

Seroprevalence of SARS-CoV-2 Among Firefighters/Paramedics in San Francisco, CA

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Objectives: Despite having close contact with the general public, members of the San Francisco Fire Department (SFFD) reported relatively few cases of COVID-19 during the first half of 2020. Our objective was to explore evidence for prior undetected infections by conducting a seroprevalence survey, and to document both risk and protective factors for prior COVID-19 infection. **Methods:** This cross-sectional study assessed workplace practices and exposures of SFFD personnel during the first 6 months of 2020 via questionnaire and documented prior COVID-19 infections by serologic antibody testing using an orthogonal testing protocol. **Results:** Of 1231 participating emergency responders, three (0.25%) had confirmed positive COVID-19 antibody results. **Conclusions:** Safe workplace practices, community public health intervention, and low community infection rates appear to have been protective factors for emergency responders in San Francisco during our study period.

Keywords: coronavirus, emergency responders, firefighters, occupations, paramedics, personal protective equipment, respiratory protective devices, seroepidemiologic studies

BACKGROUND

The Pandemic

The first cases of infection with the SARS-CoV-2 virus (COVID-19) were identified in the San Francisco Bay area on January 31, 2020. Since then, the City and County of San Francisco (CCSF) has reported fewer cases per capita compared with other regions in the United States and California. As of December 31, 2021, California as a whole had recorded 5614 cases of COVID-19 per 100,000 residents, whereas CCSF has reported 2903 cases per 100,000.^{1,2} Emergency responders such as firefighters, emergency medical technicians (EMTs) and paramedics have served the public, during medical and non-medical calls, throughout the pandemic. Despite having close contact with the general public (including potential work-related exposure to individuals with COVID-19 infection), members of the San Francisco Fire Department (SFFD) had reported no cases of COVID-19 at the time this study was proposed (late April 2020).

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The authors have no conflicts of interest to disclose.

Ethical Considerations: UCSF IRB #20-31090. Consent completed using REDCap and on paper in accordance with IRB approved process.

Clinical Significance: This study gives insight into the effectiveness of implementing protective workplace practices for emergency responders in response to the COVID pandemic and understanding of incidence of prior COVID-19 infection among emergency responders in a major US city during the first half of 2020.

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Emergency Responders At-Risk

First responders, such as firefighters, EMTs, and paramedics, are at the frontlines in the fight against SARS-CoV-2. They play a critical role in responding to patient calls, triaging patients, providing medical care, and transporting ill or injured patients in often uncontrolled, unpredictable, and possibly hazardous environments. Despite their similarities of potential exposures, more epidemiologic studies of COVID infection have been conducted among institutional health care providers (HCPs) than first responders. For example, a study conducted in the United Kingdom and the United States by Nguyen et al,³ reported that frontline HCPs who provided direct patient care had at least a threefold increased risk of reporting a positive COVID-19 test and manifesting symptomatic COVID-19 infection, compared with the general population. In addition, Black, Asian, and minority ethnic HCPs had at least a fivefold increased risk of COVID-19 infection compared with the non-Hispanic White general population. More research is needed to document whether first responders are similarly at increased risk of infection based on their work-related exposures.

The CCSF, through its Department of Public Health (SFDPH), took early and aggressive action to contain the spread of COVID-19. In a high-profile move to protect both civic workers and the general public, a shelter-in-place order was issued effective March 17, 2020.⁴ Within the SFFD, COVID-related precautions had begun by late January (a month-and-a-half prior to this announcement), and included enhanced use of personal protective equipment (PPE) and increased social distancing, as detailed in the Discussion Section, below. Precautions initially focused on SFFD personnel (firefighters and paramedics) interactions with persons under investigation for COVID-19 (“PUI”) but were broadened on April 3, 2020 to include all medical runs and all interactions with the public.⁵ The SFFD medical department, having received no reports of active COVID infection among departmental personnel as of late Spring of 2020, wished to explore evidence for prior undetected infections by conducting a seroprevalence survey. To this end, SFFD contacted the Division of Occupational and Environmental Medicine (DOEM) at the University of California, San Francisco (UCSF) in April of 2020 to perform a collaborative study to investigate the seroprevalence of antibodies to SARS-CoV-2 among members of the SFFD.

