SARS-CoV-2 Seroprevalence among Healthcare, First Response, and Public Safety Personnel, Detroit Metropolitan Area, Michigan, USA, May–June 2020

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To estimate seroprevalence of severe acute respiratory syndrome 2 (SARS-CoV-2) among healthcare, first response, and public safety personnel, antibody testing was conducted in emergency medical service agencies and 27 hospitals in the Detroit, Michigan, USA, metropolitan area during May–June 2020. Of 16,403 participants, 6.9% had SARS-CoV-2 antibodies. In adjusted analyses, seropositivity was associated with exposure to SARS-CoV-2–positive household members (adjusted odds ratio [aOR] 6.18, 95% CI 4.81–7.93) and working within 15 km of Detroit (aOR 5.60, 95% CI 3.98–7.89). Nurse assistants (aOR 1.88, 95% CI 1.24–2.83) and nurses (aOR 1.52, 95% CI 1.18–1.95) had higher likelihood of seropositivity than physicians. Working in a hospital emergency department increased the likelihood of seropositivity (aOR 1.16, 95% CI 1.002–1.35). Consistently using N95 respirators (aOR 0.83, 95% CI 0.72–0.95) and surgical facemasks (aOR 0.86, 95% CI 0.75–0.98) decreased the likelihood of seropositivity.

Healthcare, first response (e.g., firefighters, paramedics, emergency medical technicians), and public safety (e.g., law enforcement officers) personnel have served on the front lines of the coronavirus disease (COVID-19) pandemic response in several capacities. Many of these occupations require intensive interaction with persons with suspected or confirmed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. Both reverse transcription PCR (RT-PCR) testing for SARS-CoV-2 and assessing COVID-19 symptoms could be used to determine infection status, but not all infected persons develop symptoms or are tested within the necessary time window. Measuring antibodies to SARS-CoV-2 is necessary to inform our understanding of viral transmission dynamics in high-risk situations (*1*).

The Centers for Disease Control and Prevention (CDC) collaborated with the Michigan Department of Health and Human Services (MDHHS) Region 2 South and North Healthcare Coalitions to invite personnel working onsite in hospital, first response, and public safety settings to be tested for SARS-CoV-2 antibodies and to complete a web-based survey about workplace, occupation, use of personal protective equipment (PPE), and selected exposures. The primary study objective was to estimate the prevalence of SARS-CoV-2 antibodies among this population. A second objective was to describe associations between seroprevalence and participant and workplace characteristics.

Methods

The MDHHS Region 2 South Healthcare Coalition area is the most populous region in Michigan and comprises Monroe, Washtenaw, and Wayne (including the city of Detroit) Counties. MDDHS Region 2 North Healthcare Coalition includes Macomb, Oakland, and St. Clair Counties. The Healthcare Coalitions coordinated with 27 hospitals and 7 MDHHS Medical Control Authorities (MCAs), which supervise and

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coordinate an emergency medical services (EMS) system for a geographic region, to invite employees to participate. The protocol was reviewed by CDC human subjects research officials, who determined the activity to be public health surveillance and exempt from full institutional review board review (*2*).

Study Participants

Eligible participants for the serology survey included adults ≥18 years of age who worked onsite in a first response, hospital, or public safety setting and consented to phlebotomy and serum sample storage for confirmation of test results if needed. Persons were not eligible to participate if, in the 2 weeks before taking the survey, they reported having new symptoms of cough, shortness of breath, or change in sense of taste or smell, or had tested positive for SARS-CoV-2 by RT-PCR test using a nasal, throat, or saliva sample.

Web-Based Survey

Participating agencies shared information about the secure web-based survey (Appendix Table 1, https://wwwnc.cdc.gov/EID/article/26/12/20-3764-App1.pdf) with employees using email and onsite marketing. There was no face-to-face recruitment. Participation was voluntary and individual results were not shared with employers. CDC did not have access to personal identifiers. The survey was drafted by the investigators, reviewed by CDC subject matter experts, and was designed to require <10 minutes to complete on a personal device. Upon survey completion, participants received information about blood collection sites at their workplace or a nearby MCA location.

Specimen Collection and Testing

Blood samples were collected for SARS-CoV-2 antibody testing during May 18–June 13, 2020. Antibody testing was performed using the Ortho Clinical Diagnostics VITROS Immunodiagnostic Products Anti-SARS-CoV-2 IgG Test (https://www.orthoclinicaldiagnostics.com; specificity 100%, sensitivity 90%) (*3*). Results were reported to participants within 72 hours as negative (signal-to-cutoff ratio <1.0), positive (signal-to-cutoff ratio ≥1.0), or test not performed because of lipemia or insufficient volume.

Statistical Analysis

Of 16,403 participants, 6 (0.04%) had samples that were unable to be tested and were excluded (n = 16,397). Percent SARS-CoV-2 antibody positivity and 95% CIs were calculated. Statistical testing was conducted using Cochran-Armitage trend tests for variables with ordinal categories (2-sided tests with $\alpha = 0.05$). Non-Hispanic Native Hawaiian and other Pacific Islander (n = 31, 0.2%), Non-Hispanic American Indian/Alaska Native (n = 53, 0.3%), and other race (n = 320, 2.0%) participants were categorized as other race. The 398 (2.4%) participants who declined to report race were categorized separately and included in all analyses.

Participants could choose multiple work locations; 17.5% chose >1 location. Each work location category was represented as a separate dichotomous variable (i.e., dummy variable) to enable modeling of non–mutually exclusive categories. Participants were provided with occupation categories and a free text option. The National Institute for Occupational Safety and Health (NIOSH) assisted with coding free-text responses using the NIOSH Industry and Occupation Computerized Coding System (*4*). No categories created from free-text options reached high sample size (n<100) and were coded as "other" except for technicians (e.g., dialysis, telemetry, surgery), which were combined into a "clinical technician" category (n = 365).

Exposure to persons with confirmed COVID-19 (co-worker, household member, patient, and other person) was defined as contact within 6 feet for >10 minutes, but the question did not mention PPE use, which was assessed in separate questions. PPE use was dichotomized for each piece of equipment into "use all the time" (the recommended, or optimal, frequency when PPE is required) versus all other choices. Similarly, exposure to persons with confirmed COVID-19 was dichotomized into "yes" versus all other choices.

