COVID-19 AMONGST THE HOMELESS POPULATION

COVID-19 SURVEILLANCE OF THE HOMELESS POPULATION IN CONGREGATE LIVING SETTINGS

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LAY ABSTRACT

The homeless population was faced with unique challenges during the COVID-19 pandemic leaving them more vulnerable to the impacts of the pandemic in comparison to the general population. Homeless individuals residing in congregate living settings are thought to be at greater risk due to the large number of people in shared spaces and the constant movement of individuals through facilities. Our study objectives were to describe COVID-19 in congregate living settings over a one-year period, identify potential risk factors, and discuss if a large-scale surveillance program was feasible. We demonstrated that SARS-CoV-2 infections and outbreaks exist in the homeless population. Characteristics such as the type of facility, facility capacity, movement of individuals between facilities, and vaccination status were determined to be associated with the risk of infection. A large-scale surveillance study can benefit this population but requires the right funding and laboratory operations to be feasible.

ABSTRACT

Background
The homeless population is at high risk for SARS-CoV-2 infection and outbreaks. There have been no longitudinal studies to assess the impact on this population throughout the various stages of the pandemic. A surveillance study will allow for the observation of trends over time, the identification of potential risk factors, and the assessment of the feasibility of routine testing in this population, which can inform public health decisions on infection control and prevention in these at-risk communities.

Methods
This study was a prospective surveillance study of homeless individuals and staff in 53 facilities in Hamilton, ON from January 1 to December 31, 2021. Self-collected oral-nasal swabs were collected once a week and used for SARS-CoV-2 testing using a PCR triplex.

Results
A total of 42,331 tests were conducted for 3155 clients and 1823 staff. There were 295 unique infections among clients and 117 unique infections among staff. The overall positivity rate of SAR-CoV-2 among all facilities was 1%. Isolation centres had the highest positivity rate (4.26%), followed by drop-in sites (1.91%), emergency shelters (1.08%), supportive housing (0.61%), and offices (0%). There were 52 outbreaks across 23 of the facilities. The median (interquartile range) for size and duration (days) of outbreaks was 4 (2,8) people and 8 (3,14) days, respectively. Individual-level risk factors for infection in congregate settings were being a client (OR=2.30, 95% CI 1.43-3.68), visiting two or more facilities (OR=1.72, 95% CI 1.13-2.61), and no vaccination (OR=2.03, 95% CI 1.37-3.02). Facility-level risk factors for infection were emergency shelters (OR=1.88, 95% CI 1.16-3.05) and facility capacity of 26-50 people and over 100 people (OR=3.52, 95% CI 1.59-7.80; OR=5.24, 95% CI 2.43-11.31).

Conclusion
Our findings support the presence of SARS-CoV-2 in the homeless population and the potential for large outbreaks. A large-scale surveillance program proves to be a promising intervention in effectively reducing transmission in this population provided the availability of funding and the appropriate lab support for high-capacity testing. Both individual and facility-level risk factors need to be considered in any public health effort that looks to minimize the transmission of infectious diseases in the homeless population.

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LIST OF ABBREVIATIONS

aOR	Adjusted odds ratio
CDC	Centers for Disease Control and Prevention
COVID-19	Coronavirus disease of 2019
CT	Cycle threshold
GEE	Generalized estimating equations
HIV	Human immunodeficiency viruses
ICES	Institute for Clinical Evaluative Sciences
IQR	Interquartile range
MERS-CoV	Middle East respiratory syndrome coronavirus
MRSA	Methicillin-resistant *Staphylococcus aureus*
PCR	Polymerase chain reaction
PEH	People experiencing homelessness
PPE	Personal protective equipment
RCT	Randomized controlled trial
rt-PCR	Real-time polymerase chain reaction
SARS-CoV-1	Severe acute respiratory syndrome coronavirus 1
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SD	Standard deviation
WHO	World Health Organization
95% CI	95% Confidence Interval

DECLARATION OF ACADEMIC ACHIEVEMENT

I, Julia Maciejewski, declare that the thesis titled, "COVID-19 Surveillance of the Homeless Population in Congregate Living Settings", to be my work. I am the sole author of this thesis and took part in all stages of the study under the supervision of Dr. Marek Smieja. The thesis was reviewed and edited by the following individuals on my thesis committee: Dr. Marek Smieja, Dr. Elizabeth Alvarez, and Dr. Lawrence Mbuagbaw. The Infectious Disease Research Group at St. Joseph's Healthcare Hamilton was responsible for the establishment of the surveillance program and the testing of specimens for data collection.

Chapter 1
Introduction

Emergence of COVID-19

In Wuhan, China, a group of patients experiencing shortness of breath and fever were identified on December 12, 2019.[1] By December 31, 2019, there would be a cluster of pneumonia cases with unknown etiology. [1] The genetic sequence of the unknown pneumonia virus was shared by Chinese public health officials and at the time was labelled as Wuhan-Hu-1.[1] On January 7, 2020, Chinese authorities officially identified the causative agent as a novel Coronavirus. It would be only two days later that China would have its first death caused by the novel virus. [1]

By January 13, 2020, the first lab confirmed case outside of China was identified in Thailand. [1] Samples from suspected cases in the United States had confirmed on January 20th that the virus had made its way to North America. [1] By the end of January 2020, World Health Organization (WHO) declared the SARS-CoV-2 outbreak as a Public Health Emergency of International Concern and the world witnessed its first lockdown due to the virus. [1] In February 2020, the disease caused by SARS-CoV-2 was named COVID-19 and Italy became a COVID-19 hotspot. [1] On March 11, 2020, WHO declared COVID-19 a worldwide pandemic. [1]

SARS-CoV-2 was not the first coronavirus encountered by the world. In previous years there had been SARS-CoV-1 and MERS-CoV, as well as four seasonal coronaviruses regularly infecting humans (229E, NL63, NKU-1 and OC43). Belonging to the genus *Coronaviridae*, these viruses are pleomorphic single-stranded RNA viruses. [3]

They are also characterized by crown-shaped peplomers that would become the primary target for the majority of vaccinations. [3] In comparison with previous Coronaviruses, SARS-CoV-2 possesses 80% phylogenetic identity with SARS-CoV-1 and 50% similarity with MERS-CoV. [3]

COVID-19 is classified as a severe acute respiratory disease. Spread through human-to-human contact, the main route of transmission is through direct contact with aerial droplets which can be spread by conversation, coughing, and sneezing [2]. Studies have emerged since the beginning of the pandemic providing evidence airborne transmission through aerosols is plausible. [65] Airborne transmission can be influenced by certain favourable conditions such as exposure in indoor settings, inadequate ventilation, prolonged exposure time, high viral load, and a lack of masking by infected individuals [65]. SARS-CoV-2 can affect both an individual's upper and lower respiratory tract which can lead to serious illnesses such as pneumonia [3]. Infected symptomatic individuals commonly experience fever, headache, cough, myalgia, sputum production, diarrhea, dyspnea, and pneumonia [3]. As of August 2022, there have been over 600 million confirmed cases and 6.4 million deaths worldwide due to COVID-19. [4]

COVID-19 In Congregate Living Settings

Public health responses to COVID-19 including lockdowns, screening protocols, testing and assessment centres, and vaccination programs, were put in place to identify infected individuals and reduce transmission. However, these public health measures may not be reaching a proportion of the population that has been demonstrated to be at high risk for poor health outcomes and lack access to healthcare. Populations in congregate settings such as nursing homes, prisons, and shelters were disproportionately impacted by large outbreaks. [11,21] A congregate living setting is defined as a facility where individuals live, stay overnight, and use shared spaces. [44]

Congregate living facilities had participated in common strategies such as, masking in common areas, entrance screening, physical distancing, routine testing for healthcare workers, symptomatic testing, and isolating people who tested positive as common efforts in prevention among these settings.[13] However, there were factors specific to congregate living facilities that minimize the effectiveness of these efforts. Social distancing and masking were not always possible for those that live together and have shared spaces. [11,21] In many congregate living settings, it was not uncommon for 2 or more individuals to share a room due to limited capacity. Common areas such as kitchens and living rooms, were often shared by the whole facility. Furthermore, many of these facilities found themselves either at capacity or in urgent need of overflow support.

Due to these challenges, there have been large outbreaks in a variety of congregate living facilities in which there was a higher prevalence of cases within these facilities compared to the general population. [10,16] For example, incarcerated populations have experienced disproportionately higher rates of COVID-19 related illness, hospitalization, and death when compared with the general US population.[18] In addition to the strategies mentioned above, a Texas federal prison also incorporated cohort housing units for daily activities and head-to-toe sleeping arrangements.[16] Despite these efforts and

79% of the 233 incarcerated individuals being fully vaccinated, during a Delta variant outbreak, 74% (172/233) incarcerated individuals within one of the housing units were positive for SARS-CoV-2.[16] In a Louisiana correctional facility, the identification of a single staff positive resulted in mass testing using real-time reverse transcription-polymerase chain reaction (rt-PCR), which would identify another 71 (72%) additional cases among 98 incarcerated individuals. [18]

Long-term care homes and specialized nursing facilities have also been greatly burdened with outbreaks. Serial testing at a specialized nursing facility in Minnesota, USA reported 64% positivity in residents and 33% in staff.[20] Weekly surveillance of residents and staff in long-term care facilities in California, USA showed a consistent pattern of transmission driving large outbreaks [19] Surveillance showed that a single infection was followed by a rapid spread of infections consisting of the same SARS-CoV-2 lineage. The same viral lineage circulating among patients was identified in healthcare providers. [19] In addition, staff working in any of these settings were either having contact with multiple individuals within the facility and in some cases, were working at multiple sites. [19,45] In March 2020, the CDC identified staff working multiple sites to be the likely source of spread in Washington.[19] Genome sequencing identified facility-specific clustering of viral genomes, showing intra-facility transmission.[20]

Certain individual-level characteristics of individuals in these populations may put them at risk of severe COVID-19 infections. Evidence suggests age and pre-existing comorbidities are associated with greater risks of severe infection and death. [14,64] As long-term care homes consist of older patients with the majority experiencing underlying health conditions, they are a particularly vulnerable population. The risk of severe infection associated with pre-existing co-morbidities was described in a study in the United States that analyzed hospital discharge records of incarcerated individuals who had undergone evaluation in the emergency department. In comparison to the general population visiting the emergency department, numerous underlying medical conditions such as pulmonary disease, liver disease, tobacco use, substance use disorder, and serious mental illness, were more common among incarcerated people with COVID-19 in the emergency department. [17] These incarcerated individuals were also more likely to be hospitalized, experienced more frequent readmission, and had increased mortality in comparison to the general population evaluated in the emergency department. [17] Transmissibility during the pre-symptomatic phase has been described by a number of studies. [66-69] In one study, 35% of transmission was accounted for by pre-symptomatic cases and 24% by asymptomatic cases. [66] High proportions of asymptomatic cases have been identified in congregate settings including prisons, campuses, long-term care homes, and specialized nursing facilities.[10] Asymptomatic infections in congregate settings should also be considered in mitigation efforts, as asymptomatic cases play a role in the transmission and will not be identified by most passive strategies that test symptomatic individuals.

COVID-19 in the Homeless Population

Homelessness is defined as "the situation of an individual or family who does not have a permanent address or residence; the living situation of an individual or family who does not have stable, permanent, appropriate housing, or the immediate prospect, means and ability of acquiring it".[24] Worldwide, it is estimated as of 2017, that 150 million people are homeless and 1.6 billion live in inadequate housing. [46] In Canada, a survey conducted at the beginning of the COVID-19 pandemic in July 2020, estimated that 1.6 million Canadians have experienced homelessness at one point in their lives.[23] Approximately 235,000 Canadians were estimated to experience homelessness annually, measured by absolute homelessness defined as individuals who reside in unsheltered locations, emergency shelters, and fixed-term transitional housing. [63] People experiencing homelessness (PEH) are believed to be at an increased risk of acquiring SARS-CoV-2 infection and spreading the virus due to their transient nature, diverse living situations, as well as the crowding and poor ventilation that can be experienced in congregate living settings.

Historically, it has been shown that infectious diseases within homeless populations are a cause for concern. [36] Evidence exists to suggest communicable diseases exist within the homeless population at a greater prevalence than the community-dwelling population, including Tuberculosis, Hepatitis B, Hepatitis C, HIV, Swine flu, and MRSA. [36, 47] The COVID-19 pandemic gave rise to numerous studies that aimed to assess the prevalence of SARS-CoV-2 infection within homeless communities. A proportion of these studies were able to demonstrate a high positivity rate in the homeless population when compared to the community-dwelling population. [5,22,34-36] More concerning, was the evidence that PEH residing in congregate living settings, such as shelters, were at higher risk of SARS-CoV-2 infection than PEH living in more informal settings such as encampments. [26,34,37-39] As seen in other types of congregate living communities, the COVID-19 pandemic has disproportionately affected people experiencing homelessness, with many outbreaks being described among major cities. [5,28,31]

There are three prominent studies that aimed to consider a diverse homeless population including those living on the streets, in slums, squats, shelters, and encampment sites. [21] One of the most comprehensive studies was done in Ontario, Canada, from January 23 to July 31, 2020, using linked health administrative data to compare prevalence rates of SARS-CoV-2 infection among people with a recent history of homelessness and community-dwelling individuals. [21] Individuals with a recent history of homelessness were identified using case definitions established by multiple databases including Canadian Institute for Health Information, Discharge Abstract Data, and ICES PSTLYEAR data sets, among others. [21] The study included 29,407 individuals with a recent history of homelessness and 14,494,301 community-dwelling housed individuals. [21] Hazard ratios for testing positive were analyzed over two time periods categorized as peak and re-opening periods. [21] The pre-shutdown period was excluded from the analysis as there were no positive cases among people with a history of homelessness. [21] Individuals with a recent history of homelessness were almost 4 times more likely to test positive compared to community-dwelling individuals during the peak period and approximately twice as likely to test positive during the re-opening period. [21]

Similar findings were shown in a prospective cohort of people experiencing homelessness that took place in Marseille, France in 2020. Over two testing periods, participants over the age of 18 were recruited to be tested for SARS-CoV-2 antibodies and participated in face-to-face surveys. During the first testing period from June 5 to August 5, 2020, a seroprevalence of 6% (74/1241) was captured. The second testing period saw a significant increase in seroprevalence with 19% (136/721) testing positive. The general population of Marseille showed a much lower rate of seroprevalence of 3.0% and 6.5%, from May to June and November to December, respectively. The study not only demonstrated a higher seroprevalence of SARS-CoV-2 among homeless individuals in comparison to the general population but also a significant increase in seroprevalence within the homeless community from the time of initial testing to repeat testing. [48] Another study assessed the prevalence of SARS-CoV-2 among the homeless community during the first wave in Toronto, Canada. [26] A retrospective review of data collected from an outreach testing program was conducted and included a total of 97 sites consisting of shelters, encampments, physical distancing sites, drop-in services, and respite sites. [26] The testing approach involved a combination of active case-finding and outbreak management, in which testing occurred throughout the study period even if positive cases weren't identified and in response to positive cases identified through community testing or symptomatic screening. [26] From April 17 to July 31, 2020, these sites had a period prevalence of 8.5% which was much higher than the prevalence found in the general population. [26] Mass testing through active case-finding could have overestimated the comparison to the general population, as testing in the general population was done on a symptomatic or positive contact basis.

