Characterizing SARS-CoV-2 infection burden and COVID-19 vaccination intent and uptake in congregate shelters in Seattle, WA

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Abstract

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Community-based surveillance studies can be appropriately leveraged to characterize the burden of emerging pathogens, especially in hard-to-reach populations such as people experiencing homelessness (PEH). Prior respiratory viral studies among PEH populations have shown evidence of increased morbidity and mortality compared to the general population, likely associated with a high prevalence of co-occurring health conditions, though they are scant and limited to single time-point cross-sectional sampling with small sample sizes. Both homeless shelter residents and staff are at higher risk of SARS-CoV-2 infection because of residing or working in congregate settings. However, reported SARS-CoV-2 infection burden in this population has been variable and reliant on cross-sectional or outbreak investigation data without sufficiently accounting for sociodemographic characteristics and temporal trends.

Challenges to reduce severe outcomes related to COVID-19 among PEH include access to COVID-19 vaccination and a history of disproportionately low vaccine intent. Further, understanding the continuum of vaccine intent and how it is unique within shelter populations has not been well elucidated, despite being necessary for successfully tailored COVID-19 vaccination campaigns.

In the following dissertation aims, we address these gaps. In **Chapter 2** we calculated the incidence of laboratory-confirmed SARS-CoV-2 infection among shelter residents and staff over the study period. We also identified individual-level risk factors associated with SARS-CoV-2 infection among shelter staff vs. shelter residents. Additionally, we identified individual-level risk factors associated with symptomatic COVID-19 compared to asymptomatic infection among all SARS-CoV-2 positive participants. In **Chapter 3** we described and assessed the individual-level sociodemographic and health characteristics associated with COVID-19 vaccination intent and uptake among shelter residents and staff. Additionally, we evaluated population-level and within-person changes in vaccination intent and uptake using repeated measures over the study period.

To accomplish these aims, we leveraged data from an active surveillance study of acute respiratory illness (ARI) and asymptomatic viral infection in congregate shelters in the Seattle-King County area, conducted from 1 October 2019 through 31 May 2021. Participants had nasal specimen and survey data collected in a repeated cross-sectional manner during two types of recruitment events: routine surveillance and outbreak testing for SARS-CoV-2. Individual participants were not followed longitudinally, but eligible individuals may have multiple encounters throughout the study period as routine testing was used as a study recruitment tool and proactive public health strategy.

Among 12,915 collected nasal specimens from 2,930 unique participants, we observed 4.74 (95% CI 4.00 – 5.58) SARS-CoV-2 infections per 100 individuals at risk (residents: 4.96, 95% CI 4.12 – 5.91; staff: 3.86, 95% CI 2.43 – 5.79) were identified. Most infections were asymptomatic at the time of detection (74%) and detected during routine surveillance (73%); however, outbreak testing yielded higher test positivity compared to routine surveillance (2.7% vs. 0.9%).

Among those infected, residents were less likely to report symptoms than staff. Participants that received that season's influenza vaccine and were current smokers had significantly lower odds of having an infection detected.

Furthermore, we found that from 11/1/2020 – 2/28/2021, a total of 969 unique staff (n=297) and residents (n=672) participated and provided 3,966 survey responses regarding COVID-19 vaccination intent and uptake. Among residents, 53.7% were vaccine accepting, 28.1% reluctant, 17.6% deliberative, and 0.6% already vaccinated, whereas among staff, 56.2% were vaccine accepting, 14.1% were reluctant, 16.5% were deliberative, and 13.1% already vaccinated at their last survey. We observed higher odds of vaccine deliberation or reluctance among Black/African American individuals, those who did not receive a seasonal influenza vaccine, and those with lower educational attainment. There was no significant trend towards vaccine acceptance.

Altogether, our findings provide a more nuanced understanding of SARS-CoV-2 infection burden and COVID-19 vaccine intent trends in a high-risk, underserved population. It is imperative that shelter-based routine surveillance including SARS-CoV-2 testing of all persons, regardless of symptom profile, is essential in ascertaining the true burden of SARS-CoV-2 infections among residents and staff, and that public health authorities planning vaccination campaigns in shelters take an intersectional, person-centered approach to addressing important health inequities.

Table of Contents

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Chapter 1: Introduction

Respiratory viruses and homeless populations

Respiratory pathogens are the leading infectious cause of deaths in the U.S. and globally.[1] People experiencing homelessness (PEH) have disproportionately higher morbidity and mortality from these diseases than the general population.[2–4] PEH may be at high risk for acquisition and transmission of respiratory pathogens in a shelter environment due to overcrowding, inadequate ventilation, and poor sanitary conditions.[5–7] Furthermore, lack of access to care for chronic conditions such as diabetes and chronic lung disease, alongside higher rates of mental illness, substance use, and malnutrition, may increase susceptibility to infection.[3,8,9] Past studies have observed greater risk of complications and poorer outcomes for viral respiratory pathogens, including respiratory syncytial virus (RSV) and influenza, in homeless patients.[10] Research has also shown that those experiencing homelessness are likely to delay seeking care for acute infections, and when they do, they are largely dependent on hospital and emergency services.[11,12] Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the coronavirus disease 2019 (COVID-19) pandemic in the U.S. therefore poses an unprecedented threat to homeless populations.

Homelessness in Seattle-King County and COVID-19 risk in shelters

Seattle/King County, Washington (WA) is among the top 3 cities in the U.S. with the largest number of people experiencing homelessness.[13] Seattle’s most recently available Point-In-Time Count from 2022, an annual national count of homelessness in the U.S., found that 13,368 people were experiencing homelessness in the county, representing a 14% growth from numbers observed in 2020.[14] According to the county’s Homeless Management Information System (HMIS) data, 43% of these individuals were sheltered (e.g., residing in emergency shelters or transitional housing) in 2022.[14] The Centers for Disease Control and Prevention reports that, in confluence with the high prevalence of medical conditions associated with severe COVID-19 among PEH, the congregate living arrangements in homeless shelters heighten the risk of SARS-CoV-2 transmission in these settings compared to the general population.[15] Homeless service providers and staff may also face greater risk of exposure to SARS-CoV-2 infections as a result of working in shelter conditions with shared hygiene facilities and constrained capacity to social distance.[7]

COVID-19 surveillance data limitations in homeless populations

Despite well-elucidated concerns of the heightened risk of respiratory illnesses among shelter residents and staff, the availability of consistent SARS-CoV-2 testing in shelters has been variable. Robust testing data are vital to tracking and mitigating viral transmission given the transiency and exposure risk factors of PEH compared to the general population.[3] Reported SARS-CoV-2 prevalence data and COVID-19 burden from congregate shelters across the U.S. has been heterogeneous and predominantly based on cross-sectional surveillance data or singular outbreak investigations reliant on public health data capture systems. Testing methodologies, in addition to regional differences in background community prevalence, may attribute to the observed heterogeneity.[5–7] These studies' limitations include a lack of temporal and sociodemographic data collected. A dearth of long-term surveillance data from shelters has also limited prior efforts made to calibrate models to identify the most effective infection control practices at mitigating transmission in congregate shelters.[16]

Vaccination among people experiencing homelessness

Challenges to reduce severe outcomes related to COVID-19 include access to COVID-19 vaccination[8,17,18] and a history of disproportionately low general vaccine intent among PEH.[17,19,20] Studies have found key enablers to any vaccine uptake among PEH are convenient locations and times, and incorporation of vaccination into routine health and social care, while main barriers included high levels of mistrust in the medical system and vaccine misinformation among PEH.[21,22] An understanding of vaccination intent for a novel pathogen in a pandemic context is important to tailor vaccine campaign strategies to maximize improvements in socio-culturally informed vaccine uptake in hard-to-reach populations such as PEH.

Despite evidence of available COVID-19 vaccines' high efficacy and safety,[23,24] as well as widespread availability in the U.S., evidence from various geographic regions and public health jurisdictions suggests lower vaccination coverage among PEH compared to the general population.[25–27] While prior studies have examined PEH vaccine uptake and disparities with housed populations,[28] these studies' key limitations include selection bias towards PEH who more frequently engage with healthcare providers, exclusion of shelter staff vaccine intent, and analysis of the continuum of vaccination intent in this population. It is therefore critical to examine COVID-19 vaccination barriers and facilitators among PEH recruited through community-based research efforts rather than clinical or hospital records, as well as shelter staff's intent and uptake and temporal trends.

Contribution of this project

To fill these knowledge gaps, we collected and analyzed survey and nasal specimen data as part of an active surveillance study of acute respiratory illness (ARI) and asymptomatic viral infections in congregate shelters in the Seattle-King County area conducted from 1 October 2019 through 31 May 2021. This study was nested within the Seattle Flu Study (SFS), a multi-arm community-based prospective study investigating respiratory virus transmission dynamics in the greater Seattle area that began 6 January 2019.[29] Our study population represented a wide range of shelters serving a diverse demographic of sheltered PEH, including families with small children, young adults, and shelter staff who are reasonably representative of Seattle-King County's sheltered homeless population.[30] The overall objective of this dissertation is to understand the SARS-CoV-2 infection burden, primary infection risk factors, and COVID-19 vaccine intentions to improve case detection and vaccination interventions in congregate shelters providing services for PEH.

The following dissertation consists of two research chapters and a concluding statement. In **Chapter 2** we calculated the incidence of laboratory-confirmed SARS-CoV-2 infection among shelter residents and staff over the study period. We also identified individual-level risk factors associated with SARS-CoV-2 infection among shelter staff vs. shelter residents. Additionally, we identified individual-level risk factors associated with symptomatic COVID-19 compared to asymptomatic infection among all SARS-CoV-2 positive participants. In **Chapter 3** we described and assessed the individual-level sociodemographic and health characteristics associated with intent to vaccinate against COVID-19 and COVID-19 vaccine uptake among shelter residents and staff. Population-level change in COVID-19 vaccination intent and uptake over the study period was also examined. Additionally, we evaluated within-person change in vaccination intent among individuals with repeated measures over the study period.

This research aims to contribute to sustainable infrastructures that support rapid deployment of evidence-based approaches to viral respiratory surveillance methods and appropriate vaccination interventions in sheltered populations of PEH, especially within a pandemic-context. The work described in this dissertation provides a novel assessment of timely, extensive data collection in partnership with a population that has been historically marginalized and underserved by the medical and clinical research communities.

Chapter 2. Incidence of SARS-CoV-2 infection and associated risk factors among staff and residents at homeless shelters in King County, Washington: an active repeated cross-sectional community surveillance study

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Preface

This Chapter contains a manuscript prepared for submission (currently under review) to the journal *Epidemiology and Infection*.

While data collection was ongoing, all SARS-CoV-2 infections included in this Chapter were reported immediately to Public Health Seattle-King County's Communicable Disease Epidemiology & Immunization team by myself and another research coordinator.
We also participated in weekly meetings held with Public Health, Health Care for the Homeless, homeless service providers, and other community partners to harmonize infection data and surveillance response among Seattle-King County's homeless population.

In developing this Chapter, I conceptualized the research question and data analysis plan, executed the analyses and sensitivity analyses and led manuscript writing while incorporating co-author feedback. Once I had gathered and documented all co-author statements of approval for the manuscript's journal submission, I led the drafted manuscript text through five rounds of revision as part of the Centers for Disease Control and Prevention clearance process. I also successfully created and delivered an oral presentation of these findings to researchers and public health practitioners in the field at The National Health Care for the Homeless Conference and Policy Symposium (NHCHC 2022), from May 10-13, 2022, in Bellevue, Washington.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the view of the US Centers for Disease Control and Prevention.

Abstract

Background

Shelter residents and staff are at higher risk of SARS-CoV-2 infection as a result of residing or working in congregate settings. However, reported SARS-CoV-2 infection burden in this population has been variable and reliant on cross-sectional or outbreak investigation data.

Methods

We used data from an active surveillance study in 23 homeless shelters in King County, Washington to estimate the incident occurrence of laboratory-confirmed SARS-CoV-2 infection and associated risk factors among a population of shelter residents and staff during 1/1/2020 - 5/31/2021. Illness surveys and nasal swabs were collected for SARS-CoV-2 testing by RT-PCR for residents aged ≥3 months and staff, regardless of symptoms.

Results

We collected 12,915 specimens from 2,930 unique participants. We identified 4.74 (95% CI 4.00 – 5.58) SARS-CoV-2 infections per 100 individuals at risk (residents: 4.96, 95% CI 4.12 – 5.91; staff: 3.86, 95% CI 2.43 – 5.79). Most infections were asymptomatic at time of detection (74%) and detected during routine surveillance (73%); however, outbreak testing yielded higher test positivity compared to routine surveillance (2.7% vs. 0.9%). Among those infected, residents were less likely to report symptoms than staff. Participants that received that season's influenza vaccine and were current smokers had lower odds of having an infection detected.

Conclusions

While the proportion of infections captured is uncertain, routine surveillance that includes SARS-CoV-2 testing of all persons is essential in ascertaining the true burden of SARS-CoV-2 infections among residents and staff of congregate settings.

Key Words: homeless shelter; SARS-CoV-2 incidence; surveillance; infection risk factors

Background

The coronavirus disease 2019 (COVID-19) pandemic has posed unprecedented challenges to the more than 580,000 people experiencing homelessness (PEH) in the United States each night.[31] These challenges highlight systemic inequities in the U.S. that adversely impact existing health conditions, access to health care, and work and living conditions, potentiating a disproportionate risk of contracting SARS-CoV-2 and its subsequent clinical manifestations among PEH.[32] Difficulty with social distancing, quarantine, hygiene facility access, access to healthcare, and high prevalence of chronic diseases led to early concern that PEH staying in shelters would be at greater risk of morbidity and mortality from COVID-19.[33,34] Homeless service providers may also face greater risk of exposure to SARS-CoV-2 as a result of working in a congregate living setting.[7]

Despite these concerns, implementation of available and consistent SARS-CoV-2 testing in shelters has been challenging. Robust testing data are vital to mitigating viral transmission through early identification and isolation of cases, especially given the transiency of PEH.[3] Available data on SARS-CoV-2 infection prevalence and COVID-19 disease burden in congregate shelters across the U.S. has been variable. Most surveillance studies have relied on cross-sectional data or been centered on single outbreak investigations in specific geographies, limiting their generalizability.[6,7,35,36]

King County in Washington State has one of the largest populations of PEH in the US.[30] We previously described early characteristics of SARS-CoV-2 in King County shelters and detected a 2% test positivity rate.[35] Important questions remain as to whether certain individual or shelter-level characteristics are associated with higher risk of infection among shelter residents and staff. In this study, we aimed to characterize the burden of disease among a diverse shelter population using data collected from active surveillance. We captured temporal trends and estimated the incidence and associated risk factors of SARS-CoV-2 infection among shelter residents and staff.

Methods

Study design overview and population

We conducted an active community-based surveillance study of SARS-CoV-2 cases in shelters across Seattle-King County from 1/1/2020 - 5/31/2021. This was a sub-study of a multiyear, cluster randomized trial (CRT) of onsite testing and treatment for influenza at nine shelters that took place from 10/1/19 – 5/31/21 .[37] In brief, from 1/1/2020 - 3/31/2020 the following individuals were eligible for participation: aged ≥3 months, residents at a shelter study site, and have cough alone or ≥2 new or worsening acute respiratory illness (ARI) symptoms with onset in the past 7 days. Once a month, study eligibility was extended to shelter residents aged ≥3 months regardless of symptoms. In response to the identification of SARS-CoV-2 community transmission in Washington State on 2/24/2020,[38] the first year of the influenza trial intervention was paused on April 1, 2020 and participant eligibility was expanded to include all shelter staff and residents aged ≥3 months, regardless of symptoms (Supplemental Figure 1.1).

Study setting and sampling strategy

Participants were recruited three to six days per week by research staff at selected shelters using two mechanisms: routine surveillance and outbreak testing events. These mechanisms have been previously described[35]; in brief, routine surveillance involved self-selected participation at staffed kiosks in shelters during standardized days and times. COVID-19 outbreak testing was initiated on 3/30/2020 (and conducted intermittently thereafter) in collaboration with Public Health Seattle-King County (PHSKC) with single day intensive testing for all available residents and staff at shelters where ≥ 1 SARS-CoV-2 infections were recently detected. Individual participants were not followed longitudinally, but eligible individuals may have multiple encounters throughout the study period as routine testing was used as a study recruitment tool and proactive public health strategy. Study participation was limited to once weekly, unless new or worsening ARI symptoms developed, in which case an individual was permitted to re-enroll within seven days. Participants were recruited from a total of 23 shelters over the study period. Of these shelters, 15 were sites of routine surveillance and outbreak testing when a positive case was detected, and eight were sites of outbreak testing only. Six of the 15 routine surveillance shelters were facilities that replaced shelters with established study activities when staff and residents were relocated to enable improved adherence to COVID-19 infection and prevention control measures. Research activities were immediately initiated following these relocations (Supplemental Table 1.1).

Measures

The primary outcome was incidence of reverse transcription polymerase chain reaction (RT-PCR)-confirmed SARS-CoV-2 infection during 1/1/2020 through 5/31/2021. All inconclusive testing results were classified as SARS-CoV-2 infections per PHSKC and Washington Department of Health guidelines.[39] Incidence is customarily defined as either the proportion of a population at risk that develops the outcome of interest over a specified time period (cumulative incidence) or the count of incidence cases divided by the aggregate amount of at-risk experience (incidence rate). This study describes incident infections detected through repeated cross-sectional testing in an open population of individuals that experienced homelessness or worked at a shelter at some point in study period but were not necessarily at risk for its entirety; we were not able to capture individual time-at-risk.

Survey data were collected electronically on a tablet at time of nasal swab collection. Data included participant sex, date of birth (DOB), race, ethnicity (Hispanic or Latino vs. non-Hispanic or Latino), self-reported current season receipt of an influenza vaccine, underlying medical conditions, status as shelter staff versus resident, highest education level obtained, health insurance status, employment status, and self-reported receipt of any COVID-19 vaccine doses. Smoking status included any current use of tobacco products, e-cigarettes, or vape pens. Influenza vaccine status and duration of homelessness data were based on final survey response for those who completed more than one survey. Underlying conditions included asthma, blood disorders, cancer, chronic obstructive pulmonary disease or emphysema, chronic bronchitis, immunosuppression, liver disease, heart disease, diabetes, neurologic conditions, or aspirin therapy. All variables were determined by self-report. Enrollments per unique participant was defined as the number of survey responses collected from the same participant over the study period. Sleeping arrangements were reported only by shelter residents and categorized as communal, open-plan cubicles, or private room/shared family room. Communal included sleeping in a congregate space with bunk beds, bed mats, or rooms shared with more than one family.

Participant encounters with one or more new or worsening symptoms with onset in the past seven days were defined as symptomatic, and those without any new or worsening symptoms in the past seven days were defined as asymptomatic. This phrasing aimed to specifically distinguish acute symptoms indicative of respiratory viral infection in a population with high rates of chronic illness.[40] Participants with ARI symptoms also had symptom duration data collected in response to the question, "*When did the symptoms you mentioned in the beginning of this survey become new or worsening?*" Influenza-like illness (ILI) was defined as having a fever and either cough or sore throat. COVID-19–like illness (CLI) was defined as fever and cough or fever and increased difficulty breathing.