Differences between categories were assessed by nonoverlapping 95% CIs for percent positivity. Two participants were excluded from adjusted analyses (1 participant with missing housing information and 1 participant from a nonstudy hospital; n = 16,395). To account for clustering of participants by facility/agency, generalized estimating equations were used to model the likelihood of seropositivity. Covariates were chosen a priori to represent risk of exposure and infection. Model diagnostics performed with regression analysis did not show evidence of collinearity for work location (highest values for variance inflation factor = 1.4, and condition index = 4.1), which was represented by non–mutually exclusive dummy variables entered simultaneously into the multivariable model. No interaction terms were explored. SAS 9.4 software (https://www.sas.com) was used for all analyses. ArcGIS (ESRI, https://www.esri.com) was used to map seroprevalence by agency location.

Results

Of 16,397 participants, 6.9% (95% CI 6.5%–7.3%) were positive for SARS-CoV-2 IgG, indicating previous infection. In contrast, 2.7% (95% CI 2.5%–3.0%) reported having previously tested positive by RT-PCR using a nasal, throat, or saliva sample. Participant age ranged from 19 to 82 years (mean 42.1, SD 12.2). Seroprevalence was lower among those ≥65 years of age (3.2% of the sample; seroprevalence 3.5%, 95% CI 2.1%–5.4%) compared with all younger age groups (Table 1). Women, 68.6% of participants, had a similar seroprevalence to men. Non-Hispanic Black participants made up 7.3% of the sample and had the highest seroprevalence (16.3%, 95% CI 14.2%–18.5%) compared with other race/ethnic groups, including Non-Hispanic White participants (6.0%, 95% CI 5.6%–6.4%), who made up 78.4% of the sample. Seroprevalence among participants by facility ranged from 0.5% to 17.9% and was inversely related to distance of the facility from the Detroit geographic center. Seroprevalence was highest (11.0%, 95% CI 10.3%–11.7%) among participants at facilities within 15 km of Detroit's center and lowest (1.8%, 95% CI 1.4%–2.2%) at locations 30–55 km away (Figure 1). Higher seroprevalence with closer proximity to Detroit was observed among most participants, regardless of occupation and healthcare setting (Appendix Figure 1). Among participants who reported close contact (within 6 feet) with a person with confirmed COVID-19 for ≥10 minutes, seroprevalence was highest among those with exposure to a household member (34.3%, 95% CI 30.2%–38.6%). Participants living in multiunit housing had higher seroprevalence compared with those living in single-family housing (8.4%, 95% CI 7.2%–9.8% vs. 6.7%, 95% CI 6.3%–7.1%).

By work location, seroprevalence was highest among participants who worked in hospital wards (8.8%, 95% CI 8.0%–9.7%) and lowest among those working in police departments (3.9%, 95% CI 2.5%–5.8%) (Table 2). Within hospitals, lower seroprevalence was found among persons working in intensive care units (ICUs; 6.1%) and operating rooms or surgical units (4.5%) compared with participants working in wards (8.8%) and emergency departments (EDs; 8.1%). By occupation, the highest

Table 1. Seropositivity for SARS-CoV-2 among healthcare, first response, and public safety personnel, by demographic characteristics, Detroit metropolitan area, Michigan, USA, May–June 2020*

Characteristics	No. (%)	% Seropositive (95% CI)
Total	16,397 (100.0)	6.9 (6.5–7.3)
Age group, y†		
18–24	686 (4.2)	7.9 (6.0–10.2)
25–34	4,885 (29.8)	6.9 (6.2–7.6)
35–44	3,977 (24.3)	7.0 (6.2–7.9)
45–59	5,222 (31.9)	6.9 (6.2–7.6)
60–64	1,106 (6.8)	7.5 (6.0–9.2)
≥65	521 (3.2)	3.5 (2.1–5.4)
Sex		
M	5,146 (31.4)	6.7 (6.0–10.2)
F	11,251 (68.6)	7.0 (6.5–7.5)
Race/ethnicity		
Non-Hispanic White	12,858 (78.4)	6.0 (5.6–6.4)
Non-Hispanic Black	1,200 (7.3)	16.3 (14.2–18.5)
Non-Hispanic Asian	1,097 (6.7)	7.3 (5.8–9.0)
Hispanic	440 (2.7)	6.8 (4.7–9.6)
Other‡	404 (2.5)	7.2 (4.9–10.2)
Declined to answer	398 (2.4)	7.0 (4.7–10.0)
Distance of work agency/facility from Detroit centroid		
<15 km	7,194 (43.9)	11.0 (10.3–11.7)
15–30 km	4,677 (28.5)	5.5 (4.9–6.2)
31–55 km	4,526 (27.6)	1.8 (1.4–2.2)
Exposure to persons testing positive for COVID-19§		
Co-worker	6,799 (41.5)	10.0 (9.3–10.8)
Household member	519 (3.2)	34.3 (30.2–38.6)
Patient	10,389 (63.4)	7.8 (7.3–8.3)
Other person	2,709 (16.5)	11.5 (10.3–12.7)
Housing		
Multi-unit	1,762 (10.8)	8.4 (7.2–9.8)
Single family	14,634 (89.3)	6.7 (6.3–7.11)

*COVID-19, coronavirus disease; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.
†Test for trend in seropositivity statistically significant at $\alpha = 0.05$.
‡Other race/ethnicity includes non-Hispanic Native Hawaiian and other Pacific Islander, non-Hispanic American Indian and Alaska Native, and participants who indicated other race.
§Categories are not mutually exclusive.

Figure 1. Seropositivity for SARS-CoV-2 among healthcare, first response, and public safety personnel, by hospital and Medical Control Authority agency location, Detroit metropolitan area, Michigan, USA, May–June 2020. Centroid: Detroit city center. Mean SARS-CoV-2 seroprevalence within 15 km was 11.0% (red), 15–30 km, 5.5% (orange), and 31–55 km, 1.8% (yellow). Base map source: ESRI ArcGIS map for Province of Ontario and Oakland County, Michigan (https://www.esri.com). SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

seroprevalence was found among nurse assistants (12.8%) and physical therapists (10.6%) and the lowest among laboratory technicians (3.4%) and police officers (4.0%). Seroprevalence also varied by hospital-based work locations and occupation (Figure 2). Among participants working on hospital wards, the lower bound of the 95% CI for seropositivity was higher than overall seroprevalence (6.9%) for nurse assistants (13.6%, 95% CI 10.2%–17.5%), administration/clerks (11.9%, 95% CI 7.0%–18.5%), respiratory therapists (10.8%, 95% CI 7.1%–15.6%), and nurses (9.8%, 95% CI 8.5%–11.2%). Nurse assistants who worked in an "other hospital location" (15.9%, 95% CI 8.2%–26.7%) and nurses who worked in EDs (9.9%, 95% CI 8.3%–11.7%) had similarly elevated seroprevalence.

