OBSERVING FROM AFAR:

CONTINUOUS PULSE OXIMETRY FOR PEOPLE WHO SMOKE OPIOIDS TO PREVENT OVERDOSE DEATHS

BC Centre for Disease Control
Provincial Health Services Authority

CIHR Canadian Institutes of Health Research
IRSC Instituts de recherche en santé du Canada

UBC

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ACRONYMS

BC - British Columbia
COVID-19 - Coronavirus disease of 2019
PEEP - Professionals for Ethical Engagement of Peers

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Background

British Columbia (BC) faces dual public health emergencies—the overdose crisis and the coronavirus disease of 2019 (COVID-19) pandemic.[1] Tragically, there has been a further increase in overdose deaths in BC since COVID-19 was declared a public health emergency in March 2020.[2] In 2021, 2,232 people died of illicit drug toxicity, which is the highest of any year in BC's history.[3] This increased mortality is multifactorial and likely due in part to physical distancing guidance, reduced access to harm reduction services, isolation, and increased toxicity of the illicit drug supply during the COVID-19 pandemic.[2,4,5]

To illustrate the ever-changing and increasingly toxic nature of the illicit drug supply, BC has recently experienced increased contamination of illicit opioids (e.g., fentanyl) with illicit benzodiazepines, such as etizolam. These potent sedatives were detected in 53% of overdose deaths in October 2021 compared to 15% in July 2020.[6] Benzodiazepine contaminants complicate overdose response because they cause a decreased level of consciousness without respiratory depression. The opioid antidote, naloxone, can reverse opioid-induced respiratory depression but does not reverse benzodiazepine toxicity, which causes ongoing sedation.[7,8]

Smoking has become the most common route of illicit drug use.[9,10] A recent survey found that 73% and 67% of people who reported using heroin and fentanyl, respectively, smoked them.[11,12] People who smoke opioids are less likely to carry a naloxone kit,[13] potentially because of a lower perceived risk of overdose.[14,15] However, evidence suggests that overdose risk is comparable when smoking and injecting opioids.[16] Furthermore, the proportion of overdose deaths in BC related to smoking illicit drugs increased from 31% in 2016 to 56% 2020.[10]

Misperception of overdose risk and barriers to harm reduction services likely contribute to the concerning increase in smoking-related overdose fatalities in BC. For example, most overdose prevention services sites in BC do not permit smoking,[17] or restrict smoking to concealed outdoor areas,[18] limiting their utility. Moreover, BC has only 16 overdose prevention/safe consumption sites offering inhalation services.[19] The Ministry of Health has allocated funding to inhalation harm reduction services, including implementing 12 new inhalation overdose prevention services across BC.[20,21]Despite rising smoking-related overdose deaths, we know little about respiratory depression and sedation when smoking illicit opioids, and, therefore, harm reduction services remain untailored to specific risks.

A remote monitoring system is needed to increase the utility and accessibility of overdose prevention service sites for people who smoke substances. One method showing promise is continuous pulse oximetry, which measures the level of oxygen in the blood (oxygen saturation). Indeed, the Peer2Peer project with the BC Centre for Disease Control recently demonstrated the utility of non-continuous pulse oximetry to supplement overdose response by peer workers during COVID-19.[22]

Implementing continuous pulse oximetry at overdose prevention service sites could have myriad benefits. Continuous pulse oximetry would help identify service user deterioration—which is currently difficult because of physical distancing guidance, secluded inhalation spaces, and unreliable observer assessment[23] — and potentiate early interventions. Furthermore, monitoring oxygen saturation may allow responders to avoid naloxone administration when it is not indicated (i.e., decreased level of consciousness due mostly to benzodiazepine rather than opioid toxicity, where the patient is sedated but respiratory drive is preserved), thus avoiding uncomfortable and potentially dangerous consequences associated with naloxone-induced opioid withdrawal.[24] Remote monitoring also promotes staff safety by allowing them to avoid close contact when clients have reassuring oxygen levels. Currently, staff must visually assess clients in close proximity, increasing staff's risk of toxicity due to secondary exposure to smoke. Given the increasingly toxic drug supply and the rise in smoking-related deaths during COVID-19, there is an urgent need to develop and implement a remote monitoring system and study smoking-specific risks, to maximize the utility and effectiveness of harm reduction services for people who smoke drugs, and ultimately to reduce overdose deaths.