STUDY AIMS

Our objective was to conduct a collaborative, cross-sectional study of both uniformed and non-uniformed SFFD personnel, documenting both risk and protective factors for prior COVID-19 infection. The study period covered January to June of 2020. A priori explanatory variables included potential exposures (including at-work, in the general community, and at-home), risk mitigation measures (use of PPE and other health-related behaviors), and any prior testing for active COVID disease. The a priori outcome variable was serologic status for anti-SARS-CoV-2 antibodies in an analysis of venous blood collected on each participant in late June to early July 2020.

METHODS

Target Population

During the study period, the SFFD had 1854 employees with 1771 “uniformed employees” and 83 “civilians,” or administrative personnel. Uniformed employees included 810 firefighters, 392 firefighter/paramedics, and 61 per diem paramedics, supervising officers, and inspectors.

Inclusion Criteria

All active personnel of the municipal fire department in San Francisco, CA were invited to participate in this study. “Active” was defined as having been employed for at least three shifts since January 1, 2020 and status as a current employee (ie, not retired or otherwise separated from service).

Exclusion Criteria

There were no formal exclusion criteria. Participants were screened for symptoms of COVID-19 and had their temperature checked upon arrival at the testing site (this would have acted as a *de facto* exclusion criterion—as would have a positive preshift symptom screen).

Recruitment

SFFD personnel were invited by study personnel to participate voluntarily via email to their department email address, as well as via emails sent by the local union leadership and member groups (ie, United Fire Service Women, a women’s group within the SFFD). Flyers with study information were also posted in all fire stations and office buildings.

Consent

A SFFD password-controlled website included a link to the consent form. All study materials were approved by the UCSF Committee on Human Research. Online informed consent was collected through REDCap,⁶ with a few participants completing on-site paper consent. Enrollment opened on June 5, 2020 and closed on July 2, 2020.

Questionnaire

After consent and prior to venipuncture, participants completed a study questionnaire. The questionnaire was collected through REDCap, and in a few cases, on-site in hardcopy format. The questionnaire included demographic information, including date of birth, sex, and race/ethnicity. Occupational information collected included job title, approximate date of hire, and primary and additional station assignments since January 1, 2020. Information was also solicited on self-identified exposure to SARS-CoV-2 on the job through contact with the public, coworkers, or family. Those who reported encounters with a COVID-19 positive patient at work were also asked about their PPE use during suspected exposures.

In addition to eliciting a description of exposure incident-related PPE, the questionnaire asked separately about routine use of PPE: (1) on medical versus non-medical calls, and (2) before versus after March 18, 2020. The rationale for this repetitive structure was to determine whether time (pre- vs post- “shelter in place” order), or circumstance (medical vs non-medical run) influenced PPE use. We hypothesized a priori that the level and frequency of routine PPE would be greater post-shelter-in-place, as well as with medical runs.

Prior COVID-19 testing results by reverse transcription-polymerase chain reaction (RT-PCR) were also solicited, including date and location, when applicable.

Venipuncture Sampling

Venipuncture was performed at the SFFD Division of Training, with social distancing, mask-wearing, frequent hand

and surface sanitizing, and safety protocols in place. Participants were able to have their venipuncture sample collected either on-duty or off-duty. Assignment for crews to report for testing was coordinated by SFFD leadership. Those at headquarters or other office locations were able to report for testing either during their workday or before their workday. Testing took place between June 15 and July 2, 2020.