Other occupational risk factors are included in the Appendix. Participants reported the average number of times per shift since March 1, 2020, in which they had participated in aerosol-generating procedures (Appendix Figure 2) and were given a list of examples for reference (Appendix Table 1). Seroprevalence generally increased with increasing procedure frequency ($p = 0.04$ by test for trend), with the highest percent positivity among those who participated in such procedures >25 times per shift on average (9.1%, 95% CI 7.4%–11.0%). Participants also reported how frequently they used each component of PPE, using a Likert scale. Overall, there was no pattern seen in percent antibody positivity with frequency of use with any PPE component (Appendix Table 2). Among those reporting ideal frequency of use ("all the time") for a specific PPE component, seroprevalence was similar to the overall seroprevalence (Table 2).

Multivariable adjustment using generalized estimating equations was performed (Figure 3; Appendix Table 3). Factors most strongly associated with likelihood of seropositivity were exposure to a household member with confirmed COVID-19 (adjusted odds ratio [aOR] 6.18, 95% CI 4.81–7.93) and working within 15 km of the Detroit center (aOR 5.60, 95% CI 3.98–7.89 compared with 30–55 km). Compared with physicians, occupations more likely to be seropositive included nurse assistant (aOR 1.88, 95% CI 1.24–2.83) and nurse (aOR 1.52, 95% CI 1.18–1.95). Working in a hospital ED was the sole location with increased adjusted odds of seropositivity (aOR 1.16, 95% CI 1.00–1.35). Consistently wearing an N95 respirator (aOR 0.83, 95% CI 0.72–0.95) or surgical facemask (vs. using them less than "all the time") lowered the likelihood of being seropositive (aOR 0.86, 95% CI 0.75–0.98).

Discussion

Healthcare, first response, and public safety personnel in 27 hospitals and 7 MCA areas were surveyed

in the Detroit metropolitan area. Among these facilities, seroprevalence of SARS-CoV-2 IgG ranged from 0.5% to 17.9%, indicating wide variation in seroprevalence. A major role for community acquisition of SARS-CoV-2 infection is suggested by the strong association between seropositivity and working closer to the Detroit center and exposure to a household member with confirmed COVID-19. Workers remain vulnerable at home, where social distancing and PPE use may be difficult and likelihood of exposure during presymptomatic or asymptomatic periods is high. Similar patterns have been found in other studies of healthcare worker infections, in which community or household exposure to persons who tested positive for SARS-CoV-2 was the primary predictor of seroconversion (*5*,*6*). The geographic distribution of seroprevalence among first responders in this study was related to population-based cumulative case reporting in Michigan through April 30, 2020: higher percentage positivity for RT-PCR testing was reported for counties near the Detroit center (Oakland, Macomb, and Wayne [0.48%–1.04%]) versus lower levels for the outlying counties (Washtenaw, St. Clair, and Monroe [0.22%–0.32%]) (*7*).

Although 6.9% of participants were seropositive, only 2.7% reported a history of a positive RT-PCR test. This finding of higher seroprevalence compared with confirmed active infection is similar to other serology surveys of the general population (*8*–*10*). A study by Havers et al. estimated 6–24 times as many infections as the number of reported cases detected by RT-PCR (*8*). Our study revealed ≈2.5 times more infections than cases based on self-reported RT-PCR results. The 2.7% positivity for RT-PCR may be higher in the healthcare and first responder population compared with the general public (which ranged from 0.22% to 1.04% in the

Table 2. Seropositivity for SARS-CoV-2 among healthcare, first response, and public safety personnel, by work location, occupation, and PPE use, Detroit metropolitan area, Michigan, USA, May–June 2020*

Characteristic	No. (%)	% Seropositive (95% CI)
Work location		
Hospital emergency department	3,614 (22.0)	8.1 (7.2–9.0)
Hospital ward	4,766 (29.1)	8.8 (8.0–9.7)
Hospital intensive care unit	3,973 (24.2)	6.1 (5.3–6.9)
Hospital operating room/surgical	2,661 (16.2)	4.5 (3.7–5.3)
Other hospital location	3,260 (19.9)	6.1 (5.3–7.0)
Emergency medical services	550 (3.4)	5.3 (3.6–7.5)
Fire services	1,008 (6.2)	5.0 (3.7–6.5)
Police department	615 (3.8)	(2.5–5.8)
Occupation		
Administration/clerk	964 (5.9)	8.0 (6.4–9.9)
Clinical technician†	365 (2.2)	5.5 (3.4–8.3)
EMT/medical first responder/paramedic‡	1,158 (7.1)	5.2 (4.0–6.6)
Firefighter§	330 (2.0)	6.7 (4.2–9.9)
Imaging technician	719 (4.4)	4.2 (2.8–5.9)
Laboratory technician	293 (1.8)	3.4 (1.7– 6.2)
Midlevel clinician	566 (3.5)	4.6 (3.0–6.7)
Nurse	6,426 (39.2)	7.7 (7.1–8.4)
Nurse assistant	641 (3.9)	12.8 (10.3–15.6)
Other¶	688 (4.2)	6.8 (5.1–9.0)
Other health#	200 (4.6)	7.5 (4.3–12.1)
Pharmacist	321 (2.0)	4.4 (2.4–7.2)
Physical therapist	235 (1.4)	10.6 (7.0–15.3)
Physician	2,297 (14.0)	6.1 (5.1–7.1)
Police/corrections officer	785 (4.8)	4.0 (2.7–5.6)
Respiratory therapist	409 (2.5)	8.3 (5.8–11.4)
PPE		
Gown use all the time	9,316 (56.8)	6.9 (6.4–7.5)
Glove use all the time	11,887 (72.5)	7.0 (6.5–7.5)
N95 respirator use all the time	7,316 (44.6)	6.9 (6.3–7.5)
PAPR use all the time	695 (4.2)	7.6 (5.8–9.9)
Goggles/face shield all the time	6,581 (40.1)	6.5 (5.9–7.1)
Surgical facemask all the time	9,452 (57.6)	6.6 (6.1–7.1)

