Clinical Infectious Diseases

MAJOR ARTICLE

Occupations Associated With Severe Acute Respiratory Syndrome Coronavirus 2 Infection and Vaccination, US Blood Donors, May 2021–December 2021

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Background. There are limited data on the risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection in the United States by occupation. We identified occupations at higher risk for prior SARS-CoV-2 infection as defined by the presence of infection-induced antibodies among US blood donors.

Methods. Using a nested case-control study design, blood donors during May–December 2021 with anti-nucleocapsid (anti-N) testing were sent an electronic survey on employment status, vaccination, and occupation. The association between previous SARS-CoV-2 infection and occupation-specific in-person work was estimated using multivariable logistic regression adjusting for sex, age, month of donation, race and ethnicity, education, vaccination, and telework.

Results. Among 85 986 included survey respondents, 9504 (11.1%) were anti-N reactive. Healthcare support (20.3%), protective service (19.9%), and food preparation and serving related occupations (19.7%) had the highest proportion of prior infection. After adjustment, prior SARS-CoV-2 infection was associated with healthcare practitioners (adjusted odds ratio [aOR], 2.10; 95% confidence interval [CI], 1.74–2.54) and healthcare support (aOR, 1.82; 95% CI, 1.39–2.40) occupations compared with computer and mathematical occupations as the referent group. Lack of coronavirus disease 2019 vaccination (aOR, 16.13; 95% CI, 15.01–17.34) and never teleworking (aOR, 1.17; 95% CI, 1.05–1.30) were also independently associated with prior SARS-CoV-2 infection. Construction and extraction occupations had the highest proportion of unvaccinated workers (30.5%).

Conclusions. Workers in healthcare, protective services, and food preparation had the highest prevalence of prior SARS-CoV-2 infection. Occupational risks for SARS-CoV-2 infection remained after adjusting for vaccination, telework, and demographic factors. These findings underscore the need for mitigation measures and personal protection in healthcare settings and other workplaces.

Keywords. SARS-CoV-2; occupation; COVID-19; vaccination.

Protecting the health of workers was a central concern early in the coronavirus disease 2019 (COVID-19) pandemic and remains important today. The pandemic sparked unprecedented attention and dialogue around opportunities for telework, sick leave policies, mask use, and social distancing in the workplace. Studies examining risk of workplace severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) exposure initially focused on healthcare workers, many of whom had direct contact with infected patients [1–3]. The risk of COVID-19 among "essential workers," whose jobs are critical to societal functioning and cannot be completed remotely, was considered in early COVID-19 vaccination allocation guidance [4]. Clusters of COVID-19 disease were reported in certain industries, such as meat processing, grocery, transportation, and other categories where workers were often in close proximity to others [5–9]. Differences in COVID-19 risk by occupation have also been reported from other countries [10–14].

To our knowledge, a comprehensive assessment of risk for SARS-CoV-2 infection, including details about workplace characteristics among workers across a full range of occupations in the United States, is not available. Analyses incorporating vaccination status and the level of telework into risk by occupation are limited. This presents a challenge to public health and policymakers who need to identify high-risk groups for targeted prevention strategies, such as vaccine education, vaccine booster dose recommendations, or other effective mitigation measures [15]. Our goal was to identify occupations at higher risk for COVID-19 using the presence of infection-induced antibodies as the outcome among US blood donors.

Received 01 September 2022; editorial decision 01 November 2022; published online 14 November 2022

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Clinical Infectious Diseases® 2023;76(7):1285–94

https://doi.org/10.1093/cid/ciac883

METHODS

Study Design and Population

From 4 May 2021 to 31 December 2021, 347 447 first-time anti-spike (S) reactive American Red Cross (ARC) donors as well as all anti-S nonreactive donors were eligible for an electronic survey approximately 2 weeks after donation if they were aged 18 years or older, were accessible by email, and spoke English. For this nested case-control study, a sample of US blood donors donating to the ARC and meeting eligibility criteria for receiving an electronic survey during the study period (4 May 2021 and 31 December 2021) were included. At donation, donor data including age, sex, race and ethnicity, ZIP code of residence, and self-report of any prior COVID-19 vaccination were collected.

Serologic Testing and Case Definition

Serologic testing included assays for anti-S and anti-nucleocapsid (N) antibodies at the blood donation. Anti-S reactivity captures both infection- and vaccination-induced antibodies; because approved vaccines do not include nucleocapsid antigens, anti-N reactivity indicates infection-induced antibodies only. Anti-S reactivity was assessed with the Ortho VITROS anti-SARS-CoV-2 S1 Total Ig Assay, which has a sensitivity of 90.0% (range, 76.9–96.0) and specificity of 100% (99.1–100) [16]. Anti-N reactivity was assessed with the Roche Elecsys anti-N assay (sensitivity, 100%; range, 88.3–100) and specificity of 99.8% (range, 99.7–99.9) or ORTHO anti-N assay (sensitivity, 90.0%; range, 80.8–95.1) and specificity of 99.1% (range, 98.4–99.5)) [16]. The Roche Elecsys anti-N total immunoglobulin assay exhibits high durability over time [17, 18]. Cases were defined as donors with anti-N reactivity; all other donors were considered controls. Donors who reported no vaccination but were anti-S reactive and anti-N nonreactive (n = 145) were excluded from the analysis. In this study, prior SARS-CoV-2 infection refers to the presence of anti-N antibodies.

Survey

An electronic survey was sent (Supplementary Survey) 2 to 6 weeks after donation to those meeting the inclusion criteria (n = 347 447). The survey included questions about prior SARS-CoV-2 infection, close contact exposures, symptoms, COVID-19 testing, COVID-19 vaccination history and dates, and underlying conditions. Additionally, questions on employment, occupation and industry, telework, workplace mitigation measures, masking, and sick leave policies were included.