Methods

Project Purpose

This project implemented a novel continuous pulse oximetry monitoring protocol using a participatory research approach to improve the utility and effectiveness of overdose prevention service sites for people who smoke opioids, in light of COVID-19 and the increasingly toxic drug supply.

We will use the findings to develop harm reduction messaging, expand remote monitoring to other overdose prevention service sites and private residences, and inform the development of monitoring applications for safer drug use.

Project Objective

The project's primary objective was to evaluate the effectiveness, feasibility, and acceptability of the novel continuous pulse oximetry monitoring protocol. The secondary objective was to describe the incidence, timing, duration, and severity of hypoxemia while smoking opioids.

Project Setting

We implemented the project at four overdose prevention service sites in BC with smoking facilities: Overdose Prevention Society in Vancouver, Rock Bay Landing, Travelodge (run by AIDS Vancouver Island Health & Community Services) and SOLID Outreach Society in Victoria (see Appendix A for pictures of these sites). We implemented our continuous pulse oximetry protocol at these sites from March to August 2021.

Project Design

We used a participatory/community-based research design, in which we collaborated with people with lived/living experience of substance use (peer researchers) throughout study planning, implementation, data analysis, and knowledge translation. We co-developed the study procedures and instruments with the Professionals for Ethical Engagement of Peers (PEEP), a peer advisory committee advising the BC Centre for Disease Control on provincial policies and initiatives.[25] We worked closely with each overdose prevention service site to identify site-specific needs and facilitate project implementation. We recruited and trained peer researchers at the four partnering overdose prevention service sites in Vancouver and Victoria to implement the following study processes: enrolling participants, obtaining consent, and collecting data. We trained peer researchers in a hybrid manner with virtual and in-person sessions to follow physical distancing recommendations.

Data Collection

The peer researchers used paper forms to collect participant data, structured observations, and interviews. Trained abstractors then transcribed these data into an electronic data capture project on REDCap, a secure web-based program to construct and manage surveys and databases.

Participant Baseline and Smoking Data

The peer researchers used standardized surveys to collect information on participants' demographic, health, and drug use characteristics that could influence their risk of hypoxemia and overdose. These characteristics included age, gender, employment status, housing status, medical history, and substance use history. Peer researchers also asked participants about their perceived risks of smoking opioids and whether they had smoked opioids alone in the past three days (and if so, why). Individual participants were allowed to enroll only once per day, however, individuals could enroll multiple times on different days during the study period.

Oxygen Saturation and Protocol Implementation Data

After collecting baseline data, peer-researchers implemented the monitoring protocol. To monitor oxygen saturation, we used the Masimo Radius PPG ™ Tetherless Pulse Oximeter and the Masimo Rad-97 ™ remote patient monitor (see Appendix B for pictures of the monitors).[26,27] The pulse oximeter comprises a wristband and a sensor wrapped around the participant's fingernail like an adhesive bandage. It connects to the remote monitor via Bluetooth and can maintain a connection up to 100 feet (30 meters). The Bluetooth connection is established by tapping a Bluetooth chip on the monitor and inserting it into the wristband. We used TRACE Software to capture, store, and export clinical oxygen saturation data. Data was stored on the monitoring device and then downloaded once a week for data analysis.

Peer researchers attached the pulse oximeter to each participant's wrist and finger before the participant smoked opioids. The peer researcher recorded the times of inhalation(s). Before and while smoking opioids, the pulse oximeter measured and transmitted participants' blood oxygen levels to the remote monitor, which was viewed in real-time by overdose prevention service site staff. An alarm was triggered on the remote monitor when blood oxygen levels fell to 90% or below for a duration of 15 seconds. Overdose prevention staff were trained to assess the individual and implement appropriate interventions. Following the oximetry protocol, participants stayed at the overdose prevention service site for 30 minutes of further monitoring.

Peer researchers conducted structured observations throughout the study to identify whether the protocol was implemented as planned and whether overdose prevention service site staff could maintain physical distancing as expected. While participants were smoking, peer researchers used a standardized data collection form and recorded times of inhalations, times of any alarms, time required for overdose prevention service site staff to respond, participants' status, and any overdose interventions.