*Work location categories are not mutually exclusive: 17.2% of participants reported ≥1 workplace. EMT, emergency medical technician; PAPR, powered air purifying respirator; PPE, personal protective equipment; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.
†Includes dialysis, telemetry, cardiovascular, extracorporeal membrane oxygenation (ECMO), respiratory, emergency/critical care, anesthesia, endoscopy, orthopedic, surgical, neurodiagnostic, urology, audiology, and radiation technicians.
‡Includes firefighter/medical first responder.
§Includes fire inspector and fire marshal.
¶Includes dietary staff, environmental staff, social worker/chaplain, maintenance staff, supervisor.
#Includes dentist, medical examiner, orderly, phlebotomist, therapy aide, trainee.

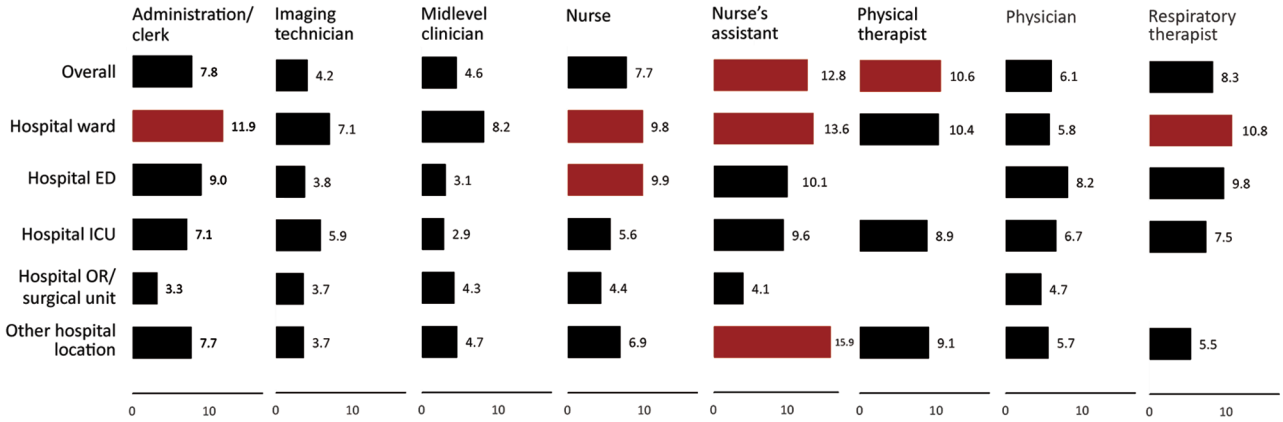

Figure 2. Seropositivity for SARS-CoV-2 among healthcare personnel by selected occupation and hospital work location, Detroit metropolitan area, Michigan, USA, May–June 2020. Red bars: lower 95% CI for percent positive is >6.9% (overall percent positive). Other hospital locations are all other locations not specifically listed in the chart (e.g., radiology, laboratory). Estimates not shown for categories with sample size <25 participants. ED, emergency department; ICU, intensive care unit; OR, operating room; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

6 Michigan counties) as a result of targeted and repeated testing of personnel in hospitals and emergency medical services settings (*11*). Even so, surveillance of these occupational groups in Detroit based on self-reported RT-PCR testing results would have identified a minority of infections.

Healthcare workers are known to be at occupational risk for SARS-CoV-2 exposure (*12*). Participants in occupations that may involve frequent and prolonged patient contact, such as nurse assistants and nurses (*13*,*14*), were more likely to be seropositive than physicians. Multivariable analysis revealed a weak association between lower seropositivity and consistent use of N95 respirators and surgical facemasks. Lower seroprevalence was observed among participants who reported high use of PPE despite shortages and reuse/extension protocols that could be hypothesized to lower the observed effectiveness of PPE. These and other confounding factors may obscure the role PPE plays in preventing infection, and it may be necessary to account for multiple factors in studies assessing the effect of PPE. The lower likelihood of seroprevalence associated with working in the controlled environments of a hospital ICU or surgical ward may reflect the impact of additional mitigation measures, including clear identification of infected persons and environmental and engineering controls (*15*). This pattern of lower seropositivity among staff in higher-risk versus lower-risk hospital settings has been described previously (*16*). However, even within healthcare work settings, some workers such as nurse assistants had a higher risk of infection than those in other roles. This finding highlights the concern that certain occupations may require additional focus on assessing and controlling factors related to transmission.

Together, these analyses of community and workplace factors show the contribution of community acquired infection to seropositivity among Detroit area healthcare workers. For 3 hospital settings (hospital ward, ED, and ICU) that could be compared across healthcare occupations, seropositivity rose with closer proximity of the facility to the Detroit center. This pattern suggests that regardless of occupation or work location, community acquisition was a common underlying factor of infection risk. There are 2 related implications. First, the observed impact of PPE may be reduced given the background impact of community acquisition of SARS-CoV-2 infection. Second, reducing community spread through population-based measures may directly protect healthcare workers on 2 fronts: reduced occupational exposure as a result of fewer infected patients in the less controlled workplace settings such as the ED, and reduced exposure in their homes and communities.

After adjusting for other factors, we found that women were less likely than men to be seropositive. This pattern was seen only in adjusted analysis; women's lower risk may have been obscured by their disproportionate representation in the occupations at higher risk of infection. Women represented 69% of the sample but made up 86% of those in nursing and nurse assistance.