Data Analysis

Survey responses about occupation and industry were captured using free text. Responses were coded to standard 2010 Census occupation codes and 2012 Census industry codes using the National Institute for Occupational Safety and Health Industry and Occupation Computerized Coding System. Occupation codes were grouped into 23 "simple recode" categories developed by the National Center for Health Statistics for the National Health Interview Survey [19] (Supplementary Methods).

Demographic information, COVID-19 vaccination status, and occupational and workplace characteristics were described using summary statistics. Continuous variables were expressed as means and standard deviation, and categorical variables were expressed as counts and column percentages. For univariate analysis, a *t* test with equal variances was used for continuous variables and χ^2 test for categorical variables. See Supplementary Methods for details on vaccination status definitions.

Covariates established as risk factors for SARS-CoV-2 infection were included in the multivariable model. Reported close contact exposure to SARS-CoV-2 was not included because of potential collinearity. Adjusted odds ratios (aOR) were calculated using multivariable unconditional logistic regression modeling (mixed-effects model with covariates and a random intercept for geographic location) the association between occupation and previous infection as defined by anti-N reactivity. The odds of prior infection by occupation controlling for age, sex, race and ethnicity, geographic location, vaccine status, and amount of telework were determined. The computer and mathematical occupations category was chosen as the reference group because of its recognizable and relatively homogenous detailed occupations and a priori estimation of low risk. A random intercept was included to account for differences by state of residence. Sensitivity analyses excluding 100% teleworkers and the telework covariate were completed. Another sensitivity analysis excluded vaccinated cases for whom vaccination did not precede infection (or dates were missing) and unvaccinated cases for whom the date of infection was not available.

In a secondary analysis, we examined the outcome of prior SARS-CoV-2 infection after reclassifying occupations into essential worker categories based on US Census industry and occupation codes. Additionally, a secondary analysis on the association of occupation with vaccination status controlling for relevant covariates was completed. Analyses were conducted using R statistical software (version 4.0.3) and the *lme4* package [20].

Ethical Review

Distribution of this survey underwent ARC institutional review board approval. This activity was reviewed by the Centers for Disease Control and Prevention (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. Sect. 241(d); 5 U.S.C. Sect. 552a; 44 U.S.C. Sect. 3501 et seq).

RESULTS

Cohort Description

Approximately 3 194 220 individuals donated blood between 4 May 2021 and 31 December 2021 [21]. After exclusion of donors who did not receive testing, who were not first time anti-S reactive, and who did not allow email contact, a total of 347 447 surveys were distributed to donors who met the inclusion criteria. We collected 86 131 survey responses among 86 014 unique donors (response rate = 25%) (Figure 1). Survey responses were submitted between 15 July 2021 and 9 February 2022. There were 145 responses excluded because of having anti-S reactivity, anti-N non-reactivity, and no history of vaccination (Figure 1). Among 85 986 eligible responses, there were 9504 (11.1%) cases and 76 482 (88.9%) controls (Figure 1, Table 1). A higher proportion of survey responses came from females versus males (59.6% versus 40.4%) (Table 1). The median age of donors was 55 years. Among respondents, 90.2% were non-Hispanic White and 2.0% were Non-Hispanic Black. Most respondents (67.2%) had a college degree or higher. One-quarter of respondents (25.9%) had 1 or more chronic illnesses and 9.6% reported prior COVID-19 (healthcare diagnosis or positive test). At time of survey completion, 15.5% of respondents were unvaccinated and 84.4% reported 1 or more doses of COVID-19 vaccine (Table 1).

Occupation and Prior Infection Risk

More than one-fourth of respondents (24 408, 28.4%) reported no employment since March 2020, whereas 61 503 (71.5%) reported some employment (Table 1). Among 61 503 respondents reporting employment, 4.1% did not provide an occupation title and 4.7% of responses were designated as "insufficient information" by the automated National Institute for Occupational Safety and Health Industry and Occupation Computerized Coding System coder. Management occupations, office and administrative support occupations, and education, training, and library occupations were the most common National Center for Health Statistics simple categories (Supplementary Table 1). Some occupations were underrepresented (eg, food preparation and serving) and some overrepresented (eg, architecture and engineering) among ARC respondents compared to the US population (Supplementary Table 2). Among those with employment, 11 929 (19.4%) reported 100% telework during the pandemic (Table 1). Ability to telework varied widely by occupation with exclusive telework highest among computer and mathematical occupations (54.0%) (Supplementary Table 3). Of 46 612 respondents reporting in-person work, most were salaried employees (86.9%) and commuted to work in a private vehicle (93.6%) (Table 2). A majority reported workplace adoption of risk mitigation measures ranging from 20.0% with changes to ventilation systems to 85.3% with a mask requirement; only 3.4% of respondents reported that none of 8 mitigation measures queried was taken (Table 2, Supplementary Table 4). Similarly, 85.0% agreed with statements that their management prioritized employee safety and provided adequate training on risk mitigation (Table 2). A majority of in-person workers believed their primary occupation increased their risk for SARS-CoV-2 infection (50.9%), whereas 17.9% believed their work decreased their risk (Table 2).

In the overall population (Table 1), cases were more likely than controls to report prior COVID-19 (healthcare diagnosis or positive test, 63.5% versus 2.9%) and close contact exposure to someone with SARS-CoV-2 (55.5% versus 22.1%) and less likely to report 100% telework (12.1% versus 20.4%) or COVID-19 vaccination (64.8% versus 86.8% receiving one or more doses). Among 5318 cases reporting both employment and previous vaccination, 1781 (33.5%) were vaccinated after known SARS-CoV-2 infection date and were classified as being unvaccinated for multivariable modeling.

