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RESEARCH ARTICLE

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Excess risk of SARS-CoV-2 infection among in-person nonhealthcare workers in six states, September 2020–June 2021

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Abstract

Background: While the occupational risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection for healthcare personnel in the United States has been relatively well characterized, less information is available on the occupational risk for workers employed in other settings. Even fewer studies have attempted to compare risks across occupations and industries. Using differential proportionate distribution as an approximation, we evaluated excess risk of SARS-CoV-2 infection by occupation and industry among non-healthcare workers in six states.

Methods: We analyzed data on occupation and industry of employment from a six-state callback survey of adult non-healthcare workers with confirmed SARS-CoV-2 infection and population-based reference data on employment patterns, adjusted for the effect of telework, from the U.S. Bureau of Labor Statistics. We estimated the differential proportionate distribution of SARS-CoV-2 infection by occupation and industry using the proportionate morbidity ratio (PMR).

Results: Among a sample of 1111 workers with confirmed SARS-CoV-2 infection, significantly higher-than-expected proportions of workers were employed in service occupations (PMR 1.3, 99% confidence interval [CI] 1.1–1.5) and in the transportation and utilities (PMR 1.4, 99% CI 1.1–1.8) and leisure and hospitality industries (PMR 1.5, 99% CI 1.2–1.9).

Conclusions: We found evidence of significant differences in the proportionate distribution of SARS-CoV-2 infection by occupation and industry among respondents in a multistate, population-based survey, highlighting the excess risk of

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SARS-CoV-2 infection borne by some worker populations, particularly those whose jobs require frequent or prolonged close contact with other people.

KEYWORDS
COVID-19, epidemiology, occupational exposure, occupational health, SARS-CoV-2

1 | INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes Coronavirus Disease 2019 (COVID-19), is an occupational as well as a public health hazard.[1] Throughout the pandemic, data from public health surveillance and field investigations, as well as anecdotal evidence from media reports, have suggested that certain worker groups experience increased risk of contracting COVID-19 due to their work. Epidemiologic evidence points to occupational acquisition of COVID-19 among healthcare personnel[2–5] and case clusters have been associated with various workplaces including hospitals,[6] long-term care facilities,[7,8] correctional facilities,[9,10] homeless shelters,[11,12] and meat and seafood processing plants.[13–17] This evidence implies that transmission of SARS-CoV-2 occurs in the workplace and that workers in certain occupations or industries could be at increased risk for infection. Factors suspected to be associated with increased risk of occupational acquisition of COVID-19 include close contact with COVID-19 patients in healthcare settings; working in close proximity with coworkers, customers, or the public, especially for prolonged periods; working in densely populated, enclosed, or poorly ventilated workplaces; and the requirement for in-person work.[2–17]

During the initial months of the pandemic, many "non-essential" businesses were closed temporarily to mitigate the spread of COVID-19, and workers were furloughed or shifted to remote work.[18–20] Establishments with onsite operations considered essential remained open, however, and their workers continued to report to their workplaces.[21,22] Within 2–3 months, most states began to lift restrictions on many workplaces that had been previously closed, and many more workers returned to the workplace.[23,24] COVID-19-specific workplace hazard controls and other mitigation measures, such as worker screening, safe distancing policies, physical barriers, and the use of masks and other personal protective equipment, were implemented to varying degrees, depending on the type of establishment and other factors.[25,26]

Throughout the pandemic, characterization of the role of occupational transmission has been considered vitally important both for understanding community transmission dynamics and for the implementation of control measures, as evidenced by school and business closure decisions and occupation-based prioritization of vaccine distribution.[18,19,27,28] However, in the United States, the full range of high-risk occupations and industries has not been reliably identified nor have the occupation- and industry-specific risks been reliably quantified because the data necessary for such analyses are not available. As a result, public health policy decisions had to be made based on incomplete or hypothetical information.

Workplace-based investigations can identify specific transmission chains responsible for occupational clusters and may help identify specific features or characteristics of the work environment associated with increased risk. However, they cannot quantify occupation- or industry-specific risks relative to the overall employed population. Therefore, they cannot adequately identify high-risk worker populations. Furthermore, because considerable SARS-CoV-2 transmission originates from pre- or asymptomatic cases,[29] the work-relatedness of many, if not most, occupational cases cannot be established. For example, a previous analysis of data from the survey used for the present study found that, among non-healthcare workers who worked in-person just before infection with SARS-CoV-2, 57.2% reported no known exposure or reported they did not know if they had exposures.[30] When specific work-related cases are not explicitly identified, occupational risk can only be inferred based on differences between worker populations, such as industry or occupation groups, or between workers and non-workers.

A full understanding of the occupational risk of SARS-CoV-2 infection requires the systematic, case-based collection of standard occupational data, including occupation and industry of employment, from (at a minimum) all cases who were employed within 14 days of symptom onset or a positive test. In the United States, however, surveillance systems for SARS-CoV-2 infection capture almost no occupational information from non-healthcare workers. Data for the few occupational items included in these systems are also rarely reported, even for healthcare personnel.[2,3] As a result, national surveillance data are inadequate to assess workplace exposures to SARS-CoV-2 or to identify worker groups at increased occupational risk of infection.