Specimen Collection

Mid-turbinate nasal swabs were obtained using a sterile nylon flocked nasal swab (Copan Diagnostics) by a member of the research staff until 3/6/2020, after which participants were instructed to self-collect a mid-turbinate nasal swab while observed by study staff. Due to supply shortages, anterior nare swabs replaced the use of mid-turbinate swabs from July 2020 through October 2020. See “Appendix A” for specimen testing details.

Statistical Analysis

The primary unit of analysis was unique participants, with corresponding individual-level characteristics taken from their last survey response. Participant encounters from unique individuals were dropped in this analysis following a positive or inconclusive test result; no repeat infections were included (n = 543; Supplemental Figure 1.2). Encounters from the same participant were linked and assigned a unique identifier *post hoc* using their name and DOB. Incongruous name spellings due to clerical error were addressed using a function of the Levenshtein distance, a metric used to measure the differences between two character strings.[41] Survey records were manually assigned to the same individual if the two names fell above a pre-specified value of similarity (>0.8 in the interval [0,1]) and had the same DOB. If two survey records had the same name but one-digit discrepancy in the DOB, the same unique identifier was assigned.

Incidence of SARS-CoV-2 infection was expressed as cases per 100 unique participants at risk, and described by age group, sex, race, ethnicity, and shelter type. The overall incidence of SARS-CoV-2 infection was calculated by dividing the total number of confirmed cases across all shelters by the total number of unique participants tested over the study period with 95% confidence intervals (CI). While it was not possible to determine person-time at risk for this population, on average resident participants self-reported a 5-month duration of stay at the shelter where their sample was collected. Anecdotal evidence provided by management suggests shelter staff were employed on average 8-12 months over the study period. Our assumption that most infections were captured in this study is reasonable as outbreak testing events were also initiated by positive test results detected outside of the study's surveillance as a result of our close collaboration with public health and shelter management. We also collected survey data on past positive SARS-CoV-2 test results from 11/1/2020 - 5/31/2021 and found that the aggregate number of infections detected by our surveillance closely matched those self-reported by participants over this time period.

Temporal trends of SARS-CoV-2 test positivity were also reported by epidemiologic week, a standardized method of counting weeks to allow for data comparison year after year;[42] all tests collected, regardless of participants' frequency of testing, were included.

Participant-level characteristics were summarized by using frequencies, percentages, and interquartile ranges. We used a chi-square test for independence for categorical variables (or Fisher's exact test for when cells had less than 10 observations) and a t-test for continuous variables of individual-level participant characteristics and SARS-CoV-2 infection, separately among shelter residents and shelter staff.

To estimate corresponding adjusted associations with SARS-CoV-2 infection among staff and residents separately (Table 1.3a) and symptomatic COVID-19 disease among all infected participants (Table 1.3b), respectively, we used generalized linear mixed models (GLMM), treating shelter as a random effect. Variables were selected for these models using a causal diagram approach. Risk factors included in the final multivariable models were checked for multicollinearity and convergence issues due to excessive missingness (i.e. "duration of homelessness" which was not asked of shelter staff). Descriptive statistics for test-level variables (Table 1.1c) are presented but were not considered for inclusion in the multivariable models as we were primarily interested in fixed individual-level exposures. Separate models were run for shelter residents and staff.

Ethics approval was obtained from the University of Washington Human Subjects Division. The CDC determined that the study was conducted consistent with applicable federal law and CDC policy (see 45 C.F.R part 46; 21 C.F.R. part 56).

Results

Participant characteristics

Overall, 12,915 nasal swab specimens were collected from 2,930 unique participants from 1/1/2020 through 5/31/2020. Of these participants, 2,360 were shelter residents (80.5%) and 570 (19.5%) were shelter staff (Table 1.1a). Each participant was tested a median of two times (interquartile ranges (IQR) of [4] and [5] among residents and staff, respectively) over the study period. The median age of residents and staff was 37 years (range: 0 – 85 years) and 32.5 years (range: 18 – 81 years), respectively. A majority of residents self-identified as male (64.3%) compared to a majority of staff self-identifying as female (58.2%). A preponderance of residents self-identified as Black (39.3%) whereas the majority of staff self-identified as White (55.0%). Receipt of seasonal influenza vaccine for the corresponding influenza season was reported by 42.5% of residents and 51.1% of staff. Among residents, 45.6% (n=611) had experienced chronic homelessness (duration ≥1 year) and 17.5% (n=191) of residents were employed.

Among unique participants, 80.3% (n=1,894, Table 1.1b) of residents and 89.5% (n=510) of staff were asymptomatic when specimens were collected. Among symptomatic participants (residents, n=466; staff, n=60), the most commonly reported symptoms were cough (51.5%), sore throat (33.5%) and fatigue (32.6%) for residents; cough (25.0%), fatigue (25.0%), sore throat (26.7%) and headache (26.7%) for staff. Based on their last survey response, 18.6% of residents and 49.3% of staff had received ≥1 COVID-19 vaccine dose; however, only 15% of these individuals completed their final study enrollment from 3/31/2021 onwards (when vaccine eligibility expanded to include anyone living in congregate settings[43], limiting interpretability.

<u>Shelter characteristics</u>

Table 1.1c presents shelter characteristics by SARS-CoV-2 test result. Nearly 90% (n = 11,506) of swabs were collected during routine surveillance testing events and a predominance were collected from shelters serving mixed gender adults (36.4%, n = 4,700 residents and staff). Most resident encounters were from participants sleeping in private/shared rooms or rooms serving single family units (62.4%, n=6,144).

<u>Overall and stratified incidence of SARS-CoV-2 infection</u>

A total of 139 cases of SARS-CoV-2 infection were detected over the study period. The overall estimated incidence of infection was 4.74 (95% CI 4.00 – 5.58) cases per 100 individuals at risk. Among unique shelter residents the incidence was 4.96 (95% CI 4.12 – 5.91) cases per 100 individuals at risk, compared to 3.86 (95% CI 2.43 – 5.79, Table 1.2) among staff. Incidence was highest among residents aged ≥65 years (7.69 cases per 100, 95% CI 3.90 – 13.35). Among residents, incidence was higher for those male-identifying (5.32, 95% CI 4.24 – 6.59), whereas higher incidence was observed among female-identifying staff (5.92, 95% CI 2.84 – 7.87). Black participants had the highest observed incidence of infection compared to other racial groups (residents: 6.81, 95% CI 5.12 – 8.83; staff: 6.21, 95% CI 2.88 – 11.46). When stratifying by shelter type, incidence was lower at youth shelters (1.41, 95% CI 0.46 – 3.27) compared to adult and family shelters. Incidence was higher among symptomatic (6.84 cases per 100, 95% CI 4.84 – 9.35) compared to asymptomatic individuals (4.28, 95% CI 3.51 – 5.17, Figure 1.1).

Among 2,930 persons tested, SARS-CoV-2 infections peaked in Week 37 of 2020 with 15 unique participants testing positive, with additional peaks in infections observed in Week 17 and Week 51 of 2020 and continued detection observed through the duration of the study period (Figure 1.2a). Among 12,915 tests performed, SARS-CoV-2 test positivity peaked earlier at 9% in epidemiologic week 17 of 2020 (Figure 1.2b). The proportion of participant encounters self-reporting at least one dose of a COVID-19 vaccine is represented in Figure 1.2c; we observed a consistent trend towards increased vaccine uptake from Week 4 (January 24th) in 2021 through the end of the study period.

Combining data from residents and staff, most infections were asymptomatic at time of detection (74%, 103/139, Table 1.1b) and detected during routine surveillance (73%, 101/139, Table 1.1c). Overall test positivity was 1.2%, however, outbreak testing yielded higher positivity (2.7%, 38/1,409 vs. 0.9%, 101/11,506, Table 1.1c).

Factors associated with SARS-CoV-2 infection

Based on unique participants' last surveys (N = 2,930), unadjusted models show that among residents, Black race (OR= 1.83, 95% CI 1.15 – 2.99) was significantly associated with higher odds of SARS-CoV-2 infection, whereas residents who were current smokers had a decreased odds of infection (OR = 0.53, 95% CI 0.36 – 0.79). Adjusting for other model variables (Table 1.3a), residents who smoked had 66% (aOR = 0.34, 95% CI 0.20 – 0.59) lower odds of SARS-CoV-2 infection compared with non-smokers, and residents who had received that season's influenza vaccine had 46% (aOR=0.54, 95% CI 0.33 – 0.90) lower odds of infection compared with those who had not received an influenza vaccine. Among staff, Native Hawaiian and Other

Pacific Islander (NHPI) race was also identified with a significant association, however the validity of this finding is undermined by the small sample size of NHPI participants.

Individual factors associated with symptomatic COVID-19 disease

When assessing factors associated with symptomatic COVID-19 among unique participants (n = 36) with SARS-CoV-2 infections detected (n = 139), the only variable significantly associated with symptomatic infection was staff versus resident status (Table 1.3b). Adjusting for other variables, shelter residents had 70% (0.30, 95% CI 0.10 – 0.97) lower odds of reporting ≥1 new or worsening symptom within 7 days of sample collection compared to shelter staff.

Discussion

From 1/1/2020 through 5/31/2021, we detected an incidence of 4.74 SARS-CoV-2 cases among people experiencing homelessness per 100 persons at risk. Among King County's estimated population of 2.26 million people, there were 106,347 confirmed cases reported from the start of the pandemic through 5/31/21; an incidence of 4.71 cases per 100 persons can be calculated based on these figures.[44] This striking similarity in disease burden may be reflective of this study's early focus on testing asymptomatic individuals: if only symptomatic individuals in our study received testing, as was largely the case for the greater King County community during the early months of the pandemic, the denominator of persons-at-risk may have been smaller but more likely to test positive. Calculated incidence as a result would have been higher in the shelters compared to the general population. As of 1/4/22, PEH comprised 1.4% of COVID-19 cases in King County but only represented 0.5% of its population.[45] Additionally, 12.4% of PEH cases reported to PHSKC were hospitalized due to COVID-19 disease compared to 3.3% in King County's general population.[45] A population level study in Wales, UK found that SARS-CoV-2 prevalence among PEH was lower than the general population.[46] However, this study and others may not account for the differential healthcare seeking behavior or time at risk between PEH and non-PEH which may result in an under-detection of infections when testing is performed in a clinical setting.

A model of SARS-CoV-2's potential effect among the U.S.'s PEH population published in late March 2020 projected that 40% would be infected at the peak of the pandemic due to conditions at homeless service sites and a high prevalence of medical comorbidities.[47] Measured against this projection, comparable results were reported in an adult shelter in Boston where an outbreak investigation yielded 36% test positivity, while one in San Francisco yielded even higher test positivity (67%)[6,48] These estimates and results from specific outbreak testing demonstrate a substantially higher burden than what was observed in this study.[47] The infection rate may differ substantially depending on whether testing was done due to an outbreak or for contact tracing or as surveillance. A systematic review of studies addressing COVID-19 and health-related outcomes in PEH and shelters' staff estimated a pooled SARS-CoV-2 prevalence of 32% among PEH in an outbreak context compared to 2% in the absence of an acute outbreak.[7] This analysis, however, was limited by the relatively short observational periods of its comprised studies compared to our study's prolonged surveillance period.

A substantial proportion of the SARS-CoV-2 infections in our study were asymptomatic at the time specimen were collected. This is likely a consequence of the intensive surveillance in both symptomatic and asymptomatic individuals and the onsite testing presence three to six days per week. Prior studies of seropositive cases in shelters found that individuals with no symptoms at time of testing accounted for 68-85% of all cases.[35,49–51] An Atlanta, Georgia, USA,-based study of symptom evolution of PEH staying in isolation hotels after testing positive for SARS-CoV-2 found that 32% of community referrals became symptomatic after testing positive and 83% of isolation hotel clients reported symptoms at some point.[52] Our participants were not longitudinally followed post-infection detection, but these data add to the evidence that mitigation efforts should be based upon pre-emptive routine testing of all staff and residents of congregate living settings, as opposed to symptom-based testing.

SARS-CoV-2 positive staff were more likely than residents to be tested while symptomatic. This has important implications. Regardless of policies in place, staff members may have worked while experiencing COVID-19 symptoms due to unavailability of paid sick leave, fear of job loss,[53] or dedication to their roles as essential workers. A study of SARS-CoV-2 molecular epidemiology in shelters found evidence that most infections were the result of intra-shelter transmission while staff working across multiple facilities may have introduced the virus into some of the observed facilities.[54] Due to staff's increased likelihood of engaging in social mixing with the broader community and evidence of SARS-CoV-2 infectivity peaking around time of symptom onset,[55] shelter outbreaks could potentially be more often introduced by staff than residents, while disproportionately affecting vulnerable shelter residents.

We found that the highest test positivity was detected in adult male shelters, all of which provided services 24 hours per day. Comparatively, the youth shelters included in this study, which had the lowest observed test positivity, closed services during the day, likely reducing social mixing in both formal and informal communal spaces. King County and the City of Seattle's swift creation of nearly 2,000 new spaces (i.e. beds, isolation or quarantine areas) in homeless service sites likely had a substantial impact on mitigating transmission.[52,56,57] The lack of significant association between sleeping arrangements and risk of infection in our study suggests that other factors, such as intra-shelter social mixing patterns, are facilitating virus transmission, especially in facilities with non-congregate sleeping arrangements but shared hygiene and communal spaces. Relatedly, a simulation study found that in shelters at high risk of a SARS-CoV-2 outbreak, no additional infection control strategy is likely to prevent outbreaks.[16] This evidence supports the prioritization of augmented non-congregate housing options for PEH to reduce transmission.

Our findings suggest that, over a prolonged surveillance period, environmental and behavioral factors may obfuscate associations between SARS-CoV-2 infection and individual-level risk factors. The protective association between influenza vaccination and SARS-CoV-2 infection observed among residents is consistent with prior evidence suggesting that influenza vaccination may reduce the risk of SARS-CoV-2 infection or severe COVID-19.[58–60] However, there is a high probability of confounding variables in many studies and no consensus about the relationship between influenza vaccination and risk of SARS-CoV-2 infection.[61–63] The negative association between smoking and positive test result, observed in other studies with documented methodological limitations,[64] may be the result of smokers spending more time in outdoor spaces or attributing COVID-19-related symptoms to smoking and therefore being less likely to seek testing.[65] These same associations were only observed among residents, however, limiting our ability to conclude if reflective of true biological mechanisms, behavioral differences, or confounding due to unobserved variables.

This study is subject to several limitations. The repeated cross-sectional nature of this study in an open population where participant time-at-risk was not calculable likely resulted in an underestimation of the true disease burden. For these reasons, more specific measures of disease occurrence such as “cumulative incidence” or “incidence rate” could not be applied to this study population. Another limitation is our inability to differentiate between pre-symptomatic, asymptomatic, and convalescent cases due to the cross-sectional design of this study and limiting self-report of new or worsening from <7 days. There was also a high degree of missingness for certain variables that were added mid-study as we learned more about SARS-CoV-2 and COVID-19 disease. However, sensitivity analyses showed this had little effect on the associated risk factors assessed through multivariable regression. Finally, organizational infection prevention methods instituted to mitigate transmission were not routinely collected in this study and therefore their impact could not be examined.

Conclusion

To our knowledge, this is the first study to capture temporal trends and estimate incident SARS-CoV-2 infections among shelter populations through prolonged, active surveillance efforts. Our findings suggest that routine surveillance for SARS-CoV-2 that includes testing of all persons, regardless of symptoms, is essential in ascertaining the true burden of disease among residents and staff of congregate settings. As evidence suggesting a transition to SARS-CoV-2 endemicity grows,[66] additional studies are recommended to assess the cost-effectiveness of routine shelter-based SARS-CoV-2 testing and impact of transmission mitigation efforts in low resource, congregate living settings.

Table 1.1a. Participant characteristics by SARS-CoV-2 RT-PCR test result, by shelter staff and residents, based on last survey response*, January 1, 2020-May 31, 2021 (N=2,930)

	Residents				Staff			
	Positive (n = 117, %)†	Negative (n = 2243, %)	Total (N = 2360)	P-value	Positive (n = 22, %)	Negative (n = 548, %)	Total (N = 570)	P-value
Demographic								
Median age (IQR)	41.0 (39.0)	37.0 (31.0)	37.0 (32.0)	0.30	38.0 (14.8)	32.0 (22.0)	32.5 (22.0)	0.28
Age group				0.26				0.99
<5 y	9 (5.2%)	165 (94.8%)	174 (7.37%)		NA	NA	NA	NA
5-11 y	13 (6.7%)	180 (93.3%)	193 (8.18%)		NA	NA	NA	NA
12-17 y	6 (5.7%)	99 (94.3%)	106 (4.49%)		NA	NA	NA	NA
18-49 y	45 (3.9%)	1096 (96.1%)	1140 (48.3%)		18 (4.0%)	434 (96.0%)	452 (79.3%)	
50-64 y	33 (5.5%)	571 (94.5%)	604 (25.6%)		4 (4.1%)	94 (95.9%)	98 (17.2%)	
≥65 y	11 (7.7%)	132 (92.3%)	143 (6.06%)		0 (0.0%)	20 (100.0%)	20 (3.51%)	
Sex				0.30				0.19
Male	79 (5.3%)	1405 (94.7%)	1484 (64.3%)		6 (2.6%)	227 (97.4%)	233 (41.8%)	
Female	35 (4.2%)	789 (95.8%)	824 (35.7%)		16 (4.9%)	309 (95.1%)	325 (58.2%)	
Race				**0.02**				**<0.01**

American Indian and Alaskan Native	4 (4.4%)	87 (95.6%)	91 (4.68%)		0 (0.0%)	7 (100.0%)	7 (1.34%)	
Asian	0 (0.0%)	59 (100.0%)	59 (3.03%)		1 (2.1%)	47 (97.9%)	48 (9.16%)	
Black/African American	52 (6.8%)	712 (93.2%)	764 (39.3%)		9 (6.2%)	136 (93.8%)	145 (27.7%)	
Multiracial	9 (4.5%)	193 (95.5%)	202 (10.4%)		1 (4.5%)	21 (95.5%)	22 (4.20%)	
Native Hawaiian and Other Pacific Islander	2 (1.6%)	122 (98.4%)	124 (6.38%)		4 (28.6%)	10 (71.4%)	14 (2.67%)	
White	27 (3.8%)	678 (96.2%)	705 (36.2%)		6 (2.1%)	282 (97.9%)	288 (55.0%)	
Hispanic/Latinx ethnicity				0.60				0.99
No	96 (5.0%)	1810 (95.0%)	1906 (82.7%)		20 (3.9%)	491 (96.1%)	511 (90.3%)	
Yes	17 (4.3%)	382 (95.7%)	399 (17.3%)		2 (3.6%)	53 (96.4%)	55 (9.72%)	
Smoker				**<0.01**				0.99
No	79 (6.3%)	1180 (93.7%)	1259 (53.3%)		17 (3.8%)	429 (96.2%)	446 (78.2%)	
Yes	38 (3.5%)	1063 (96.5%)	1101 (46.7%)		5 (4.0%)	119 (96.0%)	124 (21.8%)	
Received seasonal influenza vaccine for corresponding influenza season				0.13				0.51

No	72 (5.7%)	1197 (94.3%)	1269 (57.5%)		12 (4.4%)	258 (95.6%)	270 (48.9%)	
Yes	39 (4.2%)	898 (95.8%)	937 (42.5%)		9 (3.2%)	273 (96.8%)	282 (51.1%)	
Median no. of enrollments[‡] (IQR)	4.00 (10.0)	2.00 (4.0)	2.00 (4.0)	**<0.01**	5.50 (10.8)	2.00 (5.0)	2.00 (5.0)	0.16
Self-reported duration of homelessness				**0.02**				
<6 months	11 (2.2%)	493 (97.8%)	504 (37.6%)		NA	NA	NA	NA
6-12 months	5 (2.2%)	220 (97.8%)	225 (16.8%)		NA	NA	NA	NA
12-24 months	9 (6.2%)	135 (93.8%)	144 (10.7%)		NA	NA	NA	NA
>24 months	23 (4.9%)	444 (95.1%)	467 (34.9%)		NA	NA	NA	NA
Highest education level				0.99				**<0.01**
Less than high school	18 (3.7%)	472 (96.3%)	492 (37.3%)		1 (14.3%)	6 (85.7%)	7 (2.17%)	
High school / GED	16 (3.6%)	424 (96.4%)	439 (33.3%)		7 (11.1%)	56 (88.9%)	63 (19.6%)	
Some college	12 (3.9%)	293 (96.1%)	305 (23.1%)		0 (0.0%)	81 (100.0%)	81 (25.2%)	
Bachelors or higher	3 (3.6%)	80 (96.4%)	83 (6.29%)		9 (5.3%)	162 (94.7%)	171 (53.1%)	
Employed[§]				0.56				0.99
No	36 (4.0%)	867 (96.0%)	902 (82.5%)		1 (4.5%)	21 (95.5%)	22 (6.77%)	
Yes	10 (5.2%)	181 (94.8%)	191 (17.5%)		16 (5.3%)	287 (94.7%)	303 (93.2%)	

Health insurance					**0.02**				0.99
	No	2 (1.0%)	189 (99.0%)	191 (14.1%)		0 (0.0%)	10 (100.0%)	10 (3.13%)	
	Yes	50 (4.3%)	1116 (95.7%)	1166 (85.9%)		17 (5.5%)	293 (94.5%)	310 (96.9%)	

Abbreviations: IQR = interquartile range; NA = not available; GED = General Educational Development
**Final survey response were not collected on the same calendar dates within the study period and are instead representative of the last study encounter from each unique participant*
†All columns apart from "Total" have calculated row percentages; "Total" column percentages calculated exclude missing responses
‡Refers to the number of times each unique participant enrolled in the study and had a nasal specimen/survey collected
§Shelter staff included both unpaid volunteers and paid employees.