Occupations with the highest proportion of prior infection were healthcare support occupations (20.3%), protective service occupations (19.9%), and food preparation and serving related occupations (19.7%) (Supplementary Table 1). The largest detailed occupation in the protective service occupations category is police and sheriff's patrol officers (Supplementary Table 12). Cooks, waiters, and waitresses were the largest detailed occupations in the food preparation and serving occupations category (Supplementary Table 12). In adjusted analysis, the highest point estimates for odds of prior infection were in healthcare practitioner occupations (aOR, 2.10; 95% confidence interval [CI], 1.74–2.54) and healthcare support workers (aOR, 1.82; 95% CI, 1.39–2.40) compared with computer and mathematical occupations (Figure 2, Supplementary Table 5). Registered nurses and physicians and surgeons were the largest detailed occupation groups in the healthcare practitioner occupations category (Supplementary Table 12). Nursing, psychiatric, and home health aides (37.8%), medical assistants (20.7%), massage therapists (10.0%), and dental assistants (8.2%) were the most represented healthcare support worker occupations (Supplementary Table 12). In addition to healthcare workers, other occupation categories including community and social service, education, legal, and protective service also had increased odds of prior infection in adjusted analyses compared with those in computer and mathematical occupations (Supplementary Table 5). In a sensitivity analysis restricting cases to those with known temporal relationship of vaccination and infection, healthcare occupations consistently had the highest point estimates for association with prior infection compared with computer and mathematical occupations (Supplementary Table 6). In sensitivity analysis excluding those reporting 100% telework and another removing telework, the association between occupation and prior infection was magnified but with overlapping confidence intervals (Supplementary Table 7).

Lower reported telework was associated with significantly increased odds of previous infection both in unadjusted and

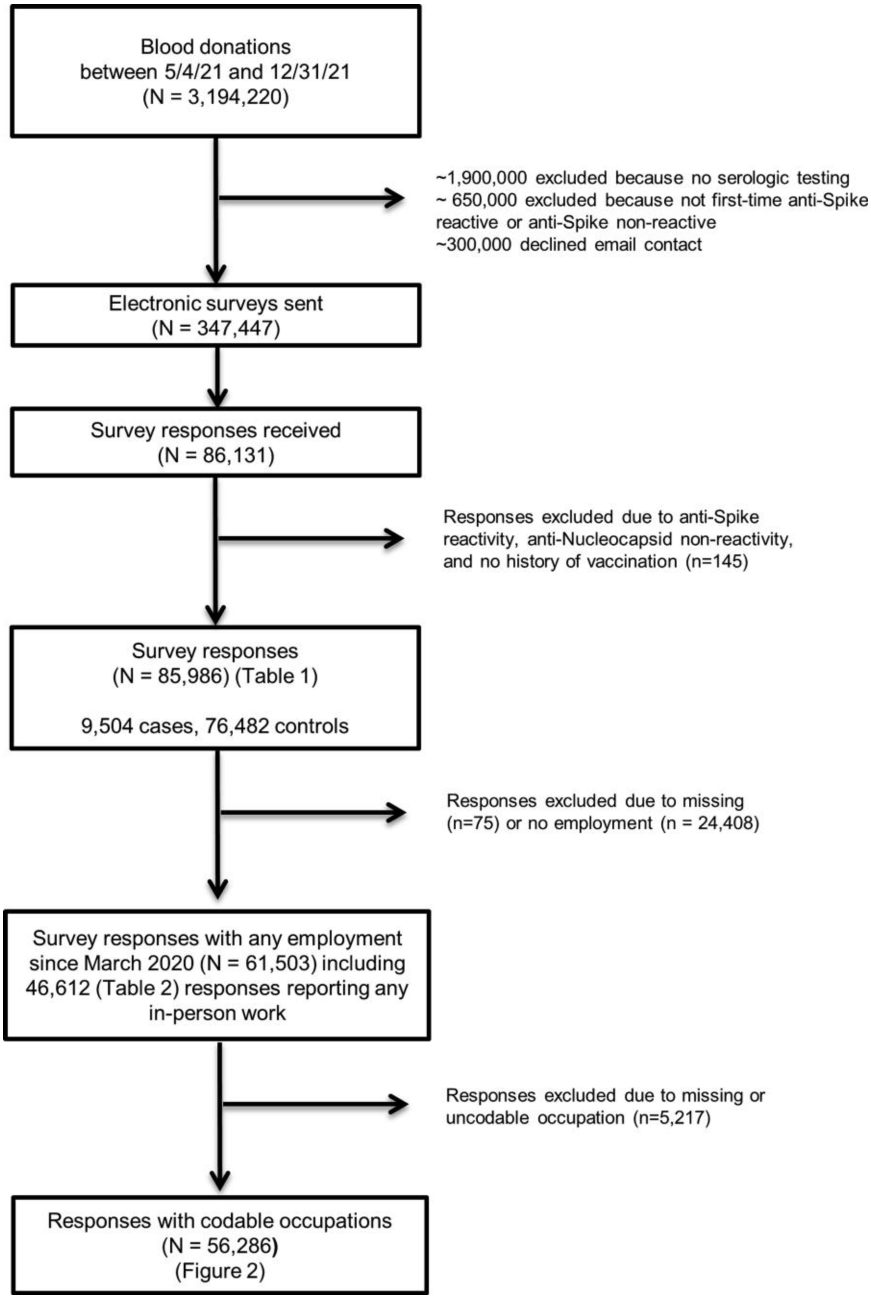

Figure 1. Number of survey responses from American Red Cross blood donors collected and included in the primary analysis.

adjusted analyses; those who teleworked >0% and <25% of the time had an odds of prior infection that was 1.4 times as high as those who teleworked 100% of the time. (Supplementary Table 5). After adjusting for occupation and other covariates, cases were more likely to be non-Hispanic Black (aOR, 1.37; 95% CI, 1.11–1.70) or Hispanic (aOR, 1.54; 95% CI, 1.31–1.81) than controls. Respondents with prior SARS-CoV-2 infection had odds of being unvaccinated that were 16.1 times those of respondents without prior SARS-CoV-2 (Supplementary Table 5).

