SHORT REPORT

Epidemiology of SARS-CoV-2 antibodies among firefighters/paramedics of a US fire department: a cross-sectional study

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ABSTRACT

Objectives We estimate the point seroprevalence of SARS-CoV-2 antibodies in the frontline firefighter/paramedic workforce of a South Florida fire department located in the epicentre of a State outbreak.

Methods A cross-sectional study design was used to estimate the point seroprevalence of SARS-CoV-2 antibodies using a rapid immunoglobulin (Ig)M-IgG combined point-of-care lateral flow immunoassay among frontline firefighters/paramedics collected over a 2-day period, 16–17 April 2020. Fire department personnel were emailed a survey link assessing COVID-19 symptoms and work exposures the day prior to the scheduled drive-through antibody testing at a designated fire station. Off-duty and on-duty firefighter/paramedic personnel drove through the fire station/training facility in their personal vehicles or on-duty engine/rescue trucks for SARS-CoV-2 antibody testing.

Results Among the 203 firefighters/paramedics that make up the fire department workforce, 18 firefighters/paramedics (8.9%) tested positive for SARS-CoV-2 antibodies, of which 8 firefighters/paramedics (3.9%) were IgG positive only, 8 (3.9%) were IgM positive only and 2 (0.1%) were IgG/IgM positive. The positive predictive value (PPV) of the serological test is estimated to be 33.2% and the negative predictive value is 99.3%. The average number of COVID-19 case contacts (ie, within 6 feet of an infected person (laboratory-confirmed or probable COVID-19 patient) for ≥15 min) experienced by firefighters/paramedics was higher for those with positive serology compared with those with negative (13.3 cases vs 7.31 cases; p=0.022). None of the antibody positive firefighters/paramedics reported receipt of the annual influenza vaccine compared with firefighters/paramedics who tested negative for SARS-CoV-2 antibodies (0.0% vs 21.0%; p=0.027).

Conclusion Rapid SARS-CoV-2 IgM-IgG antibody testing documented early-stage and late-stage infection in a firefighter workforce providing insight to a broader medical surveillance project on return to work for firefighters/paramedics. Given the relatively low PPV of the serological test used in this study back in April 2020, caution should be used in interpreting test results.

Key messages

What is already known about this subject?

- Among all occupations, those employed as first responders, that is, firefighters/paramedics, are at greatest risk for COVID-19 infection, as they can encounter diseases and infections daily and typically work in close proximity to one another and the communities they serve.

What are the new findings?

- We found the seroprevalence of SARS-CoV-2 antibodies (immunoglobulin (Ig)G only, IgM only or IgG/IgM) estimated in a cross-sectional study of 203 frontline firefighters/paramedics from a municipal fire department was 8.9% of the workforce, of which eight firefighters/paramedics (3.9%) were IgG positive only, eight (3.9%) were IgM positive only and two (0.1%) were IgG/IgM positive.
- None of the antibody positive firefighters/paramedics reported receipt of the annual influenza vaccine compared with firefighters/paramedics who tested negative for SARS-CoV-2 antibodies (0.0% vs 21.0%; p=0.027).

How might this impact on policy or clinical practice in the foreseeable future?

- A comprehensive medical surveillance programme for first responders that includes SARS-CoV-2 antibody testing can inform policy for return to work algorithms.

INTRODUCTION

Key direction from the US Centers for Disease Control and Prevention (CDC) on how to protect first responders from coronavirus evolved following the first American COVID-19 case and the exposure of at least one firefighter.[1] Among all US jobs, those employed as first responders, that is, firefighters/paramedics, are at greatest risk for COVID-19 infection, as they can encounter diseases and infections daily and typically work in close proximity to one another and the communities they serve.[2] Many first responders are already under quarantine due to direct exposure with COVID-19 cases, potentially challenging fire department staffing resources and emergency responder workforce responsiveness.[3] While firefighters/paramedics use personal protective equipment (PPE) and engineering controls at work, fire departments are operating in the dark

Table 1 Sociodemographic and work characteristics among firefighters who participated in voluntary serological COVID-19 antibody test (n=203)