While the occupational risk of SARS-CoV-2 infection for healthcare personnel has been evaluated in several studies,[31–34] less information is available on occupational risk for workers employed in other settings. Studies of the incidence[35] or seroprevalence[36,37] of infection have been conducted on occupationally-based cohorts that are not limited to healthcare personnel, but these cohorts include limited occupational categories, mainly first responders. Some states have published population-based reports of COVID-19 incidence[38,39] or mortality[40–42] by occupation or industry. However, incomplete ascertainment of cases' occupation and industry limits the validity of rates and therefore of any relative risk estimates. One recent population-based study assessed the relative risk of COVID-19 by occupation and industry in Wisconsin.[43] A recently published case-control study of some 86,000 US blood donors also calculated the relative odds of SARS-CoV-2 seropositivity by occupation, but its generalizability is limited to the population of blood donors.[44] To our knowledge, no other multistate, population-based study of the relative risk of confirmed SARS-CoV-2 infection by occupation or industry from the United States has yet been published. In an unpublished study available as a preprint, Chen et al. calculated mortality risk ratios by occupation and industry using 2020 death certificate data from 46 states available from the National Center for Health Statistics.[45] However, mortality rates are not likely to reflect the occupational risk of infection well because they are a function of both infection risk and case fatality ratios.

The purpose of this study was to evaluate the excess risk of SARS-CoV-2 infection by occupation and industry groups among nonhealthcare workers in six states, using the differential proportionate distribution of cases as an approximation.

2 | METHODS

To estimate the excess risk of SARS-CoV-2 infection among workers by occupation and industry, we analyzed case data from a callback survey of employed adults with confirmed SARS-CoV-2 infection and population-based reference data on employment patterns from the US. Bureau of Labor Statistics (BLS). We described the differential proportionate distribution of infection across occupation and industry groups using the proportionate morbidity ratio (PMR).

2.1 | Case data

Data on the demographic and occupational characteristics of a sample of employed civilian adults with SARS-CoV-2 infection confirmed by reverse transcription polymerase chain rection (RT-PCR) test were collected via a survey conducted between September 2020 and June 2021 in six states: California, Georgia, New Hampshire, North Carolina, Pennsylvania, and Wisconsin. State health departments in each of the participating states identified potential subjects among RT-PCR positive cases aged 18–64 years identified in their state surveillance systems. Additional inclusion criteria were assessed using screener questions at the beginning of the survey. Eligible subjects had to have (1) worked in-person (i.e., at their usual workplace) at a job for at least 1 day during the 2 weeks before illness onset or, if asymptomatic, positive test and (2) not identified as healthcare personnel, where healthcare personnel were defined as "all paid and unpaid persons working in healthcare settings who have the potential for exposure to patients or to infectious materials." Cases among health care personnel were not interviewed because our objective was specifically to evaluate risk among other occupational and industry groups and because participating states had limited resources to administer callback surveys. All interviews of eligible respondents were conducted by telephone using a standardized questionnaire. English and Spanish versions of the questionnaire were available. Interpreter services were used to interview respondents who chose to be interviewed in any other languages, based on the English version of the questionnaire. Each participating state health department developed their own sampling plan to account for state-specific needs, capacity, and variation in COVID-19 incidence patterns. The state-specific sampling methodologies used to compile this data set are described in detail in the supplementary Appendix B of Free et al.[30]

Narrative descriptions of respondents' occupation and industry of employment for their main job—the job at which they worked the most hours—were elicited using the following questions: for occupation, "what kind of work did you do? (e.g., janitor, cashier, auto mechanic, construction laborer)," and, for industry, "what kind of business or industry did you work in? (e.g., elementary school, clothing manufacturing, restaurant, construction company)," respectively. Responses were captured verbatim in free-text fields and coded to standardized 2010 Census occupation codes and 2012 Census industry codes using the National Institute for Occupational Safety and Health (NIOSH) Industry and Occupation Computerized Coding System (NIOCCS).[46] Codes were grouped into 10 major and 22 detailed civilian occupation categories and into 13 major and 51 detailed civilian industry categories using the standard Census classification system.[47]

Additional demographic, occupational, and clinical variables were also collected. For this study, these variables were used to describe the study sample but were not used to standardize the PMRs because not all aggregate reference data used in PMR calculation were readily available by occupation and industry and by the demographic variables commonly used for standardization.

2.2 | Statistical analyses

Because actual denominators were not known, occupation- and industry-specific incidence rates could not be directly calculated. Additionally, because only cases were contacted for the callback survey, a sample of non-cases was not available for comparison. We therefore used PMRs to compare the proportionate occurrence of SARS-CoV-2 infection by occupation and industry in our study sample with that which would be expected based on the known distributions of occupation and industry in the population from which the sample was drawn. Under the null hypothesis that occupation and industry are not related to the risk of infection, we expected that observed cases would follow the same distribution as occupation and industry in the source population.

PMRs were calculated as the ratio of the total observed number of cases in our study sample for each occupation and industry group to an expected number. The expected number for each group was calculated by applying state-specific 2020 occupation and industry employment proportions from the Current Population Survey (CPS)[48] to the total number of cases in each respective state's study sample and summing those numbers across the six states, accounting for the differing contribution of cases from each state.

Each state's occupation- and industry-specific employment proportions were adjusted to account for the effect of widespread use of telework as a pandemic mitigation measure[49] on the occupation- and industry-specific proportions of people working in-person during the study period and for the exclusion of healthcare personnel from the study sample. A combined adjustment factor, calculated as the product of a telework adjustment factor (TAF) and a category adjustment factor as described below, was applied to the number of workers in each occupation and industry group, yielding adjusted employment numbers. The final adjusted occupation- and industry-specific employment proportions were calculated by dividing the adjusted employment numbers for each occupation and industry group by the total adjusted employment.