COVID- 19 In Congregative Living Settings Serving People Experiencing Homelessness

From these prevalence studies and numerous others, evidence began to emerge indicating that from all the different types of sites that people experiencing homelessness reside in, congregate settings, specifically shelters were associated with the highest prevalence and the most significant increased risk of infection. [26, 48, 49, 35] At the beginning of 2020, cumulative cases identified in Canada were due to travel. [26] Later in the year, a shift was observed in the origin of cumulative cases from travel to long-term care home residents, shelters, and other congregate communities [26]. A cross-sectional study was done using data collected from a mobile outreach COVID-19 testing program for shelters in Toronto, Canada. Testing was done from April 1 to July 31, 2020, and included 20 shelter locations. [22] Testing was done for outbreak and surveillance purposes and from 1000 SARS-CoV-2 tests, 8% (80/1000) were positive. [22] However, the majority of positives occurred during outbreak testing, in which there was a 14% (69/504) positivity rate. [22] Respite sites, drop-in sites, and encampments had lower rates of positivity in comparison to shelter sites. [26] This can potentially be explained by the fact that individuals residing in encampments spend more time outdoors and in less proximity to others. Even individuals using drop-in services rather than shelters spend a significant less amount of time indoors, potentially decreasing their risk of a positive contact. Shelters have been a point of concern for outbreak risk throughout the pandemic due to shelter characteristics that are thought to increase transmissibility such as facilities with high resident density and shared spaces. A study done in Wales, UK which used administrative data and considered both PCR and antibody serology tests, found people experiencing homelessness to have a SARS-CoV-2 prevalence of 5% compared to 5.6% found in the general population between March 1, 2020, and March 1, 2021. [47] The authors noted that this finding while contrasting results found by other studies, may be due to the fact that Wales had a policy response in which they had moved away from communal accommodation for people experiencing homelessness and that their cohort would be saturated with individuals living roofless and other informal housing rather than shelters. [47] Although the study's findings contrast with what we have seen in other studies in which typically the homeless community has a higher positivity rate, the study also highlights congregate living among the homeless population as a potential risk factor.

There have also been large shelter outbreaks documented in four US cities that demonstrate high incidence in shelters. A study based out of Seattle, including 14 shelters, found a 2% positivity rate (29/1434). [50] The study also found that 85.7% of positive cases were ones who slept in a communal space in the past week. [50] In another study in Seattle, testing in 3 shelters found 18% (35/195) of shelter residents and 21% (8/38) of staff to have tested positive for SARS-CoV-2. [31] A large shelter in San Francisco encountered a large-scale COVID-19 outbreak in April 2020. [51] Cases were shown to be widely distributed throughout the shelter, reinforcing the risk of congregate living in highly populated shelters without the capacity for social distancing. [51] SARS-CoV-2 positivity among residents was 67% (100/150) and 17% (10/60) among staff. [51] The authors noted that this high positivity rate occurred during low community incidence in the San Francisco area. [51] Boston also had an outbreak at a large shelter in April 2020, in which a 36% (147/408) positivity rate was found among residents and staff. [28] One of the largest mass testing events in the homeless community was done in Atlanta, Georgia from April 7 to May 6, 2020. Testing was done in 24 shelters and 9 unsheltered sites, resulting in 2860 tests. [39] Prevalence of SARS-CoV-2 was found to be 2.1% (36/1684) in shelters, 0.5% (3/628) in unsheltered events, and 1.3% (7/548) in staff. [39] The mass testing done in Atlanta supported previous findings that individuals staying at shelters are at higher risk of infection. [39] However, if testing in the general population was primarily passive testing of symptomatic individuals, the risk of infection in people experiencing homelessness in comparison to the general population may be overestimated.

Risk Factors for SARS-CoV-2 Infection Among People Experiencing Homelessness

Understanding the epidemiology of SARS-CoV-2 infection is important for learning about transmission and identifying at-risk populations in order to reduce transmission and prevent outbreaks. However, it is equally as important to consider why these particular populations are at-risk and what factors cause the increase in risk compared to the general population. A retrospective cohort in Louisville, USA investigated the incidence of COVID-19 among homeless and non-homeless emergency department patients. [52] The rate of testing positive for COVID-19 in the homeless population was higher than in the non-homeless population. However, when adjusted for age, gender identity, race, and insurance there was no significant difference between homeless status and positive test. [52] The authors noted that utilization of emergency department services may be underestimated if fewer homeless individuals are seeking COVID-19 testing in the case that a high proportion are experiencing asymptomatic infection. [52] It should be taken into consideration that the status of homelessness does not necessarily cause an increased risk of infection but that the individual characteristics among homeless people and shelter characteristics are what create the increased risk of infection.

Many of the studies assessing risk factors of COVID-19 infection in people experiencing homelessness have been cross-sectional in design. The risk factors considered in these studies are age, gender, race, comorbidities, substance use, and smoking. There are mixed conclusions on age as a risk factor. A study in Chicago, Illinois conducted point prevalence testing in 21 homeless shelters. [38] The study reported that people experiencing homelessness that were above the age of 55 years old had a higher prevalence of SARS-CoV-2 infection in comparison to those who were 40 years old or younger. [38] However, a study in Marseille, France conducting mass testing during two periods throughout the year found age to be not statistically significant. [48]. Although the described studies conducted mass testing rather than symptomatic testing and reported an age distribution, there is still a risk of selection bias in which older individuals are expected to present with more symptoms and therefore may be more likely to get rested, overestimating age as a risk factor. In contrast, if older individuals are more likely to be symptomatic and have pre-existing comorbidities, they may be evaluated at emergency departments rather than study surveillance which could underestimate age as a risk factor. Further studies are needed to establish age as a risk factor for SARS-CoV-2 infection. No statistically significant association has been found between gender or race and testing positive for SARS-CoV-2. [34,38,48,50]

There have been inconsistent findings specifically in the homeless population, on the association between comorbidities and testing positive for COVID-19. A study comparing outcomes of people experiencing homelessness and community-dwelling individuals in US emergency departments found that PEH with COVID-19 were found to have several underlying medical conditions in comparison to the general population. [17] The prevalence of comorbidities has also been shown to be high among shelter residents, with 39.4% to 53.3% reporting at least one comorbidity. [34,50] In a cross-sectional study considering comorbidities that included obesity, diabetes, cancer, chronic renal failure, and respiratory and cardiovascular conditions found the highest prevalence of SARS-CoV-2 infection was among those who were older or had a comorbidity. [34] However, in the same study, it was observed that those with psychiatric and addiction comorbidities had a 2.2-fold lower seroprevalence. It was suggested that this observation is because individuals with psychiatric and addiction comorbidities are stigmatized and excluded from social interactions, therefore limiting their exposure to positive contacts in a social capacity. [34] In contrast to the studies above, a lower prevalence of comorbidities among shelter residents testing positive for SARS-CoV-2 when compared with those testing negative has also been observed. [37] The observed differences in risk of infection for individuals who have a comorbidity seen in some of these studies could be due to different populations within shelter systems in different cities. Access to healthcare and socioeconomic aspects of each city or region can vary and affect the population that is included in these cross-sectional studies. In addition, some people experiencing homelessness might exhibit an increased risk of infection with comorbidities if they are receiving a COVID-19 diagnosis while being treated for other conditions or the infection may itself worsen underlying health conditions resulting in a required visit to an emergency department or COVID-19 testing.[17] The latter is quite possible as PEH tend to frequent emergency departments as a first-line resort to healthcare over primary care providers as the general population does. [17]

Mobility among homeless individuals has also been shown to be a significant risk factor in acquiring SARS-CoV-2 and makes it challenging to uphold certain infection control and prevention protocols. A study assessing mobility among 1272 individuals living in the streets, slums, and shelters in Marseille, France found that the number of different accommodations since the beginning of the pandemic was significantly associated with having a positive serologic test. [42] The most mobile individuals, determined by the number of different dwellings, had a greater risk of testing positive. [42] More importantly, the locations of clusters of cases were explained by the mobility of homeless individuals within different neighbourhoods. [42] During the pandemic, the movement of homeless individuals in Marseille, France living in the streets and squats moving into emergency accommodations such as shelters increased after a lockdown was put into place. [42] This could have not only caused cases from the community to be brought into shelters but put shelters in a state of overflow and high resident density.

There are shelter characteristics that have been shown to affect the prevalence of SARS-CoV-2 infection within shelters. One of the most significant factors is shared spaces, particularly bedrooms and bathrooms. A study screening homeless individuals in Brussels, Belgium living in shelters reported that 5% of those who tested positive had shared a room with an individual who was positive. [43] Another study showed both that a higher prevalence of infection was found among those who shared a room with over 20 people but that increasing the number of private bathrooms had reduced the number of infections. [38] In addition to shared spaces, a shelter's ability to physically distance also has a significant impact on infection rates. A strong correlation was demonstrated between social distancing and the reduction of COVID-19 case growth. [53] The higher the resident density within shelters, the harder it is to accommodate proper social distancing and sleeping arrangements. A cross-sectional study looking at COVID-19 prevalence across 5 shelters, found that the shelter with the highest prevalence was unable to accommodate sleeping arrangements at least 6 feet apart due to its limited capacity and high population density. [37]

Studies have described infection prevention and control practices during the COVID-19 pandemic in the general population, however, studies assessing these factors during the pandemic in congregate living settings in homeless populations specifically are limited. A large-scale study that included 63 shelters from 7 US urban areas sought to examine shelter characteristics and infection prevention practices during universal rt-PCR testing in shelters. [54] The median prevalence of SARS-CoV-2 among the 63 shelters was 2.9%. [54] Site assessments took place from March 30 to June 1, 2020, an average of 13 days after point prevalence testing. [54] The study found that shelters were less likely to have a high prevalence of infection when utilizing head-to-toe sleeping arrangements, not allowing symptomatic staff to work, and providing medical services. [54] The study also found that staff training, staff symptom screening, and face mask use were not associated with prevalence. [54]

Health Outcomes Among People Experiencing Homelessness Infected with SARS-CoV-2

Another significant gap in the literature is studies on health outcomes. Only one study compares outcomes of COVID-19 among people experiencing homelessness and the general population in 800 US hospitals who were either hospitalized or evaluated in the emergency department. [17] The study found that people experiencing homelessness with COVID-19 who visited the hospital had a higher frequency of hospitalization, experienced a longer duration of stay at the hospital, and had more frequent readmissions than the general population. [17] However, it was also observed that people experiencing homelessness were less likely to die. [17] Another study looking at risk factors for SARS-CoV-2 in 21 homeless shelters in Chicago, USA found that 13% (57/431) of residents were hospitalized due to COVID-19, 4.4% (19/431) were required to go to the intensive care unit, and 2 of the residents died (2/431, 0.5%). [38] In Canada, it was found that people experiencing homelessness were over 20 times more likely to be admitted to hospital during peak periods of cases, were more likely to require intensive care, and had a higher 21-day mortality rate. [21]

SARS-CoV-2 Screening and Mitigation Practices Used in Homeless Congregate Living Settings

Congregate settings, such as homeless shelters, face implementation challenges in many of the mitigation and infection control practices used in the general population. These challenges arise from inadequate resources such as limited staffing, facility space, and lack of guidance from public health authorities. [55] Certain factors can make establishing prevention and control protocols difficult, for example, distrust from residents, individuals suffering from mental illness or substance use, and as mentioned previously high resident density. [55] The transient nature of the homeless community also further complicates these protocols with strategies such as contact tracing and exposure investigation which become extremely difficult in shelters with high mobility. [27,55] Two common strategies are increasing physical distancing and utilizing personal protective equipment. As previously mentioned, physical distancing is important in congregate settings, especially in shared spaces for group activities, bathrooms, and sleeping arrangements. Creating new shelter spaces overall and increasing spaces specifically for sleeping arrangements have demonstrated to have the potential to reduce the risk of spread of SARS-CoV-2. [55,59] However, the amount of space required to achieve the necessary spacing is not available in most shelters. Although personal protective equipment such as masks is a widely used strategy in the general population, with frequent supply shortages, shelters cannot ensure a reliable amount of PPE will be available for all staff and residents on a consistent basis. Environmental interventions such as routine cleaning and disinfection of spaces and hand washing stations have previously been shown to help prevent outbreaks of acute respiratory infections in shelters. [62] The effects of educational interventions on infection control have not been well studied but have been shown to open a line of communication with clients on infection control practices. [62] These two strategies are not enough on their own to prevent rapid spread within shelters. [62] Isolation procedures and quarantine centres are reported to be essential to outbreak management, however, if shelters are only using symptomatic screening strategies, isolation procedures lose their effectiveness in the case of asymptomatic infections. [62]

As a primary screening tool for new and current residents, the majority of shelters have used symptom screening. Symptoms used for screening varied depending on location and guidelines provided through local public health units. Although widely used, symptom screening may underestimate and not identify all infections. Symptoms may be missed if they are hidden by other medications or residents may underreport symptoms due to fear of losing placement in the shelter. [43] The biggest risk with symptom screening is missing asymptomatic cases. Asymptomatic cases are characterized by the absence of symptoms but have the same infectivity as those presenting with symptoms. [43] Many shelters have reported a high proportion of asymptomatic cases which are a particularly difficult challenge in infection control and prevention in congregate settings as they can unknowingly transmit infection to a large number of people in a short amount of time. [33, 35, 37, 43, 48, 50, 51] Surveillance and outbreak studies in shelters have shown that waiting for the detection of symptomatic cases may be too late to prevent super-spreading events. [43, 51].

Due to the need to identify asymptomatic cases in addition to symptomatic cases at a more efficient turn-around speed, shelters and other congregate settings began to establish surveillance programs and testing events using rapid antigen testing or rt-PCR testing in addition to other current screening strategies. A simulated cohort of sheltered homeless adults was used to assess the clinical outcome and cost-effectiveness of strategies for COVID-19. [61] The simulated cohort was from April 2020 to August 2020 and included 2,258 adults. [61] Cost-effectiveness was compared for five strategies which included daily symptom screening accompanied by PCR testing if symptomatic, universal PCR testing every 2 weeks, hospital-based COVID-19 care, alternate care sites for mild/moderate cases, and temporary housing. [61] Each of these strategies were compared to no intervention. [61] Daily symptom screening coupled with alternative care sites resulted in 37% fewer infections and 46% lower costs. [61] Adding PCR testing every two weeks further decreased the number of infections. [61] Temporary housing paired with biweekly PCR testing was the most effective but was also the costliest strategy. [61] Based on different epidemic scenarios in the US, it was found that a strategy encompassing daily symptom screening with PCR testing for those who test screen-positive, along with alternative care sites was the most efficient strategy and cost-saving option relative to no intervention. [61] However, adding universal biweekly PCR testing in addition to daily screening, resulted in clinical benefits at an incremental cost of $1000 per case prevented. [61] Reducing PCR testing from biweekly to every 7 days resulted in further benefits with another $1000 per case prevented. [61] Strategies that used alternative care sites had substantially decreased costs compared to using hospital-based care. [61] With many shelters relying on symptom screening alone, one of the most important findings from this cohort simulation was that daily symptom screening coupled with universal PCR testing had lower overall costs than daily screening alone. [61]

Molecular Testing for SARS-CoV-2 Used in Homeless Congregate Living Settings

There has been debate on which is the preferred molecular test in congregate living settings. Testing with rt-PCR is advantageous with its high diagnostic accuracy, however, it is expensive and requires specialized staff. It is argued that despite its lower diagnostic accuracy in comparison to rt-PCR, rapid antigen tests are preferable in shelter settings as they are inexpensive, do not require much training, and have a quicker turnaround time. A prevalence study originating from Vatican City used both rt-PCR and rapid antigen testing to determine SARS-CoV-2 prevalence in the homeless population. [33] The study enrolled 1665 participants, both children and adults, in which 650 individuals were tested by both rt-PCR and rapid antigen testing. [33] There were 53 individuals with concordant positive results from both tests. [33] However, there were 27 additional cases that were positive by rt-PCR and negative by rapid-antigen testing and 5 cases that were negative by rt-PCR and positive by rapid-antigen testing. [33] Similarly, a pilot study was conducted in San Francisco, USA comparing frequent testing with the BinaxNOW rapid-antigen test and rt-PCR in shelters. [56] The pilot found rapid antigen testing to be a viable alternative to rt-PCR testing on the condition that it was done in high frequency. [56] Rt-PCR was performed on the first 40 asymptomatic participants that tested negative by rapid-antigen testing and resulted in 5% testing positive by PCR (2/40). [56] The study highlighted the need for high adherence to twice weekly testing to be able to detect early infections with rapid-antigen tests. [56] On repeat testing, one of the rt-PCR positives was found to be negative by both tests, indicating that this individual may have been testing positive from a previous infection or at the end period of a current infection, and highlights the difficulty with high sensitivity from rt-PCR testing. [56] Although there are advantages and disadvantages for both molecular tests, studies that have used universal testing, regardless of whether it was rt-PCR or rapid antigen testing, found a high proportion of asymptomatic cases that would have been missed with other screening techniques. [43, 56]

The Atlanta study previously described, in which facility-wide testing was conducted in 24 shelters and 9 unsheltered locations, found that in comparison to rt-PCR, symptom screening has a sensitivity of 14% and a specificity of 89% for detecting SARS-CoV-2. [39] Compared to the first week of testing, repeat testing conducted 3- 4 weeks later at four of the included shelters, saw a significant decrease in the prevalence of SARS-CoV-2 infection. [39] This finding reinforces the benefits of universal testing within shelters as it allows for early identification of cases and allows for timely isolation of those who are positive for SARS-CoV-2 as a way to interrupt transmission in the shelters. [39] There were similar findings in Brussels, Belgium when conducting universal testing in 52 shelters. [43] During the first week of testing, there was a seroprevalence of 19.6% but then a decrease was observed to seroprevalence ranging from 0 -4.7% in the shelters. [43] The authors noted the significant decrease in prevalence could have been associated with the overall decrease in prevalence in the general population during that time. [43] These results could also be explained by selection bias in the initial cohort.

