. However, because infection risk was increased even with adequate PPE, our results suggest the need to ensure proper use of PPE and adherence to other infection control measures. Further intervention studies investigating modifiable risk factors for health-care worker-related SARS-CoV-2 infection, ideally accounting for differential exposure according to race and ethnic background and care location, are urgently needed to support our observational findings.

For the **HDRUK Innovation Gateway** see https://healthdatagateway.org

For the **Coronavirus Pandemic Epidemiology Consortium** see https://www.monganinstitute.org/cope-consortium

For **data updates** see https://covid.joinzoe.com

Contributors

LHN, DAD, MSG, JW, SO, CJS, TDS, and ATC contributed to study concept and design. LHN, DAD, MSG, JW, SO, RD, JC, CJS, TDS, and ATC contributed to acquisition of data. LHN, DAD, MSG, ADJ, C-GG, WM, RSM, DRS, C-HL, SK, and MS contributed to data analysis. LHN, DAD, and ATC contributed to initial drafting of the manuscript. All authors contributed to interpretation of data and critical revision of the report. SO, CJS, TDS, and ATC contributed to study supervision.

Declaration of interests

JW, RD, and JC are employees of Zoe Global. TDS is a consultant to Zoe Global. DAD and ATC previously served as investigators on a clinical trial of diet and lifestyle using a separate smartphone application that was supported by Zoe Global. All other authors declare no competing interests.

Data sharing

Data collected in the COVID-19 Symptom Study smartphone application are being shared with other health researchers through the UK National Health Service-funded Health Data Research UK (HDRUK) and Secure Anonymised Information Linkage consortium, housed in the UK Secure Research Platform (Swansea, UK). Anonymised data are available to be shared with HDRUK researchers according to their protocols in the public interest. US investigators are encouraged to coordinate data requests through the Coronavirus Pandemic Epidemiology Consortium. Data updates can be found online.

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