In a secondary analysis, with occupation and industry classified into 9 essential worker categories based on groupings used for vaccine allocation during phase 1B of the pandemic vaccine rollout [4], the odds of prior SARS-CoV-2 infection compared with non-essential workers were estimated (Supplementary Table 8). Respondents with prior infection were significantly more likely to be healthcare workers (aOR, 1.34; 95% CI, 1.22–1.48), first responders (aOR, 1.50; 95% CI, 1.16–1.95), and education workers (aOR, 1.11; 95% CI, 1.01–1.23) compared with respondents without prior infection (Supplementary Table 9).

Table 1. Demographic Characteristics, Comorbidities, COVID-19 Vaccination, and Employment Status of Blood Donors With and Without Prior SARS-CoV-2 Infection

	Case (n = 9504) n (%)	95% CI	Control (n = 76 482) n (%)	95% CI	Total (n = 85 986) n (%)
Sex					
Female	5897 (62.0%)	61.1–63.0	45 357 (59.3%)	59.0–59.7	51 254 (59.6%)
Male	3607 (38.0%)	37.0–38.9	31 125 (40.7%)	40.3–41.0	34 732 (40.4%)
Age, median (IQR), y	51.0 (39.0–60.0)	—	56.0 (43.0–64.0)	—	55.0 (43.0–63.0)
Age category, y					
18–34	1549 (16.3%)	15.6–17.1	8675 (11.3%)	11.1–11.6	10 224 (11.9%)
35–54	4175 (43.9%)	42.9–44.9	27 043 (35.4%)	35.0–35.7	31 218 (36.3%)
55–74	3619 (38.1%)	37.1–39.1	38 390 (50.2%)	49.8–50.5	42 009 (48.9%)
75+	161 (1.7%)	1.4–2.0	2374 (3.1%)	3.0–3.2	2535 (2.9%)
Race and ethnicity[a]					
Non-Hispanic White	8407 (88.5%)	87.8–89.1	69 163 (90.4%)	90.2–90.6	77 570 (90.2%)
Non-Hispanic Black	226 (2.4%)	2.1–2.7	1475 (1.9%)	1.8–2.0	1701 (2.0%)
Hispanic	483 (5.1%)	4.6–5.5	2307 (3.0%)	2.9–3.1	2790 (3.2%)
Asian	189 (2.0%)	1.7–2.3	2030 (2.7%)	2.5–2.8	2219 (2.6%)
American Indian	31 (0.3%)	.2–0.5	180 (0.2%)	.2–.3	211 (0.2%)
Other	155 (1.6%)	1.4–1.9	1154 (1.5%)	1.4–1.6	1309 (1.5%)
Missing	13 (0.1%)	.1–.2	173 (0.2%)	.2–.3	186 (0.2%)
US Census region					
Midwest	2932 (30.9%)	29.9–31.8	20 103 (26.3%)	26.0–26.6	23 035 (26.8%)
Northeast	1554 (16.4%)	15.6–17.1	17 317 (22.6%)	22.3–22.9	18 871 (21.9%)
South	2570 (27.0%)	26.2–28.0	18 830 (24.6%)	24.3–24.9	21 400 (24.9%)
West	2440 (25.7%)	24.8–26.6	20 191 (26.4%)	26.1–26.7	22 631 (26.3%)
Missing	8 (0.1%)	.0–.2	41 (0.1%)	.0–.1	49 (0.1%)
Highest educational status					
High school graduate or less	849 (8.9%)	8.4–9.5	5190 (6.8%)	6.7–7.0	6039 (7.0%)
Some college	2467 (26.0%)	25.1–26.9	15 832 (20.7%)	20.4–21.0	18 299 (21.3%)
College graduate	3829 (40.3%)	39.3–41.3	30 967 (40.5%)	40.1–40.8	34 796 (40.5%)
Postgraduate degree	1847 (19.4%)	18.6–20.2	21 167 (27.7%)	27.4–28.0	23 014 (26.8%)
Missing	512 (5.4%)	4.9–5.9	3326 (4.3%)	4.2–4.5	3838 (4.5%)
≥1 comorbidity[b]					
Yes	2435 (25.6%)	24.7–26.5	19 814 (25.9%)	25.6–26.2	22 249 (25.9%)
No	6919 (72.8%)	71.9–73.7	55 433 (72.5%)	72.2–72.8	62 352 (72.5%)
Missing	150 (1.6%)	1.3–1.8	1235 (1.6%)	1.5–1.7	1385 (1.6%)
Reported prior COVID-19 diagnosis[c]					
Yes	6031 (63.5%)	62.5–64.4	2243 (2.9%)	2.8–3.1	8274 (9.6%)
No	3374 (35.5%)	34.5–36.5	73 300 (95.8%)	95.7–96.0	76 674 (89.2%)
Missing	99 (1.0%)	.8–1.3	939 (1.2%)	1.2–1.3	1038 (1.2%)
Reported any close contact exposure to SARS-CoV-2					
Yes	5274 (55.5%)	54.5–56.5	16 918 (22.1%)	21.9–22.4	22 192 (25.8%)
No	1889 (19.9%)	19.1–20.7	43 937 (57.4%)	57.1–57.8	45 826 (53.3%)
Unsure	2337 (24.6%)	23.7–25.5	15 602 (20.4%)	20.1–20.7	17 939 (20.9%)
Missing	4 (0.0%)	.0–.1	25 (0.0%)	.0–.0	29 (0.0%)
COVID-19 vaccination status[d]					
Unvaccinated	3315 (34.9%)	33.9–35.8	9995 (13.1%)	12.8–13.3	13 310 (15.5%)
1 dose	155 (1.6)	1.4–1.9	562 (0.7%)	.7–.8	717 (0.8%)
1 dose (Janssen vaccine)	555 (5.8%)	5.4–6.3	5129 (6.7%)	6.5–6.9	5684 (6.6%)
2 doses	4787 (50.4%)	49.4–51.4	54 290 (71.0%)	70.7–71.3	59 077 (68.7%)
3 doses	656 (6.9%)	6.4–7.4	6405 (8.4%)	8.2–8.6	7061 (8.2%)
4 doses	4 (0.0%)	.0–.1	22 (0.0%)	.0–.0	26 (0.0%)
Missing	32 (0.3%)	.2–.5	79 (0.1%)	.1–.1	111 (0.1%)
Employment status					
Any employment since March 2020	7462 (78.5%)	77.7–79.3	54 041 (70.7%)	70.3–71.0	61 503 (71.5%)
No employment since March 2020	2032 (21.4%)	20.6–22.2	22 376 (29.3%)	28.9–29.6	24 408 (28.4%)
Missing	10 (0.1%)	.1–.2	65 (0.1%)	.1–.1	75 (0.1%)