Characteristics	Total sample N N (%)*	COVID-19 antibody test result		P value
		Positive (IgG, IgM or IgG/IgM) n (%)*	Negative n (%)*	
Total	203 (100.0)	18 (8.9)	185 (91.1)	
Age groups				0.677
21–30 years old	33 (16.3)	2 (11.1)	31 (16.8)	
31–40 years old	51 (25.1)	6 (33.3)	45 (24.3)	
41–50 years old	67 (33.0)	7 (38.9)	60 (32.4)	
51 years and older	52 (25.6)	3 (16.7)	49 (26.5)	
Sex				0.328
Male	188 (93.5)	16 (88.9)	172 (94.0)	
Female	13 (6.5)	2 (11.1)	11 (6.0)	
Race				0.899
White	154 (78.2)	15 (83.3)	139 (77.7)	
Black or African–American	9 (4.6)	0 (0.0)	9 (5.0)	
Multi-race	8 (4.1)	1 (5.6)	7 (3.9)	
Other	26 (13.2)	2 (11.1)	24 (13.4)	
Ethnicity				0.57
Hispanic/Latinx	149 (75.6)	15 (83.3)	134 (74.9)	
Non-Hispanic/non-Latinx	48 (24.4)	3 (16.7)	45 (25.1)	
Marital status				0.721
Married/unmarried couple	139 (72.4)	12 (66.7)	127 (73.0)	
Divorced, widowed, separated	21 (10.9)	2 (11.1)	19 (10.9)	
Single	32 (16.7)	4 (22.2)	28 (16.1)	
Educational attainment				0.767
High school/GED	16 (8.3)	1 (5.9)	15 (8.5)	
Some college	135 (69.9)	11 (64.7)	124 (70.5)	
College graduate	42 (21.8)	5 (29.4)	37 (21.0)	
Body mass index				0.154
Normal weight	32 (16.9)	5 (31.3)	27 (15.6)	
Overweight	101 (53.4)	9 (56.3)	92 (53.2)	
Obese	56 (29.6)	2 (12.5)	54 (31.2)	
Influenza shot in the past 12 months				0.027
Yes	35 (18.9)	0 (0.0)	35 (21.0)	
No	150 (81.1)	18 (100.0)	132 (79.0)	
Smoking status				0.543
Current smoker	0 (0.0)	0 (0.0)	0 (0.0)	
Former smoker	8 (4.6)	1 (6.3)	7 (4.4)	
Never smokers	167 (95.4)	15 (93.8)	152 (95.6)	
Career firefighter tenure				0.419
Years±SD	15.9 ± 9.2	14.1 ± 8.1	16.0 ± 9.3	
Time at current department				0.732
Years±SD	15.3 ± 9.1	14.6 ± 8.4	15.3 ± 9.1	
Current rank				0.129
Firefighter/paramedic/EMT	79 (40.7)	4 (22.2)	75 (42.6)	
Driver/operator	30 (15.5)	5 (27.8)	25 (14.2)	
Inspector/fire investigator	7 (3.6)	1 (5.6)	6 (3.4)	
Lieutenant	47 (24.2)	7 (38.9)	40 (22.7)	
Captain	18 (9.3)	0 (0.0)	18 (10.2)	
Battalion/deputy/division chief	13 (6.7)	1 (5.6)	12 (6.8)	
Any symptoms in the past 2 weeks				0.064
Yes	18 (9.0)	4 (22.2)	14 (7.7)	
No	181 (91.0)	14 (77.8)	167 (92.3)	
Days with symptoms since onset				0.005
Average days±SD	5.7 ± 4.3	11.7 ± 2.5	4.6 ± 3.7	
COVID-19 case contact past 2 weeks at work				0.653
Yes	93 (51.7)	7 (43.8)	86 (52.4)	
No	43 (23.9)	5 (31.3)	38 (23.2)	
Not sure	44 (24.4)	4 (25.0)	40 (24.4)	