There have been a limited number of studies assessing the feasibility of adopting universal testing in shelters. A prospective feasibility cohort was conducted in Germany to assess the feasibility of a voluntary, self-swabbing testing program for SARS-CoV-2 in homeless shelters and the feasibility regarding specimen collection and workload. [57] The study recruited a single shelter that was equipped with 106 beds in shared rooms that could occupy up to six adults at a time. [57] Weekly PCR testing on saliva or self-collected nasal-oral swabs took place over three weeks, from July 9 – July 29, 2020. In this time, the shelter was over capacity with 124 residents and had approximately 10 new admissions a week. [57] Out of 124 residents, the program approached 93 residents to participate. [57] Individuals who consented and did not consent were comparable by age and language spoken, however, there were a higher proportion of females among non-consenting individuals. [57] In the first week, the program achieved a high retention rate of 93.6% which remained high for the next two weeks. [57] Overall, the study found it feasible to have a surveillance program within homeless shelters, however, a high workload is involved and a way to overcome a large volume of samples with a quick turnaround time needs to be established for the program to be successful. [57]

In April 2020, a hospital-led, community-partnered COVID-19 testing, and prevention program was established in Toronto, Ontario. The program included 32 shelter sites and assessed the program based on feasibility and adoption. [58] Feasibility was measured by number of sites utilizing the program's services and the median time from referral to service delivery. [58] Adoption was measured by the proportion of sites and staff that adopted the program's services. [58] From April 20, 2020, to August 15, 2020, 1566 nasopharyngeal swabs were tested, resulting in 64 positives. [58] In terms of feasibility and adoptability among the 32 sites, 30 completed intake assessment, 24 participated in mobile testing for SARS-CoV-2, and 15 received further infection control and prevention support. [58] Over 80% of sites changed more than two infection control and prevention practices after training. [58] Questionnaires provided to shelter staff had the consensus that the program was feasible and acceptable, with all sites reporting satisfaction. [58] The study concluded that the high acceptability and satisfaction of the mobile program, suggests there is a great need for such services within the homeless community, especially in congregate settings. [58]

Outbreak Prevention and Surveillance Studies in Hamilton, Ontario, Canada

Since the beginning of the COVID-19 pandemic, there have been many collaborations among our groups in Hamilton, Ontario, Canada focusing on infection control and prevention in local homeless shelters. One of the first interventions seen early on in the pandemic was a pilot study of a COVID-19 testing and support program done in collaboration with the Shelter Health Network, shelter operators, and local public health unit. [59] The program aimed to mitigate the risk of COVID-19 outbreaks in homeless shelters by increasing shelter capacity and implementing rapid testing. During the study, shelter bed capacity was increased from 341 shelter beds across 8 shelter sites to 395 beds through the addition of 3 hotel sites, a temporary men's shelter, and an isolation centre. [59] The increase in space made physical distancing of sleeping arrangements between residents possible and created lower density. [59] As of March 17, 2020, rt-PCR testing was implemented in which residents and staff who failed daily symptom screening were swabbed with nasopharyngeal swabs by a trained healthcare worker. [59] Residents that tested positive would be transported by a dedicated transport vehicle to the isolation centre. [59] Staff testing positive would be told to self-isolate at home. [59] During the pilot, 245 nasopharyngeal swabs were taken, with 141 swabs being from staff and 104 swabs from residents who had failed daily symptom screening. [59] Among residents, there was a prevalence of 1% (1/104) of SARS-CoV-2 infection and a 5% prevalence among staff. [59] Test turnaround time achieved an average of 14 hours from arrival of specimens to the lab to time of result. [59]. The results of the study demonstrated a need to establish an approach within these high-risk congregate settings that consisted of rapid testing, isolation, and physical distancing to successfully prevent outbreaks. [59] The prevalence of SARS-CoV-2 could have been underestimated in this study as only those failing symptom screening were tested meaning that asymptomatic cases went undetected.

In the same year, our group initiated a prospective cluster-randomized control trial to compare the effectiveness of four different surveillance strategies across 11 homeless shelters in the City of Hamilton. [60] The three intervention arms were compared against testing only in symptomatic patients, defined as those who failed screening or seeked care for potential COVID-19 symptoms as seen in the pilot study described above. [60] In addition to symptomatic testing, the intervention arms were as follows: once weekly self-collected oral swab regardless of symptoms, once weekly self-collected oral-nasal swab regardless of symptoms, and once weekly nurse collected nasopharyngeal swab regardless of symptoms. Nasopharyngeal swabbing was performed for symptomatic cases in the remaining group. [60] There were 101 residents and 184 staff members who participated in nasopharyngeal swabbing. [60] Due to a decline in weekly adherence, feedback from participants that nasopharyngeal swabbing was uncomfortable, and concerns about little to no swab collection, the protocol was amended to offer only oral swabs and oral-nasal swabs. [60] Oral swabbing was done by 1749 residents and 2778 staff members. [60] Oral-nasal swabbing was done by 1888 residents and 3047 staff members. [60] Overall, the study found that self-collection with oral swabs and oral-nasal swabs were more tolerated than nasopharyngeal swabs and were more likely to result in better adherence to weekly surveillance. [60] It was found that oral-nasal swabs detected more cases than oral swabs, however it should be noted that discontinuation of the nasopharyngeal intervention arm resulted in a limited comparison against these two swab types. [60]

There was a major expansion of the surveillance study in 2021 into a prospective cohort study. As of 2021, the study was providing testing in 53 shelter sites in the Hamilton region. The study implemented self-collected oral-nasal swabs for SARS-CoV-2 testing. The definition of homeless individuals was expanded to include those living in emergency shelters, temporary housing, halfway houses, detox and treatment programs, foster care, and assisted living.

The prospective study aims to overcome gaps found in the current literature. Many of the studies described above were short in duration, ranging from several weeks to a few months. However, these short durations would not allow an accurate description of the epidemiology of COVID-19 in shelters as a whole, rather they can only give a snapshot of what happened during a certain period. This is a significant limitation as certain studies may be biased to a range of periods from lockdown periods to peak periods, and re-opening periods. These studies are not able to observe long-term patterns that will show COVID-19 in homeless shelters considering time trends, implementation of different public health interventions, and introduction of new variants. With this prospective study, data from a 12-month period will be used to analyze these long-term trends.

Another limitation in previous literature is the use of small selective samples. Studies that consider only a single or a few shelters cannot be considered representative of the homeless shelter population. These studies can have an overrepresentation of certain characteristics including gender, age, comorbidities, and other factors that can significantly skew observations. With the prospective cohort including 53 units and participants representing a range of age groups, genders, access to healthcare, and comorbidities, the study aims to be more representative of the homeless shelter population in the Hamilton region. Testing has also been selective, with some studies exclusively including only symptomatic cases and others including only residents and not staff members. Evidence points to a high proportion of asymptomatic cases within shelters and therefore the literature may be significantly underestimating prevalence within shelters. There is also evidence of staff members having similar or slightly lower prevalence to residents and should be included in shelter population samples as they have the potential to contribute to transmission. Our prospective study offers voluntary testing to all residents and staff within the units to ensure all symptomatic and asymptomatic cases are detected. Furthermore, the feasibility studies presented above contributed a lot of knowledge on implementation and need of surveillance services within homeless shelters. However, our prospective study will be the first study to evaluate the impact of a surveillance program on reducing transmission within these congregate settings.

Summary

There is an abundance of evidence that SARS-CoV-2 prevalence is high among the homeless population and in some cases higher than the community-dwelling population. Congregate living facilities, particularly shelters are one of the most at-risk settings for transmission of SARS-CoV-2. The pandemic has highlighted many of the challenges faced by shelters when it comes to infection control and prevention. Shelters with higher prevalence of infection often are unable to create adequate social distancing arrangements, lack the facility space to reduce shared accommodations, and face resource shortages such as personal protective equipment. In addition, shelter residents are also at risk due to individual characteristics such as age and comorbidities. However, data on these individual risks are limited and more large-scale studies are needed to further explore these risks.

Shelters have used many common mitigation strategies, including the use of PPE, increased physical distance, and symptomatic screening. While symptomatic screening supports outbreak prevention, outbreaks continue to occur potentially attributable to asymptomatic spread. It is evident that asymptomatic cases exist within the shelter systems at a high rate and therefore it is necessary for shelters to employ universal molecular testing in addition to current symptomatic screening. There is an urgent need for surveillance programs that utilize universal testing within these high-risk shelter settings for outbreak management. Both rt-PCR and rapid antigen testing have been found to be adequate diagnostic tests for outbreak management in shelters, though both have their own set of advantages and disadvantages pertaining to turnaround time, costs, and diagnostic accuracy.

Although the literature on COVID-19 in the homeless population continues to grow, there is still a need for studies that are longer in duration and include a more representative sample of the homeless community. More studies considering the long-term epidemiology of COVID-19 need to be done to account for changes in seasonality, local policy changes, and interventions to determine how it affects the homeless community and outbreak management in congregate living facilities. Although literature on the feasibility of universal testing is emerging, there is a greater need for program evaluations to determine operational feasibility, acceptability to stakeholders, and the extent of impact that surveillance programs have on reducing SARS-CoV-2 infections and the severity of outbreaks.

In this thesis, I plan to use data from the prospective surveillance study in Hamilton, Ontario to better understand the epidemiology of COVID-19 in homeless congregate living settings from January 1, 2021, to December 31, 2021. In the thesis, I plan to describe COVID-19 in the homeless population living in congregate settings and identify factors potentially associated with increased risk of infection that need to be considered when implementing transmission and outbreak prevention strategies. The length of the study will allow for a comparison of the impact of the surveillance program through the different phases and dynamics of the pandemic including province mandates such as lockdowns and high community incidence.

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CHAPTER 2

A Retrospective Analysis of SARS-CoV-2 Infection Amongst the Homeless Population: Observing Trends, Outbreaks, and Feasibility of Large-Scale Surveillance

Introduction

Homelessness is a public health concern encountered globally and limited data are available on this population. [8] Health records can be hard to obtain or non-existent for many of these individuals due to suboptimal access to healthcare.[20] Follow-up and sampling that is considered representative of the homeless population is difficult due to the high mobility of these individuals. Although estimates on homeless populations are limited, with the increased presence of encampments seen in cities and the capacity overflow within shelters it is evident that homelessness continues to rise. [24] One of the many burdens faced by the homeless population is the spread of communicable diseases, and previous studies have shown that communicable diseases exist within the homeless population at greater rates than in community-dwelling populations. [8, 12] The facilities that serve the homeless community are thought to be at increased risk of disease transmission due to crowding, the transient nature of homeless individuals, shared living spaces, and limitations in infection control resources. Some examples of these facilities include shelters, housing programs, drop-in sites also known as day centres, respite sites, substance use treatment centres, and food banks.

In December 2019, COVID-19, a disease caused by SARS-CoV-2, was first identified in China and quickly spread globally. Many were affected by the spread of

SARS-CoV-2 worldwide, but it did not affect everyone equally. [21] Despite multi-faceted strategies including, testing laboratories, and vaccination rollouts, at-risk groups such as the homeless population were left with a shortage of tools and guidance to effectively reduce the impact of the pandemic. Strategies such as personal protective equipment (PPE), lockdowns, symptomatic-only testing and symptom screening were targeted toward symptomatic infections and populations that had the resources to integrate these strategies. [22, 23] The use of PPE and physical distancing were not an option for many facilities serving the homeless community. [22, 23] Shortages and price increases of PPE made it difficult to obtain, and limited facility capacities lead to overflow, making social distancing impossible in certain situations. [22, 23] In 2021, provincial masking policies in Ontario, Canada required masking in all public indoor spaces and encouraged wherever physical distancing was not possible. Some individuals with medical conditions could be exempt from wearing a mask where required. Masking policies could have varied for shelters across the province. In Hamilton, Ontario, facilities that were part of the Shelter Health Network required staff to wear masks and expected clients to wear a mask if they were meeting with staff. However, since these congregative living settings were considered to be their place of residence, clients were not required to wear masks but were encouraged to do so.

Stay-at-home orders and regional or country-wide lockdowns were measures only applicable to those with a place of residence. In 2021, Ontario was regionally phasing out of the first stay-at-home order in early February but by April a second province-wide shutdown and a second stay-at home order were put in place. The introduction of vaccinations was faced with restrictions on eligibility and limited supply. In Ontario, vaccines started to become available towards the end of December 2020 however, individuals who were 18 or older, had high-risk health conditions, or could not work from home were not eligible for vaccinations until May 2021. For people experiencing homelessness, additional obstacles to accessing vaccines were due to inadequate access to healthcare and limited channels for information.[20] In addition, data on vaccine coverage and its effectiveness in congregate settings were sparse. Testing was also essential in identifying cases, particularly asymptomatic cases, to isolate and reduce transmission. [25] Most commonly, symptom screening and temperature checks were established at entry points. [25] During certain periods of the pandemic, eligibility for testing would be restricted to those showing symptoms or having a positive contact. However, it has been shown that a large proportion of infected individuals are asymptomatic, and a significant number of infections are missed with these commonly used screening and testing strategies. [5, 7, 9, 11, 13, 14, 15]

Studies in Canada, the US, and Europe have demonstrated an increased positivity rate of SARS-CoV-2 amongst the homeless population in comparison to community-dwelling populations. [1,2,6-8] Although there is a limited amount of data on this population, the few existing cohort and cross-sectional studies have been able to show the potential impact of the pandemic on this population. Reported positivity rates range from 0.5% to 67% from sheltered and unsheltered cohorts. [3, 4, 10, 13, 15] Risk of infection varied by the various dynamics of the pandemic. In 2020, the risk of infection for homeless individuals was reported to be 4 times as likely during peak COVID-19 case periods and 2 times more likely during reopening periods. [16] It was also found that during the peak period, hospitalization for COVID-19 was 20 times more likely for homeless individuals in comparison to the general population, required intensive care due to COVID-19 was 10 times more likely and fatality within 21 days of the first positive result was 5 times more likely. [16] A retrospective analysis of shelters, drop-ins, and encampments in Toronto, Canada from April 17 to July 31, 2020, reported that shelter positivity rates were found to be higher than the epidemic curve for the City of Toronto.[3] Drop-in and encampment sites showed lower rates of SARS-CoV-2 than shelters.[3]

In 2020, our research group at Research St. Joseph's Hamilton conducted a prospective cluster-randomized control trial in 8 homeless shelters in Hamilton, Ontario. The study compared four different surveillance regimens for SARS-CoV-2 in symptomatic and asymptomatic individuals. Regardless of symptoms, once weekly self-collected oral swabbing, once weekly self-collected oral-nasal swabbing, and once weekly nurse-collected nasopharyngeal swabbing was tested against swabbing in symptomatic patients only. It was found that once-weekly self-collected oral (buccal)-nasal swabs regardless of symptoms was effective in identifying asymptomatic and symptomatic SARS-CoV-2 in this population. With an oral (buccal)-nasal swab often referred to as an oral-nasal swab, an individual first rotates the swab between their cheeks and lower gums on both sides, and then inserts the swab straight back into their nose until resistance is felt. The swab is rotated and left to sit for a few seconds on both sides of the nose. In 2021, the RCT was expanded into a prospective cohort study, increasing SARS-

CoV-2 surveillance in 11 shelters to 53 facilities serving the homeless population in Hamilton, Ontario and implemented the use of self-collected oral-nasal swabs from the RCT.