Serologic Analysis

Serology testing was performed using a chemiluminescent microparticle immunoassay to screen for Immunoglobulin G (IgG) antibodies in plasma directed against the nucleocapsid protein of SARS-CoV-2 (Abbott Laboratories, ARCHITECT i2000SR analyzer).⁷ Because the prevalence of antibodies in the general population of the San Francisco area was considered to be very low at less than 1%,⁸ an orthogonal testing algorithm was followed to reduce the probability of false positive results.⁹ Specifically, all samples testing positive in the Abbott assay were subjected to confirmatory testing in an independent chemiluminescent immunoassay for IgG antibodies in plasma directed against the S1 or S2 domains of the spike protein SARS-CoV-2 (Diasorin Inc., LIAISON XL Analyzer).¹⁰ Samples testing positive in both the Abbott assay and Diasorin assay were classified as true positive results. Samples testing positive in the Abbott assay and negative in the Diasorin assay were classified as false positive results.

Results and Information Sharing

Individual serologic results were shared with participants through REDCap, and members were alerted to available results by email and/or text message. Individuals with a positive result (including both “true positive” results and “false positive” results) were contacted by phone, to provide the opportunity for discussing result interpretation. At the conclusion of testing and preliminary data analysis, a webinar explaining the aggregate results was given by the study team to the entire SFFD workforce.

RESULTS

Of 1854 potential subjects contacted, a total of 1231 (66.4%) completed all phases of the study, including consent, questionnaire, and venipuncture. Demographic characteristics of participants and non-participants are listed in the Table 1. Comparing the two groups, non-participants were, on average, older by about 1 year, although there were no statistically significant differences between participants and non-participants in sex or years of service. Paramedics, firefighter/paramedics, and Lieutenants were more likely to participate than were EMTs and EMT/paramedics.

A total of 238 subjects reported having previously obtained RT-PCR testing for SARS-CoV-2, either under the auspices of work or independently. Of these, one (who was seronegative in this study) reported having been informed of a positive PCR result. (The relative timing of the serology test and PCR for this case is not known.)

Of the 1231 subjects who completed all phases of the study, 10 were considered “positive” for anti-nucleocapsid antibody using the Abbott assay alone. Further confirmatory testing with the Diasorin assay for anti-spike protein antibody yielded three subjects who were “confirmed positives,” based on concordant test results for the two assays.

Self-reported routine use of PPE followed predicted patterns, with a higher level of protection during medical versus non-medical public runs (both pre- and post-shelter-in-place), as well as an increased level of protection after the March 17 shelter-in-place order (Figs. 1 and 2). On non-medical runs approximately 40% of respondents reported wearing “no PPE” prior to the shelter-in-place order, which dropped to 10% after the order (Fig. 1). Use of respiratory protection increased significantly on medical and non-medical runs, with both surgical mask and N-95 wear

TABLE 1. Demographics of Participants and Non-Participants

Characteristic	Participants		Non-Participants	
	Mean (SD)	Range	Mean (SD)	Range
Age, yrs	44.09 (9.48)	21–68	42.85 (9.37)	22–70
Years of service	12.35 (9.09)	0–51	11.94 (9.40)	0–44
	Participants		Non-Participants	
	N (%)		N (%)	
Gender				
Female	178 (14.6)		79 (14.6)	
Male	1019 (85.4)		461 (85.4)	
Non-binary or prefer to self-describe	10 (0)		0 (0)	
Race				
American Indian or Alaska Native	20 (1.5)		1 (0.2)	
Asian	261 (19.2)		87 (15.9)	
Black or African American	107 (7.9)		60 (11)	
Native Hawaiian or Other Pacific Islander	60 (4.4)		10 (1.8)	
White	715 (52.7)		283 (51.8)	
Latino	194 (14.3)		105 (19.2)	
Job title				
Firefighter	569 (47.1)		243 (45)	
Firefighter/Paramedic	122 (10)		8 (1.5)	
EMT/Paramedic	176 (14.6)		167 (30.9)	
Fireboat	3 (0.3)		4 (0.7)	
Inspector	30 (2.5)		11 (2)	
Investigator	5 (0.4)		3 (0.6)	
Training, Community Service, Incident Support	14 (1.2)		3 (0.6)	
Lieutenant	158 (13.1)		50 (9.3)	
Captain	91 (7.5)		34 (6.3)	
Chief	40 (3.3)		16 (3)	

quadrupling on non-medical runs post-shelter in place, and N-95 wear tripling on medical runs. Similarly, use of eye protection more than doubled on both types of runs, and use of disposable gowns increased more than threefold.