Occupation- and industry-specific TAFs were calculated as shown in Equation (1):

$$TAF = 1 - p_i \tag{1}$$

where p_i was the estimated national proportion of workers in each occupation and industry group who teleworked full time. National estimates of the proportions of workers teleworking full time in each occupation and industry group were derived from aggregate American Time Use Survey (ATUS) data covering the period May 10–December 31, 2020.[50] We defined full-time telework as working from home for at least 90% of the average daily hours worked in each occupation and industry group on an average day. Multiplying the complement of the cumulative Poisson probability of full-time telework, given the average number of hours worked from home, by the proportion of workers who spent any time working from home yielded the estimated occupation- or industry-specific proportion of workers who teleworked full time. This is given by Equation (2):

$$p_i = \left(1 - \sum_{x=0}^{k_i-1} \frac{e^{-\lambda_i}\lambda_i^x}{x!}\right)(q_i) \tag{2}$$

where q_i is the proportion of workers in the ith occupation or industry group who worked any hours at home, λ_i is the average daily work hours for the ith occupation or industry group, k_i is $0.9\lambda_i$ (i.e., full-time telework), and x is the number of hours worked at home.

For some industry and occupation groups, the proportion of workers who teleworked full time could not be calculated solely using ATUS data. ATUS estimates of the proportion of workers who spent any time working from home were suppressed for certain groups because they did not meet publication standards. These were: the (1) farming, fishing, and forestry; (2) construction and extraction; (3) installation, maintenance, and repair; and (4) production occupation groups and the (5) agriculture, forestry, fishing and hunting and (6) mining, quarrying, and oil and gas extraction industry groups. In these cases, we substituted occupation- or industry-specific estimates of the average monthly proportion of workers who worked from home at any time in the previous 4 weeks due to the pandemic during September 2020 through June 2021. The data for these substitute estimates came from supplemental questions that were added to the CPS beginning in May 2020.[51] For two occupation and one industry groups, ATUS estimates of the average number of hours worked from home were also suppressed. These were: the (1) construction and extraction and (2) transportation and material moving occupation groups and the (3) mining, quarrying, and oil and gas extraction industry group. Because no comparable data were available from any other source, the TAF for these groups defaulted to 1. Since these groups had very low percentages of any telework, a TAF of 1 likely accurately reflected the proportion of workers who did not work outside the home.

The category adjustment factor was applied to the two occupation (professional and related and service) and one industry (education and health services) groups that included significant numbers of healthcare personnel and served to further reduce the employment proportions of those groups to the extent they comprised healthcare personnel. The factor was calculated as 1-q, where q was the state-specific proportion of employment in each group accounted for by workers employed in healthcare occupations, based on 2020 or 2019 data from the BLS Occupational Employment and Wage Statistics (OEWS) program. Healthcare occupations included those in the healthcare practitioners and technical occupations and healthcare support detailed occupational groups. Detailed employment data by occupation were available for 2020, but detailed data on employment by occupation within industries were only available for 2019. The category adjustment factors for all other occupation and industry groups in all states were set to 1 under the assumption that they included minimal or no healthcare personnel.

PMRs greater than or less than 1 indicate higher or lower than expected proportions of events within that occupation or industry group.

Exact 99% confidence intervals surrounding the PMRs were calculated using the mid-P exact method.[52] PMRs were considered statistically significant if the null value, 1, was excluded from the 99% confidence interval. We used 99% rather than 95% confidence intervals to partially compensate for the increased type I error risk associated with multiple testing; still, significant PMRs should be interpreted as hypothesis generating, given the large number of comparisons.

Analyses were conducted using Microsoft Excel for Microsoft Office 365 and Epi Info 7.

This activity was reviewed by CDC and was conducted consistent with applicable federal law and CDC policy (45 C.F.R. part 46.102(l)(2), 21 C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq).

3 | RESULTS

Of the 9,483 people contacted for the survey, 1174 agreed to participate. This included 13 respondents who were interviewed in Spanish and 11 respondents who were interviewed in languages other than English or Spanish. Of the 1174 respondents, 63 were excluded from the analysis because their occupation or industry of employment coded to a military or healthcare-related category ($n = 35$), they had missing or uncodable responses for both occupation and industry ($n = 25$), or their age was out of range for the survey ($n = 3$), resulting in a final analytic sample of 1111 cases. Of these, codable responses for occupation and industry were available for 1083 and 1090 respondents respectively.

Based on nonmissing data, the respondents who were eligible for the survey but were excluded for missing or uncodable occupation and industry data did not differ significantly from the analytic sample in terms of age ($n = 17$, $t = -0.44$, $p = 0.66$), gender ($n = 14$, Fisher's exact $p = 0.48$), race/ethnicity ($n = 11$, Fisher's exact $p = 0.32$), or education ($n = 14$, Fisher's exact $p = 0.15$).

The distributions of demographic, employment, and clinical characteristics in the analytic sample are presented in Table 1. The distributions of the sample by major and detailed industry and occupational groups are presented in Tables 2 and 3. The distributions of gender and race/ethnicity by major occupation and industry groups are presented in Table 4.

PMRs for SARS-CoV-2 infection by occupation and industry and their 99% confidence intervals are presented in Table 5.

By occupation, a significantly higher-than-expected proportion of SARS-CoV-2 infections in the sample was in the service occupation group (PMR 1.3, 99% CI 1.1–1.5). This group includes protective service; building and grounds cleaning and maintenance; personal care and service; and food preparation and serving related occupations. Significantly lower than expected proportions of cases were in the professional and related (PMR 0.7, 99% CI 0.6–0.9) and farming, fishing, and forestry (PMR 0.3, 99% CI 0.0–0.8) occupation groups.

By industry, significantly higher-than-expected proportions of cases were in the transportation and utilities (PMR 1.4, 99% CI 1.1–1.8) and leisure and hospitality (PMR 1.5, 99% CI 1.2–1.9) industry groups. The leisure and hospitality industry group included the arts, entertainment, and recreation and accommodation and food services industries. Significantly lower than expected proportions of cases were in the professional and business services (PMR 0.5, 99% CI 0.4–0.7), education and health services (excluding health care personnel) (PMR 0.7, 99% CI 0.5–0.9), and agriculture and related (PMR 0.4, 99% CI 0.1–0.8) industry groups.