In this chapter, I analyze the data from the prospective cohort study to describe COVID-19 within the homeless population during 2021. The longitudinal nature of the study allows for the observation of trends associated with the varying dynamics of the pandemic and will be the first study to describe characteristics, such as size and duration, of SARS-CoV-2 outbreaks in this population. I will also discuss the feasibility of a large-scale surveillance program to be able to reduce transmission and outbreak severity by facilitating early identification of SARS-Cov-2 infected individuals in the homeless population.

Methods

Study Design

We conducted a prospective cohort study of SARS-CoV-2 infection among homeless individuals utilizing congregate living settings and other services associated with Shelter Health Network in Hamilton, Ontario. From January 1st until December 31st, 2021, clients and staff from 53 facilities were offered voluntary self-swabbing once weekly. Testing was offered voluntarily to both clients visiting the facilities and staff to ensure all symptomatic and asymptomatic cases were detected to prevent underestimating the presence of SARS-CoV-2 in this population.

The facilities include 14 emergency shelters, 24 housing programs, 7 drop-in sites, 2 isolation centres and 6 staff offices. Emergency shelters provide temporary accommodation for people who were in urgent need of a place to stay. Depending on the emergency shelter, individuals were either provided with dormitory-style accommodation or private rooms. Supportive housing sites offered affordable housing, usually apartments, and on-site support for those at risk of or experiencing homelessness. Drop-in sites were facilities that were open during the day and offered a variety of services including medical, legal, employment assistance, support for addiction and those fleeing violence, and some were food banks. Offices were primarily for administrative staff, however, there were some offices, particularly for foster care, where clients and staff would meet. Isolation centres were large spaces with socially distanced beds where known positive clients would be transferred to and therefore the surveillance study only tested staff in isolation centres. Swabs were also available at the Shelter Health Network office for staff and residents suspected of symptomatic infection and was categorized as a drop-in site.

Eligible study participants were adults, 18 years and older, visiting one of the Shelter Health Network sites in Hamilton, Ontario. Individuals 17 years and younger were also eligible and informed verbal consent was obtained from a parent or guardian. Those unable or unwilling to give consent were excluded. Verbal consent was obtained from residents by trained and delegated members of the study and shelter teams. Staff in the facilities were able to provide their own consent and register for participation in the study. The study protocol was approved by the Hamilton Integrated Research Ethics Board (HiREB # 13060).

Data Collection

Collected swabs were linked to results by barcode, along with participant demographic and health information and documented in an online platform hosted by a data management company, Verto Health. At the time of registration name, date of birth, participant type (client or staff), vaccination status, and location of testing were collected. Age was deduced from date of birth. The gender of all participants was determined retrospectively using Gender API [17], a gender detection software that predicts an individual's gender based on their first name. The software uses a database of 6,084,389 names from 191 countries and provides an estimated probability of the accuracy of the gender designation for each name. [17] Four gender detection tools were evaluated on the proportion of misclassifications and nonclassifications, and it was found that Gender API along with NamSor were considered more accurate tools compared to genderize.io and Wiki-Gendersort. [26] Gender API had the second lowest misclassification proportion of 1.8% compared to 1.76% for genderize.io but Gender API also had a much lower nonclassification proportion of 0.34% compared to 16.4% for genderize.io. [26]

Testing

Clients and staff participated in voluntary swabbing once weekly using oral-nasal swabs. Parents or caregivers were asked to collect an oral-nasal specimen from their children. If a child was resistant to oral-nasal sampling, oral sampling was offered and documented. Collection kits consisted of a flocked universal swab (Miraclean or iClean), a tube containing transport medium, and a QR code for registration. Written instructions were provided for sample collection and were accompanied by verbal and visual instructions from the staff providing the testing. Swabs were collected into 2 mL of transport medium, guanidine thiocyanate-based transport medium (McMaster Molecular Medium, Bay Area Health Trustee Corporation, Hamilton, Ontario). Specimens were transported to the laboratory for testing at room temperature and stored at 4°C for a maximum of 24 hours. Specimen extraction and PCR setup were done using liquid handling automation on the Microlab Vantage and STAR (Hamilton, Reno, NV). Positive PCR results would be relayed by the research coordinator to the Shelter Health Network clinicians who would disseminate the results to participants and facility staff. Specimen turnaround time of 6 hours from specimen arrival at the laboratory was maintained throughout the study. This was a specific testing route created for these samples by the infectious disease research group at St. Joseph's Healthcare Hamilton which had obtained a clinical diagnostic license and incorporated the testing into the normal workflow. Testing of the specimens was funded by the Ontario Ministry of Health.

A laboratory-developed triplex reverse transcriptase polymerase chain reaction (RT-PCR) was performed on the CFX96 Touch Real-time PCR thermocycler (BioRad, Mississauga, Ontario) using the Luna Universal probe One-Step-RT-qPCR kit (New England Biolabs, Whitby, Ontario) and 5 μL template of the extracted sample. The triplex assay targets include the SARS-CoV-2 E gene, 5'-UTR gene and RNase P (internal control). An internal control was included as it reduces a potential source of false negatives due to insufficient specimen collection, incomplete extraction, or inhibition of amplification. Staff in the infectious disease research lab at St. Joseph's Healthcare Hamilton conducting testing were blinded to participants' identity and symptomatic status. Specimens with insufficient volume of transport medium, incorrect swab placement, or tubes with missing swabs were excluded and not tested.

Outcomes

The primary outcome was the incidence of SARS-CoV-2 infection, defined as a positive PCR result. If all targets in the PCR triplex resulted in a cycle threshold (CT) value of 36.99 or less, it was considered a positive result. Any other combination of CT values would be interpreted using an algorithm shown in Figure 2-8. A co-primary outcome was outbreak incidence. An outbreak was defined as the presence of two or more PCR-confirmed positives from unique individuals in the same facility within 14 days.

Statistical Analysis

Descriptive analysis was performed at the participant level to summarize the demographic, health, and behavioural characteristics of the participants at baseline. Participant characteristics were divided by client, staff, and an additional subgroup categorized as unknowns for individuals whose participant type was unidentified. Participant mobility was defined as the movement between facilities and was measured by whether participants' tests were registered at 2 or more facilities.

For participants who tested positive more than once, infections were considered unique if the following positive tests were not within 90 days of the initial positive result. If a participant tested positive more than once within 90 days, the date of the first positive result was used as the date of infection onset. Positivity rates were calculated by dividing unique positive infections over the total amount of tests conducted, to prevent overestimating the positivity of SARS-CoV-2 due to repeat positives from the same individual within 90 days. Positive SARS-CoV-2 cases over the one-year period were plotted against the 7-day rolling average of daily cases in Hamilton, Ontario and in relation to province-wide changes relevant to the pandemic. [18]

Facility-level descriptive analysis was used to summarize the number of clients and staff participating in testing in each facility, as well as the number of SARS-CoV-2 infections. Facilities were categorized as emergency shelters, supportive housing, drop-in centres, isolation centres, and administration offices. Number of outbreaks were calculated at the facility level and defined as the presence of more than two PCR-confirmed positives from unique individuals within 14 days. Outbreak duration was calculated as the number of days from the first confirmed positive to the last confirmed positive case in a given outbreak. Public health declaration of outbreaks would also include an additional 7 – 14 days of ongoing surveillance from the last confirmed positive case depending on recommendations at the time. Outbreak size was defined by the number of individuals, staff and clients, with a confirmed positive sample.

Results

Participant Demographics

The SARS-CoV-2 surveillance program served 53 homeless facilities from January 1st to December 31st, 2021. A total of 42,331 tests were conducted throughout the year for 5430 unique participants. The median number of tests conducted per participant was 2 (IQR = 2,5). Among this group, 58% were clients, 33% were staff members, and in 9% an individual's participant type was unknown. Table 2-1 summarizes the demographics of each participant type. The mean age of clients was 39 years (SD= 18.37), 1784 (56.5%) were male, 1298 (41.1%) were female, and sex was unknown for 73 (2.3%) participants. The mean age of staff was also 39 years (SD= 15.19), 543 (29.8%) were male, 1257 (69%) were female, and sex was not reported for 23 (1.2%) individuals. Both clients and staff cohorts had a high proportion of individuals with unreported vaccination status. Of those that did report their vaccination status, the majority indicated having at least one dose in both groups. When assessing participant mobility, 832 clients and 297 staff had visited two or more facilities throughout the study period.

SARS-CoV-2 Positivity Rates

Out of the 42,331 tests, 48% of tests were conducted for clients, 50% of tests were conducted for staff, and 2% for unknowns. There were 345 (1%) invalid tests which were excluded from subsequent analysis. There were 585 positive tests, resulting in a SARS-CoV-2 positivity rate of 1.4% (585/41986) in this population. Those who tested positive collected on average 2 swabs for the same infection. There were 291 clients who tested positive at least once, 116 staff, and 19 unknowns. It is also important to note that 4 clients had tested positive for a second SARS-CoV-2 infection beyond 90 days from the onset of the first infection. SARS-CoV-2 positivity was highest amongst clients at 9.4% (295/3155). SARS-CoV-2 positivity for staff was found to be 6.4% (117/1823) and only 1 staff member tested positive for a second SARS-CoV-2 infection. The unknown group had a SARS-CoV-2 positivity of 4.2% (19/452). The overall SARS-CoV-2 positivity rate considering only unique infections was 1% (431/41986). Considering only unique infections, the positivity rates among facility types were 1.08% (219/20340) for emergency shelters, 0.61% (82/13542) for supporting housing, 1.91% (128/6706) for drop-in sites, 4.26% (2/47) for isolation centres, and no positive cases were found in administration offices.

Outbreaks

There were a total of 52 outbreaks in 23 out of the 53 facilities. Figure 2-5 displays the number of outbreaks among the different facility types. The outbreaks occurred in 10 emergency shelters, 9 supporting housing sites, 3 drop-in sites, and 1 isolation centre. The majority of outbreaks occurred in emergency shelters and supportive housing, each accounting for 23 and 18 outbreaks, respectively. Drop-in sites accounted for 10 outbreaks and 1 outbreak occurred in an isolation centre. The median (interquartile range) for outbreak size was 4 people (2,8). The median (interquartile range) for duration was 8 days (3, 14). The outbreaks varied in size, 13 outbreaks consisted of 2 people, 29 outbreaks had between 3 to 9 people, and 9 outbreaks had 10 or more individuals. Figure 2-4 shows the distribution of outbreaks throughout 2021 by facility type. There were two large and prolonged outbreaks. The first occurred February 19 – April 13, 2021, in an emergency shelter with 29 SARS-CoV-2 cases over 54 days. The other occurred February 4 – March 18, 2021, also in an emergency shelter with 59 SARS-CoV-2 cases over 43 days. Out of the 371 participants involved in outbreaks, 74% were residents, 23% were staff, and 3% were of unknown participant type. There were approximately 3 times as many clients than staff involved in the outbreaks. There were over 3 times the number of clients than staff involved in emergency shelter outbreaks. For outbreaks in supportive housing, 4 times as many clients were involved than staff. Drop-in sites had an even distribution of staff and client cases involved in outbreaks.

Discussion

Over the course of 2021, 42,331 SARS-CoV-2 tests were conducted, and the number of tests were proportionally distributed between clients and staff. We found the age distribution between clients and staff to be similar. A higher proportion of clients were male, and a higher proportion of staff was female. Many participants in both cohorts did not report vaccination status. However, out of those who did report vaccination status, vaccination was almost 2 times higher among staff members than clients. Clients were found to have slightly more movement between the facilities in comparison to staff members.

The data also show that surveillance was potentially able to reduce transmission and the extent of outbreaks in this population. The overall positivity rate of 1.0% was much lower than what has been reported in previous studies in similar populations. Figure 2-1 summarizes positive SARS-CoV-2 cases over the one-year period plotted against the 7-day rolling average of SARS-CoV-2 cases in Hamilton, Ontario for 2021. [18] Throughout the year, positivity among the homeless population remained below the 7-day rolling average of SARS-CoV-2 cases in Hamilton. This is in contrast to what was found in a study in Toronto, Ontario, where the positivity rate in shelters was the same or higher in most instances than the average positivity rate in Toronto. [2]

Figure 2-1 shows SARS-CoV-2 peak incidence periods for both the homeless population and the general population during 2021. In January 2021, the province of Ontario declared its second state of emergency and placed additional stay-at-home orders. These measures were put in place to mitigate the rising number of SARS-CoV-2 cases in Ontario at the time. However, by early February there was a rise in SARS-CoV-2 cases in the homeless population in Hamilton, while the Hamilton community cases were still low. This first peak of infections for the homeless community in 2021 preceded the rise of Hamilton cases and the declaration of Ontario's third COVID-19 wave in March. In early August, a similar event occurred in which another peak in homeless SARS-CoV-2 cases preceded the rise of Hamilton cases. In December, there is an almost simultaneous rise in homeless and Hamilton SARS-CoV-2 cases.

It is possible that changes in the dynamics of the pandemic can account for the trend in cases seen between the homeless and the general population. Figure 2-2 shows positive cases categorized by participant type in relation to events occurring in Ontario relevant to the pandemic. During the first peak of SARS-CoV-2 cases in the homeless population, there is the confirmation of the first case of the Beta variant in Ontario on February 1, 2021, and the first confirmation of the Gamma variant in Ontario on February 7, 2021. Before the second peak of cases in the homeless population in August 2021, Ontario entered the late stages of its re-opening plan in July 2021. At the end of

November 2021, Ontario reported two cases of the new Omicron variant, followed by a large rise in cases in both the homeless and general Hamilton population.

Although the rise of infections seen throughout the year may be influenced by the introduction of new variants, it would not explain why rises in cases are detected in the homeless population before the general population. The surveillance data plays a significant role in understanding transmission in the homeless population. The two largest outbreaks in the homeless community occurred during the two peaks in cases observed in February and August 2021, suggesting that there is a potential relation between transmission of SARS-CoV-2 cases between the homeless community and the general population. In addition, active surveillance of the homeless population regardless of symptoms could have identified milder cases early on before they were identified in the general population where testing was typically restricted to those presenting with symptoms.

The SARS-CoV-2 positivity for clients was almost double that for staff members. As described above, cases for clients were highest in February, August, and December. For staff members, case numbers remained relatively steady throughout the year and the only rise in cases was observed in December. The positivity among staff members was high and show that staff potentially have a part in transmission due to exposure to positive individuals within the facility or in the community. The higher proportion of positive cases among clients in comparison to staff members was consistent for all facility types as seen in Figure 2-3. The difference in vaccination rates and movement between shelters may account for the significant differences in positivity between participant types. The difference in masking requirements could also explain the differences in positive cases among participant types. Clients were only expected to wear masks when in contact with staff but were not required to wear masks when in their place of residence with other clients, therefore limiting the exposure more with staff but not with other clients. This could also explain the high positivity among staff, particularly for staff that work in facilities where clients reside, as they are more exposed to an environment where masks are not required for clients. Whether the positivity rate between facility types is considered with participant cohorts together or on their own, drop-in sites have the highest positivity rate, followed by emergency shelters and supportive housing sites. The high positivity rate observed in isolation centres was due to the small number of tests conducted and only 2 positive cases reported for staff.

Another significant finding was that drop-in sites had almost 2 times the positivity rate in comparison to emergency shelters and supportive housing sites. This contrasts with the findings in other studies in which the positivity rate for residents was higher in congregate living sites than in drop-in sites and shows the positive impact of routine surveillance in congregate living settings. The higher positivity in drop-in sites could be due to increased client turn-around seen in day centres compared to congregate living settings. If asymptomatic testing is only offered once weekly, more individuals may be captured during their stay in a shelter or supportive housing program, whereas individuals visiting a day centre may visit on a day when testing is not available and potential cases will be missed and cause increased transmission.