continued

Table 1 continued

Characteristics	Total sample N N (%)*	COVID-19 antibody test result		P value
		Positive (IgG, IgM or IgG/IgM) n (%)*	Negative n (%)*	
Average COVID-19 case contacts				0.022
Average cases±SD	7.73 ± 6.3	13.3 ± 4.8	7.31 ± 6.2	
Average time spent with COVID-19 positive person				0.025
Less than 5 min	15 (17.0)	6 (42.9)	9 (12.2)	
5–30 min	66 (75.0)	8 (57.1)	58 (78.4)	
Greater than 30 min	7 (8.0)	0 (0.0)	7 (9.5)	
Used any PPE during COVID-19 encounter				0.383
Yes, any PPE	87 (93.5)	6 (85.7)	81 (94.2)	
No PPE use	6 (6.5)	1 (14.3)	5 (5.8)	
Number of PPE items used with COVID-19 positive person				0.79
Average count PPE used (one to six items)	3.3 ± 1.4	3.1 ± 1.6	3.3 ± 1.4	

*Differences in subtotal population sample due to item non-response or missing. Case contact=when a firefighter was within 6 feet of an infected person (laboratory-confirmed or probable COVID-19 patients) for at least 15 min; COVID-19 positive person indicates an individual with laboratory-confirmed COVID-19 test; PPE items included gloves, double gloves, N-95 respirator, fluid resistant sleeves, eye protection and gown.
EMT, Emergency Medical Technician; GED, General Educational Development; Ig, immunoglobulin; PPE, personal protective equipment.

regarding the prevalence of coronavirus in the workforce. Strategies that limit the spread of the SARS-CoV-2 virus within their workforce and tools that provide near real-time decision-making on firefighter/paramedics return to work algorithms and infection control strategies are needed.

Serological antibody tests, despite their limitations, are critical tools for assessments of SARS-CoV-2 exposure, infection and potential immunity.[4 5] Current testing for the SARS-CoV-2 virus largely depends on labour-intensive molecular techniques that can often be delayed by days, limiting their utility in return to work algorithms for a fast-paced emergency responder workforce.[6 7] Recent studies have documented that asymptomatic individuals might contribute to SARS-CoV-2 transmission, further complicating efforts to limit the spread of the virus.[8 9] As part of a complementary and broader comprehensive COVID-19 medical surveillance programme, reliable antibody detection assays would enable more accurate estimates of SARS-CoV-2 prevalence and incidence in the first responder workforce. A joint collaborative partnership between city government, fire department, local union and an academic medical centre supported the implementation of the Firefighter Tracking, Resources, and Assessment of COVID-19 Epidemiology (F-TRACE) project, supporting the coordination, tracking and educational resources of COVID-19 contact, presumptive and confirmed cases among fire department personnel. In the present study, we estimate the point seroprevalence of SARS-CoV-2 antibodies among frontline firefighter/paramedics of a South Florida fire department located in the epicentre of a State outbreak.

METHODS

Study design, participants and recruitment

Secondary data analysis of cross-sectional information collected as part of the fire department's F-TRACE project was used to estimate the point seroprevalence of SARS-CoV-2 antibodies among frontline firefighters/paramedics collected over a 2-day period, 16–17 April 2020. Firefighters/paramedics of a US fire department in Florida were invited by department and local union leadership to voluntarily consent to participate in a one-time surveillance assessment for SARS-CoV-2 antibodies. Fire department personnel were emailed a survey link assessing COVID-19 symptoms and work exposure characteristics the day prior to the scheduled drive-through antibody testing at a designated fire station. Off-duty and on-duty firefighter/paramedic personnel drove through the antibody testing fire station in their personal vehicles or on-duty engine/rescue trucks for SARS-CoV-2 antibody testing. Off-duty firefighters/paramedics could wait in the fire station parking lot for 10–15 min to receive the results of their antibody test, while on-duty personnel were instructed to return to their fire station immediately. The fire department infection control officer (ICO) followed up directly with any on-duty firefighter personnel who tested positive for SARS-CoV-2 antibodies. The ICO immediately quarantined the firefighter/paramedic, conducted reflex nasal swab (reverse transcription PCR (RT-PCR)) testing and closely monitored coworker firefighters at the fire station as part of the comprehensive F-TRACE project. A total of three firefighters/paramedics did not participate in the surveillance project, of which two were out of the geographic area because of scheduled vacation and one declined to participate for religious reasons (response rate=98.6%).