Self-reported use of PPE during runs involving suspected or confirmed COVID-19 patients was collected in free-form text and coded for use of “no PPE,” surgical mask, N95 respirator, eye protection, gloves, and gown. Of the 574 participants who reported contact with a confirmed or suspected COVID-19 patient, 526 provided further information on their PPE use. Of these, 91.4% reported wearing a surgical mask or N95 (with 65% specifically reporting use of an N95 respirator), 81.5% reported use of eye protection, and 57.9% wore a gown. Six participants reported no PPE use. Of these, five described circumstances where PPE use was not feasible, such as during a surf rescue.

DISCUSSION

Seroprevalence Comparisons

Community seroprevalence in the San Francisco Bay area was found to be about 1% in late April 2020.¹¹ Our study found seroprevalence of 0.24% among SFFD members in late June 2020. Although local-regional factors such as variation in rates of infection may have contributed, members of the SFFD live across the entirety of the San Francisco Bay area and some commute from other states. Although addresses of participants were collected, the survey was not formatted to require city and state. This prevented us from collecting complete information about where participants reside. Among participants with complete address information collected in our survey, a majority of participants live within 50 miles of CCSF (86%), and seven participants listed out-of-state addresses (three in Oregon, two in Idaho, one in Arizona, one in Washington). Based on survey responses showing very high implementation of protective work practices, these practices may have contributed to a level of infection lower than that of the surrounding community during the time period of this study.

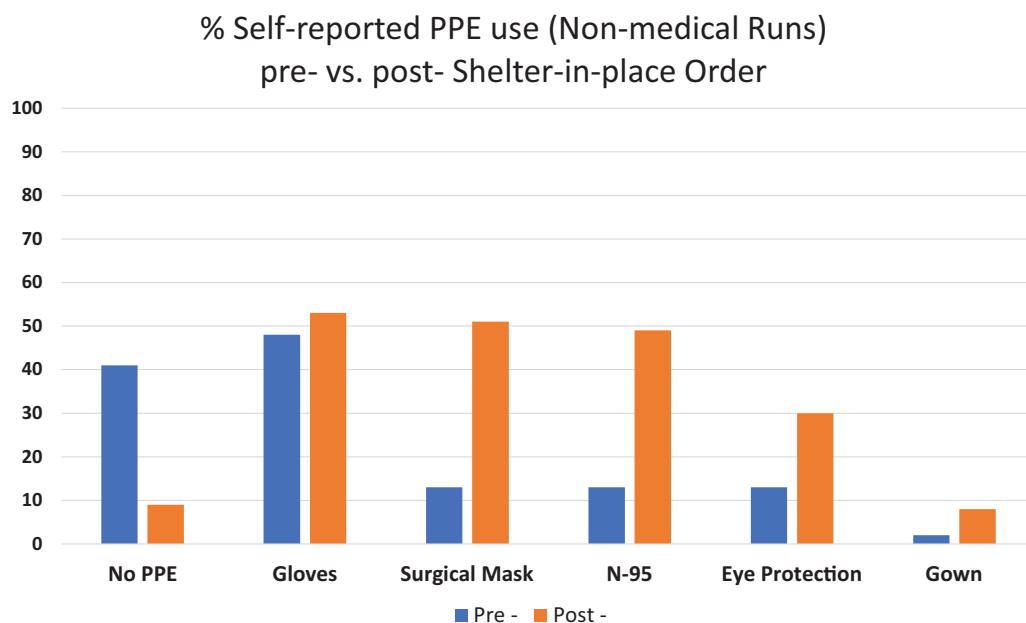


FIGURE 1. Self-reported PPE use on non-medical runs. Use of individual PPE measures increased significantly after the CCSF shelter-in-place order ($P < 0.0001$ for surgical mask, N-95, eye protection, gown; $P < 0.05$ for gloves). Self-reported use of “no PPE” decreased significantly ($P < 0.0001$). CCSF, City and County of San Francisco; PPE, personal protective equipment.