Our data show that outbreaks are prevalent in these settings and if not caught early on can increase in severity by size and duration. Emergency shelters and supportive housing sites in this study, both congregate living facilities, demonstrate to be most susceptible to outbreaks. Although beyond the scope of this study, facility-level factors should be assessed in these facilities in future studies to determine the reasoning behind the increased occurrence of outbreaks and the appropriate interventions to minimize them. There was a high proportion of clients involved in outbreaks in comparison to staff. This could be due to several reasons including differences in the use of masks, and vaccination status or clients may be in contact with more individuals due to dormitory-style accommodations. A lot more clients than staff visited two or more facilities during the study. There is a possibility that if clients are exposed to positive contacts by visiting drop-in sites during the day where we've reported high positivity rates and returning to the shelters or housing sites at night, it could be driving up the number of positive cases in general for clients or the number of outbreaks in the congregate living facilities.

In this analysis, our outbreak findings show a potential positive impact of the surveillance program. Less than half of the facilities in this study experienced an outbreak. In figure 2-7, the distribution of outbreaks by size and duration is shown. The majority of outbreaks in these facilities were small in size and of short duration. This contrasts many of the SARS-CoV-2 outbreaks described in previous studies, which tend to be large and of extended durations. Supportive housing and drop-in sites had outbreaks that were small in size and short in duration with few outbreaks showing an increase in size and duration. The isolation centre only experienced one mild outbreak consisting of two staff members. In emergency shelters, a few larger and prolonged outbreaks are observed, however, the majority of outbreaks were small and short. Our data suggest that intervention with weekly surveillance may have played a role in reducing the number of larger outbreaks within congregate living facilities. Both emergency shelters and supportive housing show many small-scale outbreaks that could have potentially become larger without surveillance.

Our findings support that a large-scale surveillance program for the homeless population is feasible and may potentially reduce transmission and the extent of outbreaks. Certain components of our surveillance program enabled us to successfully maintain testing in 53 facilities over a one-year period. The first is the automation of testing processes in the research laboratory. Integration of liquid handling systems allowed for high-capacity testing with a rapid turnaround time. The amount of testing needed to support this population would not be feasible with manual methods. We did not compare our turnaround time of 6 hours from collection to results to the turnaround time in other laboratories conducting SARS-CoV-2. However, for this study, showing that a rapid turnaround time that is less than 24 hours is achievable is important as it allows the facilities to identify and isolate positive cases before more individuals are exposed within the facility or before the individual positive for SARS-CoV-2 moves on to another facility or non-shelter site. This also applies to minimizing transmission through staff, particularly those who work in multiple facilities.

The feasibility of the program is due to more than just the automation of testing within the laboratory. Coordination of providing swabbing kits to multiple sites, creating processes for delivery of specimens in the lab, and the communication of results was all critical in creating an effective surveillance program. Collaboration with the staff of the Shelter Health Network was essential in communicating results and timely isolation of positive cases. Shelter Health Network clinicians who work directly with the staff and clients on a regular basis were critical in disseminating testing results to all the sites. Furthermore, building trust and forming relationships with the clients was important in encouraging participation. Historically, some clients lack trust in the healthcare system or some fear what would happen if they were to test positive. During swab collection, our team would provide education on testing and on isolation procedures to help overcome those barriers and encourage participation.

Strengths

One strength of the study is that we were able to obtain pragmatic real-world data for a large sample size of a population that is challenging to study and collect data on. The study is further strengthened by the use of longitudinal data. This allowed us to observe trends that could be missed with shorter studies. Including both clients and staff in our study population allowed us to consider all aspects of SARS-CoV-2 spread and outbreaks within these facilities increasing the generalizability of the study. In addition, the study population consisted of facilities providing services to homeless individuals of different age groups, and genders, and to those with different needs such as substance use support and mental health services. The diverse range of facilities included increased the generalizability of our findings to be more representative of the homeless population, at least within Hamilton, Ontario.

Limitations

Our study is not without potential limitations. The first limitation was encountered with testing being voluntary which may have introduced selection bias. Further selection bias is risked due to individuals not having access to facilities at certain periods due to capacity limits experienced during the pandemic, resulting in individuals who would normally utilize these services not having the opportunity to be tested. In addition, symptomatic individuals may have been tested through the emergency department and would not have been collected into our surveillance database. Third, the need to rapidly implement the program during the pandemic resulted in some data not being captured which may have affected the accuracy of estimates. The average weekly occupancy for the facilities was not obtained and would have allowed for estimates of incidence. Information on symptomatic status was inconsistent and therefore was not included. Vaccination status was not available for a high proportion of participants. Gender was not collected at the time of registration and the Gender API software was used to determine the gender of each participant based on the first name. However, the software does not account for cultural differences, gender identity, and unique naming situations. Estimates on mobility were based on records of a participant receiving a SARS-CoV-2 PCR test at multiple locations. However, it is possible that the mobile nature of the population was underestimated, as participants may have visited multiple facilities but may not have been tested at each or tested in a setting outside of the study such as an emergency department. Lastly, the discussion on the feasibility of the surveillance program lacks an in-depth analysis on costs, operational requirements, regulations, stakeholder acceptability, ethical considerations, and sustainability, to be able to assess the feasibility of implementing a large-scale surveillance program in this population in another setting.

Conclusion

Our findings support that SARS-CoV-2 is prevalent in the homeless community and that without proper mitigation strategies, the impact of the pandemic can be detrimental to this population. Clients and staff are both sources of transmission and there may be risk factors that cause higher positivity in clients compared to staff. This retrospective analysis demonstrated that a large-scale surveillance program in the homeless population is feasible and has the potential to reduce the spread of SARS-CoV-2 in this population and limit the extent of outbreaks. Our large testing capacity and rapid turnaround time allowed for efficient identification and isolation of positive cases. Surveillance is not only crucial in identifying cases in the homeless population but allows us to understand transmission in this population to better identify what mitigation strategies are needed and where to target them. While a surveillance program may be an effective and feasible intervention to reduce transmission, further studies need to be done to understand risk factors both on an individual and facility level that may influence transmission. Studies are also needed to understand the relationship of SARS-CoV-2 transmission between the homeless population and the general population.

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Table 2-1. Demographics of Homeless Individuals and Facility Staff in Hamilton, Canada in 2021.

Characteristics	No. (%) of Clients n= 3155	No. (%) of Staff n=1823	No. (%) of Unknown n=452
Age, yr			
≤18	396 (12.6)	6 (0.3)	44 (9.7)
19-24	216 (6.8)	245 (13.4)	36 (8.0)
25-49	1622 (51.4)	1111 (60.9)	210 (46.5)
50-64	669 (21.2)	342 (18.8)	94 (20.8)
>65	240 (7.6)	104 (5.7)	41 (9.1)
Age, mean (SD), yr	39.42 (18.37)	39.22 (15.19)	40.34 (19.56)
Age, median (IQR), yr	39 (28,52)	35 (27,49)	28 (26.5,53)
Sex			
Male	1784 (56.5)	543 (29.8)	205 (45.4)
Female	1298 (41.1)	1257 (69.0)	228 (50.4)
Unknown	73 (2.3)	23 (1.2)	19 (4.2)
Vaccine Status			
Yes	902 (28.6)	927 (50.9)	15 (3.3)
No	507 (16.1)	98 (5.4)	6 (1.3)
Not Reported	1746 (55.3)	798 (43.7)	431 (95.4)
Visited >1 Unit			
Yes	832 (26.4)	297 (16.3)	13 (2.9)
No	2323 (73.6)	1526 (83.7)	433 (95.8)

Table 2-2. SARS-CoV-2 testing and result frequency by participant type.

Population	Tests Conducted (Not including invalid tests)	Tests Conducted (Not including invalid tests and repeat positives)	Positive Tests (% Positivity)	Unique Infections (% Positivity)	Negative Tests	Invalid Tests
Clients	19995	19889	401 (2.0)	295 (1.5)	19594	232
Staff	21214	21169	162 (0.8)	117 (0.6)	21052	108
Unknown	777	774	22 (2.8)	19 (2.5)	755	5
Total	**41986**	**41832**	**585 (1.4)**	**431 (1.0)**	**41401**	**345**

Table 2-3. SARS-CoV-2 testing and result frequency by facility type.

Facility	Tests Conducted (Not inlcuding invalid tests)	Tests Conducted (Not including invalid tests and repeat positives)	Positive Tests (% Positivity)	Unique Infections (% Positivity)	Negative Tests	Invalid Tests
Emergency Shelters	20340	20256	303 (1.5)	219 (1.1)	20037	169
Supportive Housing	13542	13523	101 (0.7)	82 (0.6)	13441	107
Drop-In Sites	6706	6655	179 (2.7)	128 (1.9)	6527	62
Isolation Centres	47	47	2 (4.3)	2 (4.3)	45	0
Offices	1351	1351	0 (0)	0 (0)	1351	7
Total	**41986**	**41832**	**585 (1.4)**	**431 (1.0)**	**41401**	**345**

Figure 2-1. Daily SARS-CoV-2 case count among the homeless population versus the 7-day rolling average of new COVID-19 cases in Hamilton, Canada, 2021.

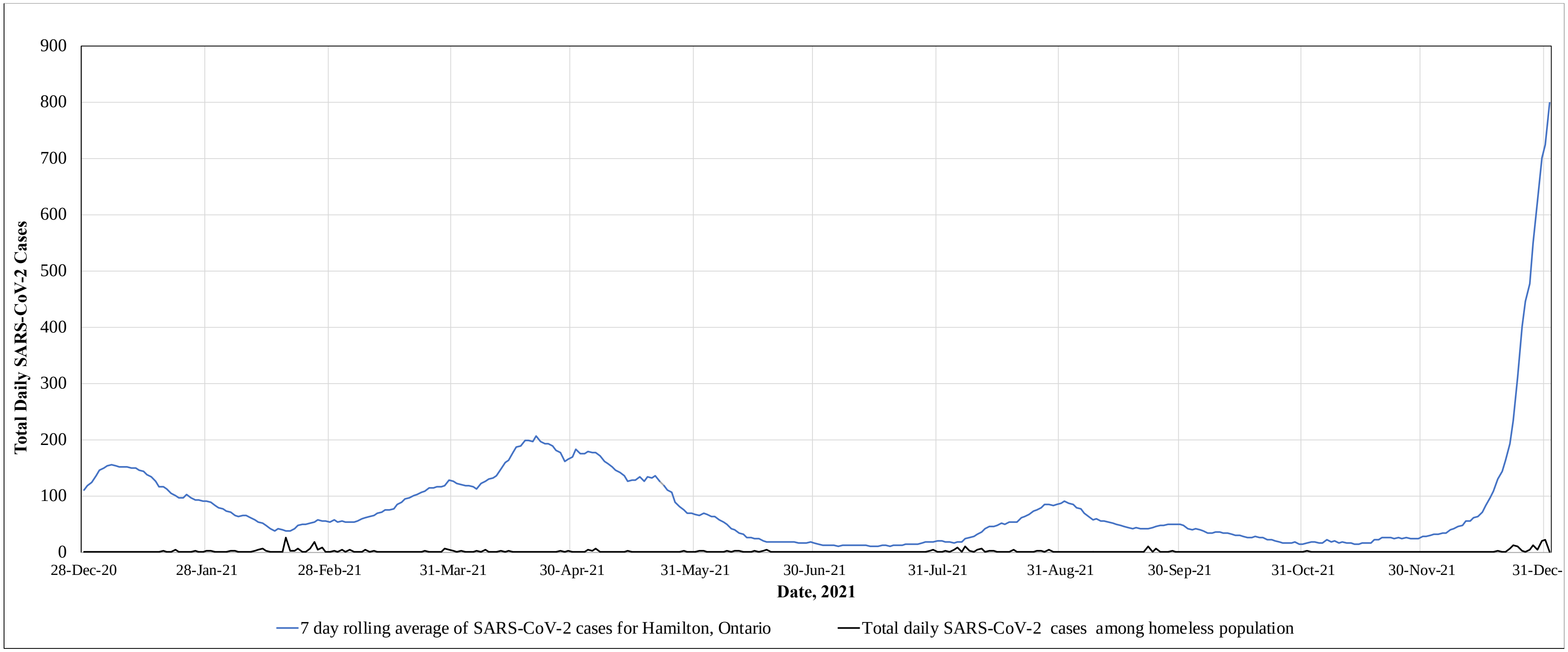


Figure 2-2. Distribution of SARS-CoV-2 cases in the homeless population in relation to pandemic-related events over the year

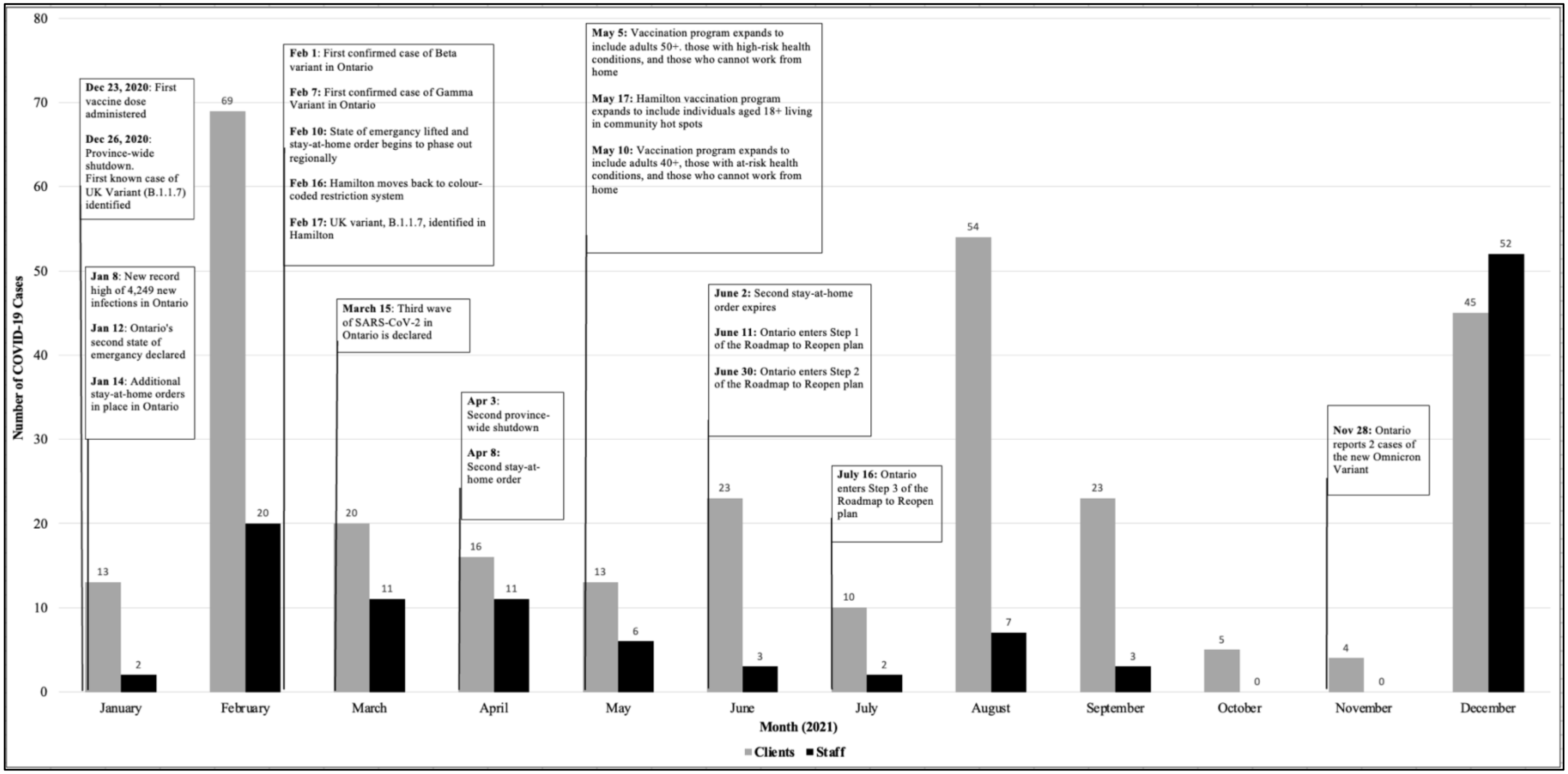


Figure 2-3. The proportion of SARS-CoV-2 cases by participant and facility type.