Effectiveness, Feasibility, and Acceptability Outcomes

After each participant completed the monitoring protocol, peer researchers administered a second participant survey. They also surveyed overdose prevention service site staff every two weeks. These surveys assessed participants' and staff members' experiences with continuous pulse oximetry monitoring (e.g., pros and cons) and asked them to rate their satisfaction with the equipment and monitoring protocol using simple Likert scales. Peer researchers asked participants to indicate their willingness to participate in pulse oximetry monitoring at overdose prevention service sites in the future. Participants received $20 as an honorarium and each overdose prevention service site received $10 per enrollment to compensate for time and assistance.

Peer researchers also completed a self-survey after each participant's visit reporting their satisfaction and experience with the continuous pulse oximetry monitoring (e.g., pros and cons).

Data Analysis

Descriptive Summaries of Events and Participants

We summarized demographic, health, and drug use characteristics of respondents using means and standard deviations for continuous variables, and proportions for categorical variables.

Given our community-based study design that allowed individual participants to enroll in the study multiple times on different days, we examined the overlap of different demographic and health status variables to estimate how many data entries could be potential duplicates. We evaluated records that matched completely on all variables of age, gender, race, comorbidities, overdose prevention service site, date participated in study and participant anonymous identifier.

We summarized individual-level variables (e.g., demographic information, health comorbidities) after removing potential duplicates. We summarized event-specific variables (e.g., participant reports of type of opioid currently being used, recent opioid use patterns, oxygen saturation data during current monitoring event and post monitoring surveys) using the total number of smoking observation events as a denominator.

Oxygen Saturation Data

We completed a literature review to inform our approach to the oxygen saturation data analysis. Our study team, which includes a clinician, an epidemiologist, and a statistician, evaluated data and made key decisions on optimal analytic approaches. For each observed opioid smoking monitoring event, we matched oxygen saturation data with recorded times of inhalation from the structured observations. In an exploratory analysis, we plotted line graphs of oxygen saturation readings throughout recorded time for all individuals to better understand patterns and trends related to inhalation. We calculated summary measures of oxygen saturation levels and dynamics for each individual. We are in the process of creating more complex statistical models to better understand relationships between oxygen levels, participant comorbidities, and drug use patterns.

Effectiveness, Feasibility, and Acceptability Outcomes

We analyzed the data from the post-monitoring surveys using a thematic deductive process. We transcribed responses to open-ended questions verbatim. These responses were imported into- and organized with- NVivo 12, a qualitative data management software.[28] We presented the key themes to the peer researchers for discussion and data validation.

We collaborated with the partnering overdose prevention service sites, peer researchers, and PEEP to interpret the qualitative data. We facilitated data validation via focus groups, where the project coordinator and peer researchers discussed themes and findings from the qualitative data analysis.

Approvals

This study received research ethics approval from the University of British Columbia Research Ethics Board (H20-02443).