Table 1. Continued

	Case (n = 9504) n (%)	95% CI	Control (n = 76 482) n (%)	95% CI	Total (n = 85 986) n (%)
Telework status among those with employment (n = 61 503)					
Reported % of time teleworking since March 2020, mean (SD)	32.7 (39.7)	—	46.6 (42.9)	—	45.0 (42.7)
0%	2709 (36.3%)	35.2–37.4	14 771 (27.3%)	27.0–27.7	17 480 (28.4%)
>0%–<25%	1308 (17.5%)	16.7–18.4	7790 (14.4%)	14.1–14.7	9098 (14.8%)
25%–<50%	570 (7.6%)	7.0–8.3	3790 (7.0%)	6.8–7.2	4360 (7.1%)
50%–<75%	492 (6.6%)	6.0–7.2	4187 (7.7%)	7.5–8.0	4679 (7.6%)
75%–<100%	836 (11.2%)	10.5–11.9	9217 (17.1%)	16.7–17.4	10 053 (16.3%)
100%	900 (12.1%)	11.3–12.8	11 029 (20.4%)	20.1–20.7	11 929 (19.4%)
Missing	647 (8.7%)	8.0–9.3	3257 (6.0%)	5.8–6.2	3904 (6.3%)

Cases are defined as respondents with anti-nucleocapsid antibody reactivity and controls as respondents without anti-nucleocapsid antibody reactivity from blood donations from May 2021 through December 2021. A total of 145 responses from individuals who were anti-spike reactive, anti-nucleocapsid nonreactive, and with no history of vaccination were excluded from this analysis. Analysis includes 85 775 unique respondents with 211 individuals responding to the survey twice because of seroconversion. For comparison, the US Census Bureau 2020 population estimates are: female 51.3%, ages 18–34 years 30.0%, ages 35–54 years 32.7%, ages 55–74 years 28.7%, ages ≥75 years 8.6%, non-Hispanic White 57.8%, non-Hispanic Black 12.1% (https://data.census.gov/cedsci/table).

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SD, standard deviation.

[a]All categories are non-Hispanic unless otherwise indicated. "Other" refers to self-identification in this category.

[b]Comorbidities include chronic lung disease or severe asthma, cardiovascular disease, high blood pressure, diabetes, or immunocompromising condition.

[c]Prior COVID-19 includes healthcare diagnosis or positive viral, antigen, or antibody test for COVID-19.

[d]Vaccination status represents reported vaccination at the time of survey response (2–6 weeks after blood donation). This does not reflect reclassification of vaccination status based on timing of infection and vaccination done in the multivariable statistical analysis.

Occupation and COVID-19 Vaccination Status

The highest proportion of respondents who were unvaccinated at the time of responding to the survey were in construction and extraction (30.5%), installation, maintenance, and repair occupations (30.4%), and protective service occupations (29.9%) (Supplementary Table 10). The occupations with the highest proportion of fully vaccinated individuals were legal occupations (91.8%), life, physical and social science occupations (92.0%), and computer and mathematical occupations (89.4%) (Supplementary Table 10). Among the 24 408 respondents reporting no employment during the pandemic, 87.8% were fully or partially vaccinated (Supplementary Table 10).

After adjustment for sociodemographic factors (sex, age, month of donation, race and ethnicity, and education level), compared with computer and mathematical occupations, the top 3 occupations with higher odds of not reporting any COVID-19 vaccinations were in protective service (aOR, 3.11; 95% CI, 2.58–3.75), construction and extraction (aOR, 2.97; 95% CI, 2.46–3.58) and installation, maintenance, and repair (aOR, 2.83; 95% CI, 2.35–3.41) (Figure 3, Supplementary Table 11). Compared with computer and mathematical workers, healthcare support workers had increased odds of being unvaccinated (odds ratio, 2.28; 95% CI, 1.86–2.78). Highest educational status was closely associated with vaccination status; those with a high school degree or less had 3.08 times the odds (95% CI, 2.83–3.36) of being unvaccinated compared with those with a postgraduate degree (Supplementary Table 1*F*).

DISCUSSION

Using the largest sample of respondents in the United States with SARS-CoV-2 serology to date, the 3 occupation sectors with the highest proportion of prior infection were those related to healthcare, protective service, and food preparation with prevalence (19%–20%) nearly 3-fold that of subjects reporting computer and mathematical occupations (6.7%). After adjustment for age, sex, race and ethnicity, highest education, vaccination status, and amount of telework, prior SARS-CoV-2 infection remained significantly elevated for healthcare workers, consistent with other studies [14]. Several other occupations, including community and social service, education, legal, and protective service among others had increased adjusted odds for prior infection compared with computer and mathematical occupations.