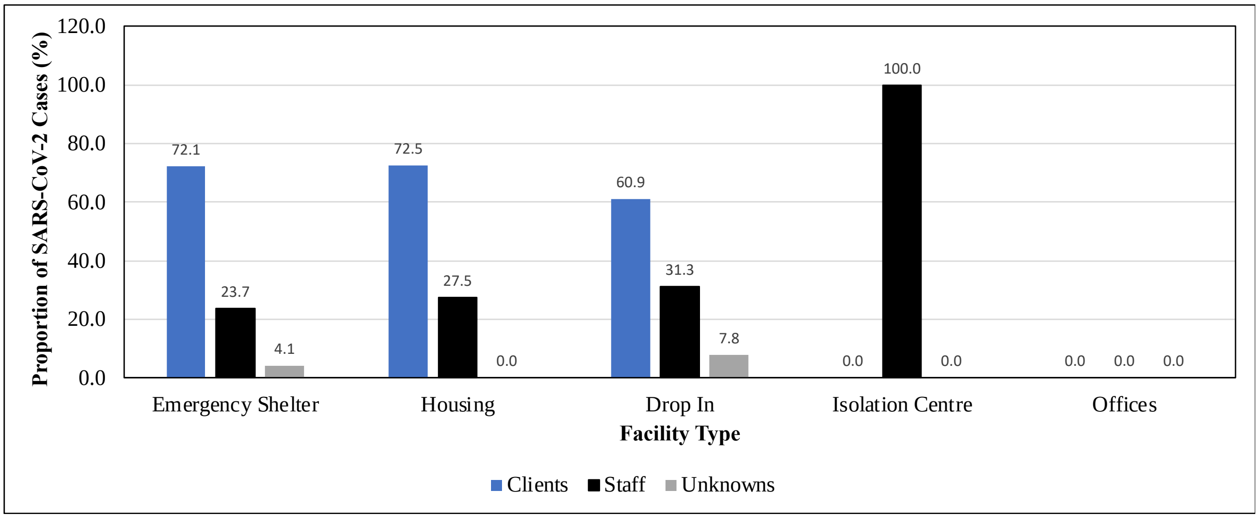


Figure 2-4. Distribution of outbreak sizes by the facility and start date.

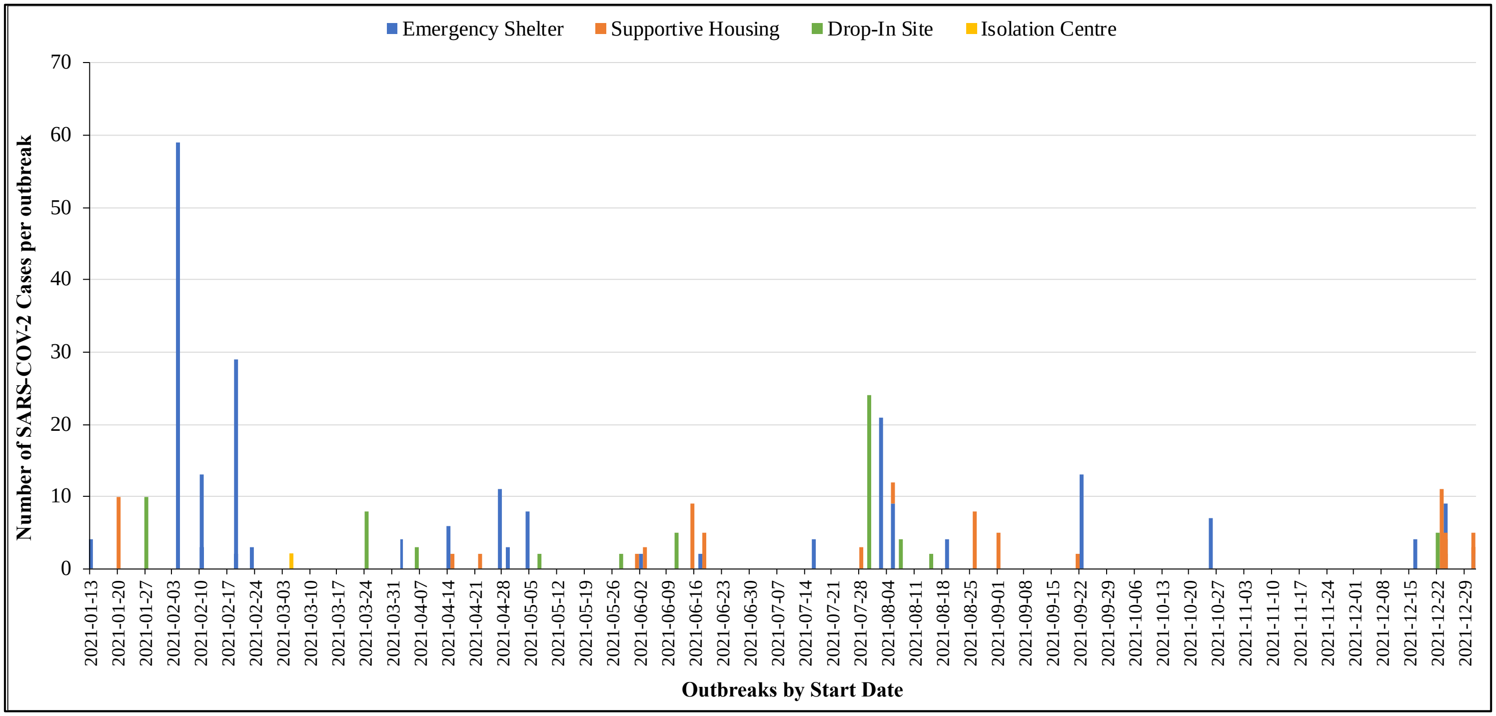


Figure 2-5. The proportion of outbreaks by facility type for the homeless population in Hamilton, Canada, 2021.

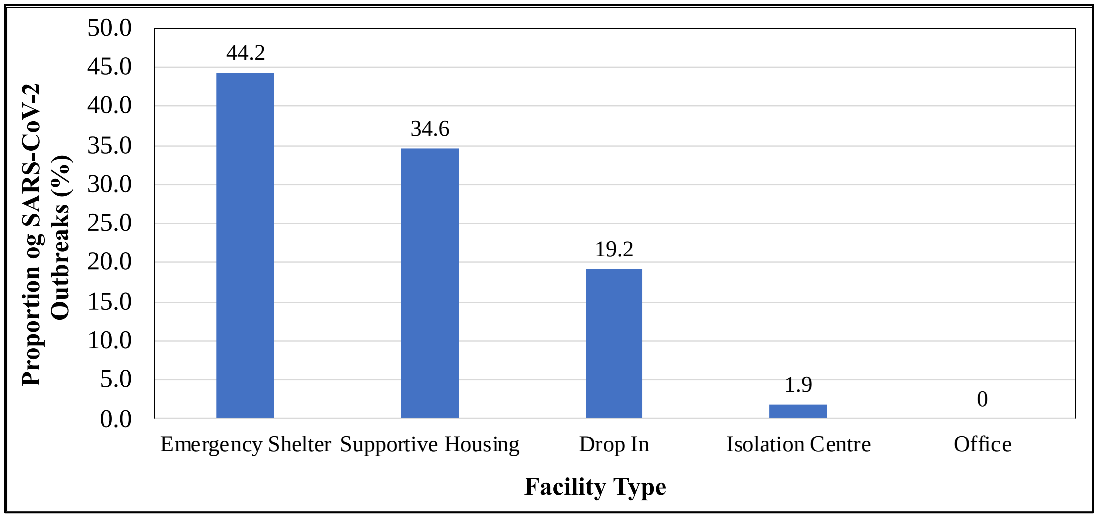


Figure 2-6. The proportion of participant types involved in outbreaks.

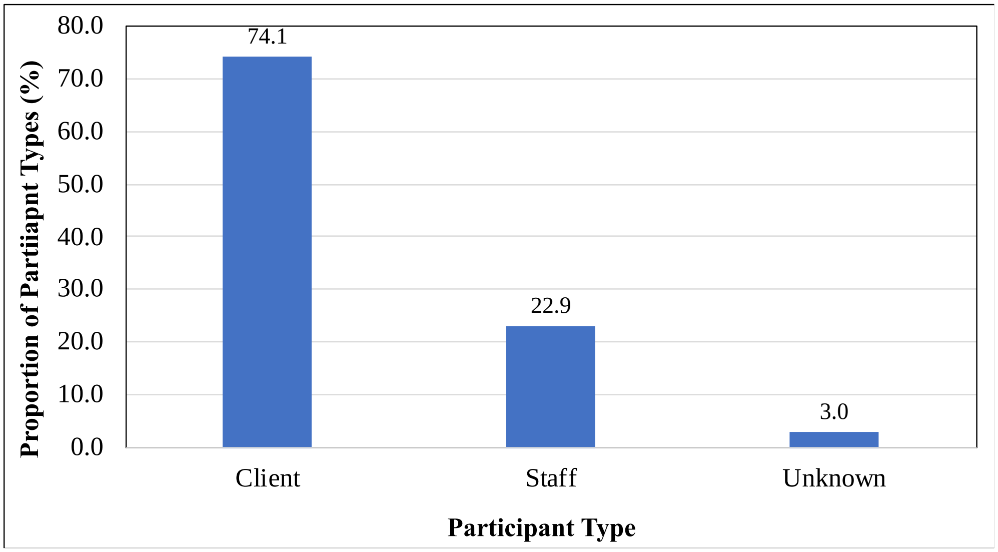
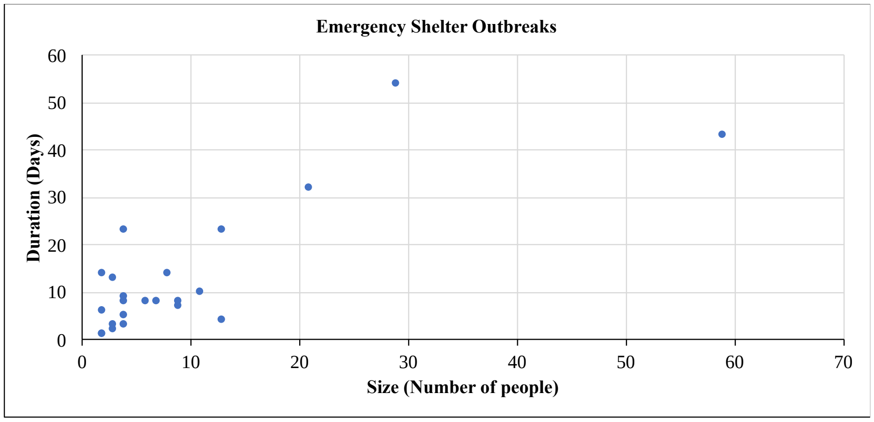
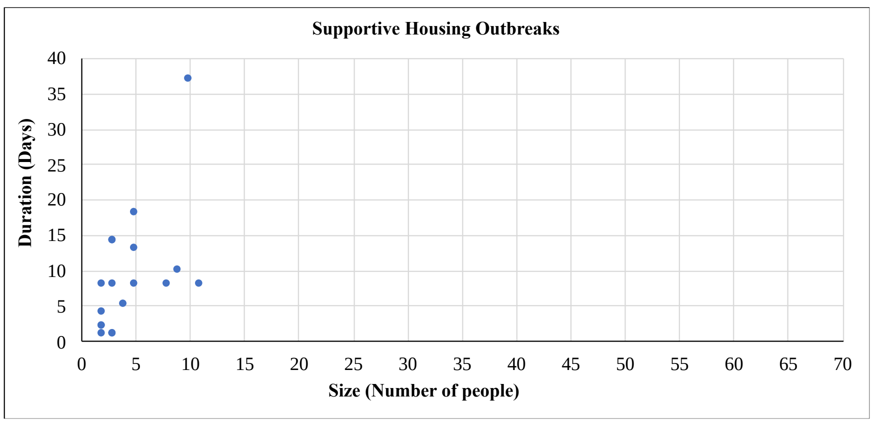


Figure 2-7. Comparison of size and duration of SARS-CoV-2 outbreaks by facility type.





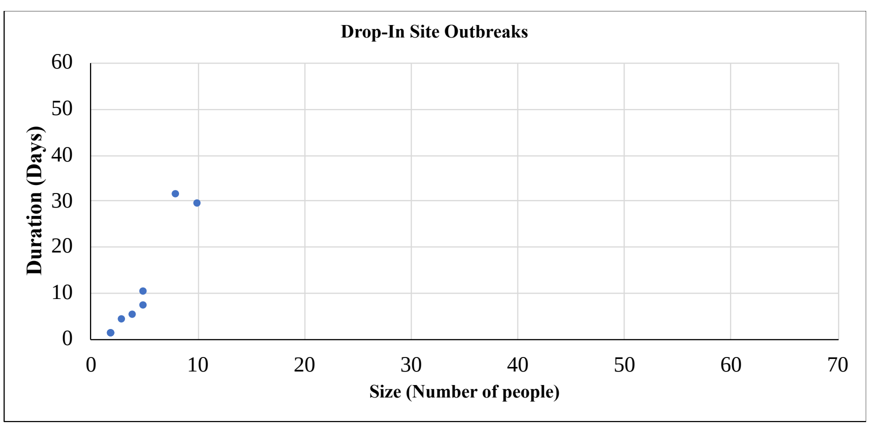
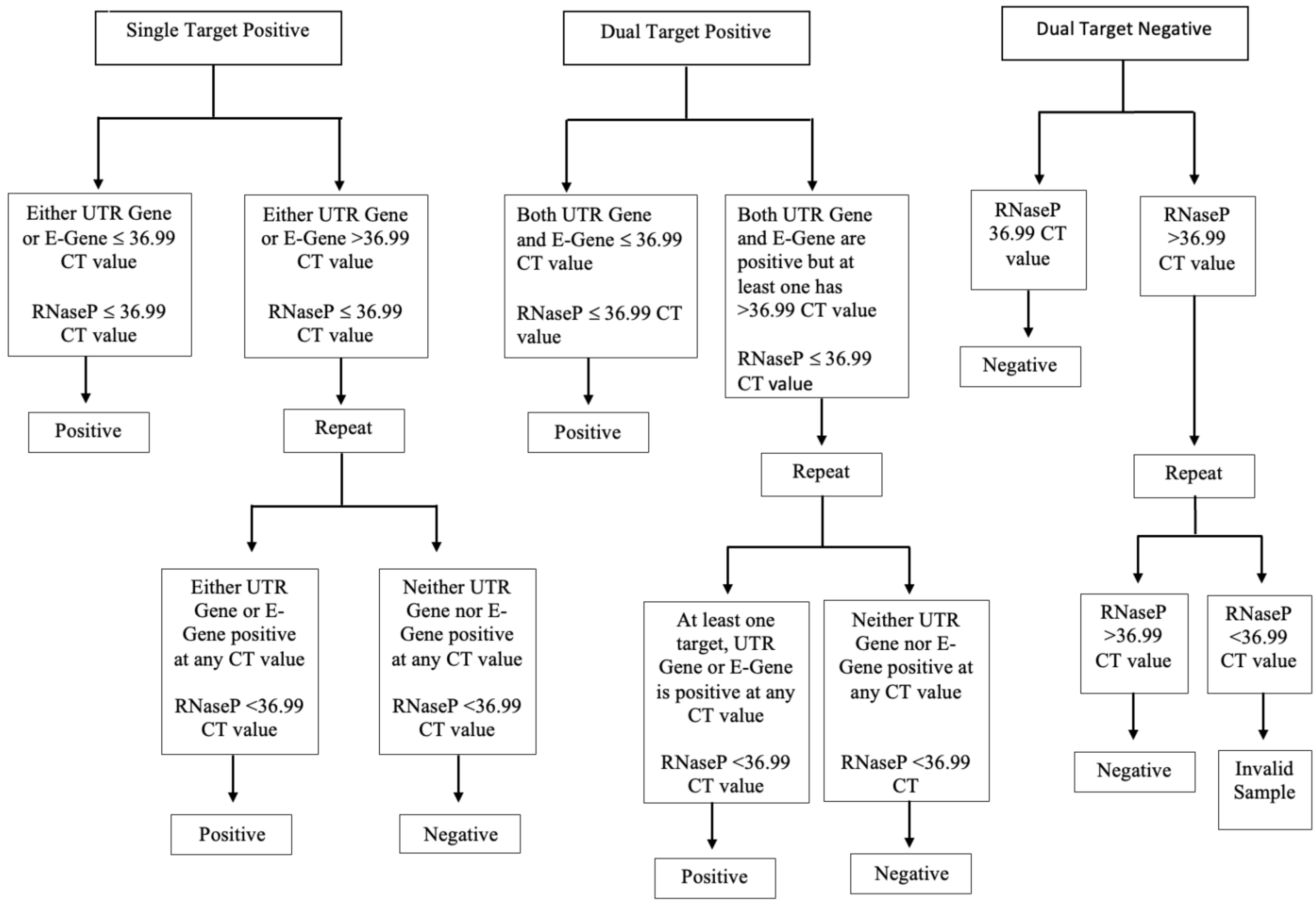


Figure 2-8. Flow diagram of an algorithm used to interpret SARS-CoV-2 PCR results for specimens processed as part of the shelter surveillance study in Hamilton, Ontario; 2021.