Participants ≥65 years of age were less likely to be infected than younger workers. This pattern may be the result of measures to protect older workers

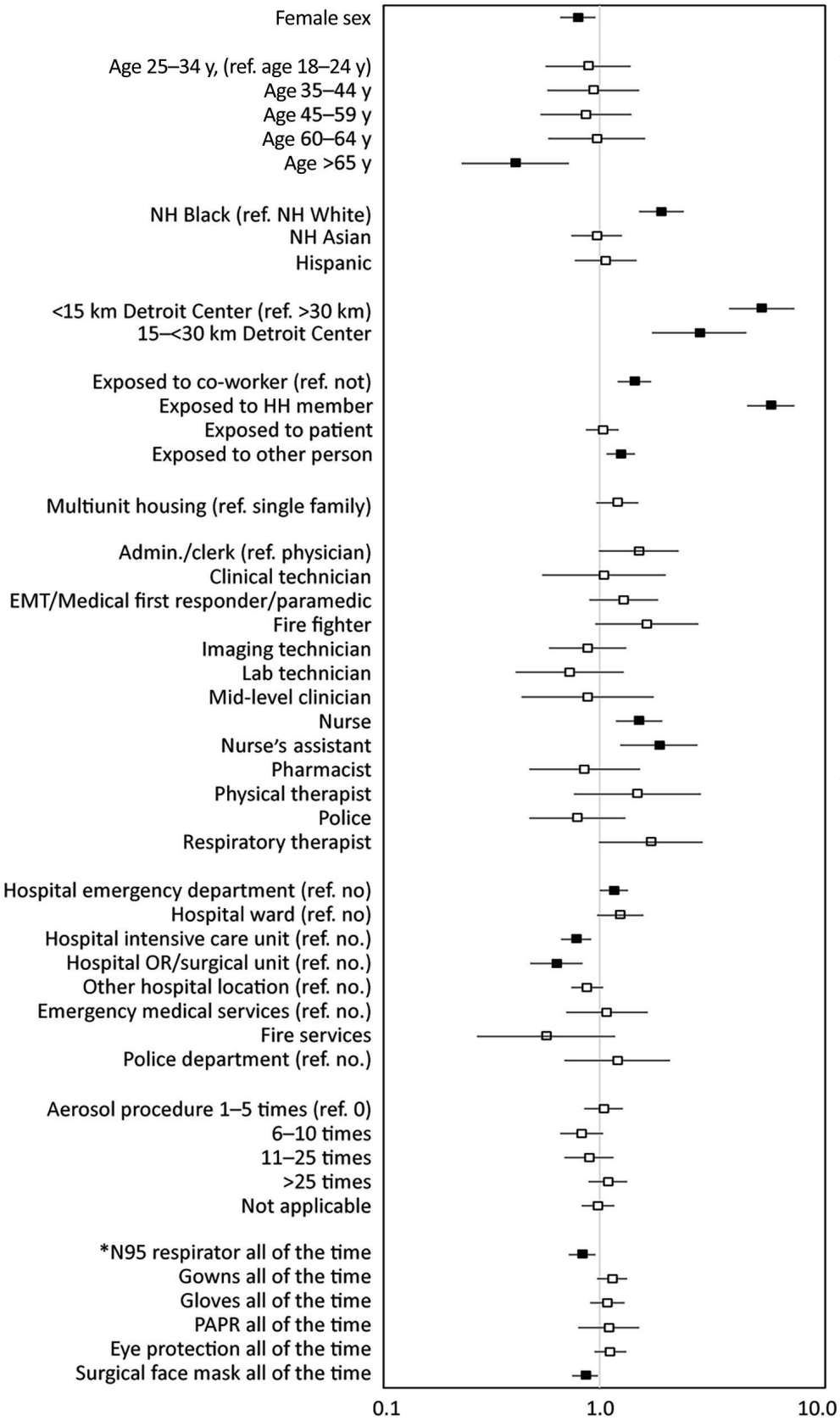

Figure 3. Adjusted odds ratios and 95% CIs for seropositivity for SARS-CoV-2 among healthcare, first response, and public safety personnel, Detroit metropolitan area, Michigan, USA, May–June 2020. Adjusted model was estimated using generalized estimating equations including all variables shown. Participants with other occupations, of other race/ethnicity, or who declined to provide their race/ethnicity are included in the models, but not shown as separate categories. Workplace variables are not mutually exclusive. Reference categories are noted in parentheses for each section. ED, emergency department; EMT, emergency medical technician; HH, household; Med 1st resp, medical first responder; NH, non-Hispanic; PAPR, powered air-purifying respirator; ref., reference; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2. *Reference groups for personal protective equipment variables are all other responses with less frequency than "all the time."

from high-risk situations or from greater precautions taken among this group. A population study that also observed lower seroconversion among older persons found that older persons were less likely to live with a household contact (*17*). Seroconversion may also diminish with age in general (*17*), although other studies showed no pattern by age or higher seroprevalence among older persons (*18*,*19*). Participants of non-Hispanic Black race/ethnicity remained more likely to be seropositive than non-Hispanic white participants, even after adjustment. Community-level surveillance of COVID-19 infection and SARS-CoV-2 infection has demonstrated overrepresentation of minority groups in population-adjusted analyses (*20*,*21*). One hypothesis for the higher risk of infection among Black and Hispanic persons is employment in jobs without possibility of working remotely (*22*). Unfortunately, the survey did not collect information about occupation and workplace of household members. We speculate that the higher risk of exposure/infection among non-Hispanic Black versus non-Hispanic White participants in our study likely reflects uncontrolled confounding by factors for which data were not available.

Some limitations must be considered. The survey was a convenience sample with unknown representativeness: 80% of the 20,650 employees anticipated by MCA and hospital contacts to be eligible participated but agency participation varied, with highest participation among hospital personnel. The cross-sectional design precluded determining the source of exposure. In addition, comprehensive exposure data (e.g., travel, commuting, social exposures) were not collected. Because of the limited questionnaire length, PPE questions did not probe donning and doffing training, participant familiarity with PPE use, or reuse or extension protocols that may have affected effectiveness (*11*). No additional questions were asked about other workplace infection control practices. Another potential source of bias is the healthy worker effect, in which persons with prolonged COVID-19 infection or sequelae would not have been onsite to participate. Seroprevalence may be underestimated, given that the sensitivity of the antibody test was less than 100%. It is also possible that participants who were infected did not seroconvert (*23*; F. Gallais et al., unpub. data, https://www.medrxiv.org/content/10.1101/2020.06.21.20132449v1), but it is unknown whether lack of seroconversion may have occurred systematically between occupations (e.g., those exposed more intensely or with more severe illness may be more likely to develop antibodies) (*24*). Although more recent infections may have not been detected, it is unlikely that this varied systematically across groups. Strengths included coverage of a large number of personnel at hospitals and first response/public safety facilities and pairing antibody testing with questionnaire data to enable focus on a high-risk population.