4 | DISCUSSION

Significantly higher-than-expected proportions of workers with SARS-CoV-2 infection in this survey sample reported working in the service occupation group and in the transportation and utilities and leisure and hospitality industry groups. Many workers in these occupations and industries must work in close proximity to customers, clients, and coworkers,[53] likely increasing their risk for occupational exposure to SARS-CoV-2. These findings are broadly consistent with those of other studies that have found evidence for increased risk of SARS-CoV-2 infection among workers in occupation and industry subgroups included in our high-risk groups.[38,43,44,54]

The overrepresentation of some sociodemographic groups in select occupations and industries is associated with inequities in

TABLE 1 Characteristics of a 6-state sample of non-healthcare in-person workers with SARS-CoV-2 infection.

Characteristic	Frequency (%[a])
Total	1111 (100.0)
Age group (years)	
18–24	151 (13.8)
25–34	259 (23.7)
35–44	232 (21.3)
35–54	229 (21.0)
55–64	220 (20.2)
Gender	
Male	597 (55.0)
Female	481 (44.3)
None of these	8 (0.7)
Race/Ethnicity	
Hispanic or Latino	264 (24.3)
Non-Hispanic AIAN/NHOPI[b]	11 (1.0)
Non-Hispanic Asian	29 (2.7)
Non-Hispanic Black	174 (16.0)
Non-Hispanic Multiracial	11 (1.0)
Non-Hispanic White	599 (55.1)
Education	
Less than high school	73 (6.7)
High school or equivalent	318 (29.4)
Some college	380 (35.1)
Bachelor's degree or higher	312 (28.8)
Work more than one job	53 (4.8)
Work full time at main job	855 (77.9)
Work arrangement	
Self employed	77 (7.0)
Permanent employee	965 (88.2)
Paid by temp agency or contractor	13 (1.2)
Independent contractor or freelancer	23 (2.1)
Other work arrangement	16 (1.5)
Reported underlying medical condition(s)[c]	433 (39.0)
COVID-19 outcomes	
Asymptomatic	89 (8.0)

(Continues)

TABLE 1 (Continued)

Characteristic	Frequency (%[a])
Symptomatic[d]	958 (86.5)
Hospitalized	61 (5.5)

[a]Sample percentages are out of the total number of non-missing responses for each variable. Counts may not sum to the total.

[b]American Indian or Alaskan Native (AIAN); Native Hawaiian or Other Pacific Islander (NHOPI).

[c]Underlying medical conditions queried included cancer, chronic kidney disease, chronic obstructive pulmonary disease, immunocompromised state from solid organ transplant, obesity, serious heart conditions, sickle cell disease, type 2 diabetes mellitus, pregnancy, current smoking status, and other chronic diseases.

[d]Symptoms queried included fever or chills, cough, shortness of breath or difficulty breathing, fatigue, muscle or body aches, headache, new loss of taste or smell, sore throat, congestion or runny nose, nausea or vomiting, diarrhea, and other symptoms.

work-related injury and illness,[55] as well as in health more broadly, since work is a primary determinant of income, access to healthcare, and social prestige and connectedness.[52] When society's long-standing racial, ethnic, economic, and gender inequities combine with differential working conditions that influence viral transmission, some worker populations may experience increased risk of SARS-CoV-2 infection. Nationally, women, racial and ethnic minority workers, and low-income workers disproportionately comprise many of the occupation and industry groups found in this survey to have significantly elevated PMRs for SARS-CoV-2 infection.[56–60] This occupational segregation and differential distribution of SARS-CoV-2 infection among occupation and industry groups may exacerbate existing health disparities; work-related infectious disease and the need for improved worker protections for worker populations at greatest risk of infection during the COVID-19 pandemic and future public health crises are important health equity concerns.

The service occupation group had the highest PMR for SARS-CoV-2 infection of all occupation groups. Service occupations include building and grounds cleaning and maintenance, food preparation and serving related, personal care and service, and protective service occupations.[47] This finding is consistent with our previous finding that, when asked about specific known exposures to COVID-19, the largest proportions of respondents in protective service and personal care and occupations reported known workplace exposures. Elevated cumulative incidences of COVID-19 have been previously identified among building and grounds cleaning and maintenance, personal care and service, and protective service workers.[54] Nationally, women, Black workers, and Hispanic or Latino workers are overrepresented within the service occupation group, even when healthcare support workers are excluded. These populations are particularly over-represented within some occupational subgroups; women comprise 77% of workers in personal care and service occupations and Hispanic and Latino workers comprise 38% of workers in building and grounds cleaning and maintenance occupations, in comparison to 47% and 18% of the total employed population, respectively.[56] Black and Hispanic or Latino workers were similarly overrepresented in our study sample; they comprised 22% and 31% of the services occupational group respectively, compared with 16% and 24% of the overall sample and 12% and 18% of the employed US population. In the study sample, the distribution of workers across the detailed occupational subgroups within the services major occupational group

TABLE 2 Distribution of a 6-state sample of non-healthcare in-person workers with SARS-CoV-2 infection by major and detailed occupational groups.