Table 1.1b. Clinical characteristics by SARS-CoV-2 RT-PCR test result, by shelter staff and residents, based on last survey response*, January 1, 2020 through May 31, 2021

	Residents				Staff			
	Positive (n = 117, %)†	Negative (n = 2243, %)	Total (N = 2360)	P-value	Positive n = 22 (%)	Negative (n = 548, %)	Total (N = 570)	P-value
Clinical and Illness								
Underlying medical condition (≥1) ‡				0.37				0.95
No	89 (5.2%)	1611 (94.8%)	1700 (72.0%)		17 (4.0%)	407 (96.0%)	424 (74.4%)	
Yes	28 (4.2%)	632 (95.8%)	660 (28.0%)		5 (3.4%)	141 (96.6%)	146 (25.6%)	
≥1 COVID-19 vaccine dose received				0.09				0.50
No	15 (2.6%)	557 (97.4%)	572 (81.4%)		2 (2.7%)	72 (97.3%)	74 (50.7%)	
Yes	0 (0.0%)	131 (100.0%)	131 (18.6%)		0 (0.0%)	72 (100.0%)	72 (49.3%)	
COVID-like illness (CLI) §	3 (4.2%)	69 (95.8%)	72 (3.05%)	0.99	1 (50.0%)	1 (50.0%)	2 (0.351%)	0.08

Influenza-like illness (ILI) ¶	3 (3.8%)	75 (96.2%)	78 (3.31%)	0.99	2 (66.7%)	1 (33.3%)	3 (0.526%)	0.11
Reported symptoms								
None	91 (77.8%)	1803 (80.4%)	1894 (80.3%)	0.57	12 (54.5%)	498 (90.9%)	510 (89.5%)	**<0.01**
Cough	11 (9.40%)	229 (10.2%)	240 (10.2%)	0.90	3 (13.6%)	12 (2.19%)	15 (2.63%)	**0.02**
Shortness of breath	4 (3.42%)	79 (3.52%)	83 (3.52%)	0.99	2 (9.09%)	4 (0.73%)	6 (1.05%)	**0.02**
Fever	4 (3.42%)	96 (4.28%)	100 (4.24%)	0.82	2 (9.09%)	4 (0.73%)	6 (1.05%)	**0.02**
Loss of taste/smell	0 (0%)	7 (0.31%)	7 (0.30%)	0.99	1 (4.55%)	1 (0.18%)	2 (0.35%)	0.08
Sore throat	7 (5.98%)	149 (6.64%)	156 (6.61%)	0.99	3 (13.6%)	13 (2.37%)	16 (2.81%)	**0.01**
Headache	4 (3.42%)	127 (5.66%)	131 (5.55%)	0.41	3 (13.6%)	13 (2.37%)	16 (2.81%)	**0.02**
Fatigue	7 (5.98%)	145 (6.46%)	152 (6.44%)	0.99	3 (13.6%)	12 (2.19%)	15 (2.63%)	**0.02**
Other#	23 (19.7%)	365 (16.3%)	388 (16.4%)	0.40	8 (36.4%)	21 (3.83%)	29 (5.09%)	**<0.01**
Days from symptom onset to swab collection (n = 350)				**0.02**				0.55
≤2 days	8 (5.4%)	139 (94.6%)	147 (44.7%)		5 (33.3%)	10 (66.7%)	15 (71.4%)	
3-4 days	6 (6.8%)	82 (93.2%)	88 (26.7%)		0 (0.0%)	4 (100.0%)	4 (19.0%)	

5-7 days	0 (0.0%)	94 (100.0%)	94 (28.6%)		0 (0.0%)	2 (100.0%)	2 (9.52%)

**Final survey response were not collected on the same calendar dates within the study period and are instead representative of the last study encounter from each unique participant*

[†]*All columns apart from "Total" and "Reported symptoms" have calculated row percentages; "Total" column percentages calculated exclude missing responses*

[‡]*Includes asthma, blood disorders, cancer, chronic obstructive pulmonary disease or emphysema, chronic bronchitis, immunosuppression, liver disease, heart disease, diabetes, neurologic conditions, or aspirin therapy*

[§]*Fever and cough or increased difficulty breathing*

[¶]*Fever and cough or fever and sore throat*

[#]*Includes chills, diarrhea, ear pain or discharge, myalgia, runny nose, nausea/vomiting, rash, or sweats.*

Table 1.1c. Shelter-level characteristics by SARS-CoV-2 RT-PCR test result based on all participant encounters, January 1, 2020-May 31, 2021 (N=12,915)

	Residents				Staff			
	Positive (n = 117, %)*	Negative (n = 9729, %)	Total (N = 9846)	P-value	Positive (n = 22, %)	Negative (n = 3047, %)	Total (N = 3069)	P-value
Testing event				**<0.01**				**<0.01**
Routine	87 (1.0%)	8646 (99.0%)	8733 (88.7%)		14 (0.5%)	2759 (99.5%)	2773 (90.4%)	
Outbreak	30 (2.7%)	1083 (97.3%)	1113 (11.3%)		8 (2.7%)	288 (97.3%)	296 (9.64%)	
Shelter Type				**<0.01**				0.16
Adult female	3 (0.7%)	421 (99.3%)	424 (4.31%)		0 (0.0%)	204 (100.0%)	204 (6.65%)	
Adult male	33 (2.2%)	1434 (97.8%)	1467 (14.9%)		4 (1.5%)	260 (98.5%)	264 (8.60%)	
Family	46 (1.4%)	3337 (98.6%)	3383 (34.4%)		8 (0.7%)	1179 (99.3%)	1187 (38.7%)	
Mixed adult	32 (0.8%)	3910 (99.2%)	3942 (40.0%)		8 (1.1%)	750 (98.9%)	758 (24.7%)	
Youth	3 (0.5%)	627 (99.5%)	630 (6.40%)		2 (0.3%)	654 (99.7%)	656 (21.4%)	
Sleeping arrangement				0.06				--
Communal	39 (1.3%)	2869 (98.7%)	2908 (29.5%)		NA	NA	NA	
Cubicles	3 (0.4%)	791 (99.6%)	794 (8.06%)		NA	NA	NA	
Private/shared family room	75 (1.2%)	6069 (98.8%)	6144 (62.4%)		NA	NA	NA	

**All columns apart from "Total have calculated row percentages; "Total" column percentages calculated exclude missing responses*

Table 1.2. Incidence estimates for SARS-CoV-2 RT-PCR positive test result among unique study participants. Characteristics are based on last survey response*

	Residents			Staff		
Characteristic	Positive	Total tested	Incidence (95% CI) per 100 persons at risk	Positive	Total tested	Incidence (95% CI) per 100 persons at risk
OVERALL	117	2360	4.96 (4.12 – 5.91)	22	570	3.86 (2.43 – 5.79)
Age group						
<5 y	9	174	5.17 (2.39 – 9.59)	--	--	--
5-11 y	13	193	6.74 (3.63 – 11.24)	--	--	--
12-17 y	6	106	5.66 (2.11 – 11.91)	--	--	--
18-49 y	45	1140	3.94 (2.89 – 5.25)	18	452	3.98 (2.38 – 6.22)
50-64 y	33	604	5.46 (3.79 – 7.59)	4	98	4.08 (1.12 – 10.12)
≥65 y	11	143	7.69 (3.90 – 13.35)	0	20	--
Sex						
Female	35	824	4.25 (2.98 – 5.86)	16	325	5.92 (2.84 – 7.87)
Male	79	1484	5.32 (4.24 – 6.59)	6	233	2.58 (0.95 – 5.52)
Race						
American Indian and Alaskan	4	91	4.40 (1.21 – 10.87)	0	7	--

Native						
Asian	0	59	--	1	48	2.08 (0.05 – 11.07)
Black/African American	52	764	6.81 (5.12 – 8.83)	9	145	6.21 (2.88 – 11.46)
Multiracial	9	202	4.46 (2.06 – 8.29)	1	22	4.55 (0.12 – 22.84)
Native Hawaiian and Other Pacific Islander	2	124	1.61 (0.20 – 5.70)	4	14	28.57 (8.39 – 58.10)
White	27	705	3.83 (2.54 – 5.52)	6	288	2.08 (0.77 – 4.48)
Hispanic/ Latinx						
Yes	17	399	4.26 (2.50 – 6.73)	2	55	3.63 (0.44 – 12.53)
No	96	1906	5.03 (4.09 – 6.12)	20	511	3.91 (2.41 – 5.98)
Shelter type						
Adult	68	1329	5.12 (3.99 – 6.44)	12	235	5.11 (2.67 – 8.75)
Family	46	851	5.41 (3.98 – 7.14)	8	161	4.97 (2.17 – 9.56)
Youth	3	180	1.67 (0.35 – 4.79	2	174	1.15 (0.14 – 4.09)

**Final survey response were not collected on the same calendar dates within the study period and are instead representative of the last study encounter from each unique participant*

Table 1.3a. Results of logistic regression analyses, unadjusted and adjusted, for factors associated with SARS-CoV-2 infection among residents and among staff, regardless of symptom profile, January 1, 2020-May 31, 2021

	Resident (N = 2360)		**Staff (N = 570)**	
Variable	Unadjusted OR* (95% CI)	Multivariable aOR† (95% CI)	Unadjusted OR (95% CI)	Multivariable aOR (95% CI)
Age group				
<5 y	1.33 (0.60 – 2.64)	0.73 (0.27 – 1.98)	--	--
5-11 y	1.76 (0.89 – 3.23)	1.21 (0.52 – 2.84)	--	--
12-17 y	1.46 (0.55 – 3.26)	0.68 (0.19 – 2.51)	--	--
18-49 y	**Reference**		**Reference**	
50-64 y	1.41 (0.88 – 2.22)	1.25 (0.66 – 2.38)	1.03 (0.29 – 2.82)	0.71 (0.16 – 3.16)
≥65 y	2.03 (0.98 – 3.88)	1.68 (0.69 – 4.13)	0.00 – Inf.	0.00 – Inf.
Race				
American Indian and Alaskan Native	1.15 (0.34 – 3.04)	1.46 (0.46 – 4.61)	0.00 – Inf.	0.00 – Inf.
Asian	0.00 – Inf.	0.00 – Inf.	1.00 (0.05 – 6.04)	0.00 – Inf.
Black/African American	**1.83 (1.15 – 2.99)**	1.68 (0.98 – 2.86)	3.11 (1.10 – 9.44)	2.42 (0.68 – 8.59)
Multiracial	1.17 (0.51 – 2.44)	1.24 (0.54 – 2.85)	2.24 (0.12 – 13.96)	1.47 (0.14 – 15.22)
Native Hawaiian and Other Pacific Islander	0.41 (0.07 – 1.40)	0.24 (0.03 – 1.88)	**18.80 (4.27 – 77.35)**	**22.37 (3.48 – 143.80)**
White	**Reference**		**Reference**	

Smoker (ref. No)					
	Yes	**0.53 (0.36 – 0.79)**	**0.34 (0.20 – 0.59)**	1.06 (0.34 – 2.74)	0.52 (0.15 – 1.87)
Received seasonal influenza vaccine for corresponding influenza season (ref. No)					
	Yes	0.72 (0.48 – 1.07)	**0.54 (0.33 – 0.90)**	0.71 (0.28 – 1.70)	0.98 (0.32 – 3.02)

**Unadjusted odds ratio (OR) between specified factor and SARS-CoV-2 infection using logistic regression; statistically significant results are bolded.*
†*Adjusted odds ratio (aOR) for the association between the specified factor and SARS-CoV-2 infection using mixed effects logistic regression controlling for all other factors in the table, plus frequency of enrollment for each unique participant, and adjusting for correlation within each shelter (via inclusion of a random intercept). Resident model random intercept had a variance of 1.25 (SD, 1.12); staff model random intercept had a variance of 1.70 (SD, 1.30).*

Table 1.3b. Factors associated with symptomatic COVID-19 disease (n=36) among all unique participants with a SARS-CoV-2 infection detected (N=139)

Variable		Unadjusted OR (95% CI)*	Multivariable aOR (95% CI)[†]
Age group			
	<5 y	0.66 (0.09 – 3.05)	0.41 (0.04 – 4.24)
	5-11 y	0.69 (0.14 – 2.58)	0.79 (0.16 – 3.92)
	12-17 y	0.00 – Inf.	0.00 – Inf.
	18-49 y	**Reference**	**Reference**
	50-64 y	0.86 (0.34 – 2.09)	0.94 (0.30 – 2.94)
	≥65 y	0.51 (0.07 – 2.24)	0.65 (0.11 – 3.94)
Underlying medical condition (≥1)*			
	No	**Reference**	**Reference**
	Yes	1.62 (0.68 – 3.76)	2.21 (0.79 – 6.19)
Received seasonal influenza vaccine for corresponding influenza season			
	No	**Reference**	**Reference**
	Yes	0.74 (0.32 – 1.66)	0.62 (0.25 – 1.59)
Participant Type			
	Staff	**Reference**	**Reference**
	Resident	**0.34 (0.13 – 0.90)**	**0.30 (0.10 – 0.97)**

**Unadjusted odds ratio (OR) between specified factor and symptomatic COVID-19 disease (asymptomatic infection as reference group); statistically significant results have been bolded.*

[†]Adjusted odds ratio (aOR) for the association between specified factor and symptomatic SARS-CoV-2 infection using mixed effects logistic regression controlling for all other factors in the table, plus frequency of enrollment for each unique participant, and adjusting for correlation within each shelter (via inclusion of a random intercept).

Figure 1.1. Crude incidence estimates among all unique participants, plus stratifications: (a) resident vs. staff; (b) children vs. adults; (c) shelter type (adult, family, youth); (d) asymptomatic vs. symptomatic (≥1 symptom)