Key implications for the risk of SARS-CoV-2 infection among healthcare, first response, and public safety personnel include the impact of community acquisition, increased odds of exposure associated with specific healthcare occupations, and the protection provided by PPE. Effects of interventions that could be further studied and implemented include providing alternative housing to healthcare workers during times or in areas of high community prevalence and ensuring that workers in high-risk occupations are given adequate PPE, specifically N95 respirators and surgical facemasks, as well as infection control training.

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SARS-CoV-2 Seroprevalence among Healthcare, First Response, and Public Safety Personnel, Detroit Metropolitan Area, Michigan, USA, May–June 2020

Appendix

Appendix Table 1. Survey questionnaire administered to healthcare, first response, and public safety personnel, Detroit metropolitan area, May–June 2020

Question number	Questionnaire item	Response categories
1.	Name (not provided to CDC)	First Last
2.	Home address (not provided to CDC)	Street City State Zip
3.1	Phone number (mobile) (not provided to CDC)	Area code, phone number
3.2	Verify phone number (mobile) (not provided to CDC)	Area code, phone number
4.1	Email address (not provided to CDC)	(fill)
4.2	Verify email address (not provided to CDC)	(fill)
5.	County/borough of workplace	[scroll] (jurisdictions to provide list) Other (fill)
6.	Date of birth (not provided to CDC)	MM/DD/YYYY
7.1	Sex at birth	Male Female
7.2	Current gender (not provided to CDC)	Man Woman Transgender man/trans man/female-to-male (FTM) Transgender woman/trans woman/male-to-female (MTF) Genderqueer/gender nonconforming neither exclusively male nor female Other (fill) Decline to answer
8.	Sexual orientation (not provided to CDC)	Gay Straight Bisexual Something else/not sure Decline to answer
9.	Are you Hispanic or Latino/Latina?	Yes No Don't know Decline to answer
10.	What is your race? (select all that apply)	White Black/African American Asian American Indian or Alaska Native Native Hawaiian or other Pacific Islander Other Decline to answer
10A	Please select your age group	18–29 years 30–39 years 40–49 years 50–59 years

Question number	Questionnaire item	Response categories
		60–64 years 65–69 years 70 years or older
11.1	What is your occupation?	Nurse (e.g., RN, APRN, LPN) Midlevel clinician (e.g., PA, NP, nurse-midwife) Nurse assistant (e.g., CNA) Physician (e.g., MD, DO) Student or trainee Medical examiner Mortuary technician Police officer Firefighter Paramedic Emergency medical technician Medical first responder Corrections officer or corrections staff Respiratory therapist Occupational/physical/speech therapist Therapy aide/assistant Pharmacist, pharmacist assistant Diagnostic imagining technologist/technician Clinical laboratory technologist/technician Phlebotomist Social worker/case manager Administration, clerk Medical records specialist/medical registrar Dietary services staff Environmental services staff Maintenance staff Orderly/transportation staff Security guard
12.1	What is your main workplace or work setting? (select all that apply) (skip question 12.2 if non-hospital response)	Emergency department Hospital ward/floor Hospital ICU Other hospital location Fire station/department Police station/department Correctional facility Medical examiner office Other (fill)
12.2	What hospital do you work at?	[scroll] (jurisdictions to provide list) Other (fill)
13.1	Since March 1st, how many weeks have you worked in this setting?	Weeks (scroll) [min of 1, max of 20]
13.2	Since March 1st, on average, how many shifts did you work per week in this setting?	Shifts (fill) [min of 1, max of 14]
13.3	Since March 1st, on average, how many hours did you work per shift?	Hours (scroll) [min of 1, max of 24]
15.1	In the course of your work, how often did you use personal protective equipment (PPE) when within 6 feet of a person with suspected or confirmed COVID-19? All the time Most of the time Sometimes Rarely/never Not applicable	Gown (Go to Q 18)
15.2		Gloves (Go to Q 18)
15.3		N95 respirator (Go to Q 16)
15.4		Powered air purifying respirator (PAPR) (Go to Q 17)
15.5		Goggles or face shield (Go to Q 18)
15.6		Surgical facemask (Go to Q 18)
15.7		Other respirator (Go to Q 18)
16.	In the last year, have you been fit tested for the respirator you wore?	Yes No Don't know

Question number	Questionnaire item	Response categories
17.	In the last year, have you been trained to use the respirator you wore?	Yes No Don't know
18.	Since March 1, on average, how many times per shift did you participate in any aerosol-generating procedures for suspected or confirmed COVID-19 patient(s)? Examples: Open suctioning of airways Sputum induction Cardiopulmonary resuscitation Endotracheal intubation and extubation Noninvasive ventilation (e.g., BiPAP, CPAP) Bronchoscopy Manual ventilation	More than 25 times 10–25 times 6–10 times 1–5 times 0 Not applicable
19.1	Did you spend more than 10 minutes within 6 feet of a coworker who tested positive for COVID-19?	Yes No Don't know
19.2	Did you spend more than 10 minutes within 6 feet of a household member who tested positive for COVID-19?	Yes No Don't know
19.3	Did you spend more than 10 minutes within 6 feet of any other person who tested positive for COVID-19?	Yes No Don't know
20	How many times were you tested for COVID-19? (nasal, throat, or saliva sample)	(scroll) [indicate 0 if none] (if 0 Go to 23.1)
21.	Have you ever had a positive result for COVID-19?	Yes No Don't know
22.	Approximately, when was the last time you were tested for COVID-19 in 2020 (excluding blood testing for exposure to SARS-CoV-2)?	MM/DD Don't know
23.1	Since March 1, have you experienced any of the following symptoms?	Fever
		Chills
		Cough (new onset or worsening of chronic cough)
		Sore throat
		Shortness of breath or difficulty breathing
		Vomiting
		Diarrhea (≥3 looser than normal stools/24hr period)
		Muscle aches
		New loss in sense of smell or taste
		Headache (new onset or worsening headache)
		Other (fill)
24.	When did these symptoms start? (estimate as best as possible)	MM/DD Don't know
25.	Did you seek healthcare for these symptoms?	Yes No Don't know
26.	Were you hospitalized for COVID-19 illness?	Yes No Don't know
27.	Do you live in a single-family home or multi-unit housing (like an apartment)?	Single family Multi-unit Other (fill)
28.	Number of household members currently in the residence including yourself (resident, family, live-in staff, roommates, and long-term visitors)	Specify (scroll)
29.	What is your height?	Feet Inches
30.	What is your weight?	Weight in pounds
31.1	Do you have any of the following chronic medical conditions?	Diabetes
		Hypertension (high blood pressure)
		Chronic heart disease