These findings suggest that occupation remains an important risk factor for SARS-CoV-2 infection, especially for occupations requiring in-person contact, even after controlling for vaccination status and demographic factors. The association of work-related contact and SARS-CoV-2 based on serologic testing has also been reported from the United Kingdom [22]. The association of infection with particular occupations in this analysis suggests that SARS-CoV-2 infection can indeed be an occupational health hazard beyond the risk workers face in their communities [23]. Framing COVID-19 as an occupational health concern can help policymakers and employers navigate COVID-19 vaccination, testing, and other mitigation recommendations in the workplace. This study supports continued efforts to reduce the risk of SARS-CoV-2 infection in healthcare and other occupational settings with demonstrably higher risk.

Although the categorization of "essential workers" is an approximation, those in healthcare, first responders (which includes many protective service workers), and education

Table 2. Occupational Characteristics of Blood Donors With and Without Prior SARS-CoV-2 Infection Reporting any in-Person Employment[a] Since March 2020

	Case (n = 6081) n, %	95% CI	Control (n = 40 531) n, %	95% CI	Total (n = 46 612) n, %
Employee type					
Self-employed	438 (7.2%)	6.6–7.9	2985 (7.4%)	7.1–7.6	3423 (7.3%)
Salaried or hourly employee	5352 (88.0%)	87.2–88.8	35 164 (86.8%)	86.4–87.1	40 516 (86.9%)
Paid by temporary agency	23 (0.4%)	.2–.6	158 (0.4%)	.3–.5	181 (0.4%)
Paid by contractor	42 (0.7%)	.5–.9	304 (0.8%)	.7–.8	346 (0.7%)
Independent contractor, consultant, or freelancer	129 (2.1%)	1.8–2.5	1221 (3.0%)	2.8–3.2	1350 (2.9%)
Other work arrangement	88 (1.4%)	1.2–1.8	611 (1.5%)	1.4–1.6	699 (1.5%)
Missing	9 (0.1%)	.1–.3	88 (0.2%)	.2–.3	97 (0.2%)
Work commute type					
Private vehicle	5780 (95.1%)	94.5–95.6	37 868 (93.4%)	93.2–93.7	43 648 (93.6%)
Shared vehicle with nonhousehold members	59 (1.0%)	.7–1.2	309 (0.8%)	.7–.9	368 (0.8%)
Public transportation	60 (1.0%)	.8–1.3	669 (1.7%)	1.5–1.8	729 (1.6%)
Taxi or ride-sharing	11 (0.2%)	.1–.3	83 (0.2%)	0.2–0.3	94 (0.2%)
Walk/bike	98 (1.6%)	1.3–2.0	1101 (2.7%)	2.6–2.9	1199 (2.6%)
Missing	73 (1.2%)	.9–1.5	501 (1.2%)	1.1–1.3	574 (1.2%)
Workplace mitigation measures					
Any of the following workplace mitigation measures taken	5799 (95.4%)	94.8–95.9	38729 (95.6%)	95.3–95.7	44528 (95.5%)
Masks required	5053 (83.1%)	82.1–84.0	34 706 (85.6%)	85.3–86.0	39 759 (85.3%)
Masks provided	4281 (70.4%)	69.2–71.5	27 727 (68.4%)	68.0–68.9	32 008 (68.7%)
Daily temperature or symptom screening	3335 (54.8%)	53.6–56.1	21 197 (52.3%)	51.8–52.8	24 532 (52.6%)
Implementing safe distancing	4685 (77.0%)	76–78.1	31 682 (78.2%)	77.8–78.6	36 367 (78.0%)
Installing Plexiglass or other barriers	2542 (41.8%)	40.6–43.0	17 016 (42.0%)	41.5–42.5	19 558 (42.0%)
Allowing teleworking	2223 (36.6%)	35.3–37.8	19 151 (47.3%)	46.8–47.7	21 374 (45.9%)
Changing/improving ventilation systems	1055 (17.3%)	16.4–18.3	8248 (20.3%)	20.0–20.7	9303 (20.0%)
Encouraging or providing vaccination	3415 (56.2%)	54.9–57.4	24 160 (59.6%)	59.1–60.1	27 575 (59.2%)
None of these workplace mitigation measures were taken	212 (3.5%)	3.0–4.0	1379 (3.4%)	3.2–3.6	1591 (3.4%)
Missing	70 (1.2%)	.9–1.5	423 (1.0%)	1.0–1.2	493 (1.1%)
Second job with in-person contact					
Yes	1470 (24.2%)	23.1–25.3	8855 (21.8%)	21.4–22.3	10 325 (22.2%)
No	4510 (74.2%)	73.1–75.3	31 146 (76.8%)	76.4–77.3	35 656 (76.5%)
Missing	101 (1.7%)	1.4–2.0	530 (1.3%)	1.2–1.4	631 (1.4%)
Paid sick leave for any illness					
Yes	3120 (51.3%)	50.0–52.6	22 385 (55.2%)	54.2–55.1	25 505 (54.7%)
No	2868 (47.2%)	45.9–48.4	17 426 (43.0%)	42.5–43.5	20 294 (43.5%)
Missing	93 (1.5%)	1.2–1.9	720 (1.8%)	1.7–1.9	813 (1.7%)
Protecting employees from exposure to COVID-19 was high priority with management					
Strongly agree	3217 (52.9%)	51.6–54.2	22 031 (54.4%)	53.9–54.8	25 248 (54.2%)
Agree	1936 (31.8%)	30.7–33.0	12 409 (30.6%)	30.2–31.1	14 345 (30.8%)
Disagree	400 (6.6%)	6.0–7.2	2589 (6.4%)	6.2–6.6	2989 (6.4%)
Strongly disagree	324 (5.3%)	4.8–5.9	1983 (4.9%)	4.7–5.1	2307 (4.9%)
Missing	204 (3.4%)	2.9–3.8	1519 (3.7%)	3.6–3.9	1723 (3.7%)
To what extent do you think your main job affected your risk of getting COVID-19 during the pandemic?					
Decreased risk	755 (12.4%)	11.6–13.3	7600 (18.8%)	18.4–19.1	8355 (17.9%)
No impact	1772 (29.1%)	28.0–30.3	9790 (24.2%)	24.7–24.6	11 562 (24.8%)
Somewhat increased risk	1904 (31.3%)	30.1–32.5	15 239 (37.6%)	37.1–38.1	17 143 (36.8%)
Substantially increased risk	1164 (19.1%)	18.2–20.2	5432 (13.4%)	13.1–13.7	6596 (14.2%)
Missing	486 (8.0%)	7.3–8.7	2470 (6.1%)	5.9–6.3	2956 (6.3%)
In the past month, did most of the people you met at work (coworkers, customers) wear masks?					
Yes	3111 (51.2%)	49.9–52.4	21 526 (53.1%)	52.6–53.6	24 637 (52.9%)
No	2481 (40.8%)	39.6–42.0	15 240 (37.6%)	37.1–38.1	17 721 (38.0%)
No contacts at work in the past month	365 (6.0%)	5.4–6.6	3087 (7.6%)	7.4–7.9	3452 (7.4%)
Missing	124 (2.0%)	1.7–2.4	678 (1.7%)	1.6–1.8	802 (1.7%)