Occupational group	Frequency (%[a])	
Management, business, and financial operations		151 (13.9)
Management occupations	110 (72.8)	
Business and financial operations occupations	41 (27.2)	
Professional and related		135 (12.5)
Computer and mathematical occupations	7 (5.2)	
Architecture and engineering occupations	30 (22.2)	
Life, physical, and social science occupations	7 (5.2)	
Community and social service occupations	15 (11.1)	
Legal occupations	2 (1.5)	
Education, training, and library occupations	61 (45.2)	
Arts, design, entertainment, sports, and media occupations	13 (9.6)	
Service (excl. healthcare support occupations)		201 (18.6)
Protective service occupations	41 (20.4)	
Food preparation and serving related occupations	70 (34.8)	
Building and grounds cleaning and maintenance occupations	52 (25.9)	
Personal care and service occupations	38 (18.9)	
Sales and related		130 (12.0)
Office and administrative support		145 (13.4)
Farming, fishing, and forestry		3 (0.3)
Construction and extraction		83 (7.7)
Installation, maintenance, and repair		44 (4.1)
Production		96 (8.9)
Transportation and material moving		95 (8.8)
Total		1,083 (100.0)

[a]Percentages for detailed groups reflect percentage of the major group that they comprise, not of the overall total.

TABLE 3 Distribution of a 6-state sample of nonhealthcare in-person workers with SARS-CoV-2 infection by major and detailed industry groups.

Industry group	Frequency (%[a])	
Mining, quarrying, and oil and gas extraction		0 (0.0)
Construction		113 (10.4)
Manufacturing		170 (15.6)
Nonmetallic mineral products	4 (2.4)	
Primary metals and fabricated metal products	11 (6.5)	
Machinery manufacturing	2 (1.2)	
Computer and electronic products	12 (7.1)	
Electrical equipment, appliance manufacturing	4 (2.4)	
Transportation equipment manufacturing	16 (9.4)	
Wood products	3 (1.8)	
Furniture and fixtures manufacturing	1 (0.6)	
Miscellaneous and not specified manufacturing	59 (34.7)	
Food manufacturing	18 (10.6)	
Beverage and tobacco products	1 (0.6)	
Textile, apparel, and leather manufacturing	7 (4.1)	
Paper and printing	10 (5.9)	
Petroleum and coal products	1 (0.6)	
Chemical manufacturing	10 (5.9)	
Plastics and rubber products	11 (6.5)	
Wholesale and retail trade		190 (17.4)
Wholesale trade	42 (22.1)	
Retail trade	148 (77.9)	
Transportation, warehousing, and utilities		107 (9.8)
Transportation and warehousing	93 (86.9)	
Utilities	14 (13.1)	
Information		13 (1.2)
Motion picture and sound recording industries	5 (38.5)	
Broadcasting (except internet)	2 (15.4)	
Telecommunications	5 (38.5)	
Internet service providers and data processing services	1 (7.7)	
Financial activities		46 (4.2)
Finance	20 (43.5)	
Insurance	5 (10.9)	
Real estate	20 (43.5)	
Rental and leasing services	1 (2.2)	
Professional and business services		62 (5.7)
Professional and technical services	22 (35.5)	
Administrative and support services	36 (58.1)	
Waste management and remediation services	4 (6.5)	
Education and health services (excl. health services)		119 (10.9)
Educational services	93 (78.2)	
Social assistance	26 (21.8)	
Leisure and hospitality		141 (12.9)
Arts, entertainment, and recreation	28 (19.9)	
Accommodation	16 (11.3)	
Food services and drinking places	97 (68.8)	
Other services		61 (5.6)
Repair and maintenance	20 (32.8)	
Personal and laundry services	21 (34.4)	
Membership associations and organizations	16 (26.2)	
Private households	4 (6.6)	
Public administration		59 (5.4)
Agriculture and related		9 (0.8)
Total		1090 (100.0)

[a]Percentages for detailed groups reflect percentage of the major group that they comprise, not of the overall total.

was similar to that seen nationally. Protective services; food preparation and serving; building and grounds cleaning and maintenance; and personal care and service occupations accounted for 20%, 35%, 26%, and 19% of the sample respectively, compared with 17%, 36%, 28%, and 19% of all US workers employed in services occupations (excluding healthcare support occupations). Nationally, full-time workers in service occupations also earn a lower weekly income than full-time workers in all occupations combined,[57] highlighting the heightened risk of SARS-CoV-2 infection experienced by workers with fewer resources to prevent, treat, and manage infection.

The transportation and utilities industry group and the leisure and hospitality industry group each had significantly elevated PMRs SARS-CoV-2 infection. Transportation and utilities industries include air, rail, water, and truck transportation; public transit; electric, gas, water, and sewage utilities; and so forth. It is important to note that this industry group represents a worker subpopulation that only

TABLE 4 Distribution of a 6-state sample of non-healthcare in-person workers with SARS-CoV-2 infection by major occupation and industry groups, gender, and race/ethnicity.