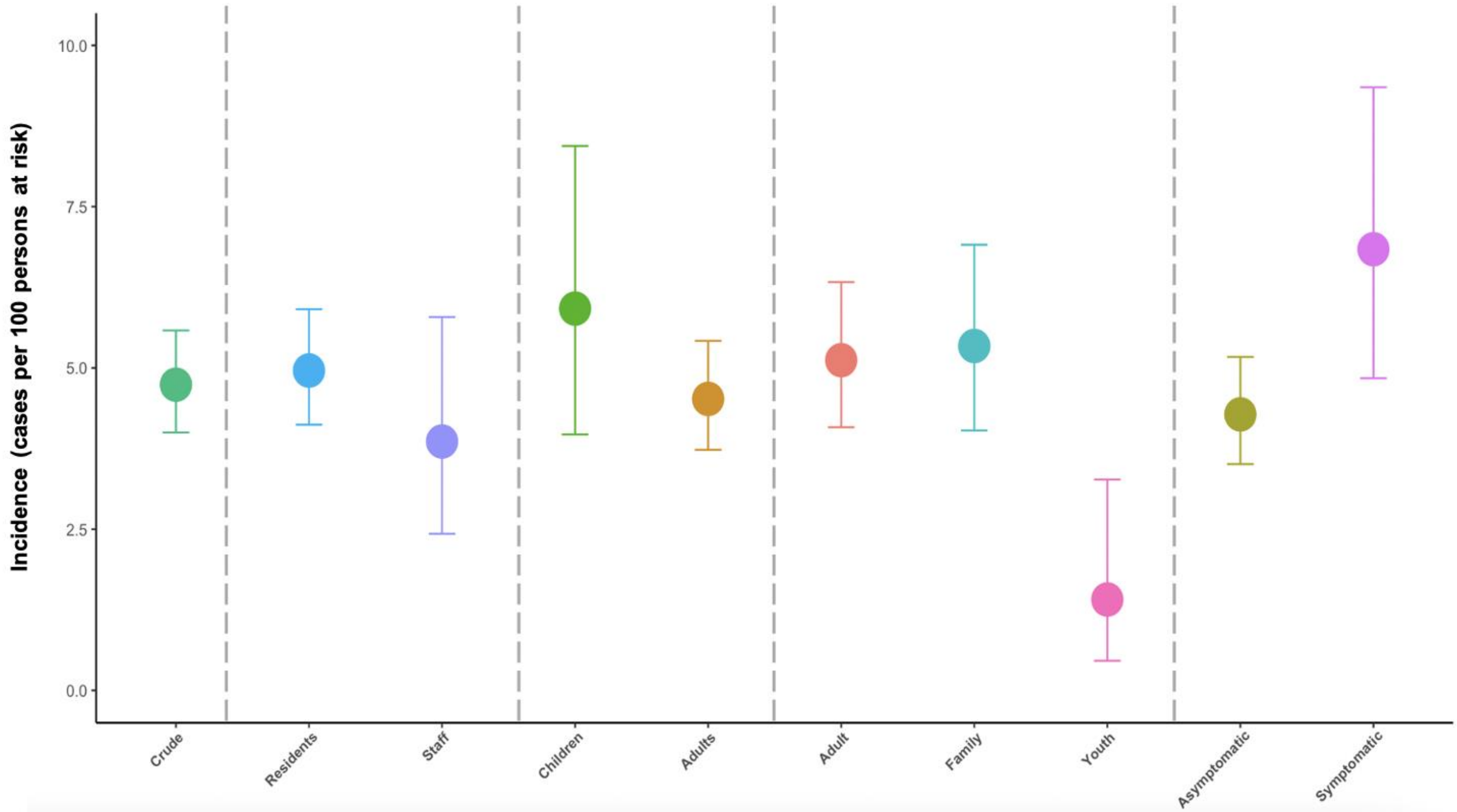
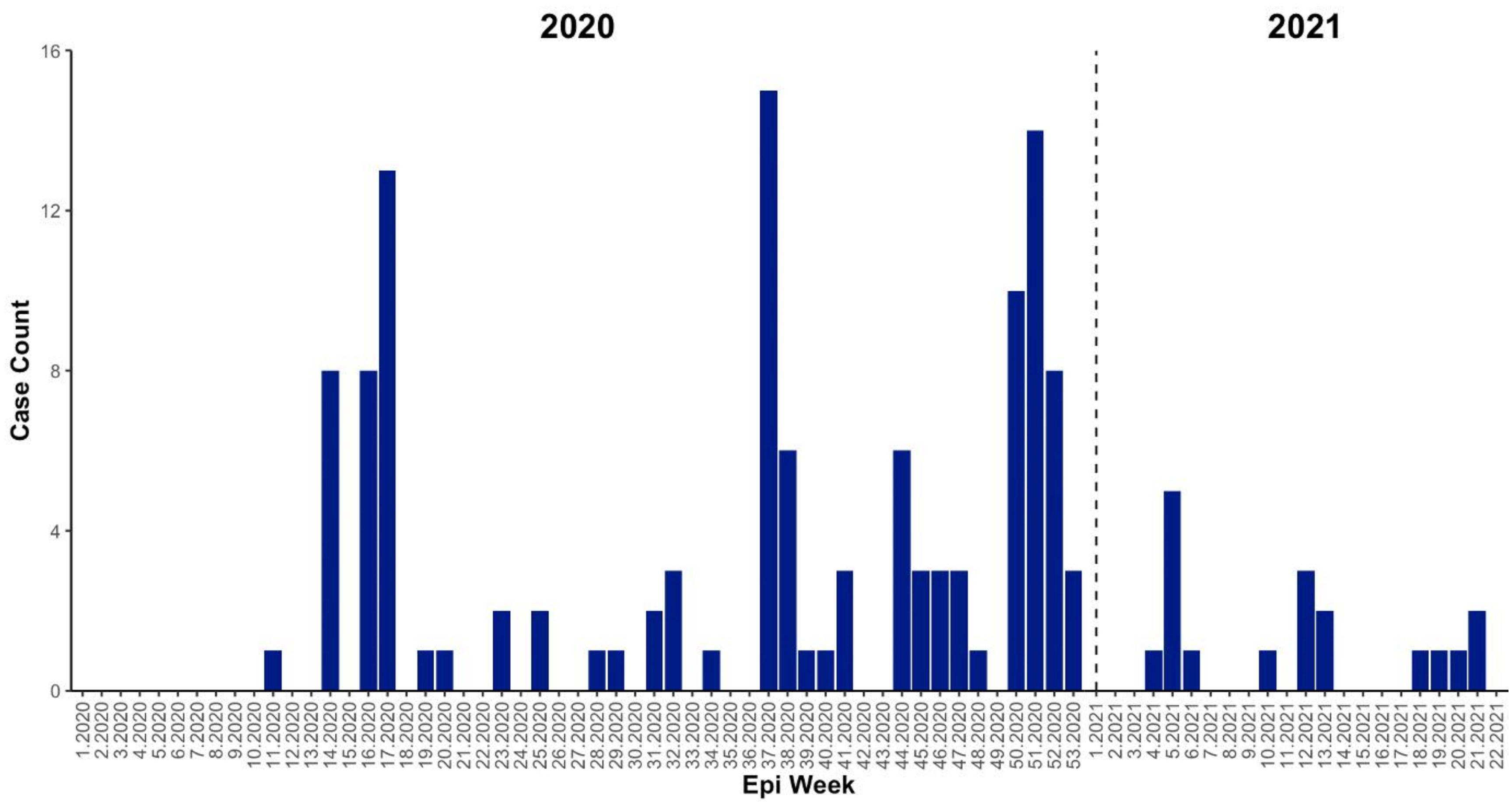
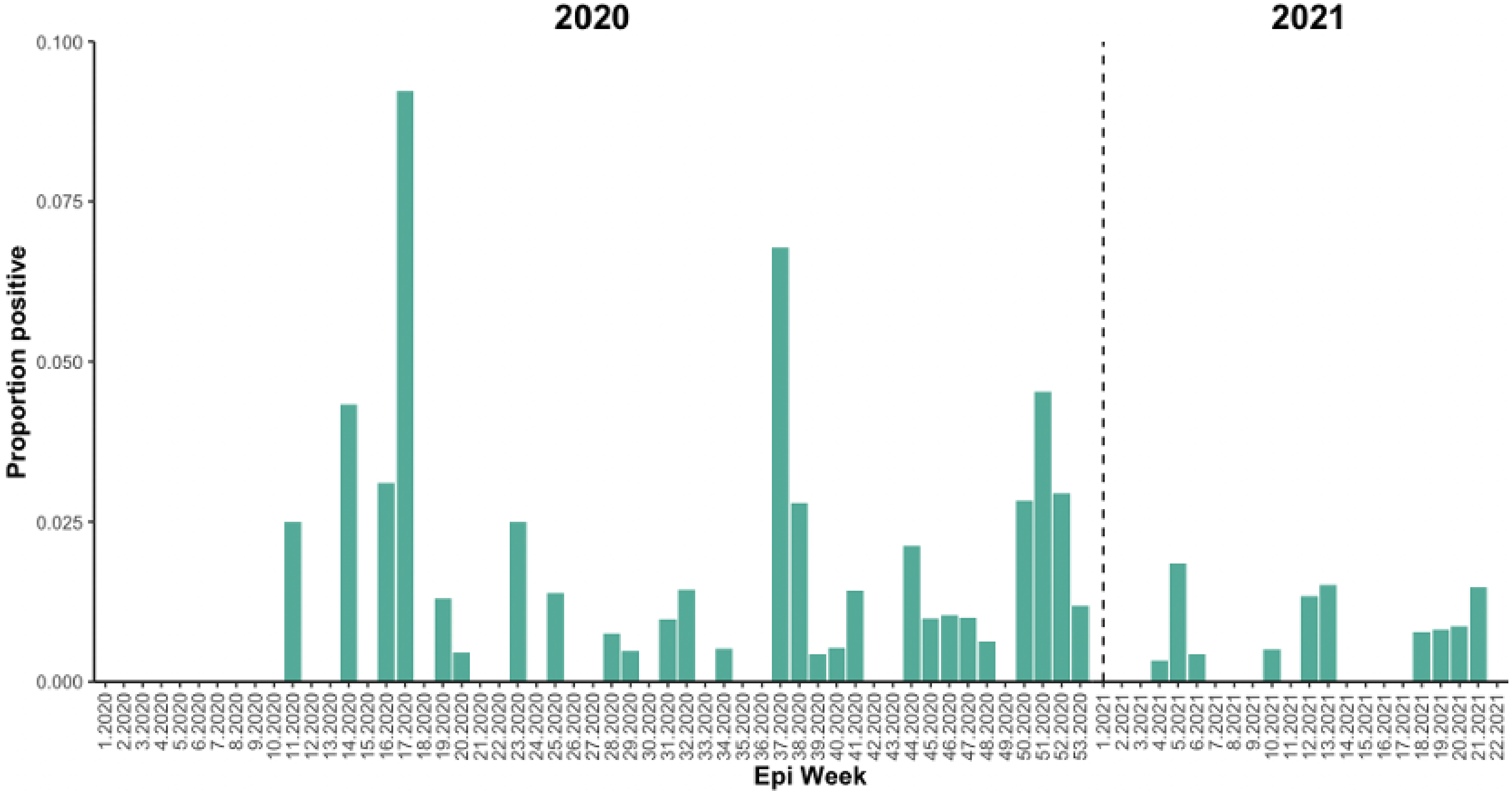


Figure 1.2a-c. Epidemic Curves of SARS-CoV-2 case count (a; N=139); test positivity (b; N=139/12,915); and COVID-19 vaccine uptake (≥1 dose) (c; N=597/12,915) by Epidemiological Week

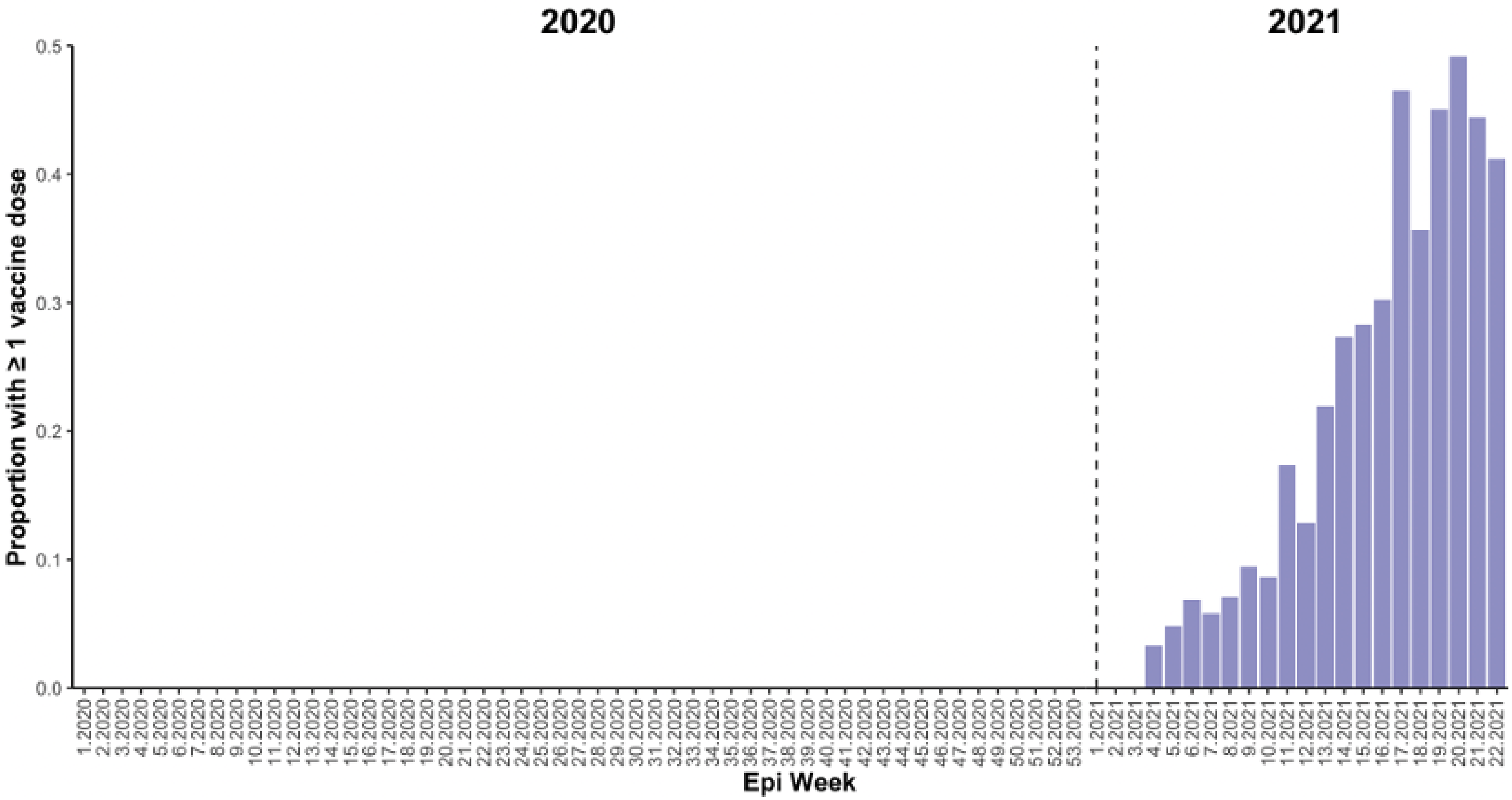
a) SARS-CoV-2 case count



b) SARS-CoV-2 test positivity



c) COVID-19 vaccine uptake

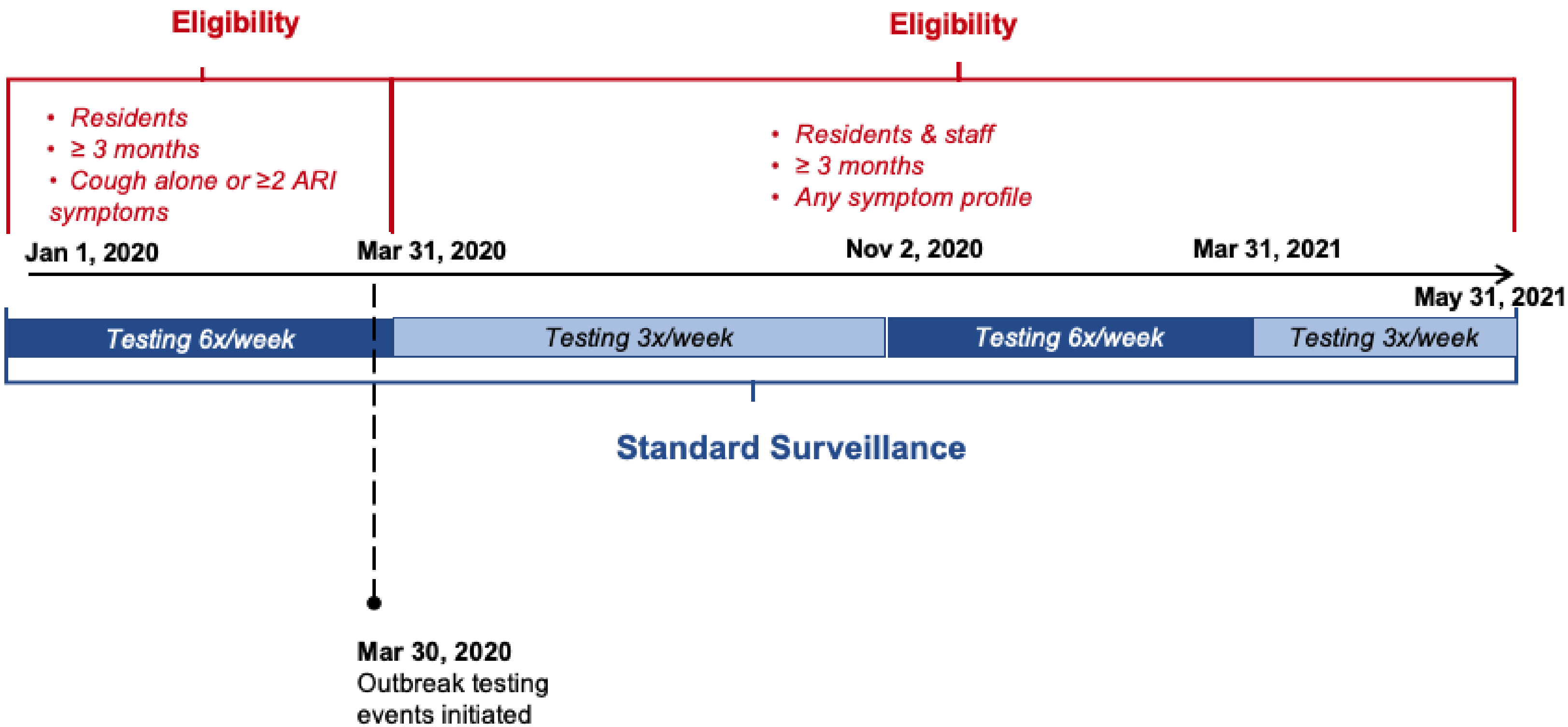


Appendix A – Specimen Testing Methods

Nasal swabs were transported to the University of Washington laboratory in Universal Viral Transport Medium (Becton Dickinson, Franklin, NJ) in ice-packed coolers and stored at 4˚C prior to testing. Testing was performed at the Brotman Baty Institute for Precision Medicine. Total nucleic acids were extracted (MagnaPure, Roche) and tested for the presence of 27 respiratory pathogens by TaqMan reverse-transcription polymerase chain reaction (RT-PCR) on the OpenArray platform (ThermoFisher), and for SARS-CoV-2 using a laboratory-developed test or research assay. For the laboratory-developed test, SARS-CoV-2 detection was performed using RT-PCR with probe sets targeting Orf1b and S with FAM fluor (Life Technologies 4332079 assays # APGZJKF and APXGVC4APX) multiplexed with an RNaseP probe set with VIC or HEX fluor (Life Technologies A30064 or IDT custome) each in duplicate on a QuantStudio 6 instrument (Applied Biosystems). The research assay employs only the Orf1b and RNaseP multiplexed RT-PCR in duplicate.

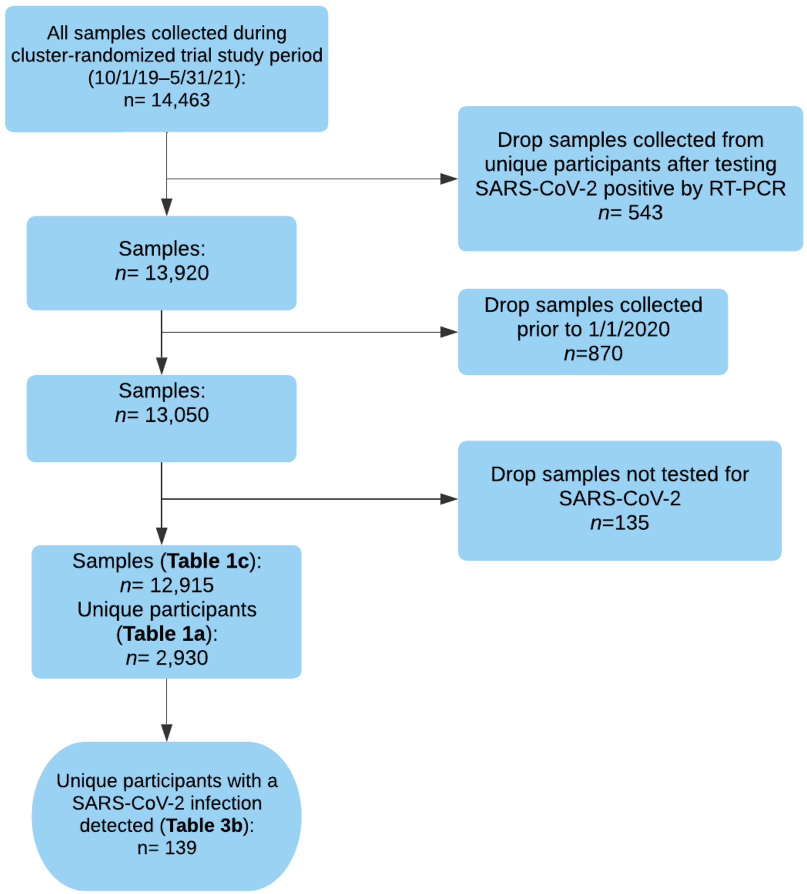
Shelter specimens collected from 2/25/2020 until 3/9/2020 were tested for SARS-CoV-2 using the research assay in real time. Specimens collected after 3/9/2020 were tested for SARS-CoV-2 using the laboratory-developed test under an Emergency Use Authorization issued by Washington State. Specimens collected prior to 2/25/2020 were tested retrospectively using a single replicate RT-PCR research assay to detect SARS-CoV-2 Orf1b.