Study survey measures and administration

Firefighters/paramedics were asked to complete two web-based survey instruments (ie, an intake form and a COVID-19 exposure form) prior to their scheduled antibody testing day. Survey instruments were administered to firefighters/paramedics via an email link sent by fire department leadership using REDCap, a secure web-based application for building and managing complex online surveys and databases.[10] The intake form consisted of a 30-item questionnaire assessing sociodemographic (ie, age, sex, race, ethnicity, educational attainment, marital status, height/weight and contact information) and work characteristics (ie, station assignment, shift schedule, firefighter tenure, rank, current job tasks, number of fire/EMS calls, second job and military experience) adapted from questions on federal surveys.[11] The COVID-19 exposure form is comprised of 29 items assessing COVID-19 firefighter/paramedic symptoms, prior COVID-19 testing, COVID-19 contacts, smoking status, receipt of influenza shot in prior 12 months, as well as a series of questions on exposure risk assessing the frequency and duration of COVID-19 patient exposures, PPE use and firefighter coworker contacts adapted from the CDC COVID-19 questionnaire.[12] We assessed the type of PPE used by the firefighter by asking, "Were you using any protective equipment when you came into contact with possible COVID-19 person? Choose all that apply." Response options included: "gloves, double gloves, N-95 respirator, fluid resistant sleeves, eye protection, and gown". A case

contact was defined as a firefighter who was within 6 feet of an infected person (laboratory-confirmed or probable COVID-19 patients) for at least 15 min; the definition is consistent with the US CDC guidelines.

SARS-CoV-2 antibody test administration

A rapid immunoglobulin (Ig)M-IgG combined point-of-care (POC) lateral flow immunoassay (BioMedomics, Morrisville, New Carolina, USA) was used for assessment of SARS-CoV-2 antibodies in participating firefighters/paramedics.[13] The sensitivity and specificity of the COVID-19 antibody assay were estimated to be 88.66% and 90.63%, respectively, based on the results for 397 infected cases and 128 non-SARS-CoV-2 infection patients in Wuhan, China.[14] The positive predictive value (PPV) of the test is estimated to be 33.2% and the negative predictive value is 99.3%. On testing day, on-duty and off-duty firefighters/paramedics drove through a structured drive-through lane at the fire station/training facility. Firefighters/paramedics rolled down their window, were approached by the F-TRACE team gowned in PPE for an initial index finger swab with rubbing alcohol, followed by a quick lancet finger puncture to allow for two drops of blood to be placed in the cassette sample well. F-TRACE team members added two drops of buffer reagent to the cassette sample well and waited 10 min for the test to complete prior to reading the results.

Data analysis

We calculated descriptive statistics for continuous variables, expressed as means with its SD, and for categorical variables, expressed as frequency and percent of the sample. We examined the main outcome of testing positive (combined IgG only, IgM only and IgG/IgM) by sociodemographic and work characteristics, by COVID-19 contacts and COVID-19 symptoms. For categorical data, we conducted Fisher's exact test to compare groups. Student's t-test was used to compare the mean days of symptom onset, firefighter tenure, time in fire department, average number of COVID-19 case contacts, average time spent with COVID-19 cases and the number of PPE items used with COVID-19 case between firefighter who tested positive versus negative. P values less than 0.05 were considered statistically significant. We performed all data management and statistical analyses using SPSS V.26 for Windows (IBM).