Table 2. Continued

	Case (n = 6081) n, %	95% CI	Control (n = 40 531) n, %	95% CI	Total (n = 46 612) n, %
Any close contact exposure to SARS-CoV-2?					
Yes	3555 (58.5%)	57.2–59.7	11 275 (27.8)	27.3–28.2	14 831 (31.8%)
At work	1418 (39.9%)	38.3–41.5	5990 (53.2%)	52.3–54.2	7408 (50.0%)
Outside of work only	2132 (60.0%)	58.3–61.6	5238 (46.5%)	45.6–47.5	7370 (49.8%)
Missing	5 (0.1%)	.0–0.3	25 (0.2%)	.1–.3	30 (0.2%)
No	1080 (17.8%)	16.8–18.7	20 670 (51.0%)	50.5–51.5	21 750 (46.7%)
Unsure	1443 (23.7%)	22.7–24.8	8596 (21.2%)	20.8–21.6	10 039 (21.5%)
Missing	3 (0.0%)	–0.1	12 (0.0%)	.0–.1	15 (0.0%)

Cases are defined as respondents with anti-nucleocapsid reactivity and controls as respondents without anti-nucleocapsid reactivity from blood donations from May 2021 through December 2021.

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

[a]Table includes respondents reporting any in-person work since March 2020 or specifically in the past 30 days. There were 942 respondents with a missing response to the survey question about any in-person work since March 2020 but reported in-person in a separate question on in-person work during the past 30 days.

workers were more likely to have prior SARS-CoV-2 infection than nonessential workers, consistent with the primary analysis. Other essential worker categories were not shown to be at increased risk for SARS-CoV-2 infection after adjustment. The increased risk for SARS-CoV-2 among healthcare workers compared with nonessential workers was also reported from the United Kingdom [14]; some data suggest more transmission from other healthcare workers rather than patients [24].

Vaccination was the most protective factor against SARS-CoV-2 infection. Unvaccinated respondents were 16 times more likely to have prior infection than fully vaccinated respondents, although this estimate is subject to bias from misclassification of vaccination status. Vaccination status varied significantly by occupation, and education level was highly associated with vaccination status [25]. Additionally, after adjustment for education and demographics, protective service and construction workers were three times as likely to be unvaccinated compared with blood donors in computer and math occupations. Improved communications tailored to occupational groups may help address concerns about vaccination.

This study builds on evidence that the COVID-19 pandemic disproportionately affects certain racial and ethnic groups [7, 26]. In California, Latino workers in the food and agricultural sector and Black workers in the transportation/logistics sectors had significantly higher risk of COVID-19 mortality compared with other racial and ethnic groups [27]. Other studies have suggested racial disparities are partly related to

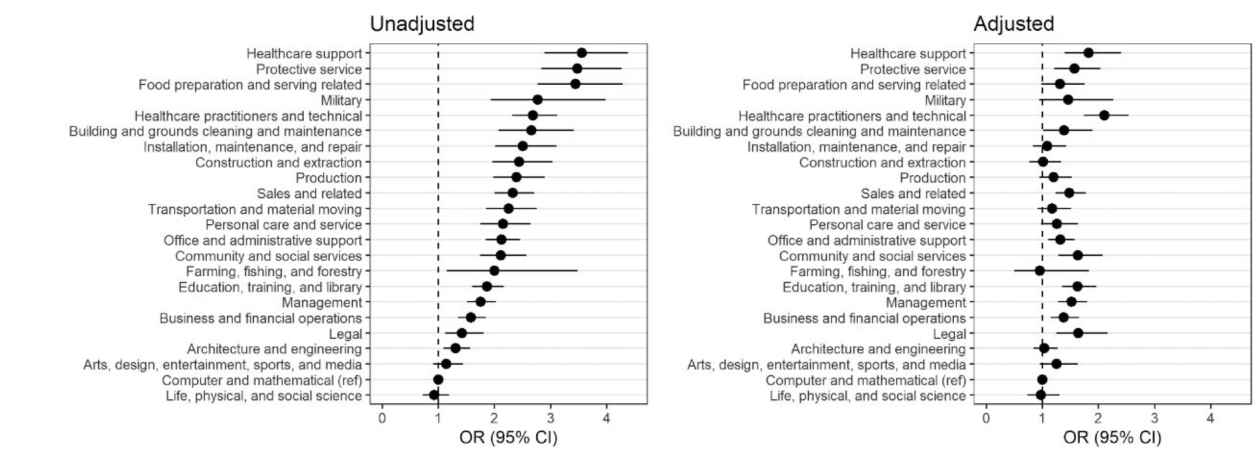

Figure 2. Unadjusted and adjusted odds ratios for occupational risk factors for severe acute respiratory syndrome coronavirus 2 infection-induced antibodies. These categories represent 23 simple occupation groupings developed by the National Center for Health Statistics. The reference category used is computer and mathematical occupations. Covariates include age, sex, race and ethnicity, amount of telework, vaccination, and month of donation. Donor state of residence is included as a random effect. Among 56 286 respondents with a codable occupation, there were 51 264 complete records with no missing data contributing to this analysis. The largest detailed occupation categories under healthcare support occupations category include nursing, psychiatric, and home health aides and medical assistants. The largest detailed occupation under healthcare practitioners and technical category is registered nurses. See Supplementary Appendix Table 11 for detailed descriptions of detailed occupations within each of these occupational categories.