Question number	Questionnaire item	Response categories
		Chronic kidney disease
		Chronic liver disease
		Asthma
		COPD/emphysema/chronic bronchitis
		Immunosuppressive condition (e.g., HIV, autoimmune disease)
		Immune-weakening medication or therapy (e.g., cancer treatment)
32.	Since March 1, have you been or are you currently pregnant? (only when sex at birth is female)	Yes No Don't know

Appendix Table 2. Percent seropositive for SARS-CoV-2 among healthcare, first response, and public safety personnel, by frequency of personal protective equipment (PPE) use, Detroit metropolitan area, May–June 2020

PPE	Use	No.	Percentage	Percent seropositive	p value*
Gowns	All the time	9,316	56.8	6.9	0.12
	Most of the time	3,335	20.3	7.6	
	Sometimes	1,285	7.8	6.0	
	Rarely or never	1,935	11.8	5.9	
	Not applicable	526	3.2	7.2	
Gloves	All the time	11,887	72.5	7.0	0.47
	Most of the time	2,150	13.1	6.7	
	Sometimes	1,171	7.1	6.8	
	Rarely or never	865	5.3	6.4	
	Not applicable	324	2.0	5.6	
N95 respirator	All the time	7,316	44.6	6.9	0.14
	Most of the time	3,537	21.6	7.8	
	Sometimes	2,252	13.7	6.8	
	Rarely or never	2,574	15.7	5.9	
	Not applicable	718	4.4	6.0	
Powered air-purifying respirator	All the time	695	4.2	7.6	0.77
	Most of the time	449	2.7	4.5	
	Sometimes	1,149	7.0	7.6	
	Rarely or never	11,560	70.5	6.7	
	Not applicable	2,544	15.5	7.5	
Goggles or face shield	All the time	6,581	40.1	6.5	0.43
	Most of the time	4,046	24.7	7.3	
	Sometimes	2,091	12.8	7.9	
	Rarely or never	2,919	17.8	6.5	
	Not applicable	760	4.6	6.8	
Surgical facemask	All the time	9,452	57.6	6.6	0.99
	Most of the time	2,901	17.7	8.1	
	Sometimes	1,756	10.7	8.3	
	Rarely or never	1,801	11.0	5.4	
	Not applicable	487	3.0	5.8	

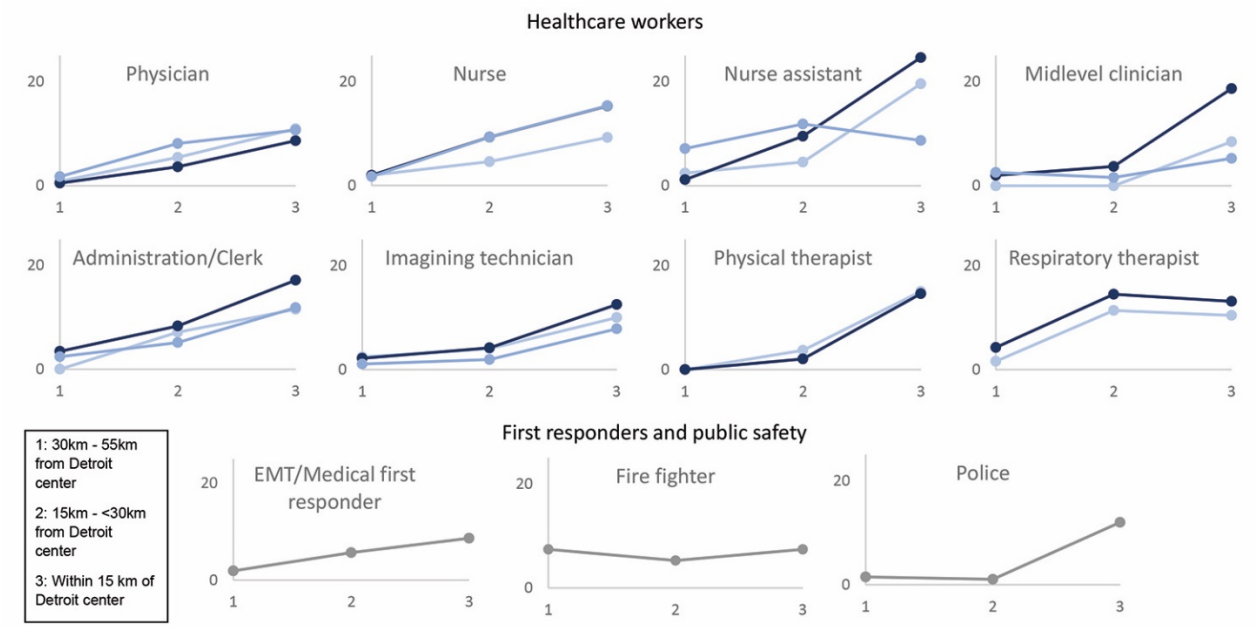
*Cochran-Armitage trend test, omitting the "not applicable" category.