	Gender				Race/Ethnicity						
		Frequency (%[a])				Frequency (%[a])					
Characteristic Occupation	Total	Male	Female	None of these	Total	Hispanic or Latino	Non-Hispanic AIAN/NHOPI[b]	Non-Hispanic Asian	Non-Hispanic Black	Non-Hispanic Multiracial	Non-Hispanic White
Management, business, and financial operations	149	85 (57.1)	63 (42.3)	1 (0.7)	149	13 (8.7)	1 (0.7)	4 (2.7)	17 (11.4)	3 (2.0)	111 (74.5)
Professional and related	133	58 (43.6)	75 (56.4)	0 (0.0)	134	14 (10.5)	2 (1.5)	6 (4.5)	7 (5.2)	1 (0.8)	104 (77.6)
Service	195	89 (45.6)	105 (53.9)	1 (0.5)	197	61 (31.0)	1 (0.5)	2 (1.0)	43 (21.8)	2 (1.0)	88 (44.7)
Sales and related	126	63 (50.0)	61 (48.4)	2 (1.6)	125	37 (29.6)	2 (1.6)	2 (1.6)	20 (16.0)	1 (0.8)	63 (50.4)
Office and administrative support	144	51 (35.4)	92 (63.9)	1 (0.7)	142	44 (31.0)	1 (0.7)	5 (3.5)	18 (12.7)	1 (0.7)	73 (51.4)
Farming, fishing, and forestry	3	0 (0.0)	3 (100.0)	0 (0.0)	3	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Construction and extraction	80	70 (87.5)	8 (10.0)	2 (2.5)	83	28 (33.7)	1 (1.2)	0 (0.0)	5 (6.0)	0 (0.0)	49 (59.0)
Installation, maintenance, and repair	43	41 (95.4)	2 (4.7)	0 (0.0)	43	5 (11.6)	0 (0.0)	1 (2.3)	5 (11.6)	1 (2.3)	31 (72.1)
Production	95	57 (60.0)	37 (39.0)	1 (1.1)	92	27 (29.4)	2 (2.2)	2 (2.2)	19 (20.7)	0 (0.0)	42 (45.7)
Transportation and material moving	91	68 (74.7)	23 (25.3)	0 (0.0)	93	28 (30.1)	0 (0.0)	6 (6.5)	29 (31.2)	2 (2.2)	28 (30.1)
Total	1059	582 (55.0)	469 (44.3)	8 (0.8)	1061	260 (24.5)	10 (0.9)	28 (2.6)	163 (15.4)	11 (1.0)	589 (55.5)
Industry											
Mining, quarying, and oil and gas extraction	0	–	–	–	0	–	–	–	–	–	–
Construction	110	97 (88.2)	11 (10.0)	2 (1.8)	112	36 (32.1)	1 (0.9)	0 (0.0)	6 (5.4)	0 (0.0)	69 (61.6)
Manufacturing	165	111 (67.3)	53 (32.1)	1 (0.6)	166	38 (22.9)	6 (3.6)	10 (6.0)	24 (14.5)	0 (0.0)	88 (53.0)
Wholesale and retail trade	186	100 (53.8)	84 (45.2)	2 (1.1)	185	43 (23.2)	0 (0.0)	9 (4.9)	41 (22.2)	3 (1.6)	89 (48.1)
Transportation and utilities	105	75 (71.4)	30 (28.6)	0 (0.0)	104	33 (31.7)	0 (0.0)	1 (1.0)	28 (26.9)	2 (1.9)	40 (38.5)
Information	13	6 (46.2)	7 (53.9)	0 (0.0)	13	2 (15.4)	0 (0.0)	1 (7.7)	2 (15.4)	0 (0.0)	8 (61.5)
Financial activities	45	15 (33.3)	30 (66.7)	0 (0.0)	46	11 (23.9)	0 (0.0)	1 (2.2)	5 (10.9)	0 (0.0)	29 (63.0)
Professional and business services	60	27 (45.0)	32 (53.3)	1 (1.7)	61	17 (27.9)	0 (0.0)	1 (1.6)	9 (14.8)	0 (0.0)	34 (55.7)
Education and health services	119	35 (29.4)	84 (70.6)	0 (0.0)	118	12 (10.2)	1 (0.9)	3 (2.5)	15 (12.7)	2 (1.7)	85 (72.0)
Leisure and hospitality	137	59 (43.1)	77 (56.2)	1 (0.7)	139	42 (30.2)	2 (1.4)	2 (1.4)	20 (14.4)	1 (0.7)	72 (51.8)
Other services	59	23 (39.0)	36 (61.0)	0 (0.0)	58	8 (13.8)	0 (0.0)	1 (1.7)	11 (19.0)	1 (1.7)	37 (63.8)

TABLE 4 (Continued)

Characteristic	Gender				Race/Ethnicity						
		Frequency (%[a])				Frequency (%[a])					
Occupation	Total	Male	Female	None of these	Total	Hispanic or Latino	Non-Hispanic AIAN/NHOPI[b]	Non-Hispanic Asian	Non-Hispanic Black	Non-Hispanic Multiracial	Non-Hispanic White
Public administration	58	33 (56.9)	24 (41.4)	1 (1.7)	58	14 (24.1)	1 (1.7)	0 (0.0)	7 (12.1)	2 (3.5)	34 (58.6)
Agriculture and related industries	9	5 (55.6)	4 (44.4)	0 (0.0)	9	6 (66.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (33.3)
Total	1066	586 (55.0)	472 (44.3)	8 (0.8)	1069	262 (24.5)	11 (1.0)	29 (2.7)	168 (15.7)	11 (1.0)	588 (55.0)

[a]Sample percentages are out of the total number of non-missing responses for each variable. Counts may not sum to the total.
[b]American Indian or Alaskan Native (AIAN); Native Hawaiian or Other Pacific Islander (NHOPI).

partially overlaps with the transportation and material moving occupational group, which was not found to have an elevated PMR. Leisure and hospitality industries include accommodation, food services, entertainment, and so forth.[47] Nationally, Black workers and Hispanic or Latino workers are overrepresented within the transportation and utilities and leisure and hospitality industry groups, respectively, in comparison to the employed US population.[58] These disparities were also observed in our study sample, where Black workers and Hispanic or Latino workers comprised 27% and 32% of the transportation, warehousing, and utilities industry group respectively, and Hispanic or Latino workers comprised 30% of the leisure and hospitality industry group. As with the services occupational group, the distribution of workers across the detailed subgroups of both the transportation, warehousing, and utilities and leisure and hospitality major industry groups in our sample were similar to the national distribution. In the study sample, workers in the transportation and warehousing and the utilities detailed industry subgroups comprised 87% and 13% of the transportation, warehousing and utilities major industry group respectively, compared with 84% and 16% of all US workers employed in the industry group. In the sample, workers in the arts, entertainment, and recreation; accommodation; and food services and drinking places detailed industry groups made up 20%, 11%, and 69% of workers in the leisure and hospitality major industry group respectively, compared with 23%, 8%, and 69% of all US workers employed in the industry group. Nationally, workers in the leisure and hospitality industry group also earn the lowest weekly wage of all workers.[59,60] As with workers in service occupations, this highlights the heightened risk experienced by workers with the fewest resources.