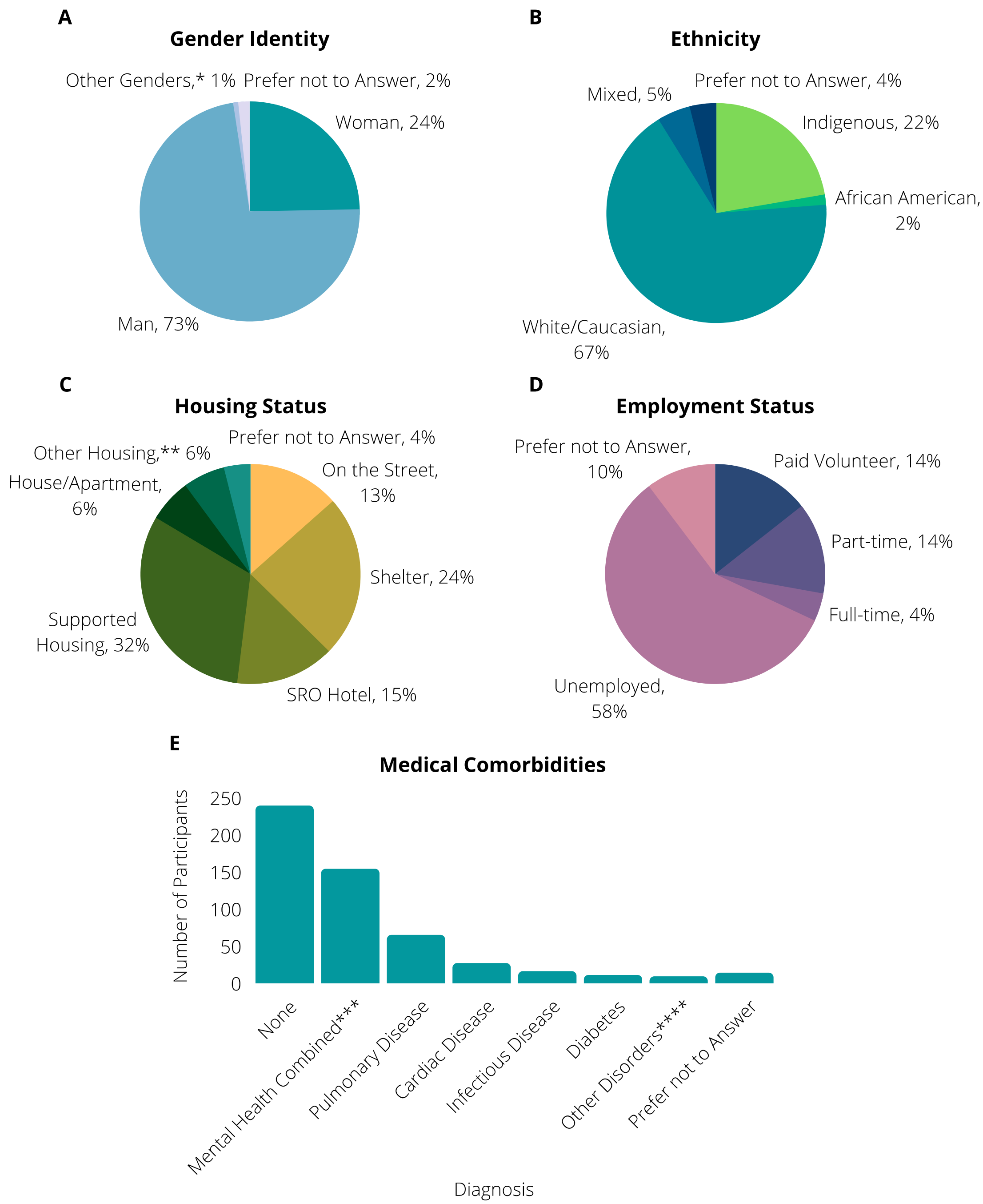
Findings

We included a total of 599 observed opioid smoking events over six months of data collection: 93 participants from the Overdose Prevention Society in Vancouver, 91 from Rock Bay Landing, 185 from Travelodge, and 230 from SOLID Outreach Society in Victoria. We obtained 599 data collection forms and post-monitoring surveys from participants (collected/administered at each opioid inhalation session), 511 post-monitoring surveys from peer researchers (administered at the end of each site visit), and 19 post-monitoring surveys from overdose prevention service site staff (administered every two weeks during the study period).

Survey Responses Characteristics

Based on our assessment for complete overlap of demographic and health status variables, we identified that, at most, 101 records representing 36 participants were potential duplicates. After removing these 36 records, 535 unique respondents remained. The mean age among these participants was 38.2 years (standard deviation [SD]: 10.2; range: 18 to 66 years old) and 72.9% were male. The mean ages of men and women were 38.8 years (SD: 10.1) and 35.8 years (SD: 10.3), respectively. Respondents' characteristics are summarized below (Figure 1 A-E).