RESULTS

Among the 203 firefighters/paramedics that participated in the F-TRACE project, 18 firefighters/paramedics (8.9%) tested positive for SARS-CoV-2 antibodies, of which 8 firefighters/paramedics (3.9%) were IgG positive only, 8 (3.9%) were IgM positive only and 2 (0.1%) were IgG/IgM positive (table 1). None of the antibody positive firefighters/paramedics reported receipt of the annual influenza vaccine compared with firefighters/paramedics who tested negative for SARS-CoV-2 antibodies (0.0% vs 21.0%; p=0.027). Although not significant, the proportion of firefighters/paramedics who reported symptoms in the 2 weeks prior to antibody testing was higher for those who tested antibody positive compared with firefighters/paramedics who were antibody negative (22.2% vs 7.7%; p=0.064). The average number of COVID-19 case contacts was significantly higher (13.3±4.8 case contacts vs 7.31±4.8 contacts; p=0.022) among firefighters/paramedics who were SARS-CoV-2 antibody positive compared with firefighters who tested negative for antibodies.

DISCUSSION

As a component of an overall medical surveillance programme, we found variation in the seroprevalence of SARS-CoV-2 antibodies among frontline firefighters/paramedics of a moderately sized US fire department. Approximately 4% of the participating firefighters/paramedics tested positive for either IgM or IgG/IgM SARS-CoV-2 antibodies, indicating recent infection from the time of immunoassay antibody testing. These findings provided timely and useful information on decision to quarantine and further evaluation through reflex RT-PCR nasal swabs. Nonetheless, caution at interpreting the results of the antibody testing is warranted. When the prevalence of COVID-19 is based on serology testing (ie, all antibodies including IgM only, IgG only and combined IgM/IgG) and the prevalence of COVID-19 is estimated to be low (eg, 5% within the workforce), the risk of false positives can be elevated. For example, if the COVID-19 serological test has 90% specificity, we estimate that its PPV will be 32.1%, thus nearly 70% of positive results will likely be false. At this same disease prevalence (~5% of the workforce), a test with 95% specificity will lead to a 50% chance that a positive result is incorrect. Similarly, it is possible that a positive result on COVID-19 antibody serology test can be due to cross-reactivity with other viruses. Different assays use antigens from different parts of SARS-CoV-2, and some combine IgM and IgG, therefore different levels of cross-reactivity with other coronavirus antibodies are possible.[15] At the time of this pilot study (April 2020), the BioMedomics COVID-19 assay was used by our team under the Emergency Use Authorisation (EUA) authority of the US Federal Drug Administration for research and community surveillance to estimate COVID-19 infectivity within the firefighter workforce.

We found that firefighter/paramedics who tested positive were significantly more likely to have greater number of contacts with COVID-19 positive patients as well as spend less time (less than 5 min) with COVID-19 positive patients compared with firefighter/paramedics who tested SARS-CoV-2 antibody negative. Among all firefighters/paramedics who tested SARS-CoV-2 antibody positive, none had reported receipt of the annual influenza vaccine in the 12 months prior to antibody testing. It may be possible that those firefighters/paramedics who tested positive engage in riskier behaviour (ie, inconsistent use of PPE) that could lead to greater risk of exposure. It is possible that an individual's vaccination behaviour can provide insight into their overall risk tolerance and work-related safety practices. For example, community-based studies evaluating risky sexual behaviour among young adults who were vaccinated against human papillomavirus showed they engaged in less risky behaviours such as being less likely to not use a condom and drink two or more times per week.[16] In our study, we found that PPE use (while not significant) was lower for firefighters who tested positive versus those who tested COVID-19 antibody negative (85.7% vs 94.2%)—more than a twofold difference. A recent systematic review examining clustering and co-occurrence of multiple risk behaviours (ie, drinking, physical activity, diet and so on) found the strongest associations by occupation (up to fourfold increased odds) and by educational attainment.[17] Furthermore, in other occupational groups like the construction workforce,[18] health behaviours have been linked to safety perceptions where obese construction workers with low physical activity were less concerned about job-related injuries.

Understanding how vaccination practices impact PPE use in first responders, a US occupational group with historically low vaccination rates,[19] can shed insight to potential strategies to improve PPE use and COVID-19 control strategies. Nonetheless, the relatively small sample size warrants repeated data collection with other fire departments. Further longitudinal research is needed to further investigate long-term immunity to the SARS-CoV-2 virus among first responders, particularly how the use of PPE mitigates rates of infection and how serological antibody testing can inform return to work strategies.

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Competing interests None declared.

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