Several occupation and industry groups had PMRs for SARS-CoV-2 infection that were significantly lower than the null. These PMRs may be due to true lower risk among some populations of workers, including those in professional and related occupations and professional and business services industries. Professional and related occupations include: computer and mathematical; architecture and engineering; life, physical, and social science; community and social service; legal; education, training, and library; and arts, design, entertainment, sports, and media occupations. Professional and business services industries include: professional and technical services; administrative and support services; and waste management and remediation services. Workers in these groups were less likely than those in many higher risk occupation and industry groups to work in close proximity to others.[53] Additionally, workers in these groups tend to earn higher incomes than the employed population as a whole[57–60] and some may benefit from sufficient job security and autonomy to utilize protective measures in the workplace.[61,62] In the context of the COVID-19 pandemic, such protective measures might include working remotely, maintaining a safe distance from others, using physical barriers, personal mask use, and requesting or requiring that clients and coworkers use masks. However, lower than expected PMRs may also be due to the inherent counterbalancing effect of PMRs, as detailed below, or to small numbers of observed cases in some worker groups in the survey sample (farming,

TABLE 5 Proportionate morbidity ratios for SARS-CoV-2 infection by occupation and industry in a 6-state sample of non-healthcare workers who worked in-person.

Characteristic	Observed Cases	Expected Cases	PMR (99% CI)[a]
Occupation			
Management, business, and financial operations	151	186.5	0.8 (0.6–1.0)
Professional and related	135	192.4	0.7 (0.6–0.9)[b]
Service (excl. healthcare support occupations)	201	156.1	1.3 (1.1–1.5)[b]
Sales and related	130	116.8	1.1 (0.9–1.4)
Office and administrative support	145	121.0	1.2 (1.0–1.5)
Farming, fishing, and forestry	3	10.8	0.3 (0.0–0.8)[b]
Construction and extraction	83	67.5	1.2 (0.9–1.6)
Installation, maintenance, and repair	44	40.7	1.1 (0.7–1.5)
Production	96	86.3	1.1 (0.8–1.4)
Transportation and material moving	95	104.7	0.9 (0.7–1.2)
Total	1083	1083.0	
Industry			
Mining, quarrying, and oil and gas extraction	0	1.9	0.0
Construction	113	90.2	1.3 (1.0–1.6)
Manufacturing	170	156.7	1.1 (0.9–1.3)
Wholesale and retail trade	190	168.7	1.1 (0.9–1.3)
Transportation, warehousing, and utilities	107	73.9	1.4 (1.1–1.8)[b]
Information	13	19.5	0.7 (0.3–1.2)
Financial activities	46	62.7	0.7 (0.5–1.0)
Professional and business services	62	118.6	0.5 (0.4–0.7)[b]
Education and health services (excl. health services)	119	171.9	0.7 (0.5–0.9)[b]
Leisure and hospitality	141	93.5	1.5 (1.2–1.9)[b]
Other services	61	58.4	1.0 (0.7–1.4)
Public administration	59	51.8	1.1 (0.8–1.6)
Agriculture and related	9	22.3	0.4 (0.1–0.8)[b]
Total	1090	1090.0	

[a]Proportionate morbidity ratio (PMR); confidence interval (CI).

[b]Indicates statistically significant PMR.

fishing, and forestry occupations and agriculture and related industries) leading to unstable estimates. Exact methods were used to estimate 99% CIs to minimize the likelihood of spurious findings from small counts.[52]

Although several studies have assessed SARS-CoV-2 diagnosis or seroprevalence by occupation among workers in a single state, occupation, or industry,[35–39] this study is among the first to use a multi-state U.S. sample to evaluate relative risk of SARS-CoV-2 infection across occupations and industries. We identified certain occupation and industry groups with elevated PMRs for SARS-CoV-2 infection, suggesting these worker populations may be at increased risk of infection during the COVID-19 pandemic and similar public health emergencies. This analysis also provides necessary context for evaluations of COVID-19 mortality by occupation and industry[40–42] by offering insight into population-level occupational SARS-CoV-2 transmission risk. While occupation or industry specific COVID-19 mortality data are generally more reliable than incidence data because case ascertainment is more complete and because mortality records are much more likely to have associated occupation and industry data included, mortality is ultimately a function of infection risk and the case fatality ratio. The risk of occupational exposure and infection is determined by characteristics of the work environment, while population-level fatality is more strongly influenced by the demographic composition of the worker population. Both outcomes must be characterized to fully understand the role of work in COVID-19 transmission, morbidity, and mortality.[63] Occupation and industry groups with the highest mortality may not be the groups with the highest risk for occupational transmission, and vice versa.

During the study period, three COVID-19 vaccines were authorized for emergency use and became available in the United States. Initially, vaccine distribution was prioritized for high-risk groups using a phased approach. Residents of long-term care facilities and healthcare workers were prioritized in the first phase (phase 1a)[27]; people aged ≥ 75 years and frontline essential workers in the second (phase 1b); and people aged 65-74, people with certain medical conditions, and essential workers not included in phase 1b in the third (phase 1c).[28] Thus, access to COVID-19 vaccines during the study period was associated with occupation. At the same time, other studies suggest that vaccine uptake differed significantly by occupation.[44,64] For example, in a SARS-CoV-2 study of 85,986 US blood donors, people employed in protective service occupations—who had early access (phase 1b) to vaccines—also had the highest adjusted odds of being unvaccinated.[44] Our survey, which was designed before COVID-19 vaccinations became available, did not include questions about vaccination status. Unfortunately, therefore, we cannot account for the potentially complicated ways that associations between occupation or industry and vaccine access and uptake may have affected the observed associations of these variables with infection risk.