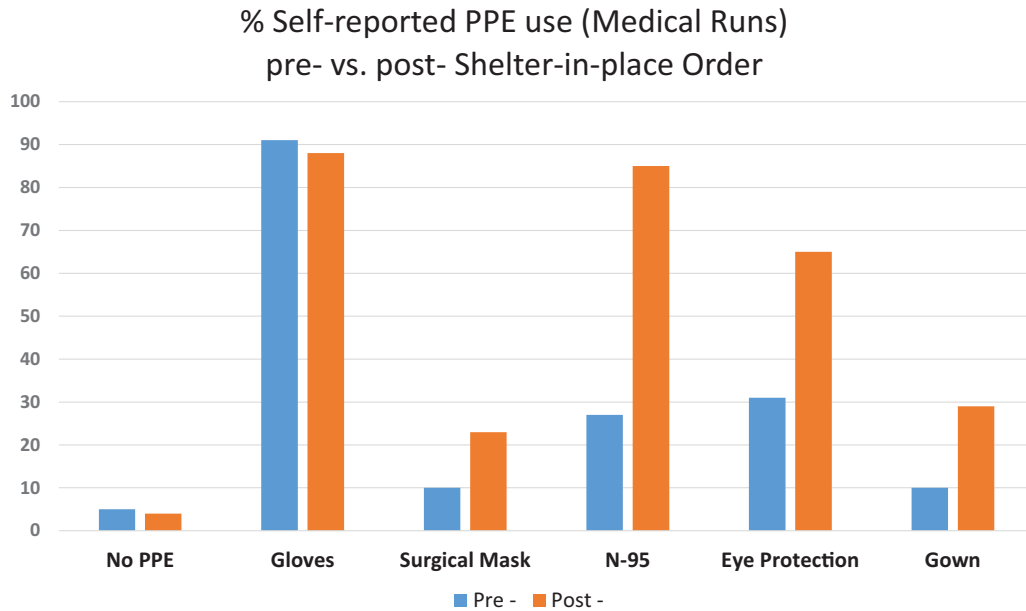


FIGURE 2. Self-reported PPE use on medical runs. Use of individual PPE measures increased significantly after the CCSF shelter-in-place order ($P < 0.0001$ for surgical mask, N-95, eye protection, gown). Self-reported use of “no PPE” did not differ from pre- to post-shelter-in-place. Anomalously, self-reported routine use of gloves decreased slightly ($P < 0.05$) post-shelter-in-place. CCSF, City and County of San Francisco; PPE, personal protective equipment.

Other studies of seroprevalence conducted in mid-2020 have shown similarly low rates among firefighters and first responders, except in instances of peak community infection. Comparatively, 0.73% of emergency responders in Lubbock, TX were found to have SARS-CoV-2 antibodies.¹² Studies of emergency responders in Arizona and Minnesota conducted from late April to May 2020 found seroprevalences of 1.5% and 1.2% respectively.^{13,14} In April 2020, during a local outbreak in South Florida, seroprevalence was found to be 8.9% in emergency responders.¹⁵

Testing Issues (confirmatory Testing and Positive Predictive Value)

Both the Abbott and Diasorin assays received FDA approval through the Emergency Use Authorization pathway and were validated and run in the UCSF Clinical Laboratories according to the manufacturer’s instructions.^{7,10} Studies by Abbott Laboratories⁷ and independent laboratories¹⁶ in large patient cohorts have determined the specificity of the Abbott assay to be 99.6% or greater. In the largest independent study of samples drawn approximately 20 or more days after symptom onset in patients with SARS-CoV-2 infection documented by RT-PCR testing ($n = 536$), the sensitivity of the Abbott assay was found to be 92.7% (95% confidence interval = 90.2% to 94.8%).¹⁷ Studies by the manufacturer and independent investigators indicate that the Diasorin assay specificity is approximately 98.6% and assay sensitivity approximately 95%.^{10,17} With the Abbott and Diasorin assays, antibody responses have been reported to be detectable up to 73 days post symptom onset and up to 82 days post a positive PCR result.¹⁷