Supplementary Figure 1.1 – Timeline of testing methodology changes*



** ARI symptoms include: fever/feverishness, cough, sore throat, shortness of breath, myalgia, headache, rhinorrhea, anosmia, nausea/vomiting; plus diarrhea, rash and ear pain/ear discharge in participants < 18 years.*

Supplemental Figure 1.2 – Study flow



Supplementary Table 1.1 – All shelter sites where sample collection occurred, routine surveillance and outbreak testing, October 1, 2019 – May 31, 2021

Shelter	Max. capacity	Resident sex	Resident age range	Sleeping arrangements available
Routine surveillance sites				
A	60	Female	≥ 18 years	Communal bunk beds
B	100	Mixed	≥ 18 years	Communal bunk beds
C	45	Mixed	18 - 25 years	Communal floor mats and bunks beds
D	185	Mixed	All ages (family shelter)	Private rooms / shared rooms / communal floor mats
E	70	Mixed	All ages (family shelter)	Private rooms / shared rooms / communal floor mats
F	60	Male	≥ 18 years	Communal bunk beds
G	275	Mixed	≥ 18 years	Private rooms / shared rooms
H	275	Mixed	All ages (family shelter)	Private rooms / shared rooms
I	45	Male	≥ 50 years	5 person dorms
J	34	Male	≥ 18 years	Individual open cubicles
K	75	Mixed	≥ 18 years	Individual open cubicles
L	200	Mixed	≥ 18 years	Communal bunk beds
M	212	Male	≥ 50 years	Communal floor mats
N	46 private rooms	Mixed	All ages (family shelter)	Private rooms / shared rooms

O	100	Mixed	All ages (family shelter)	Private rooms / shared rooms / communal floor mats

Shelter	Max. capacity	Resident sex	Resident age range	Sleeping arrangements available
Outbreak testing sites				
other_A*	100	Male	≥ 50 years	Communal floor mats
other_B	100	Mixed	≥ 18 years	Private apartments
other_C	150	Mixed	≥ 18 years	Communal floor mats
other_D	234	Mixed	≥ 18 years	Private apartments
other_E	49	Male	≥ 50 years	Communal floor mats
other_F	50	Mixed	All ages (family shelter)	Private rooms / shared rooms / communal floor mats
other_G	18	Mixed	<18 years	Communal bunk beds
other_H	20	Mixed	18 - 25 years	Communal bunk beds

** Shelters “other_A” through “other_H” used as naming mechanism for sites where only outbreak testing was conducted*

Chapter 3. Trends in COVID-19 vaccination intent and factors associated with deliberation and reluctance among adult homeless shelter residents and staff, 1 November 2020 to 28 February 2021 – King County, Washington

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Preface

This Chapter contains a manuscript accepted for publication in the journal *Vaccine* (2022 Jan 3).

In developing this Chapter, I conceptualized the research question and data analysis plan, executed the analyses and sensitivity analyses and led manuscript writing while incorporating co-author feedback. This included extensive meeting and discussion with members of Public Health Seattle-King County's Community Health Services COVID-19 Response team to ensure analysis results were presented and interpreted appropriately given the fluidity of COVID-19 vaccination services and shelter guidelines during the study period. Once I had gathered and documented all co-author statements of approval for the manuscript's journal submission, I led the drafted manuscript text through four rounds of revision as part of the Centers for Disease Control and Prevention clearance process. This data has been presented to Public Health Seattle-King County and various shelter managers of participating shelter study sites.

<u>Disclaimer</u>: The findings and conclusions in this report are those of the authors and do not necessarily represent the view of the US Centers for Disease Control and Prevention.

Abstract

Introduction: Little is known about COVID-19 vaccination intent among people experiencing homelessness. This study assesses surveyed COVID-19 vaccination intent among adult homeless shelter residents and staff and identifies factors associated with vaccine deliberation (responded “undecided”) and reluctance (responded “no”), including time trends.

Methods: From 11/1/2020–2/28/21, we conducted repeated cross-sectional surveys at nine shelters in King County, WA as part of ongoing community-based SARS-CoV-2 surveillance. We used a multinomial model to identify characteristics associated with vaccine deliberation and reluctance.

Results: A total of 969 unique staff (n=297) and residents (n=672) participated and provided 3,966 survey responses. Among residents, 53.7% (n=361) were vaccine accepting, 28.1% reluctant, 17.6% deliberative, and 0.6% already vaccinated, whereas among staff 56.2% were vaccine accepting, 14.1% were reluctant, 16.5% were deliberative, and 13.1% already vaccinated at their last survey. We observed higher odds of vaccine deliberation or reluctance among Black/African American individuals, those who did not receive a seasonal influenza vaccine, and those with lower educational attainment. There was no significant trend towards vaccine acceptance.

Conclusions: Strong disparities in vaccine intent based on race, education, and prior vaccine history were observed. Increased vaccine intent over the study period was not detected. An intersectional, person-centered approach to addressing health inequities by public health authorities planning vaccination campaigns in shelters is recommended.

Clinical Trial Registry Number: NCT04141917

Keywords: COVID-19; SARS-CoV-2; Shelter; Homeless; Vaccination; Health Inequities

Background

The coronavirus disease 2019 (COVID-19) pandemic has caused significant morbidity and mortality and highlighted socioeconomic and racial disparities. People experiencing homelessness (PEH) and the staff who work in homeless shelters are at high-risk for acquiring respiratory viral infections due to difficulty maintaining physical distance, shelter overcrowding, and sharing of hygiene facilities.[48,67,68] In the United States (U.S.), approximately 61% of 580,000 PEH reside in sheltered locations[31] and are disproportionately affected by underlying medical conditions associated with severe illness from COVID-19.[69] Therefore, addressing access and barriers to care in this population is a public health priority.

Challenges to reduce severe outcomes related to COVID-19 include access to COVID-19 vaccination[8,17,18] and a history of disproportionately low vaccine intent among PEH.[17,19,20] An understanding of vaccination intent—defined here as planning to get the COVID-19 vaccine—is important to tailor vaccine campaign strategies to maximize improvements in socio-culturally informed vaccine uptake. Available vaccines report high efficacy and safety,[23,24] and the U.S. population has had an overall increase in COVID-19 vaccine intent over the last year.[70] While many studies have examined the continuum of vaccination intent and related sociodemographic and racial disparities,[70–72] little is known about COVID-19 vaccination intent among PEH or homeless shelter staff. In this study, we assessed adult homeless shelter residents' and staffs' intent to receive COVID-19 vaccination and identified factors associated with vaccine deliberation and reluctance. We also evaluated how vaccination intent changed over a four-month study period that preceded vaccine eligibility for those in congregate settings where PEH live or access services in King County, Washington.

Methods

Study design and population

Our study used a repeated cross-sectional design to describe and identify factors associated with COVID-19 vaccine deliberation and reluctance among shelter residents and staff before vaccine eligibility. This analysis was a sub-study of community-based severe acute respiratory syndrome coronavirus (SARS-CoV-2) surveillance in homeless shelters in King County, Washington.[5] In brief, the surveillance occurred in-person six days/week using self-collected mid-turbinate nasal swabs and corresponding surveys to assess SARS-CoV-2 infection burden and associated risk factors among residents and staff. Persons aged ≥3 months whose primary residence or place of employment was at one of nine shelters were eligible for participation up to once/week. During the study period, two of the nine shelters relocated staff and residents to new facilities that enabled improved adherence to COVID-19 infection and prevention control measures. Research activities immediately recommenced following these relocations. Participant recruitment relied on consistent on-site presence of research staff and in-person messaging that regular testing was an important strategy for keeping oneself and their community safe from COVID-19 disease. Sites included a mix of adult, family, and young adult shelters, strategically selected to be sociodemographically representative of King County's sheltered PEH (Supplemental Table 2.1). Survey responses collected between 11/1/2020 through 2/28/2021 from participants aged ≥18 years were included in this analysis. All survey data were collected electronically in Research Electronic Data Capture (REDCap) on tablets; additional study details have been previously described.[5] This study was approved by the Human Subjects Division of the University of Washington Institutional Review Board (STUDY00007800).

Measures

The primary outcome of this study was the intention to be vaccinated against COVID-19 before and early in the vaccine rollout. All participants were posed the question "*Once a vaccine* *against COVID-19 becomes available to you, do you plan to get it?*" Responses were categorized as vaccine accepting ("yes"); vaccine deliberative[73] ("undecided"); or vaccine reluctant ("no"). Participants who indicated that they already received any COVID-19 vaccine doses were also considered vaccine accepting.

Survey data included participant sex, date of birth (DOB), race, ethnicity (Hispanic or Latino vs. non-Hispanic or Latino), seasonal influenza vaccine receipt, underlying medical conditions, status as shelter staff versus resident, level of highest education (a proxy for health literacy),[74] health insurance status, employment status, receipt of any COVID-19 vaccine doses, and primary reason for COVID-19 vaccination deliberation or reluctance. Influenza vaccine status was determined by self-reported receipt of the vaccine since 7/1/2020. All variables were determined by self-report, including having ever tested positive for SARS-CoV-2 (through this surveillance or another testing platform). Duration of homelessness was captured among shelter residents, with chronic homelessness defined as duration ≥1 year. Enrollments per unique participant was defined as the number of survey responses collected from the same participant over the study period.

Statistical analysis

This study allowed individuals to enroll and complete the survey multiple times (Supplemental Figure 2.1). Surveys from the same participant were linked and assigned a unique identifier using name, DOB, and sex. Incongruous name spelling due to clerical error was addressed using a function of the Levenshtein distance, a metric used to measure the differences between two character strings.[41] Survey records were manually assigned to the same individual if the two names fell above a pre-specified value of similarity (>0.8 in the interval [0,1]) and had the same DOB and sex. If two survey records had the same name and sex but one-digit discrepancy in the DOB, the same unique identifier was assigned.

We used descriptive statistics to evaluate the sociodemographic and health characteristics associated with intent to receive COVID-19 vaccine using each unique participant's last survey response, as it is most relevant to public health decision-making for continuing COVID-19 vaccine implementation efforts. For categorical variables, we used a Chi-square test for independence (or a Fisher's exact test when cells had less than 10 observations) of participant characteristics and vaccine intent, separately among shelter residents and shelter staff; a one-way ANOVA test was used for continuous variables.

To identify factors associated with COVID-19 vaccine deliberation and reluctance, we conducted a multivariate multinomial logistic regression model to calculate adjusted odds ratios (aOR) based on the last survey response. This model compares two nonordered outcome categories to a reference category. We estimated the "odds" (here, the ratio of two probabilities) a participant would be deliberative about COVID-19 vaccination, compared to vaccine accepting (i.e., intending to be or already vaccinated). We simultaneously estimated the odds a participant would be reluctant to vaccination, compared to vaccine accepting. Model covariates included age, race, ethnicity, sex, status as shelter staff versus resident, highest education level, employment status, ≥1 underlying medical condition, enrollments per unique participant, self-reported prior SARS-CoV-2 positive test result, and seasonal influenza vaccination status. Only completed surveys were included; if a subject responded "Prefer not to say" for any covariates included, they were removed as an observation from the final fitted model. We explored models for residents and staff separately; however, finding that several independent variables had fewer than 10 cases in each stratum, we decided to present a single model with a covariate for resident or staff to avoid over-parameterization. We also explored a multivariable multinomial model without influenza vaccination history in case inclusion of this variable concealed other covariates' association with COVID-19 vaccine intent due to collinearity. Coefficient and p-value results were very comparable to the original model, however, so we chose not to present the results from this sensitivity analysis.

When examining population-level change in vaccination intent over time, we overlaid events of interest that preceded widespread vaccine eligibility (Table 2.1) to see if they appeared to correspond with temporal trends in intent to receive COVID-19 vaccine.

To evaluate within-person change in vaccination intent over time, we filtered our data to include only unique participants with two or more survey responses and compared their first and last survey responses. Participants who received any COVID-19 vaccine prior to their first survey were excluded. To test whether there was a significant change in intent over the study period, we fit an unadjusted multinomial logistic model predicting self-reported receipt of or intent to receive a COVID-19 vaccine at last survey response (outcome), based on first survey response. All analyses were performed using R Statistical Software Version 4.0.3.

Results

Participant Characteristics

From 11/1/2020 through 02/28/2021, a total of 969 unique adult shelter residents (n=672) and staff (n=297) in nine shelters in King County, Washington participated and completed 3,966 surveys (Table 2.2). Each participant completed a median of two surveys over the four-month study period, with interquartile ranges (IQR) of [1.00–5.00] and [1.00–6.00], among residents and staff, respectively. The median number of days between participants' first and last survey was 53 (Supplemental Figure 2.2). The median date of first survey was 11/14/2020 (IQR: 11/05/2020–12/12/2020). The median date of last survey was 02/03/2021 (IQR: 12/28/2020–02/22/2021). A greater proportion of residents reported previously testing positive for SARS-CoV-2 than staff (10.4% vs. 5.1%).

The median age of shelter residents and staff was 41 years (range: 18–85 years) and 33 years (range: 18–81 years), respectively. Most participants identified as White (40.5% residents, 53.2% staff) or Black/African American (37.4% residents, 26.3% staff). The majority of residents (63.6%) were male compared to 36.4% of staff. Among residents and staff, 78.4% and 97.3% indicated that they had a high school education or higher, respectively. The majority (56.4%) of residents reported chronic homelessness, and 83.2% were unemployed; 28.9% had one or more underlying medical conditions. At their last survey response, 45.0% of residents and 57.5% of staff reported receiving influenza vaccine for the 2020–2021 influenza season. Prior to widespread COVID-19 vaccine eligibility within this population, four (0.6%) residents had received at least one COVID-19 vaccine dose as of their last survey response compared to 39 (13.1%) staff (Table 2.2).

COVID-19 Vaccination Intent

Among residents, 53.7% (n=361) were vaccine accepting, 28.1% (n=189) reluctant, 17.6% (n=118) deliberative, and 0.6% (n=4) already vaccinated, whereas among staff, 56.2% (n=167) were vaccine accepting, 14.1% (n=42) reluctant, 16.5% (n=49) deliberative, and 13.1% (n=39) already vaccinated at last survey (Table 2.2). The majority of participants who were COVID-19 vaccine accepting were White (62.0% residents, 87.8% staff) and Hispanic or Latino (61.0% residents, 69.0% staff). Among those with a high school education and above (n=821), vaccine acceptance increased with each level of educational attainment (51.5% to 65.1% among residents, 41.7% to 66.9% among staff). Of the residents who previously tested positive for SARS-CoV-2 (n=66), 60.6% reported COVID-19 vaccine acceptance, compared to 53.6% among those who did not (n=567). Of the residents who reported receiving influenza vaccine (n=291), 67.4% reported COVID-19 vaccine acceptance, compared to 43.4% among those who did not report influenza vaccination (n=355).

Reasons for COVID-19 Vaccine Deliberation or Reluctance

Among residents who were vaccine deliberative at last survey (n=118), the most common primary reason reported was that they needed more information (48.6%), whereas vaccine deliberative staff were most commonly concerned about vaccine safety (46.8%; Table 2.2). Among those who were COVID-19 vaccine reluctant, "Other reason" (n=140) was the most common reason given (49.1% residents, 46.2% staff), followed by concerns about vaccine safety (34.3% residents, 35.9% staff). The following reasons were aggregated into the singular "Other reason" category due to low number of responses: *"Do not have time to get vaccinated"* (n=2)*; "Want to make sure high-risk individuals get it first"* (n=4)*; "I've already had COVID-19 and don't think I need the vaccine"* (n=4)*;* and "*None of the above*" (n=130). Of the aggregated "Other reason" responses, 92.9% cited "None of the above" as their primary reason for COVID-19 vaccine deliberation or reluctance (Figure 2.1b).

The most common primary reason for not receiving influenza vaccination was "Other reason" (n=243), among both residents (57.1%) and staff (53.5%). The following reasons were aggregated into the singular "Other reason" category due to low number of responses: "*Do not have the time to get vaccinated*" (n=29); "Not required for work or school" (n=2); "*Not recommended by a doctor or healthcare worker*" (n=2); "*Not covered by health insurance*" (n=3); "*Not offered at a convenient location*" (n=12); "*None of the above*" (n=195). Of the aggregated "Other reason" responses, 80.2% cited "None of the above." Among residents, 19.4% had concerns about influenza vaccine safety and 8.8% were not worried about influenza. Among staff, 14.0% were not worried about influenza compared to 7.0% concerned about vaccine safety.

COVID-19 Vaccination Intent Over Time

When examining population-level changes in vaccination intent and uptake by week, we observed no evident temporal trend of COVID-19 vaccine intent corresponding with events of interest (Figure 2.1a). We observed a slight increase in vaccine reluctance as the proportion of vaccine deliberation decreased over the study period. Generally, we did not observe changes in reasons for vaccine deliberation or reluctance that corresponded with events of interest (Figure 2.1b). However, there was a peak in the proportion of those indicating a need for more information the week following the Emergency Use Authorization (EUA) for the BNT162b2 mRNA (Pfizer) COVID-19 vaccine (43.4%, 95% CI 0.34–0.53), with a downward trend through the end of the study period. The proportion of those indicating “Other reason” was highest in the study’s final week (41.8%, 95% CI 0.32–0.53). Of the aggregated survey responses across the study period, 27.2% cited “None of the above” as the primary reason for COVID-19 vaccine deliberation or reluctance, which remained consistent over time.

The proportion of survey responses indicating seasonal influenza vaccine receipt first surpassed those that did not in Epidemiological Week 48 (Figure 2.1c). Among 1,768 (44.6%) survey responses from participants who had not already received their influenza vaccine, we observed a decrease in those still planning to receive it and an increase in “Other reasons” for no influenza vaccination (Figure 2.1d).

Of the 589 unique participants who completed at least two surveys over the study period, 173 (29.4%) changed their intent to receive a COVID-19 vaccine between first and last response (Figure 2.2; Supplemental Figure 2.1). Of the 135 participants who were vaccine deliberative in their first survey, 60 (44.4%) remained deliberative, 46 (34.1%) became vaccine accepting and 29 (21.5%) vaccine reluctant by their last survey. Among the 125 who were initially vaccine reluctant, 78 (62.4%) remained reluctant, 23 (18.4%) became deliberative, and 24 (19.2%)

became vaccine accepting. Of the 329 who were initially vaccine accepting, 25 (7.6%) became deliberative and 26 (7.9%) became reluctant.