CHAPTER 3

Exploring Individual and Facility-Level Risk Factors for SARS-CoV-2 Infection Among Homeless Individuals in Congregate Living Facilities: A Multilevel Analysis

Introduction

In the previous chapter, data from a prospective surveillance study were used to describe the presence of SARS-CoV-2 among a homeless population, and other cohort studies were summarized, which demonstrated that SARS-CoV-2 occurred at a higher rate in homeless populations when compared to the general population. People experiencing homelessness may have individual characteristics that predispose them to an increased risk of acquiring SARS-CoV-2 infection such as age, gender, vaccination status, and how much they move around to different environments. Several facilities serving homeless communities may also encounter their own set of risk factors that contribute to increased risk of infection. In particular, congregate living spaces such as emergency shelters and supportive housing are thought to be at increased risk compared to other settings due to shared spaces and high resident density. In addition, staff working in these facilities are a possible source of SARS-CoV-2 transmission from within and outside the facilities.

Identifying individual-level and facility-level characteristics as potential risk factors for SARS-CoV-2 is important in minimizing disease transmission in the homeless population. Previous studies have identified potential risk factors to be age, mobility, comorbidities, shared spaces, facility density, and social distancing ability. [1,2,3,5,7] Gender and race were found not to be potential risk factors. [1,4,5,6,8] Understanding the sources of risk is essential in being able to provide effective guidance and support. Identifying potential risk factors can inform choices on prevention and control practices in these facilities. Facility-level risk factors may vary between facility types and therefore policies and mitigation strategies required by each facility may differ. Furthermore, if mitigation strategies are already in place but are found to be ineffective, identifying potential risk factors can help understand what mitigation strategies are needed in this specific population and where to target these strategies for the best outcome(s).

The objective of this chapter was to identify participant-level and facility-level characteristics that may be potential risk factors for SARS-CoV-2 infection in the homeless population. Using the data collected in the prospective surveillance cohort described in chapter 2, the analysis considered potential risk factors not yet considered in previous studies, including vaccination status, type of facility, and whether staff were working at a single site or multiple sites. The inclusion of staff in our study will allow us to determine if staff themselves are at increased risk of SARS-CoV-2 infection, whether staff increase the risk of infection for clients, and if their potential risk factors differ from that of clients.

Methods

Study Population

Data on participants and facilities that are part of the Shelter Health Network were collected in the prospective SARS-CoV-2 surveillance study described in Chapter 2. The surveillance study consisted of 53 facilities serving the homeless community, including 14 emergency shelters, 24 supportive housing sites, 7 drop-in sites, 2 isolation centres, and 6 administrative offices. For this analysis, only congregate living facilities, emergency shelters and supportive housing sites, were considered. We excluded 7 drop-in sites as the average number of clients visiting these sites throughout the year was not captured. We also excluded 6 office sites and 2 isolation centres as only staff testing was conducted at these sites. Surveillance testing in emergency shelters and supportive housing sites was conducted from January 1st, 2021, to December 31st, 2021, on a voluntary, once-a-week basis.

Data Collection

Data on participant demographics were collected at the time of swabbing during registration and consent. This included age, participant type (staff or client), vaccination status, and the facility in which the participant was tested. As described in the previous chapter, gender was added retrospectively using Gender API, a gender prediction software. [9] Delegated members of the Shelter Health Network and the research team collected facility-level data retrospectively by phone and email.

Statistical Analysis

We performed descriptive analyses for both participant-level and facility-level characteristics at baseline. Since many participants were tested more than once over the study period, participant characteristics were compared between participants who had tested positive for SARS-CoV-2 at least once compared to participants who never tested positive. Participant and facility characteristics were summarized with counts (%) and mean (SD) was used for age. To examine differences between variables for those testing positive and negative for SARS-CoV-2, the Chi-Square test was used for categorical variables and the independent T-test was used for continuous variables. The outcome was defined as a laboratory-confirmed positive SARS-CoV-2 PCR test result. Individual-level characteristics included age, gender, participant type, vaccination status and mobility. Participant type indicated whether the participant was a client or staff member. Vaccination status was whether a participant reported receiving at least one dose of any SARS-CoV-2 vaccine. Participant mobility was defined as whether a participant had visited two or more facilities during the study period. Facility-level characteristics included facility type, room types, facility capacity, and whether staff at a facility worked at single or multiple facilities. Facility type was used to indicate if a particular facility was considered an emergency shelter or supportive housing site. Room types indicated if a facility provided accommodation with private rooms, shared rooms, or both. Facility capacity was defined as the maximum number of people a facility could accommodate on any given day. As there were only two possible outcomes, a binary logistic regression model was used and included participant type, gender, mobility, vaccination status, age, facility type, facility capacity, room type, and staffing policy (single or multi-site) as predictors.

Adjusting for clustering among facilities and participants (multiple tests in the same participant), generalized estimation equations (GEE) were used to test whether differences in characteristics were statistically significant and used robust standard errors. An exchangeable correlation matrix was assumed. The adjusted odds ratio (aOR) and 95% confidence interval (95% CI) was reported for each predictor. Microsoft Excel was used to collect registration data and SPSS (Version:28.0.1.1) was used for analyses. Missing data were identified for participant type, age, gender, and facility capacity. Since the percentage of missing data for these variables was extremely low (0.001-1.45%), the potential impact of the missing data was negligible and was ignored in the analysis. There was a significant amount of missing data for vaccination status. Therefore, a sensitivity analysis was used to assess the impact of missing data on the model.

Results

Client Demographics

As part of the prospective SARS-CoV-2 surveillance program, 33,994 tests were conducted in emergency shelters and supportive housing as part of the Shelter Health Network in Hamilton, Ontario. Of these, 404 tests were positive for SARS-CoV-2. However, only 308 of the 404 tests were considered positive for unique infections.

Throughout the study period, a total of 2743 unique clients and 1421 unique staff members underwent testing. There were an additional 281 individuals tested whose participant type was unknown and they were excluded from further analysis. Table 1 summarizes the demographic characteristics between participants who tested positive at least once and those who only tested negative for SARS-CoV-2. Of the 2743 clients, 8% (219/2743) had tested positive for SARS-CoV-2 at least once and 92% (2524/2743) never tested positive. Clients who tested positive had a higher mean age than those who tested negative, however, this was not a statistically significant difference (MD=3.4, 95% CI 5.84-0.93, P=0.48). Of the clients that reported at least 1 dose of a SARS-CoV-2 vaccine, 8.64% (75/868) tested positive and 91.4% (793/868) tested negative but was also found not to be a statistically significant difference (X^2 (df=1) =0.532, P=0.47). More than twice the number of male clients tested positive compared to female clients (X^2 (df=1) =15.98, P<0.001). In addition, of the clients that tested positive, more than half visited two or more facilities during the study period (X^2(df=1) =73.54, P<0.001).

Staff Demographics

Of the 1421 staff tested, 5.6% (80/1421) staff had tested positive for SARS-CoV-2 at least once and 94.4% (1341/1421) never tested positive. Staff that tested positive had a lower mean age compared to those that tested negative, but the difference was found to be not statistically significant (MD=0.84, 95% CI 2.50-4.19, P=0.50). Of the staff that reported at least one dose of vaccine, only 4.4% (37/835) tested positive (X^2(df=2) =6.06, P=0.048). There was twice the number of female staff testing positive than male staff (X^2(df=1) =1.66, P=0.20). Among the staff that tested positive for SARS-CoV-2, 41.2% had visited two or more facilities during the study period (X^2(df=1) =1.68, P=0.20). Differences in gender and mobility were not statistically significant.

Individual-Level Risk Factors

After adjusting for age, mobility, vaccine status, facility type, and capacity, clients were more likely to test positive for SARS-CoV-2 than staff (aOR 2.30; 95% CI 1.43-3.68, P<0.001). Participants who had visited two or more facilities during the study period were 72% more likely to test positive for SARS-CoV-2 than those who had not visited two or more facilities (aOR 1.72; 95% CI 1.13-2.61, P=0.011). Participants who reported not receiving any doses of a SARS-CoV-2 vaccine were also more likely to test positive for SARS-CoV-2 compared to participants who reported receiving at least one dose (aOR 2.03; 95% CI 1.37-3.02, P<0.001). Gender (aOR 1.48; 95% CI 0.93-2.36, P=0.095) and age (aOR 0.99; 95% CI 0.97-1.00, P=0.062) were not significantly associated with testing positive for SARS-CoV-2. A sensitivity analysis demonstrated that with the imputation of missing vaccination status data, the parameters of the model remained unchanged.

Demographics of Facilities

There were 20,440 tests conducted across 14 emergency shelters. A total of 224 unique positive cases were identified and 20,138 negative tests. Table 2 summarizes the facility-level characteristics of both emergency shelters and supportive housing sites. The capacity of emergency shelter facilities ranged from 10 to 150 people. Private rooms were provided in 6 facilities, shared rooms were provided in 2 facilities, and 6 facilities offered both private and shared rooms. There were 3 facilities in which staff worked only at a single site and 11 facilities where staff could work multiple sites.

Across the 24 supportive housing sites included in the surveillance study, 13,554 tests were conducted. There were 84 unique positive cases identified and 13452 negative tests. The capacity in these facilities ranged from 8 to 170 people. Private rooms were offered in 12 of the facilities, shared rooms in 6 of the facilities and both types of rooms were available in 6 of the facilities. Of the 24 facilities, there were 5 in which staff worked only at a single site and 19 facilities where staff could work multiple sites.

Facility-Level Risk Factors

After adjusting for all other factors, the odds of testing positive for SARS-CoV-2 increased for participants in emergency shelters compared to those in supportive housing (aOR 1.88; 95% CI 1.16-3.05, P=0.011). For facilities with a capacity of 26 to 50 people, the odds of testing positive were higher than for facilities that have capacities of 25 people or less (aOR 3.52; 95% CI 1.59-7.80, P=0.002). For facilities with a capacity of over 100 people, the odds of testing positive were also higher than for facilities that have capacities of 25 people or less (aOR 5.24; 95% CI 2.43-11.31, P<0.001). Facilities offering only shared rooms (aOR 0.96, 95% CI 0.56-1.63, P=0.87) or both private and shared rooms (aOR 0.72; 95% CI 0.44-1.20, P=0.211) in comparison to facilities with private rooms only were not significantly associated with testing positive for SARS-CoV-2. Staff working single site (aOR 1.37; 95% CI 0.78-2.43, P=0.273) versus multiple sites were also found to be statistically non-significant predictors.

Discussion

Our findings strongly support that there are both individual-level and facility-level characteristics that predispose individuals in the homeless population to an increased risk of SARS-CoV-2 infection. Our analyses suggest that clients living in congregate settings are at twice the risk of testing positive for SARS-CoV-2 compared to staff. This could be due to factors such as attending multiple shelters or vaccination status. In table 1, it is evident that compared to staff, a higher proportion of clients had visited two or more facilities during the study period and a higher number of clients reported being unvaccinated. Compared to staff, clients had a higher proportion of unreported vaccination status. In addition, staff in the facilities were required to wear masks and clients were encouraged but not required to. The differences in adherence to masking and other personal protective equipment could be contributing to the increased risk of infection for clients, but more data will need to be collected on mask usage in the client population.

It has been suggested by a previous study that residents in shelters who had more movement in and out of a shelter are less likely to test positive for SARS-CoV-2. [4] It was suggested that those that move in and out of shelters frequently spend more time outdoors, therefore limiting their exposure inside a facility. [4] In contrast, our analysis found that individuals who visited two or more facilities during the study period were at higher risk of testing positive compared to those who did not. This may suggest that the more facilities an individual visits, the greater the increase in the risk of exposure. More movement also may indicate difficulties in follow-up in which individuals testing positive are notified after movement or contact is no longer possible due to movement. A study assessing risk factors for

SARS-CoV-2 infection in homeless shelters in Chicago, USA, also found that increases in resident mobility were associated with increased risk of infection. [1]

Our analysis also found that those who reported not receiving any doses of a SARS-CoV-2 vaccine were more likely to be infected with SARS-CoV-2 than those who reported at least one dose. After a sensitivity analysis to account for a large number of unreported vaccination statuses, vaccination was still statistically significant. This is one of the first studies to report on the effect of SARS-CoV-2 vaccines in a homeless population in preventing infection. Our data support that efforts to increase vaccination coverage in this population are important in preventing SARS-CoV-2 infection.

Our data suggest that those residing in emergency shelters are at higher risk of infection compared to those living in supportive housing. The higher risk demonstrated may be explained by the fact that emergency shelters provide short-term accommodation with a higher movement of individuals coming in and leaving the facility. The emergency shelters also encounter overflow and experience a higher resident density in shared spaces. Accommodation in supportive housing tends to be over longer periods of time compared to emergency shelters. Supportive housing also experiences fewer individuals coming in and out, and shared spaces are usually allocated to the same group of people living in a particular apartment, for example.

There was no difference in risk found between facilities providing private rooms, shared rooms or both. This is in contrast to previous findings, in which residents were found to be at increased risk of infection when sleeping in a room with other people. Previous findings were from studies conducted in the early months of the pandemic in 2020 before capacity and sleeping arrangement guidelines would have taken effect. Mitigation strategies such as social distancing, strict sleeping arrangements, and limited capacity in shared rooms may have reduced the risk of infection. In this study, data on the number of individuals in a shared room was not collected but is a factor that can also affect whether certain room types increase the risk of infection. One study found that sharing a room with more than 20 people was associated with an increased prevalence of SARS-CoV-2 infection. [1] Facilities where the staff was working either at a single site or multiple sites, were also found to be statistically not significant. We would expect facilities that have staff working multiple sites to be at increased risk. The mitigation strategies put in place during the pandemic by the facilities and the addition of surveillance from our study could have reduced the risk of infection in staff working multiple sites.

Facility capacity was found to be significant in increasing the risk of infection. As expected, facilities with higher capacities are at a significantly high risk of SARS-CoV-2 infection. Facilities that have a capacity for over 25 individuals may have different mitigation and support requirements to be able to social distance and provide safe sleeping arrangements for clients and staff compared to smaller facilities.