The seroprevalence level in this study of 0.24% (95% CI: 0.05% to 0.71%) is consistent with the seroprevalence levels of 0.1% (95% CI: 0.00% to 0.56%) and 0.26% (0.00% to 0.76%) reported by Ng et al⁸ using confirmatory orthogonal testing of samples obtained in the San Francisco Bay Area in March to April 2020 from blood donors and from non-COVID-19 patients in a tertiary care hospital, respectively. In our study and that of Ng et al,⁸ 70% to 80% of the samples that tested positive in one highly specific

screening assay (specificity of 99.6%) were found to be negative on testing with independent, highly sensitive confirmatory assays. This underscores the importance of background prevalence rates when translating intrinsic test characteristics into positive predictive values, and hence the importance of using an orthogonal testing strategy with two independent assays when studying populations with low seroprevalence rates.

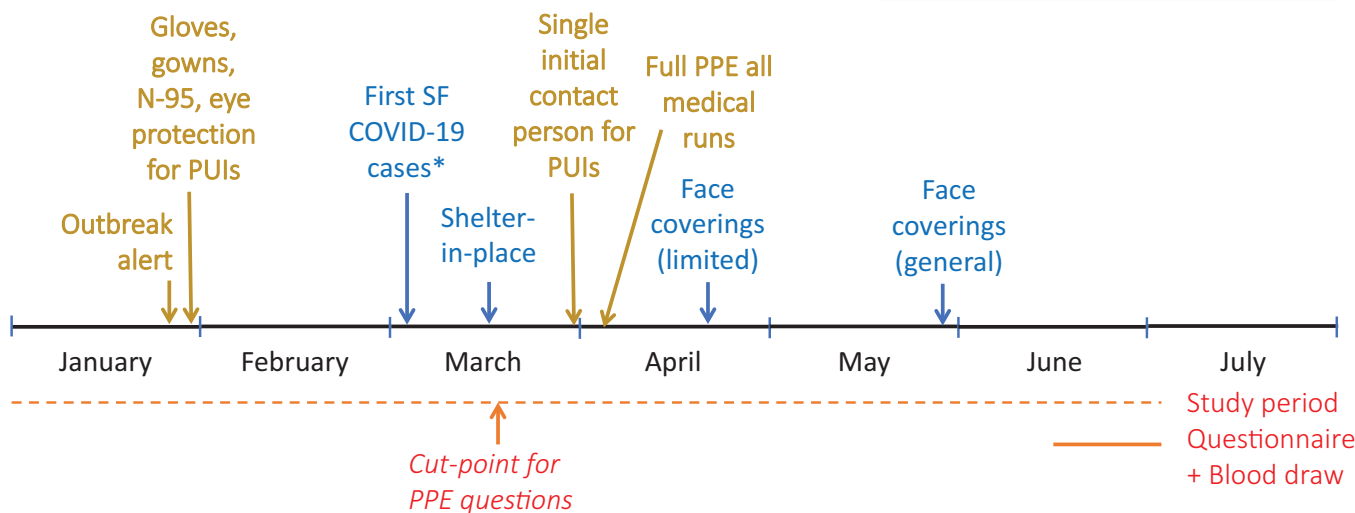
Institutional Response to Hazard

To slow the spread of COVID-19 (or “flatten the curve”), the CCSF issued a shelter in place order effective 12:01 am on March 17, 2020.⁴ In the March 27, 2020 SFFD Incident Action Plan (IAP) SFFD personnel were asked to practice social distancing of a least 6 ft. at the fire stations, to have only one member perform errands (such as refueling the rig, grocery shopping), and to not gather with other members at other stations.¹⁸