Initial vaccine deliberation compared to initial vaccine acceptance was associated with increased odds of final vaccine deliberation (aOR=11.34, 95% CI 6.41–20.05) and final vaccine reluctance (aOR=5.96, 95% CI 3.22–11.04), as compared to final vaccine acceptance. Initial vaccine reluctance compared to initial vaccine acceptance was associated with increased odds of final vaccine deliberation (aOR=9.43, 95% CI 4.66–19.08) and final vaccine reluctance compared to final vaccine acceptance (aOR=30.75, 95% CI 16.70–56.62) (Table 2.3). Therefore, initial vaccine deliberation and reluctance was highly associated with remaining deliberative or reluctant.

<u>Factors associated with COVID-19 Vaccine Deliberation or Reluctance</u>

Based on unique participants' last survey (n=752), our multivariate multinomial model showed that no prior influenza vaccination during the 2020–2021 season, Black/African American race, and education level lower than bachelor's degree were significantly associated with COVID-19 vaccine deliberation or reluctance as distinct vaccine attitude categories (Table 2.4). Adjusting for other variables, participants who had received that season's influenza vaccine had a 57% (aOR=0.43, 95% CI 0.27–0.67) lower odds of COVID-19 vaccine deliberation and a 64% (aOR=0.36, 95% CI 0.24–0.53) lower odds of COVID-19 vaccine reluctance compared with those who had not received influenza vaccine. Black/African American race was associated with a nearly 2.5-times higher odds of COVID-19 vaccine reluctance (aOR=2.47, 95% CI 1.57–3.88) and 1.7-times higher odds of COVID-19 vaccine deliberation compared to those identifying as White. Having attended some college, high school, and less than high school were each associated with higher odds of deliberation and reluctance compared to those with a bachelor's degree or higher.

Females were more likely to be vaccine deliberative compared to males (aOR=2.26, 95% CI 1.42–3.60), however female sex was not significantly associated with greater vaccine reluctance. Factors associated with vaccine reluctance, but not vaccine deliberation, included identifying with multiple races (aOR=2.41, 95% CI 1.17–4.96) compared to White race and being a shelter resident (aOR=1.96, 95% CI 1.00–3.83) compared to staff. American Indian and Alaska Native (AIAN) race was also identified with a significant association, however the validity of this finding is undermined by the small sample size of AIAN respondents.

Discussion

Intent to be vaccinated against COVID-19 was low and similar among homeless shelter residents and staff in this community-based study conducted over four months prior to widespread vaccine availability in the Seattle metropolitan area. Overall, 54% of shelter residents and 56% of staff were vaccine accepting, compared with 74% of adults in the Seattle metropolitan area as of early February 2021.[75] A survey conducted among PEH in Los Angeles between December 2020 and February 2021 reported 48% of respondents being vaccine hesitant (defined as having refused, or intending to refuse, a vaccine when offered), however change in attitude over time was not assessed.[76] Studies regarding PEH acceptance of vaccines against other pathogens were also lower when compared to the general population.[17,77,78] The substantial discrepancy in vaccine intent between our study population and the general population suggests the importance of tailored interventions by regional housing coordination bodies and homeless service providers to engage shelter residents and staff regarding COVID-19 vaccines.

Factors most strongly associated with COVID-19 vaccine deliberation or reluctance in our study included Black/African American race; lower educational attainment; and not having received seasonal influenza vaccine. Race as a factor associated with low COVID-19 vaccine intent is a consistent finding,[79,80] and has been contextualized as a symptom of underlying structural racism.[73] A study conducted among U.S. adults found 21% higher COVID-19 vaccine hesitancy among those who experienced racial discrimination compared to those who had not.[81] Racial disparities have also been persistent in influenza vaccination coverage among U.S. adults.[82,83] Higher hesitancy (42.9%) among adults without a college degree[84] and lower hesitancy among those who received an influenza vaccine (94% lower odds)[80] were also observed in nationally representative surveys. These two factors could be useful in prioritizing messaging and outreach at shelters. We were not able to conclude that racial and educational inequities are more strongly associated with vaccine deliberation/reluctance than unhoused status due to small sample sizes for several independent variables. However, we explored separate unadjusted regression models and found comparable associations among residents and staff. This suggests a need for PEH vaccine campaigns to address these factors concurrently.

Our study highlights changes in shelter residents and staff intent to be vaccinated against COVID-19 over the study period before widespread vaccine availability. Overall fluctuation of COVID-19 vaccine acceptance prior to availability has similarly been documented in the general U.S. population (71% in May 2020, 51% in September 2020, and 69% in February 2021), with demographic and socioeconomic divides.[70] In another nationally representative study that did not detect this fluctuation, the largest increase in COVID-19 vaccine acceptance was observed among Hispanic and Black respondents, while acceptance remained low among those with lower educational status.[71,72] However, we did not observe discrepancies when we explored changes in vaccine intent between subgroups in our study population. Contrary to our initial hypothesis, we did not observe an increase in vaccination intent and decrease in “need for more information” as time since EUA of COVID-19 vaccines and state-wide eligibility increased. This suggests that risk perception of COVID-19 disease may be an important unmeasured factor associated with vaccine intent, as observed in other populations.[85] For example, a study in France provides evidence that vaccination refusal is strongly associated with a lower perceived risk of severe COVID-19 and that overall intention is likely dependent on available vaccine characteristics,[86] while another study in Italy found that vaccine acceptance increased as COVID-19 risk perception increased during lockdowns.[87] This suggests that temporal trends in vaccine intent are not unique to PEH or shelter staff, and may reflect larger behavioral trends, including documented fluidity of vaccine intent.[72,84]

These findings are subject to several limitations. First, the study employed a repeated cross-sectional design and thus surveys were not conducted on the same calendar dates, but rather when the participant first and last enrolled. Challenges in linking survey records (e.g., due to participants providing inconsistent identifiable information) likely resulted in an overestimation of unique participants. Data were collected during the beginning of public COVID-19 vaccine rollout and may not reflect current vaccination intent. Results may also be subject to selection bias as vaccine intent among those willing to accept SARS-CoV-2 testing and interact with study staff may not reflect the intention of those unwilling to be tested. Furthermore, information bias may be present due to self-report, as well as social desirability bias and changes in comfort with study staff over time. Nondifferential misclassification of underlying medical conditions associated with severe COVID-19 disease may also contribute to attenuation of true associations as high blood pressure and obesity were not captured by the survey. Due to small sample size, we were not able to assess interaction terms in our multinomial multivariate model for potential effect modification. The increasing proportion of participants citing “Other reason” (specifically “None of the above”) for why they are vaccine deliberative or reluctant may reflect the limited scope of our categorical responses, which did not extend to referencing past negative experience and diminished trust in healthcare systems. It may also represent survey fatigue, as this response was similarly high among those unvaccinated against influenza.

Despite including options of “Prefer not to say” and assurances that data would not be shared with shelter administration, there may have been a tendency to respond favorably among residents due to fear of losing access to shelter services. Finally, these findings may not be representative of all King County shelters or generalizable to PEH in other locations and do not allow us to examine factors associated with deliberation or reluctance by resident versus staff.

Investigator Positionality Statement

In the spirit of reflexivity, we acknowledge the role that our socioeconomic positions and experiences may contribute to data presentation and interpretation. Co-authors have extensive experience conducting vaccine research and public health practice to improve health equity in Seattle-King County. Among co-authors, there is some familial and personal lived experience of homelessness.

Public Health Implications

This study provides critical data on low COVID-19 vaccination intent among residents and staff in homeless shelters, with no increase in vaccination intent between November 2020 and February 2021. Strong disparities in vaccination intent associated with education and race suggest that these factors should be considered as part of an intersectional approach to address health inequities by public health authorities planning vaccination campaigns in shelters. Suggested interventions include: (1) partnering with trusted organizations and those with lived experience to build relationships and deliver transparent health messaging between the community and medical institutions; (2) mobile units and community vaccination events for equitable vaccine distribution; (3) favoring person-to-person practices over reliance on web-based technology; (4) trauma-informed engagement strategies attuned to racial and socioeconomic disparities; and (5) offering flexible, non-punitive sick leave options (e.g., paid sick leave) for employees to get vaccinated and for those with symptoms after vaccination.[73] Evidence of these approaches' success are seen in their deployment by tribal communities and Urban Indian organizations.[88,89] More studies, specifically employing qualitative methodologies, are needed to evaluate the role of structural racism and low health literacy on vaccine attitudes among shelter residents and staff. Our findings support a need for continued dialogue and a person-centered approach to understanding the sociocultural complexities and dynamism of vaccine attitudes at shelters so that residents and staff may feel more receptive to make informed choices about the risks and benefits of vaccination.

Acknowledgements

We thank the shelter staff and program managers for their cooperation and collaboration throughout the participant recruitment process. A special thanks to all participants and the research assistants who assisted with data collection.

All authors attest they meet the ICMJE criteria for authorship.

Conflicts of Interest Statement

JHR no conflict; SNC no conflict; JPH: reports grants from the National Institutes of Health outside the submitted work; ACL: no conflict; EJC: no conflict; IF: no conflict; MDL: no conflict; MMS: no conflict; TMU: no conflict; CO: no conflict; MAR: no conflict; EM: no conflict; MLJ: reports receiving research funding from Sanofi Pasteur unrelated to the present work; MB: consults for Moderna, VirBio, and Merck, has received research support from Regeneron, Ridgeback, Merck, and VirBio outside the submitted work, and has received research support from the Bill and Melinda Gates Foundation during the conduct of the study. JAE: reports research support paid to her institution from AstraZeneca, GlaxoSmithKline, Novavax, Merck, and Pfizer and is a consultant for Sanofi Pasteur, AstraZeneca, and Meissa Vaccines; HYC reported consulting with Ellume, Pfizer, The Bill and Melinda Gates Foundation, Glaxo Smith Kline, and Merck. She has received research funding from Gates Ventures, Sanofi Pasteur, and support and reagents from Ellume and Cepheid outside of the submitted work.

Table 2.1. Events of interest related to COVID-19 vaccine confidence in Washington State

	Event Description	Date Implemented
1	Institution of Washington (WA) statewide restrictions on openings and public gatherings	16 November 2020
2	Emergency Use Authorization for the BNT162b2 mRNA (Pfizer) COVID-19 vaccine by the U.S. Food and Drug Administration	11 December 2020
3	Initiation of Phase 1A Tier 1 COVID-19 vaccination in WA*, extending eligibility to: • High-risk workers in health care settings • High-risk first responders • Long-term care facility residents	14 December 2020
4	Initiation of Phase 1B Tier 1 COVID-19 vaccination in WA, extending eligibility to: • All people 65 years and older • People 50 years and older living in multigenerational households • Workers in childcare settings • Pre-K-12 educators and school staff	18 January 2021
5	First discovery of the SARS-CoV-2 variant B.1.1.7 in WA	23 January 2021

*****COVID-19 Vaccine Response Team, Meehan K, Hanewall B. *COVID-19 Vaccine Prioritization Guidance and Allocation Framework*.; 2021. https://www.doh.wa.gov/Portals/1/Documents/1600/coronavirus/820-112-VaccineAllocationPrioritization.pdf

Table 2.2. Last survey responses for COVID-19 vaccine uptake, when it becomes available, from unique participants*

	Intent to Be Vaccinated, *n (%)*†											
	Resident						Staff					
	No n=189 (28.1%)	**Yes** n=361 (53.7%)	**Undecided** n=118 (17.6%)	**Received vaccine** n=4 (0.6%)	**Total** n=672	**P-value**	**No** n=42 (14.1%)	**Yes** n=167 (56.2%)	**Undecided** n=49 (16.5%)	**Received vaccine** n=39 (13.1%)	**Total** n=297	**P-value**
Median age [Range]	36.0 [18.0, 80.0]	45.0 [18.0, 85.0]	38.0 [18.0, 72.0]	48.5 [41.0, 51.0]	**41.0 [18.0, 85.0]**	<0.001	38.5 [20.0, 68.0]	29.0 [18.0, 78.0]	40.0 [21.0, 71.0]	31.0 [21.0, 81.0]	**33.0 [18.0, 81.0]**	0.004
Age group												
18-49 y	142 (31.8%)	212 (47.4%)	90 (20.1)	3 (0.7%)	**447 (66.5%)**	0.001	35 (14.5%)	139 (57.7%)	37 (15.4%)	30 (12.4%)	**241 (81.1%)**	0.33
50-64 y	35 (20%)	118 (67.4%)	21 (12%)	1 (0.6%)	**175 (26.0%)**		6 (13.3%)	23 (51.1%)	11 (24.4%)	5 (11.1%)	**45 (15.2%)**	
≥65 y	12 (24%)	31 (62%)	7 (14%)	0 (0%)	**50 (7.44%)**		1 (9.1%)	5 (45.5%)	1 (9.1%)	4 (36.4%)	**11 (3.70%)**	
Race												
American Indian/ Alaska Native	9 (34.6%)	11 (42.3%)	5 (19.2%)	1 (3.8%)	**26 (4.50%)**	0.001	1 (25.0%)	1 (25.0%)	2 (50.0%)	0 (0.0%)	**4 (1.44%)**	<0.001
Asian	2 (11.1%)	15 (83.3%)	1 (5.6%)	0 (0.0%)	**18 (3.11%)**		3 (10.3%)	19 (65.5%)	3 (10.3%)	4 (13.8%)	**29 (10.4%)**	
Black/African American	75 (34.7%)	100 (46.3%)	39 (18.1%)	2 (0.9%)	**216 (37.4%)**		29 (39.7%)	16 (21.9%)	20 (27.4%)	8 (11.0%)	**73 (26.3%)**	
Multiple	21 (44.7%)	19 (40.4%)	7 (14.9%)	0 (0.0%)	**47 (8.13%)**		0 (0.0%)	11 (64.7%)	2 (11.8%)	4 (23.5%)	**17 (6.12%)**	
Native Hawaiian/ Pacific Islander	14 (37.8%)	17 (45.9%)	6 (16.2%)	0 (0.0%)	**37 (6.40%)**		0 (0.0%)	2 (28.6%)	4 (57.1%)	1 (14.3%)	**7 (2.52%)**	
White	46 (19.7%)	145 (62.0%)	43 (18.4%)	0 (0.0%)	**234 (40.5%)**		7 (4.7%)	108 (73.0%)	11 (7.4%)	22 (14.9%)	**148 (53.2%)**	
Hispanic or Latinx	19 (19.0%)	61 (61.0%)	20 (20.0%)	0 (0%)	**100 (15.2%)**	0.12	1 (3.4%)	17 (58.6%)	8 (27.6%)	3 (10.3%)	**29 (9.90%)**	0.13
Male	113 (27.4%)	244 (59.2%)	54 (13.1%)	1 (0.2%)	**412 (63.6%)**	<0.001	10 (9.4%)	70 (66.0%)	13 (12.3%)	13 (12.3%)	**106 (36.4%)**	0.06
Duration of homelessness												
≤6 months	60 (32.8%)	87 (47.5%)	35 (19.1%)	1 (0.5%)	**183 (28.7%)**	0.24	NA	NA	NA	NA	**NA**	NA
7-12 months	34 (35.8%)	46 (48.4%)	15 (15.8%)	0 (0.0%)	**95 (14.9%)**		NA	NA	NA	NA	**NA**	
13-24 months	20 (27.4%)	42 (57.5%)	10 (13.7%)	1 (1.4%)	**73 (11.4%)**		NA	NA	NA	NA	**NA**	
≥24 months	68 (23.7%)	171 (59.6%)	46 (16.0%)	2 (0.7%)	**287 (45.0%)**		NA	NA	NA	NA	**NA**	
Highest education												
Less than high school	42 (30.0%)	75 (53.6%)	23 (16.4%)	0 (0.0%)	**140 (21.6%)**	0.02	1 (12.5%)	4 (50.0%)	3 (37.5%)	0 (0.0%)	**8 (2.70%)**	<0.001
High school / GED	74 (27.4%)	139 (51.5%)	55 (20.4%)	2 (0.7%)	**270 (41.6%)**		18 (30.0%)	25 (41.7%)	14 (23.3%)	3 (5.0%)	**60 (20.3%)**	

Some college	55 (28.1%)	112 (57.1%)	29 (14.8%)	0 (0.0%)	**196 (30.2%)**		14 (19.7%)	33 (46.5%)	20 (28.2%)	4 (5.6%)	**71 (24.0%)**	
Bachelors or higher	9 (20.9%)	28 (65.1%)	4 (9.3%)	2 (4.7%)	**43 (6.63%)**		9 (5.7%)	105 (66.9%)	11 (7.0%)	32 (20.4%)	**157 (53.0%)**	
Employed	35 (32.1%)	51 (46.8%)	23 (21.1%)	0 (0.0%)	**109 (16.2%)**	0.30	41 (14.7%)	150 (54.0%)	49 (17.6%)	38 (13.7%)	**278 (93.6%)**	0.02
Health insurance	148 (26.9%)	305 (55.4%)	95 (17.2%)	3 (0.5%)	**551 (85.2%)**	0.20	40 (14.3%)	157 (56.1%)	45 (16.1%)	38 (13.6%)	**280 (95.6%)**	0.99
Underlying medical conditions (≥1)‡	40 (20.6%)	111 (57.2%)	40 (20.6%)	3 (1.5%)	**194 (28.9%)**	0.01	7 (11.1%)	38 (60.3%)	12 (19.0%)	6 (9.5%)	**63 (21.2%)**	0.64
Median enrollments per unique participant [Range]	2.00 [1.00, 31.0]	2.00 [1.00, 27.0]	2.00 [1.00, 25.0]	12.0 [3.00, 16.0]	**2.00 [1.00, 31.0]**	0.05	1.50 [1.00, 15.0]	2.00 [1.00, 15.0]	2.00 [1.00, 20.0]	6.00 [1.00, 16.0]	**2.00 [1.00, 20.0]**	<0.001
Ever tested SARS-CoV-2 positive	13 (19.7%)	40 (60.6%)	12 (18.2%)	1 (1.5%)	**66 (10.4%)**	0.25	3 (21.4%)	6 (42.9%)	1 (7.1%)	4 (28.6%)	**14 (5.05%)**	0.20
Reason for no COVID-19 vaccine												
Concerns about vaccine safety	60 (72.3%)	NA	23 (27.7%)	NA	**83 (29.4%)**	<0.001	14 (38.9%)	NA	22 (61.1%)	NA	**36 (41.9%)**	0.005
Need more information	21 (28.8%)	NA	52 (71.2%)	NA	**73 (25.9%)**		6 (26.1%)	NA	17 (73.9%)	NA	**23 (26.7%)**	
Not worried about COVID-19	8 (72.7%)	NA	3 (27.3%)	NA	**11 (3.90%)**		1 (50.0%)	NA	1 (50.0%)	NA	**2 (2.33%)**	
Not enough time	1 (50.0%)	NA	1 (50.0%)	NA	**2 (0.71%)**		0 (0.0%)	NA	0 (0.0%)	NA	**0 (0.0%)**	
Already had COVID-19	3 (100.0%)	NA	0 (0.0%)	NA	**3 (1.06%)**		1 (100.0%)	NA	0 (0.0%)	NA	**1 (1.16%)**	
Want to prioritize high-risk persons	1 (100.0%)	NA	0 (0.0%)	NA	**1 (0.35%)**		1 (33.3%)	NA	2 (66.7%)	NA	**3 (3.49%)**	
Unlisted reason	81 (74.3%)	NA	28 (25.7%)	NA	**109 (38.7%)**		18 (72.0%)	NA	7 (28.0%)	NA	**21(24.4%)**	
Received this season's flu vaccine	56 (19.2%)	196 (67.4%)	37 (12.7%)	2 (0.7%)	**291 (45.0%)**	<0.001	9 (5.4%)	107 (63.7%)	20 (11.9%)	32 (19.0%)	**168 (57.5%)**	<0.001
Reason for no flu vaccine												
Concerns about vaccine safety	32 (51.6%)	18 (29.0%)	12 (19.4%)	0 (0.0%)	**62 (19.4%)**	<0.001	4 (50.0%)	1 (12.5%)	2 (25.0%)	1 (12.5%)	**8 (7.02%)**	0.02
Not worried about flu	10 (35.7%)	8 (28.6%)	10 (35.7%)	0 (0.0%)	**28 (8.78%)**		8 (50.0%)	3 (18.8%)	4 (25.0%)	1 (6.2%)	**16 (14.0%)**	
I plan to get the flu vaccine	6 (12.8%)	26 (55.3%)	15 (31.9%)	0 (0.0%)	**47 (14.7%)**		2 (6.9%)	21 (72.4%)	4 (13.8%)	2 (6.9%)	**29 (25.4%)**	
Other reason§¶	72 (39.6%)	83 (45.6%)	26 (14.3%)	1 (0.5%)	**182 (57.1%)**		16 (26.2%)	27 (44.3%)	15 (24.6%)	3 (4.9%)	61. **(53.5%)**	