Limitations

Our study has many strengths including longitudinal data, the inclusion of staff in analyses, and a range of facilities with clients of all genders and all ages. However, our findings are subject to limitations as well. First, we have to consider when this data was collected. During 2021, many facilities had already incorporated changes such as lowering capacity, establishing screening procedures, and rearranging policies for shared spaces or sleeping arrangements. In addition, surveillance testing was identifying and isolating positive cases. Therefore, this could potentially lead to risk factors being underestimated in this study. Second, testing was offered on a volunteer basis which produced the risk of selection bias. Third, challenges in data collection may have influenced the precision of estimates of some of the variables. There was a high proportion of unreported vaccination status across all groups but particularly in the client cohort. As stated in the previous chapter, gender was added using a gender detection software that utilized the first name to determine the gender, which could encounter errors by not being able to account for cultural differences in naming. Facility-level characteristics were added retrospectively. There could have been significant differences in the estimate of certain facility-level characteristics during the course of the study compared to when data collection took place. Fourth, although our study population included a range of facilities serving a large diversity of clients, our findings may not be generalizable to homeless individuals living in other settings that are not congregate living settings.

Conclusion

In summary, our findings strongly support that there are individual and facility-level characteristics that should be considered as potential risk factors for SARS-CoV-2 in the homeless population. Congregate living settings, in particular emergency shelters, are at high risk. Although staff and clients are both vulnerable to infection, clients seem to be at higher risk. A greater amount of infection control and public health interventions should be focused on facilities with larger capacities. In addition, future prospective studies should look to identify mobility patterns to understand the risk of mobility and to obtain more complete data on vaccination coverage in homeless communities to understand the true effectiveness of vaccination in this population. Our study highlights the importance of identifying risk factors to guide public health decisions and interventions in homeless populations. Adopting individualized strategies is critical in addressing the specific needs of homeless communities to minimize the spread of infection and effectively handle cases of infectious disease in congregate settings.

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Table 3-1. Demographics of Participants Testing Positive and Negative for SARS-CoV-2

	No. (%) of Clients		No. (%) of Staff		No. (%) of Unknown	
Characteristics	**Positive for SARS-CoV-2 n= 219**	**Negative for SARS-CoV-2 n= 2524**	**Positive for SARS-CoV-2 n= 80**	**Negative for SARS-CoV-2 n= 1341**	**Positive for SARS-CoV-2 n= 9**	**Negative for SARS-CoV-2 n= 272**
Age, yr						
≤18	18 (8.2)	283 (11.2)	4 (5.0)	27 (2.0)	0	23 (8.5)
19-24	12 (5.5)	171 (6.8)	14 (17.5)	189 (14.1)	0	21 (7.7)
25-49	112 (51.1)	1340 (53.1)	44 (55.0)	831 (62)	6 (66.7)	123 (45.2)
50-64	49 (22.4)	551 (21.8)	18 (22.5)	217 (16.2)	3 (33.3)	63 (23.2)
≥65	26 (11.9)	171 (6.8)	0	66 (4.9)	0	27 (9.9)
Age, mean (SD), yr	42.86 (17.03)	39.48 (17.75)	36.45 (15.00)	37.29 (14.79)	43.02 (10.94)	41.54 (20.43)
Age, median (IQR), yr	43 (32,56)	39 (28,52)	34 (25,48)	33 (26,46)	42 (35,52)	38 (27,55)
Gender						
Male	156 (71.2)	1441 (57.1)	27 (33.8)	384 (28.6)	8 (88.9)	104 (38.2)
Female	60 (27.4)	1031 (40.8)	48 (60)	939 (70)	1 (11.1)	154 (56.6)
Unknown	3 (1.4)	52 (2.1)	5 (6.3)	18 (1.3)	0	14 (5.1)
Vaccine Status						
Yes	75 (34.2)	793 (31.4)	37 (46.3)	798 (59.5)	1 (11.1)	9 (3.3)
No	36 (16.4)	444 (17.6)	5 (6.3)	84 (6.3)	0	5 (1.8)
Not Reported	108 (49.3)	1287 (51)	38 (47.5)	459 (34.2)	8 (88.9)	258 (94.9)
Visited >1 Unit						
Yes	121 (55.3)	697 (27.6)	33 (41.2)	458 (34.2)	3 (33.3)	28 (10.3)
No	98 (44.7)	1827 (72.4)	47 (58.8)	883 (65.8)	6 (66.7)	244 (89.7)

Table 3-2. Characteristics of Emergency Shelters and Supportive Housing Sites Part of Shelter Health Network in Hamilton, Ontario

	Emergancy Shelter n=14	**Supportive Housing n=24**
Room Type		
Private Room	6	12
Shared Room	2	6
Both	6	6
Staffing Policy		
Single-Site	3	5
Multisite	11	19
Capacity		
≤25 People	2	11
26-50 People	4	9
51-100 People	6	2
>100 People	2	1

Table 3-3. Odds Ratios of SARS-CoV-2 Infection in Clients and Staff of Emergency Shelters and Supportive Housing Sites, Adjusted for Individual- and Facility-Level Factors in a Multilevel Binary Logistic Model

Characteristic	Adjusted Odds Ratio	95% CI	P value
Individual-Level Factors			
Particiapant type			
Client	2.296	(1.434-3.677)	<.001
Staff[a]	1.0		
Age	0.986	(0.972-1.001)	0.062
Gender			
Male	1.484	(0.934-2.358)	0.095
Female[a]	1.0		
Mobility			
Yes	1.718	(1.130-2.611)	0.011
No[a]	1.0		
Vaccination status			
No	2.033	(1.368-3.022)	<.001
Yes[a]	1.0		
Facility-Level Factors			
Facility type			
Emergency Shelter	1.879	(1.156-3.052)	0.011
Supportive Housing[a]	1.0		
Facility capacity			
26-50 People	3.516	(1.585-7.798)	0.002
51-100 People	1.903	(0.700-5.168)	0.207
>100 People	5.240	(2.427-11.313)	<.001
≤25 People[a]	1.0		
Room type			
Shared	0.956	(0.560-1.632)	0.87
Both	0.724	(0.437-1.200)	0.211
Private[a]	1.0		
Staffing policy			
Single Site	1.374	(0.778-2.427)	0.273
Multisite[a]	1.0		

[a] Reference Category

CONCLUDING STATEMENT

In conclusion, the findings of this study make a significant contribution to the existing literature on COVID-19 in the homeless population. The study described the epidemiology of SARS-CoV-2 in the homeless population over a one-year timeline which has not been previously described. Trends between cases in the homeless population and the general population were observed and warrant further investigation into the association between the two. Both clients and staff were shown to contribute to SARS-CoV-2 transmission within the shelters. Although clients had higher positivity rates, staff still play a role in transmission within these facilities, and it is very important that future studies do not exclude staff. Emergency shelters and supportive housing sites are considered congregate living facilities and showed to be most at risk for SARS-CoV-2 transmission and large outbreaks. Large-scale surveillance in the homeless population was feasible under certain financial and laboratory support and demonstrated potential in reducing transmission and outbreak size and duration. The risk factors for infection identified at the individual level were being a client, being unvaccinated, and visiting two or more facilities. The risk factors for infection identified at the facility level were staying in an emergency shelter and residing in facilities with a capacity of 26-50 or over 100 people.

There are several future steps to be considered for this research. First, improving data collection methodology would benefit in collecting more complete data for this population, particularly data on vaccination status, gender, average weekly occupancy within the facilities and the number of people per room. Future studies should also consider assessing infection control and prevention practices such as masking within the shelters as these variables would help understand the effects of these practices on participant and facility risks. Second, there is a need for a study to assess the potential relationship between the transmission of SARS-CoV-2 cases between the homeless community and the general population. Third, it would be important to compare the data of this study to data on SARS-CoV-2 in the homeless population in other cities that did not implement surveillance testing to be able to understand the true impact of our surveillance program. Lastly, further assessment of the feasibility of the surveillance program is needed that considers costs and challenges faced in implementation in other cities.

APPENDICES

Appendix 1. A detailed summary of referenced SARS-CoV-2 prevalence studies

First Author	Year	Location	Study Type	Purpose	Results/Conclusion
Richard et al	2021	Ontario, Canada	Population-based retrospective	Used administrative data from to describe COVID-19 epidemiology and health outcomes compared to general population	Those with a recent history of homelessness are more likely to test positive for COVID-19 than the general population Hospital admission, intensive care and mortality rates related to COVID-19 were all substantially higher among those with a recent history of homelessness
Kiran et al	2020	Toronto, Canada	Retrospective chart audit	20 shelters participated in a mobile outreach testing program	Higher positivity rate for COVID-19 in shelter residents relative to general population Majority of positive cases identified during outbreak testing
Luong et al	2021	Toronto, Canada	Retrospective review	Used Ontario Health Toronto collected data to estimate SARS-CoV-2 prevalence	SARS-COV-2 positivity was higher in shelter residents than the community-dwelling population
Baggett et al	2020	Boston, USA	Cross-sectional	Used rt-PCR to determine SARS-CoV-2 prevalence in large homeless shelter in response to an outbreak	Prevalence among shelter residents was 36% and 88.5% positive individuals were asymptomatic
Tobolowsky et al	2020	Seattle, USA	Report	Described a COVID-19 outbreak among three homeless shelters, staff and residents tested with rt-PCR	Prevalence during initial testing was 10.5% and increased to 15.3% during repeat testing SARS-CoV-2 was found among 18% of residents and 21% of staff
Roederer et al	2021	Paris, France	Cross-sectional	Estimated seroprevalence among individuals experiencing homelessness at various sites	Seropositivity was 52% Among the location types, worker's residents had the highest positivity rate, followed by emergency shelters
Yoon et al	2020	Atlanta, Georgia	Prospective cohort	To determine SARS-CoV-2 prevalence in shelters, describe clinical outcomes, and diagnostic accuracy	Prevalence in shelter was 1.6% Prevalence in shelter clients was 4 times higher than unsheltered clients Repeat testing 3-4 weeks later at four shelters showed decreased prevalence
Mosnier et al	2021	Marseille, France	Prospective cohort	To determine SARS-CoV-2 seroprevalence among a homeless population beyond shelter sites during two testing periods	Homeless seroprevalence was higher than the seroprevalence found in the general population during both testing periods There was a significant increase in seroprevalence from first testing period to second testing period
Rogers et al	2021	Seattle, Washington	Cross-sectional	Community-based surveillance program using rt-PCR to determine SARS-CoV-2 prevalence in adult and family shelters	Most cases detected during surge testing rather than routine surveillance Prevalence was 2% and 72.4% of those who tested positive for asymptomatic
Imbert et al	2020	San Francisco, USA	Prospective cohort	To describe a COVID-19 outbreak in a large homeless shelter	Outbreak occurred during low community incidence Positivity among residents was 67% and 52% of those residents were asymptomatic Positivity among staff was 94% and 8% were asymptomatic

Appendix 2. A detailed summary of referenced SARS-CoV-2 risk factor studies

First Author	Year	Location	Study Type	Purpose	Results/Conclusion
Ghinai et al	2020	Chicago, USA	Cross-sectional	Conducted PCR testing in shelters and identified risk factors associated with infection	High prevalence of SARS-CoV-2 infection in homeless shelters Prevalence was lower for current smokers (vs never had smoked) and for non-Hispanic black (vs non-Hispanic white) Number of residents sharing a room and movement into and out of shelters are potential risk factors
Karb et al	2020	Rhode Island, USA	Cross-sectional	To determine individual and shelter characteristics associated with risk of SARS-CoV-2 infection	Prevalence was found to vary with shelter characteristics rather than individual symptoms Those testing positive had lower prevalence of comorbidities (vs those testing negative) Resident density, lack of physical distancing practice, and rate of movement of residents were associated with increased risk
Kiran et al	2020	Toronto, Canada	Retrospective chart audit	20 shelters participated in a mobile outreach testing program	Those testing positive were more likely to be older, to be identified as racialized, less likely to have a health insurance card, or to have visited another shelter in the last 14 days No association between positivity and medical history or symptoms
Rogers et al	2020	Seattle, Washington	Cross-sectional	Community-based surveillance program using rt-PCR to determine SARS-CoV-2 prevalence in adult and family shelters	Positivity was higher among those who are older and were non-smokers
Mosnier et al	2021	Marseille, France	Prospective cohort	To determine SARS-CoV-2 seroprevalence among a homeless population beyond shelter sites during two testing periods	Having stayed in an emergency shelter, being an isolated parent, and having contact with more than 5 – 15 per day was significantly associated with increased risk of infection Being a smoker was associated with lower risk of infection
Loubiere et al	2021	Marseille, France	Cross-sectional	To assess SARS-CoV-2 seroprevalence among homeless individuals in large city	Lower SARS-CoV-2 seroprevalence amongst those who report tobacco consumption and 2.2-fold lower prevalence with psychiatric and addiction comorbidities
Montgomery et al	2022	USA (multiple cities)	Cross-sectional	To compare COVID-19 hospitalizations amongst people experiencing homelessness compared to the general population	People experiencing homelessness who were evaluated in the emergency department were hospitalized more often, had longer lengths of stay, and had more frequent readmission than the general population People experiencing homelessness less likely to die compared to general population
Roland et al	2021	Brussels, Belgium	Simulated cohort	To describe SARS-CoV-2 infection prevalence at homeless shelters and identify risk factors associated with positivity rates	Shelters with highest number of infections distinctly had a higher density population, unregistered residents, poor sanitary conditions, and insufficient protection equipment

Appendix 3. A detailed summary of referenced SARS-CoV-2 mitigation and infection control studies

First Author	Year	Location	Study Type	Purpose	Results/Conclusion
Ralli et al	2021	Vatican City		Used PCR and antigen rapid tests to determine SARS-CoV-2 prevalence in people experiencing homelessness who use the primary care services	Most participants were asymptomatic and confirmed that symptom screening and temperature monitoring alone are insufficient measures to prevent transmission. Routine surveillance using molecular test are needed to identify and isolate cases
Roland et al	2021	Brussels, Belgium	Simulated cohort	To describe SARS-CoV-2 infection prevalence at homeless shelters and identify risk factors associated with positivity rates	Found a high proportion of asymptomatic cases among residents at time of testing Symptom screening is insufficient in detecting SARS-CoV-2 at shelters on its own Outbreak showed that waiting for detection of symptomatic cases may be too late to prevent superspreading events
Perri et al	2020	n/a	Analytical report	Analysis on COVID-19 challenges on people experiencing homelessness and mitigation strategies	Challenges of mitigation among people experiencing homelessness arise from inadequate resources, limited staffing, facility space, lack of guidance, mental illness, and substance abuse Increasing physical distance, especially for bathroom and sleeping arrangements if important to reduce risk of spread
Aranda-Diaz et al	2022	San Francisco, California, USA	Cohort	Pilot study to evaluate uptake and effectiveness of BinaxNOW – a rapid antigen test in shelters. Provided voluntary rapid, twice-weekly testing	Rapid antigen testing was able to detect most cases in asymptomatic patients however, the frequency of twice-weekly testing had low adherence Rapid testing provided rapid turnaround times and effective reach compared to previous detection strategies
Lindner et al	2021	Berlin, Germany	Prospective cohort (mixed methods approach)	To assess feasibility of regular, voluntary, self-sampling for SARS-CoV-2 testing in a homeless shelter and approach to universal testing	Voluntary, self-sampling for SARS-CoV-2 showed high retention rates and considered to be easier and more hygienic to collect compared to saliva Universal testing requires strategies to minimize workload for collection and processing
Loutfy et al	2022	Toronto, Canada	Cohort	To describe the development and implementation of a COVID-19 community response team, and assess adoption of program	Program found it to be feasible and acceptable, with high satisfaction reported 3 shelters that experienced outbreaks, experienced no further outbreaks after receiving support
O’Shea et al	2021	Hamilton, Canada	Pilot study	Evaluation of a testing and support program to mitigate risk of COVID-19 outbreaks in homeless shelters	Program thus far successful in preventing large outbreaks within shelter system despite detecting SARS-COV-2 in residents and staff Accessible housing, rapid testing, isolation, and physical distancing all important in outbreak prevention
Zhu et al	2022	n/a	Systematic review	Summary of prevention and mitigation strategies used for respiratory infectious disease outbreaks among people experiencing homelessness	Screening and testing regardless of symptoms facilitate case identification and limits outbreak risk Contract tracing, bed tracking and mapping needed to identify exposures