In March 2020, SFFD conducted department-wide N-95 fit testing and established a series of COVID-19 support resources: (1) assistance in completing COVID-19 potential exposure/encounter reports and restocking PPE at the stations; (2) COVID-19 advice line; (3) COVID educator (firefighter with a degree and extensive background in microbiology); (4) industrial hygienist who provided information on disinfecting, PPE, and engineering controls; and (4) the SFFD Medical Office (Department Physician and Nurse Practitioner) who evaluated exposure risks, advised members when to quarantine or isolate, and determined return to work timeline. On March 31, 2020 SFFD Administration recommended that, on medical calls, one member (EMT or paramedic) in proper PPE initiate patient contact, thereby reducing the number of SFFD members exposed to a potential PUI.¹⁹

SFFD issued a “transmission reduction mask policy” on April 3, 2020 requiring all SFFD members wear a mask when in common areas of worksites, while other members are present and unable to maintain 6 ft. of distance, at all times during meal preparation, when riding in the apparatus, and while grocery shopping or in public areas.⁵ In addition, SFFD instituted COVID-19 medical screening

KEY: San Francisco Fire Department
City & County of San Francisco



PUIs = Persons under investigation (for COVID-19); * = community-acquired COVID-19 cases

FIGURE 3. Timeline of institutional responses to COVID-19 by the San Francisco Fire Department and SF Department of Public Health.

procedures on April 3, 2020, which included temperature and symptom screening at the beginning, middle, and end of each shift. See Fig. 3 for a timeline of SFFD and CCSF public safety measures.

Implications for Other Front-Line Workers

A number of factors may have contributed to the low prevalence of prior COVID-19 infection among emergency responders in SF, at the department and community level, as ascertained at mid-year 2020. These include early adoption of PPE use, adequate PPE supplies and necessary fit-testing, protective workplace measures such as distancing, and enhanced cleaning protocols. At the community level, public health actions such as an early shelter-in-place order and universal masking likely provided a level of protection for emergency responders both at work and off the clock.

Epilogue

As community incidence increased during the second half of 2020 (ie, after our study period), SARS-CoV-2 infections within the SFFD also increased. By the end of calendar year 2020, SFFD had identified a total of 93 cases of COVID-19 among members (a 5% cumulative incidence, all but five of which occurred after our study period). By comparison, during 2020 a total of 24,607 San Franciscans (or 2.8% of the general population) were diagnosed with COVID-19.² The increase in the COVID-19 case rate among SFFD members from the first to the second half of the year was more than 17-fold, significantly greater than the increase in the general population (~5-fold; $P < 0.05$ by chi-square). On June 23, 2021 CCSF announced that all employees, including SFFD members, are required to report vaccination status by August 12, 2021.²⁰

Of note, of the five PCR-positive COVID-19 cases occurring amongst SFFD members prior to July, only one was reported through our questionnaire. The remaining four cases were in the active process of being diagnosed during our seroprevalence testing period (ie, June 2020), and likely declined participation in our study due to infection control concerns.

CONCLUSIONS

Emergency response presents a number of challenges to infection control. Emergency responders are at risk of exposure through on the job contact with members of the public with COVID-19 infection. There are circumstances where recommended PPE may not be practical, such as surf rescues. Communal living in fire houses or during special operations (such as during wildland fires) can provide the opportunity for the spread of COVID-19 infection among first responders. Off the clock, emergency responders are also potentially exposed in the community and among family and friends. We suspect that the initial vigilance in protective workplace practices and low community prevalence of COVID-19 were protective factors which limited the number of COVID-19 infections among SFFD members during the period of our seroprevalence study (ie, the first half of 2020). However, during the second half of the year any protective effect SFFD members had enjoyed appears to have been overshadowed by increased exposure prevalence on-the-job and/or non-occupational exposures in the home and community.

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