Appendix Table 3. Adjusted odds ratios and 95% confidence intervals for seropositivity for SARS-CoV2 among healthcare, first response, and public safety personnel, Detroit metropolitan area, May–June 2020*

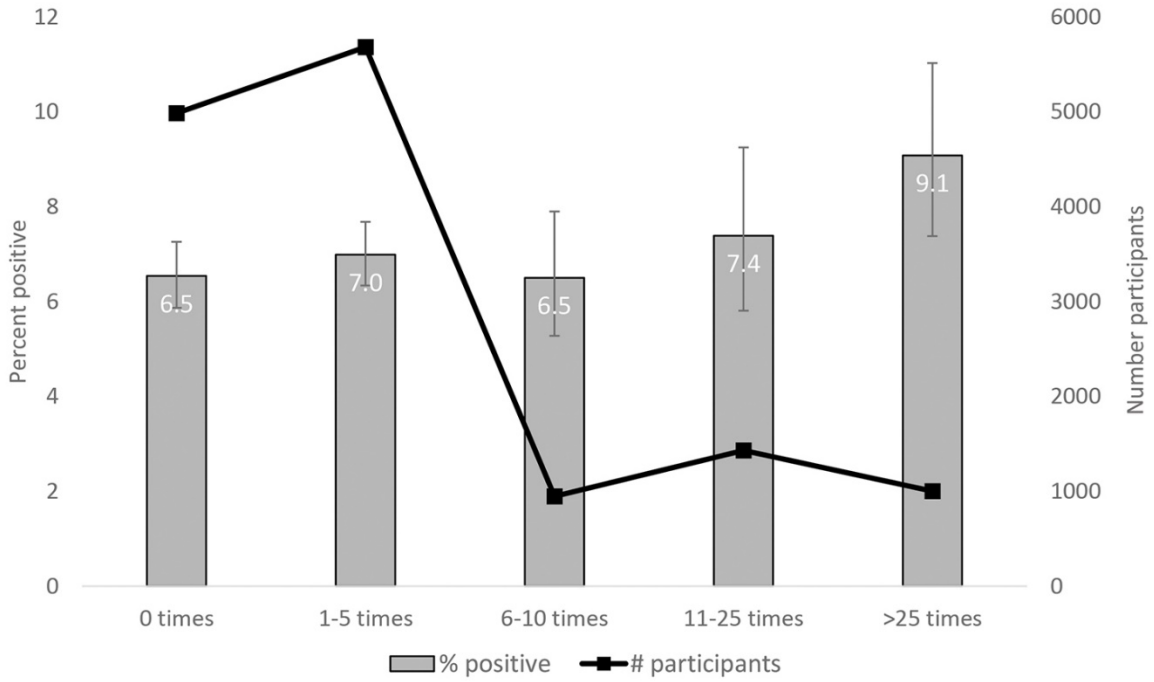
N = 16,395	Odds ratio	95% LCI	95% UCI
Sex			
Men	ref		
Women	**0.79**	**0.65**	**0.95**
Age group, years			
18–24	ref		
25–34	0.89	0.56	1.39
35–44	0.93	0.57	1.52
45–59	0.86	0.53	1.40
60–64	0.97	0.58	1.62
≥65	**0.41**	**0.23**	**0.72**
Race/ethnicity			
Non-Hispanic white	ref		
Non-Hispanic Black	**1.92**	**1.52**	**2.43**
Non-Hispanic Asian	0.97	0.74	1.26
Hispanic	1.06	0.76	1.48
Other	0.95	0.67	1.35
Decline	0.98	0.69	1.41

N = 16,395	Odds ratio	95% LCI	95% UCI
Distance of workplace from Detroit center			
<15 km from Detroit center	**5.60**	**3.98**	**7.89**
15–30 km from Detroit center	**2.88**	**1.74**	**4.77**
31–55 km from Detroit center	ref		
Exposure to COVID-19 (ref = no or unknown exposure)			
Co-worker	**1.45**	**1.21**	**1.73**
Household member	**6.18**	**4.81**	**7.93**
Patient	1.03	0.87	1.22
Other person	**1.25**	**1.08**	**1.45**
Housing			
Single family	ref		
Multi-unit	1.20	0.96	1.50
Occupation			
Physician	ref		
Administration/clerk	1.51	0.99	2.31
Clinical technician	1.04	0.54	2.02
EMT/medical first responder/paramedic	1.29	0.90	1.85
Firefighter	1.65	0.95	2.84
Imaging technician	0.88	0.58	1.33
Lab technician	0.73	0.41	1.29
Midlevel clinician	0.88	0.44	1.77
Nurse	**1.52**	**1.18**	**1.95**
Nurse assistant	**1.88**	**1.24**	**2.83**
Other	1.19	0.84	1.70
Other health occupation	1.19	0.63	2.25
Pharmacist	0.85	0.47	1.53
Physical therapist	1.49	0.76	2.92
Police	0.79	0.47	1.31
Respiratory therapist	1.72	0.99	2.99
Workplace (ref = did not work in specified workplace)†			
Hospital emergency department	**1.16**	**1.00**	**1.35**
Hospital ward	1.24	0.97	1.58
Hospital intensive care unit	**0.78**	**0.66**	**0.91**
Hospital operating room/surgical unit	**0.63**	**0.48**	**0.83**
Other hospital location	0.87	0.74	1.03
Emergency medical services	1.08	0.70	1.66
Fire services	0.56	0.27	1.18
Police department	1.20	0.69	2.10
Aerosol-generating procedure frequency			
0 times	ref		
1–5 times	1.04	0.85	1.28
6–10 times	0.83	0.66	1.04
11–25 times	0.89	0.69	1.16
>25 times	1.09	0.89	1.34
Not applicable	0.98	0.83	1.17
Personal protective equipment use frequency			
N95 respirator all the time	**0.83**	**0.72**	**0.95**
Gowns all the time	1.14	0.97	1.34
Gloves all the time	1.09	0.90	1.30
PAPR all the time	1.10	0.80	1.52
Eye protection all the time	1.12	0.94	1.32
Surgical facemask all the time	**0.86**	**0.75**	**0.98**

*Adjusted model estimated using generalized estimating equations including all variables shown. Bolded estimates are statistically significant. EMT, emergency medical technician; LCI, lower confidence interval; PAPR, powered air-purifying respirator; UCI, upper confidence interval.
†Workplace not mutually exclusive.



Appendix Figure 1. Percent seropositive by proximity to Detroit geographic center, by selected occupation and hospital workplace among healthcare personnel, and selected occupation among first response and public safety personnel, Detroit metropolitan area, May–June 2020.



Appendix Figure 2. Percent seropositive with 95% confidence interval and number of participants by average number of aerosol-generating procedures per shift among healthcare, first response, and public safety personnel, Detroit metropolitan area, May–June 2020 (n = 14,047). Excludes participants who reported "not applicable" (n = 2,350). Cochran-Armitage test trend p = 0.037 for percent positive.