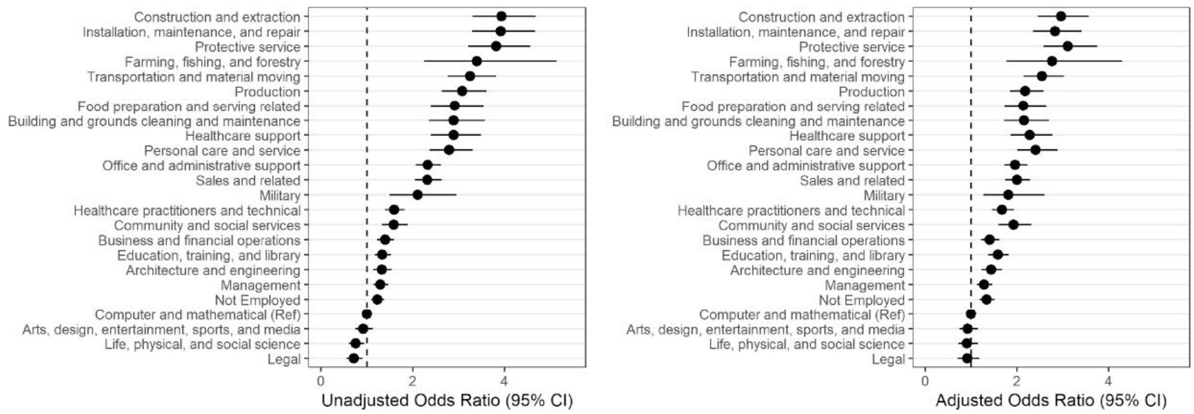

Figure 3. Unadjusted and adjusted odds ratios by occupation for never receiving a coronavirus disease 2019 vaccination. These categories represent 23 simple occupation groupings developed by the National Center for Health Statistics and an additional category for respondents reporting no employment. The reference category used is computer and mathematical occupations. Covariates include age, sex, race and ethnicity, and month of donation. Donor state of residence is included as a random effect. Among 80 694 records, there were 77 523 complete records with no missing data contributing to this analysis. The largest detailed occupation categories under healthcare support occupations category include nursing, psychiatric, and home health aides and medical assistants. The largest detailed occupation under healthcare practitioners and technical category is registered nurses. See Supplementary Appendix Table 11 for detailed descriptions of detailed occupations within each of these occupational categories. CI, confidence interval; OR, odds ratio.

occupational status, and that Black workers were more likely to be employed as "essential workers" in occupations with frequent in-person, high-density contact [26]. After adjusting for occupation and sociodemographic factors in this analysis, racial disparities for having previous SARS-CoV-2 infection persisted among non-Hispanic Black, and Hispanic respondents, suggesting reasons for racial disparities include factors beyond occupation and telework.

There are some limitations to this study. (1) The donor population is not representative of the general US working population [28]. White collar workers, females, and non-Hispanic White persons were overrepresented. The percent of respondents in our study reporting ≥1 COVID-19 vaccine dose, however, was comparable to national estimates from December 2021 [29]. (2) Infection prevention measures, particularly for healthcare workers, changed rapidly during the beginning of the pandemic; occupational risks for infection likely evolved over time [30]. Because of the use of serologic data during a single period, this analysis could not account for those changes over time. (3) The association of vaccination with prior SARS-CoV-2 infection may not be accurately estimated because many vaccinated cases were unaware of having been infected. Some cases were likely infected before vaccination and reclassifying them as unvaccinated would increase the estimated protective effects of the vaccine. (4) A proportion of individuals infected with SARS-CoV-2 may not develop anti-N antibodies, which may cause nondifferential misclassification of cases and controls [31]. (5) Serologic testing is a proxy for prior infection and may have missed some infections (∼5%–10%) [32], although antibodies tested by these assays do not have significant waning over time [17, 18, 33]. (6) Multiple exposures/infections and comprehensive factors affecting community transmission were not captured. (7) The 25% response rate may introduce bias, but such bias is likely nondifferential in terms of serologic and occupational status [34].

This study supports the conclusion that COVID-19 is associated with occupational risks. The need to protect workers in public-facing occupations and healthcare, in particular, remains important. These data can be valuable for informing mitigation interventions including future vaccine recommendations and outlining workplace risks to workers. The primary analysis and detailed Supplementary material can be a resource to public and private policymakers on the risk of SARS-CoV-2 infection, to prepare for and respond to future outbreaks of SARS-CoV-2 variants and other respiratory viruses.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Disclaimer. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention (CDC).

Financial support. The CDC funded this work reported by S. L. S. and B. R. S.

Potential conflicts of interest. S. S. reports grants or contracts from US Food and Drug Administration (FDA; TTIMS and Advance Study) unrelated to this work. B. S. reports grants or contracts from REDS-IV subcontract (support from the National Heart, Lung, and Blood Institute [NHLBI]) unrelated to this work. J. M. H. reports grants or contract from FDA (TTIMS) and NHLBI (REDS-IV). All other authors report no potential conflicts. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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