* Excludes participants that responded "Prefer not to say" when asked about vaccination intent
† All columns apart from "Total" have calculated row percentages; "Total" column percentages calculated exclude missing responses
‡ Underlying conditions include asthma, blood disorders, cancer, chronic obstructive pulmonary disease or emphysema, immunosuppression, liver disease, heart disease, diabetes, neurologic conditions or aspirin therapy
§ Aggregated responses: "Do not have the time to get vaccinated" (n=29); "Not required for work or school" (n=2); "Not recommended by a doctor or healthcare worker" (n=2); "Not covered by health insurance" (n=3); "Not offered at a convenient location" (n=12); "None of the above" (n=195)

Table 2.3. Multinomial logistic model predicting intent to receive COVID-19 vaccine at last survey response based on first response (N= 587)*

	Last Survey (ref = vaccine accepting)								
	Vaccine deliberative			Vaccine reluctant			Received at least one vaccine dose		
First Survey (ref. = vaccine accepting)	**aOR †**	**95% CI**	**P-value**	**aOR**	**95% CI**	**P-value**	**aOR**	**95% CI**	**P-value**
Vaccine deliberative	11.34	6.41 – 20.05	**<0.001**	5.96	3.22 – 11.04	**<0.001**	1.25	0.52 – 3.01	0.622
Vaccine reluctant	9.43	4.66 – 19.08	**<0.001**	30.75	16.70 – 56.62	**<0.001**	NA	NA	NA

*Excludes participants vaccinated at first response
† aOR = adjusted odds ratio

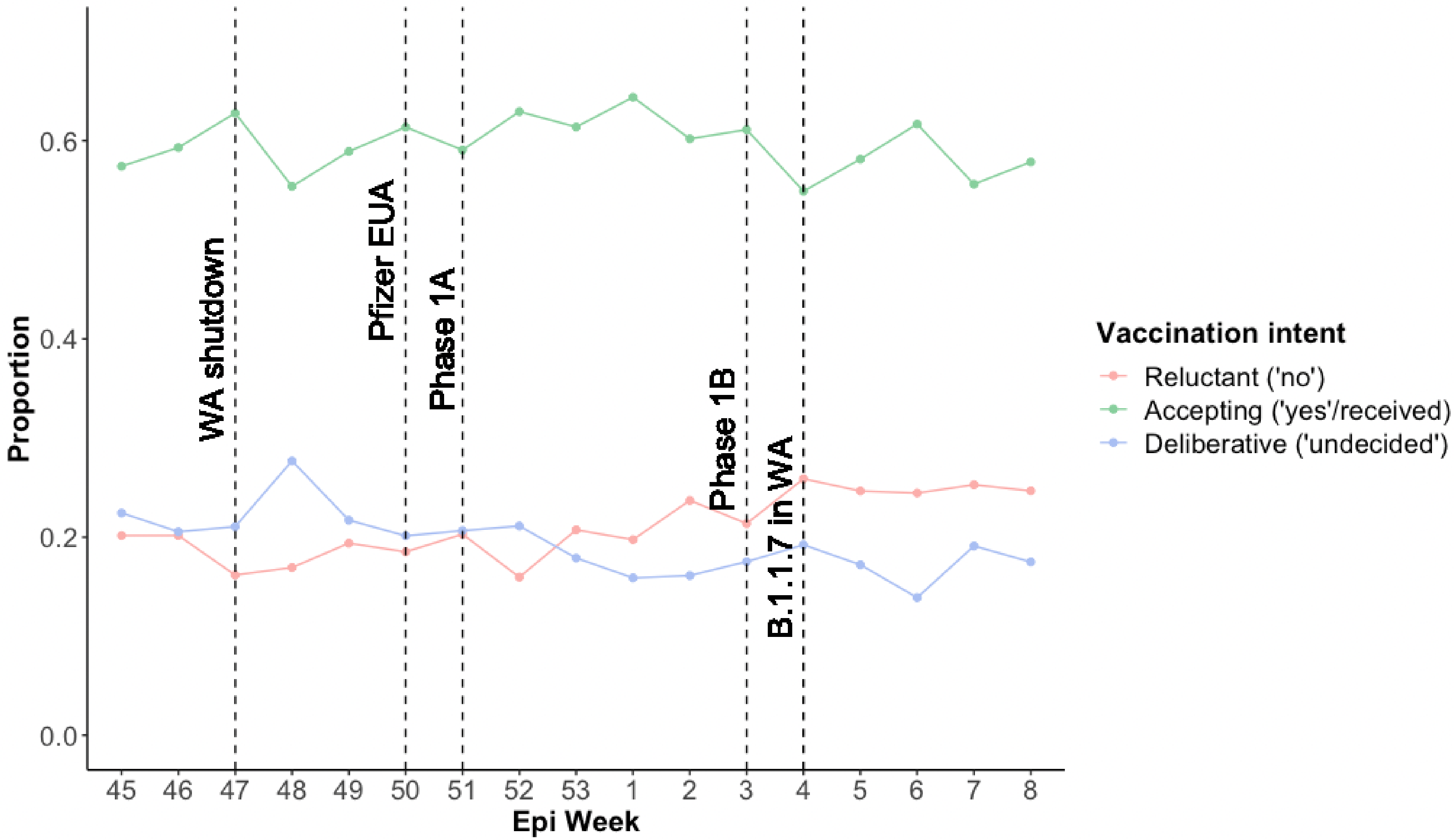
Table 2.4. Multivariate predictors of vaccine deliberation or vaccine reluctance regarding intent to be vaccinated, according to multinomial model, based on last survey response (N = 752)*

	Vaccine deliberative ("undecided" vs. "yes/received")			Vaccine reluctant ("no" vs. "yes/received")		
Characteristic	**aOR †**	**95% CI**	**P-value**	**aOR**	**95% CI**	**P-value**
Age group						
18-49 y	1.03	0.41 – 2.62	0.947	1.75	0.72 – 4.24	0.215
50-64 y	0.72	0.26 – 1.94	0.511	0.90	0.34 – 2.33	0.824
≥ 65 y		Reference			Reference	
Race						
American Indian/ Alaska Native	1.98	0.61 – 6.49	0.257	3.20	1.13 – 9.02	**0.028**
Asian	0.34	0.08 – 1.52	0.157	0.63	0.20 – 1.94	0.418
Black/African American	1.69	1.02 – 2.78	**0.040**	2.47	1.57 – 3.88	**<0.001**
Multiple	0.94	0.36 – 2.41	0.892	2.41	1.17 – 4.96	**0.017**
Native Hawaiian/ Pacific Islander	1.01	0.35 – 2.88	0.987	1.32	0.54 – 3.25	0.540
White		Reference			Reference	
Ethnicity						
Hispanic	1.29	0.59 – 2.82	0.524	0.50	0.21 – 1.20	0.120
Non-Hispanic		Reference			Reference	
Sex						
Female	2.26	1.42 – 3.60	**0.001**	1.45	0.96 – 2.17	0.076
Male		Reference			Reference	
Participant type						
Resident	1.41	0.68 – 2.91	0.358	1.96	1.00 – 3.83	**0.048**
Staff		Reference			Reference	
Highest education level						
Less than high school	3.90	1.46 – 10.36	**0.006**	3.51	1.54 – 8.03	**0.003**
High school / GED	4.69	2.06 – 10.69	**<0.001**	3.34	1.63 – 6.86	**0.001**
Some college	4.56	2.03 – 10.27	**<0.001**	3.38	1.66 – 6.90	**0.001**
Bachelors or higher		Reference			Reference	
Employed						
Yes	1.43	0.76 – 2.68	0.269	1.11	0.63 – 1.93	0.723
No		Reference			Reference	
Underlying medical conditions (≥1) ‡						

	Yes	1.36	0.84 – 2.21	0.211	0.77	0.48 – 1.23	0.268
	No		Reference			Reference	
Enrollments per unique participant							
	2	0.79	0.40 – 1.56	0.496	0.54	0.29 – 0.99	**0.045**
	3-5	1.02	0.57 – 1.83	0.949	1.05	0.64 – 1.71	0.846
	≥6	1.23	0.69 – 2.18	0.488	0.76	0.45 – 1.28	0.304
	1		Reference			Reference	
Prior SARS-CoV-2 positive test							
	Yes	0.63	0.29 – 1.36	0.242	0.50	0.25 – 1.00	**0.049**
	No		Reference			Reference	
Received flu vaccine							
	Yes	0.43	0.27 – 0.67	**<0.001**	0.36	0.24 – 0.53	**<0.001**
	No		Reference			Reference	

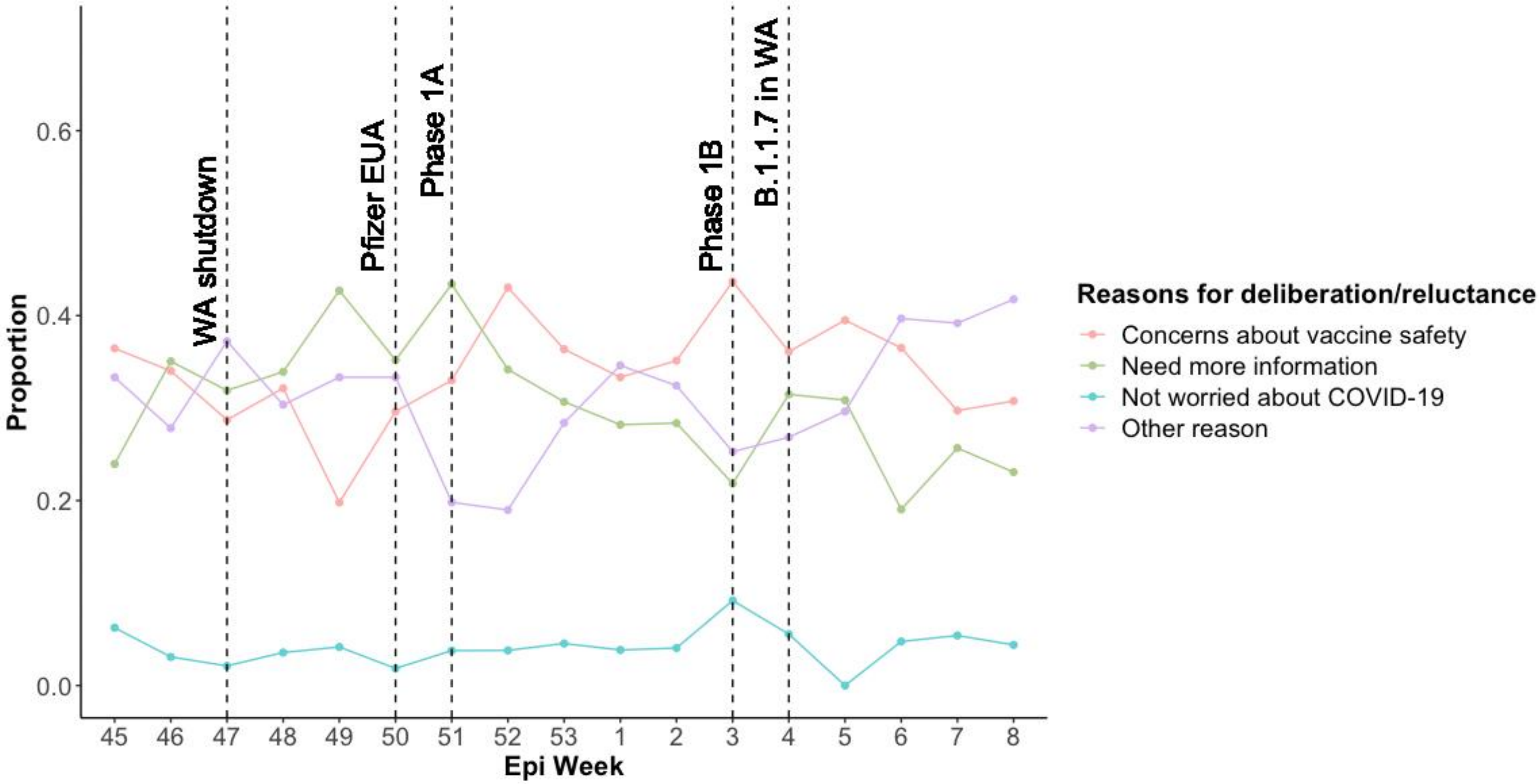
*Based on complete case responses (N=752); responses "yes" or "received vaccine" combined is the reference group for the outcome
† aOR = adjusted odds ratio
‡ Underlying conditions include asthma, blood disorders, cancer, chronic obstructive pulmonary disease or emphysema, immunosuppression, liver disease, heart disease, diabetes, neurologic conditions or aspirin therapy

Figure 2.1a. Proportion of survey responses for COVID-19 vaccine uptake when it becomes available, by Centers for Disease Control & Prevention (CDC) Epidemiological Week (N = 3,966)*



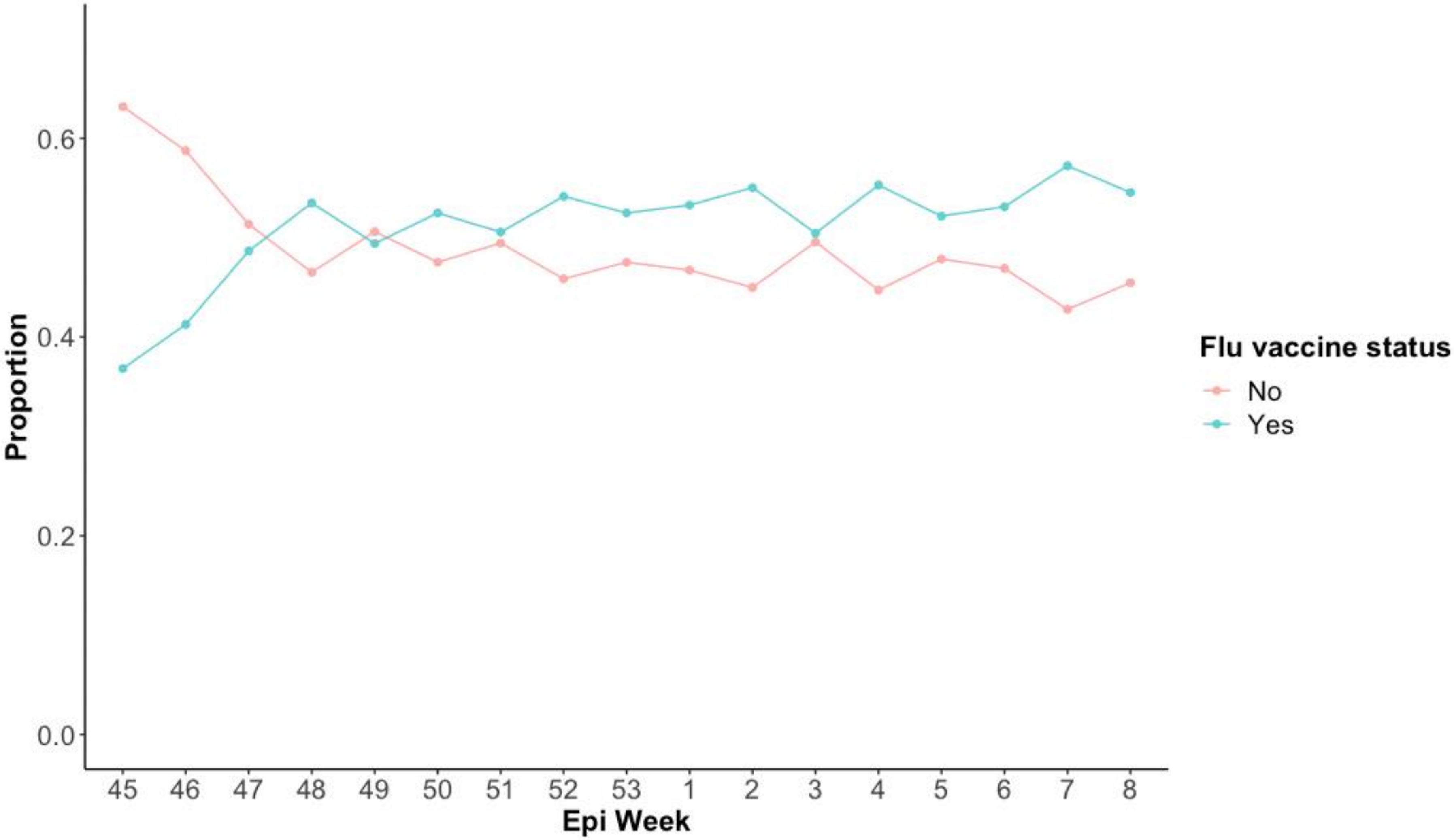
* Overlaid key events are detailed in Table 2.1 in chronological order

Figure 2.1b. Proportion of survey responses citing primary reason for COVID-19 vaccine deliberation or reluctance, by CDC Epidemiological Week (N = 1,476)*