There are several additional limitations to this study. First, the study population was limited to workers diagnosed with SARS-CoV-2 infection who survived, which could have biased results to underrepresent worker populations with higher prevalences of underlying health conditions that contribute to COVID-19 infection fatality risk. Second, we limited study eligibility to persons with SARS-CoV-2 infection confirmed by RT-PCR. Antigen tests became more popular during the survey collection period and potential cases diagnosed using these tests were not captured. Third, proportions of workers within occupations and industries teleworking varied across states and over time during the pandemic. Telework estimates are derived from national data collected from May through December 2020 and cannot fully capture this variability. Further, although our case data were collected between September 2020 and June 2021, we used 2020 averaged annual data on occupation and industry employment proportions to calculate the expected numbers of cases because state-specific data on teleworking were only available for 2020. Because pandemic-related unemployment spiked in April of 2020 with variable impacts on different sectors of the economy,[23] averaged annual data from 2020 may not accurately represent the true employment proportions during the study period. However, a comparison of 2020 and 2021 data showed that, for the six states in our study, there was little difference in the proportional employment by occupation and industry from 1 year to the next.[48] Fourth, PMRs are not adjusted for age, gender, race, Hispanic origin, or employer and individual-level behaviors that may vary between worker populations and affect SARS-CoV-2 exposure and infection, COVID-19 diagnosis, and survey participation. PMRs indicate only the relative overall morbidity experienced by survey respondents in occupation and industry groups. Neither relative morbidity from particular workplace exposures nor workers' individual risks of infection can be inferred from these analyses. Fifth, participating states designed their own survey sampling plans, which could vary with respect to the timing and geographic scope of data collection as well as certain other criteria. Consequently, respondents may not comprise a fully representative sample of all eligible cases, across either the overall study area or period. For the purposes of this analysis, we assumed that occupation and industry of employment were unrelated to survey participation and that sampling was random with respect to the distribution of these variables among all eligible cases. However, to the extent that testing and diagnosis or demographic factors affecting survey participation were also associated with occupation and industry, our analysis could have been affected by selection bias. Additionally, the low response rate to the survey is another potential source of selection bias. Sixth, as with all proportionate morbidity studies, we compare proportions, not rates. Because all proportions must sum to 1, any elevated (or low) PMR must be counterbalanced across the other groups. Seventh, small numbers of respondents in many worker populations necessitated the collapse of Census occupation and industry codes into broad occupation and industry groups for analysis, potentially smoothing over important distinctions between individual occupations and industries. However, in the major occupational and industry groups with significantly elevated PMRs, the distribution of workers across detailed occupation and industry subgroups in the sample were found to be similar to the corresponding distributions in the national population. So, it is unlikely that these findings could be due solely to overrepresentation of higher risk occupations or industries within the broad groups. Analyses were also limited to workers' main job because of small numbers of respondents with multiple jobs. Finally, the survey data are self-reported and subject to potential social acceptability bias and recall bias.

5 | CONCLUSION

We identified clear differences in proportionate distribution of SARS-CoV-2 infection by occupation and industry among respondents in a multistate survey. These findings underscore the heightened burden of SARS-CoV-2 infection borne by some worker populations, particularly those whose jobs require frequent or prolonged close contact with other people. Further focused research will be needed to fully understand specific job or workplace characteristics that contribute to the increased risk of infection borne by workers in high-risk occupations and industries. The occupation and industry groups with elevated PMRs for SARS-CoV-2 infection are disproportionately composed of women workers, racial and ethnic minority workers, and low-income workers, emphasizing the contribution of work-related SARS-CoV-2 transmission to the perpetuation of systemic health inequities. Work is a core social determinant of health and work-related characteristics, including occupation, industry, and known exposures at work, should be routinely collected in national surveillance data for all notifiable conditions to evaluate occupational risks and inform public health prevention measures.[65]

AUTHOR CONTRIBUTIONS

Matthew R. Groenewold conceived and designed the study. Matthew R. Groenewold, Hannah Free, Sherry L. Burrer, Marie Haring Sweeney, and Sara E. Luckhaupt designed and oversaw the survey used for data collection. Matthew R. Groenewold and Rachael Billock performed the statistical analyses and drafted the manuscript. Jessie Wong, Antionette Lavender, Gabriel Argueta, Hannah-Leigh Crawford, Kimberly Erukunuakpor, Nicole D. Karlsson, Karla Armenti, Hannah Thomas, Kim Gaetz, Gialana Dang, Laurel Harduar-Morano, and Komi Modji implemented the survey and participated in the acquisition of the data. All authors participated in the interpretation of the results of the analyses. All authors reviewed and critically revised the manuscript and approved the final version to be published.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

ETHICS APPROVAL AND INFORMED CONSENT

This activity was reviewed by CDC and was conducted consistent with applicable federal law and CDC policy (45 C.F.R. part 46.102(l)(2), 21 C.F.R. part 56; 42 U.S.C. §241(d); 5 U.S.C. §552a; 44 U.S.C. §3501 et seq).

DISCLAIMER

The findings and conclusions in this article are those of the authors and do not necessarily represent the views or opinions of the Centers for Disease Control and Prevention, California Department of Public Health, Georgia Department of Public Health, New Hampshire Department of Health and Human Services, University of New Hampshire, North Carolina Department of Health and Human Services, Pennsylvania Department of Health, or Wisconsin Department of Health Services.

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