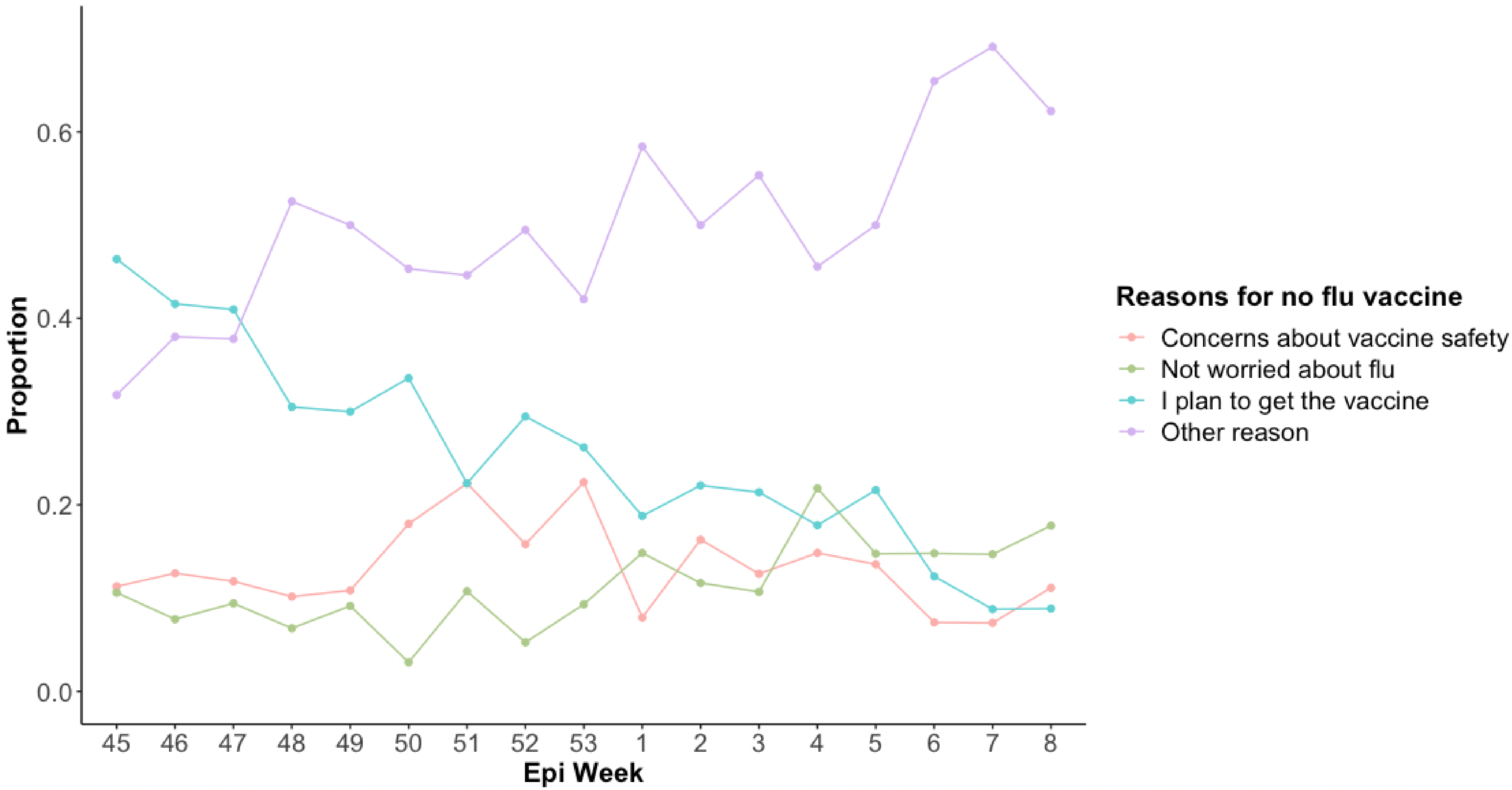
* Overlaid key events are detailed in Table 2.1 in chronological order**;** Does not include responses from those already vaccinated (n=75) or those that answered "yes" (n=2293); Overall proportion of responses that were included as "Other reason": "Do not have time to get vaccinated" (0.3%); "Want to make sure high-risk individuals get it first" (1.2%); "I've already had COVID-19 and don't think I need the vaccine" (2.3%); "None of the above" (27.2%)

Figure 2.1c. Proportion of survey responses for seasonal flu vaccine uptake, by CDC Epidemiological Week (N=3,889)*



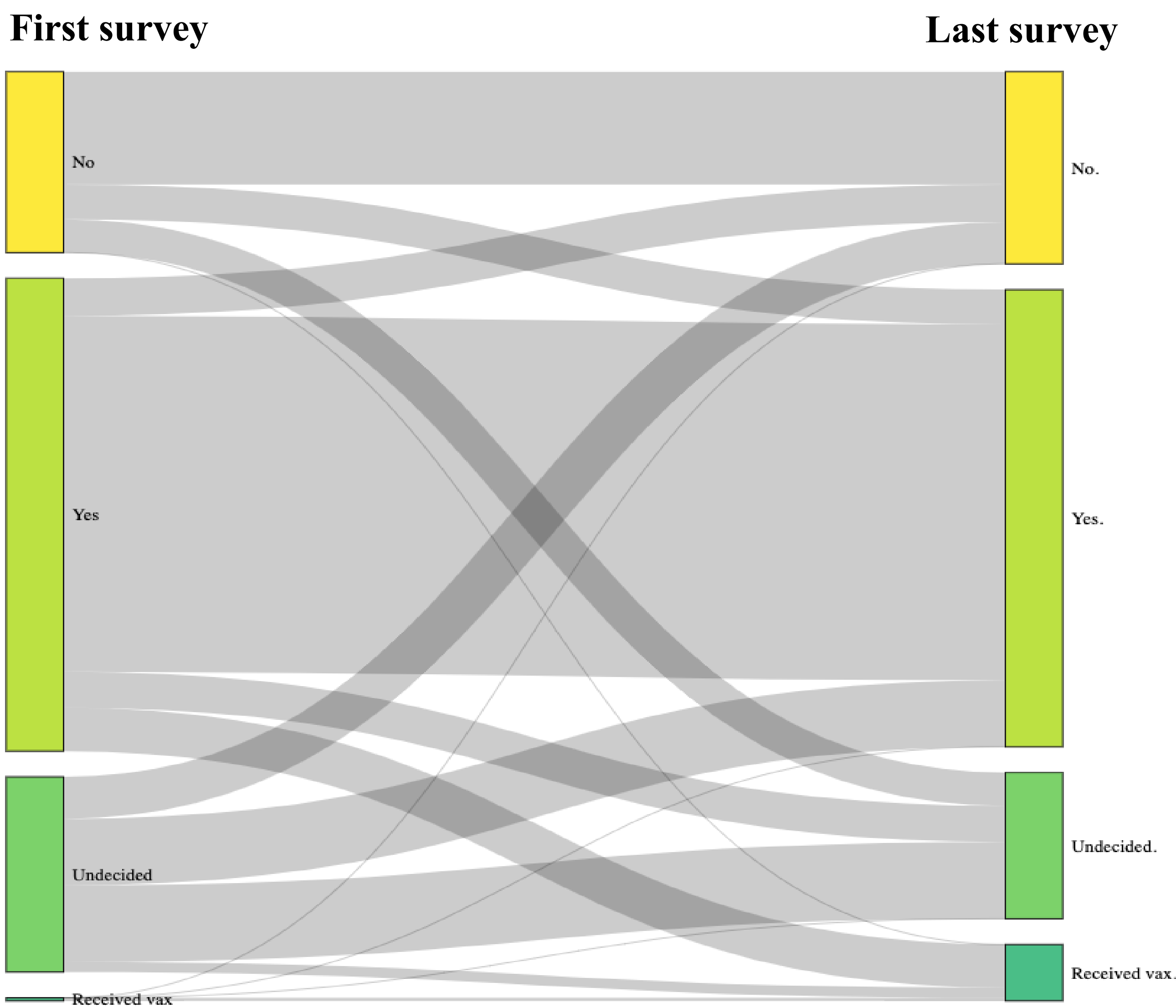
*Does not include responses from those that answered “Prefer not to say” when asked about seasonal influenza vaccine status (n=77)

Figure 2.1d. Proportion of survey responses citing primary reason for not receiving seasonal flu vaccine, by CDC Epidemiological Week (N = 1,768)*



* Does not include responses from those already vaccinated against seasonal flu (n= 1,977) or those that answered "prefer not to say" (n=144)
Overall proportion of responses that were included as "Other reason": "Do not have the time to get vaccinated" (4.2%); "Not required for work or school" (0.4%); "Not recommended by a doctor or healthcare worker" (0.2%); "Not covered by health insurance" (0.4%); "Not offered at a convenient location" (2.9%); "None of the above" (40%)

Figure 2.2. Sankey diagrams of COVID-19 vaccination intent vacillation, based on first and last survey response (N = 589)



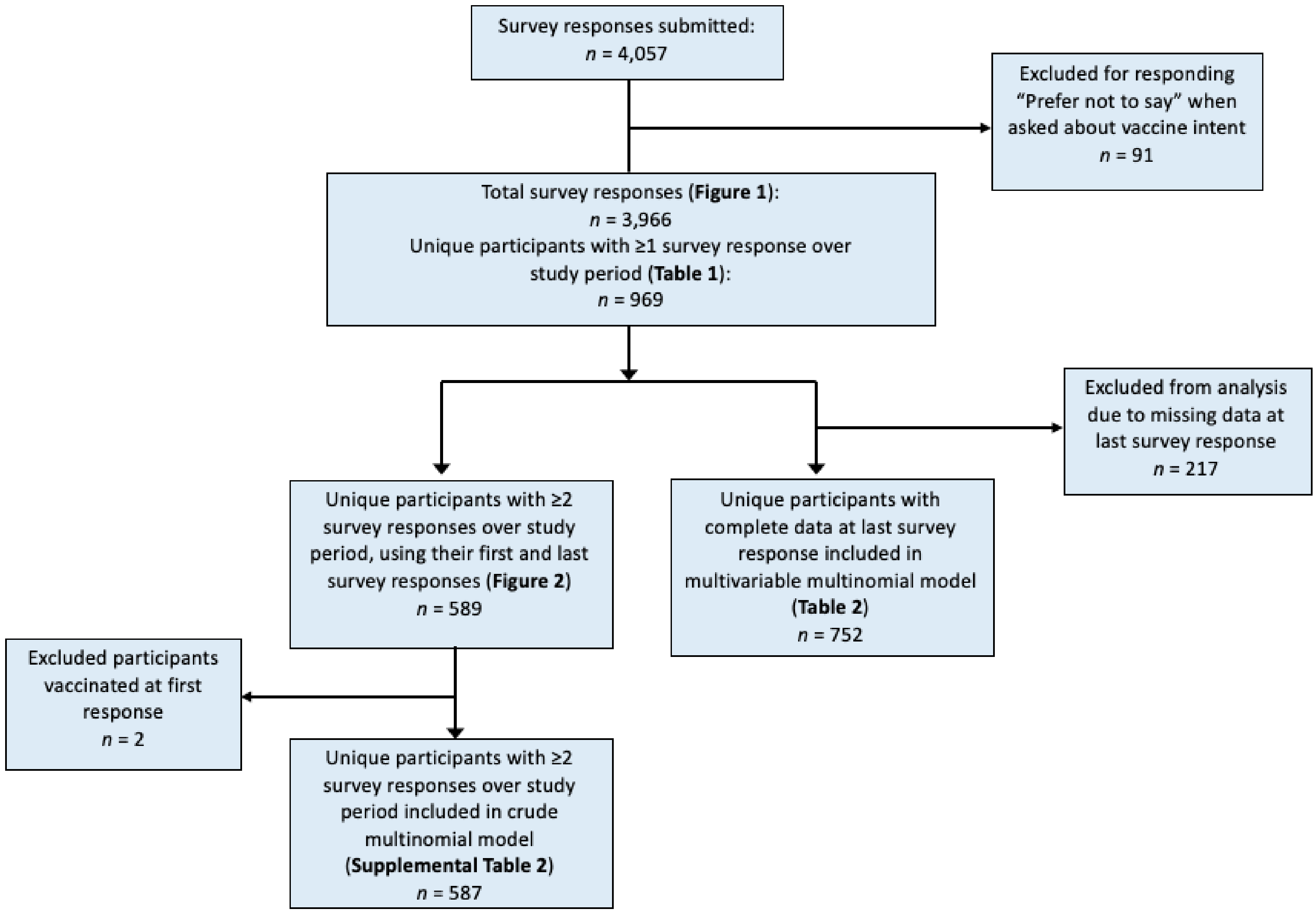
Supplemental Table 2.1. Shelter site characteristics and enrollment metrics

Shelter	Maximum capacity	Client sex	Client age range	Total enrollments (N=3966, %)
A	60	Female	≥ 18 years	182 (4.6)
B	100	Mixed	≥ 18 years	122 (3.1)
C	45	Mixed	18 - 25 years	415 (10.5)
D	185	Mixed	All ages (family shelter)	533 (13.4)
E	70	Mixed	All ages (family shelter)	103 (2.6)
F*	60	Male	≥ 18 years	82 (2.1)
G	275	Mixed	≥ 18 years	1338 (33.7)
H	275	Mixed	All ages (family shelter)	456 (11.5)
I	45	Male	≥ 50 years	223 (5.6)
J*	34	Male	≥ 18 years	262 (6.6)
K**	75	Mixed	≥ 18 years	250 (6.3)

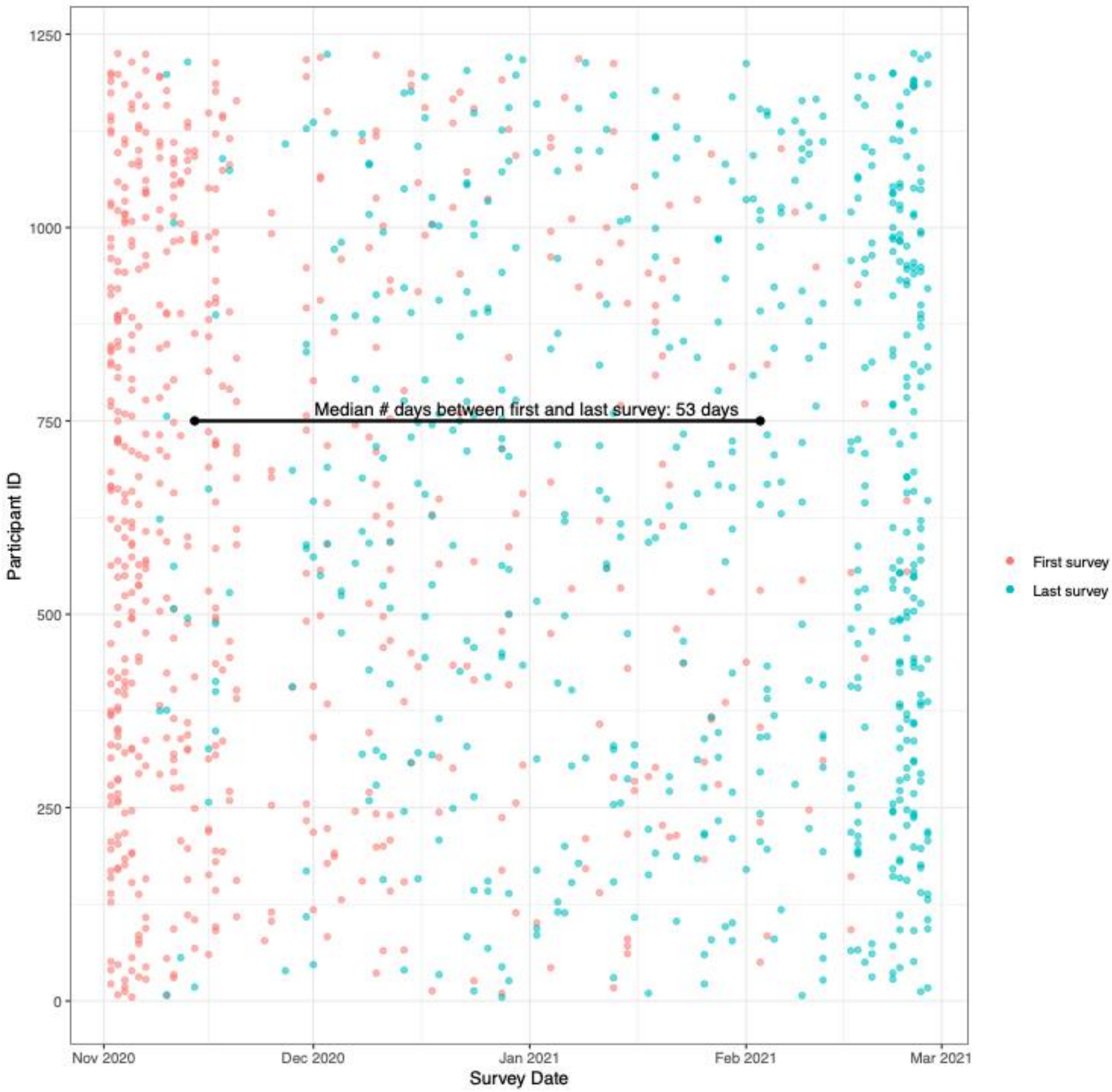
**Opened / data collection began 3 December 2020 to replace Shelter F*

*** Opened / data collection began 3 December 2020 to replace Shelter B*

Supplemental Figure 2.1 – Study flow diagram.



Supplemental Figure 2.2. Enrollment dates of unique participants' first and last survey response



Chapter 4: Conclusion

This dissertation utilized diverse sociodemographic, clinical, and shelter characteristic data to identify relevant associations with increased risk of SARS-CoV-2 infection, as well as early trends in COVID-19 vaccine intent and uptake in shelter populations that may be vital to inform vaccination campaign planning and implementation. In **Chapter 2,** we observed that the incidence of SARS-CoV-2 infection among shelter residents and staff was comparable to the general population and largely asymptomatic at the time of testing. While seemingly contradictory to the expectation that PEH may experience disproportionately high incidence of infection, our results suggested that availability of asymptomatic testing and other non-pharmaceutical interventions (i.e., non-congregate sleeping arrangements, isolation and quarantine areas, etc.) may have mitigated the risk of large-scale outbreaks in shelter settings. These findings add to the growing body of evidence that illustrates that the unique health experiences of PEH are often not captured or accurately described by traditional public health data reporting systems,[90–92] and that discordant COVID-19 surveillance methodologies mean interoperability between multiple data sources (including public health data, HMIS, and external partners) is critical to evaluating the COVID-19 burden in this population.[93]

In **Chapter 3**, we identified low COVID-19 vaccination intent among both residents and staff in shelters compared to the general population and no increase in vaccination intent over the study period, despite increased evidence of vaccine safety and effectiveness. Our findings, in conjunction with the growing body of literature assessing COVID-19 vaccination perceptions, practices, and uptake among homeless populations, reinforced an evident need for improved infectious disease communication with PEH during public health emergencies.[22,27,28,94] Overall, there is a need to employ a trauma-informed, person-centered approach from trusted medical providers and consistent messaging on vaccination resources from homeless service providers to PEH.

This research outlines a shift in emphasis from clinic or laboratory-based surveillance to community-based surveillance for respiratory viruses in a hard-to-reach population. Conducting rigorous, protracted, routine surveillance in congregate shelters provides an unprecedented understanding of temporal trends and more precise disease measure estimates of SARS-CoV-2 and future viruses with endemic or pandemic potential. Furthermore, it provides a granular assessment of vaccination intentions prior to widespread availability in a population that faces difficulty receiving vaccine confidence interventions. We hope our findings will be not only valuable for public health practitioners and homeless service providers in understanding SARS-CoV-2 epidemiology and COVID-19 vaccination intentions in shelters, but also provide motivation for successful interventions aimed at protecting other populations experiencing or at risk for health inequities against respiratory pathogens.

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