Figure 1. Demographics and Medical History of Respondents

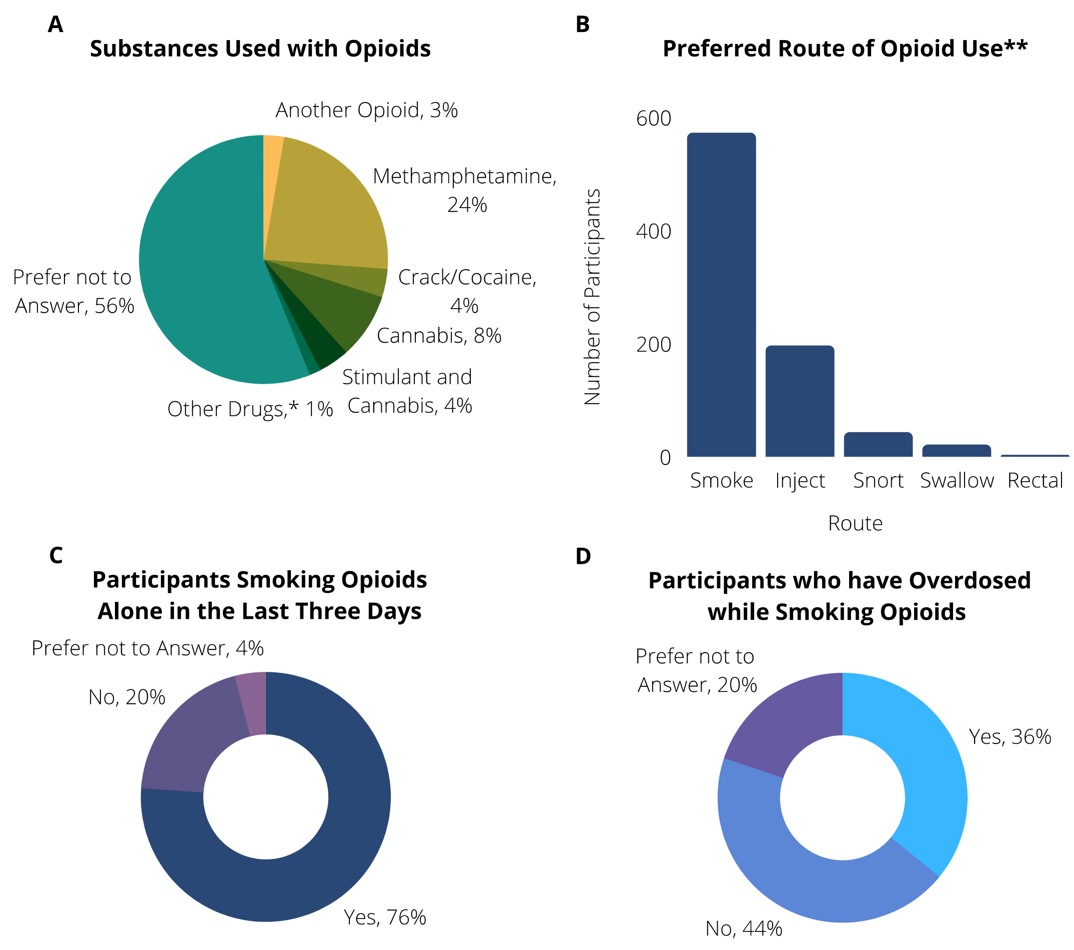


*Other genders included transgender, two-spirit, and gender-nonconforming.
**Other housing included hospital, tent, sailboat, couch-surfing, staying with friends or family, and a combination of accommodations.
9% of participants reported multiple medical comorbidities.
***Mental health combined included mental illness, brain injury, and cognitive disabilities.
****Other disorders included chronic pain, neuromuscular, renal, and rheumatologic.

Patterns of Opioid Use

For event-level data (N=599), at the time of the current visit to the overdose prevention site, 93% of participants reported using heroin, “down,” or fentanyl (n=557). Furthermore, 94% reported using heroin, “down,” or fentanyl at last use (n=563), and 48% reported mixing substances at last use (n=288). Among participants who reported smoking opioids alone in the last three days, 41% or 157 participants had experienced an overdose while smoking. Participants’ patterns of opioid use are summarized below (Figure 2 A-E).

Figure 2. Participants’ Patterns of Opioid Use



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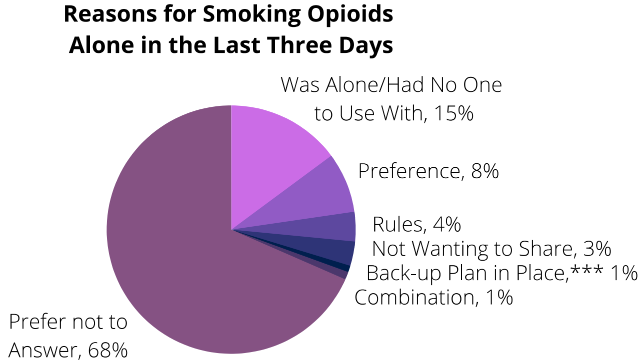


*Other drugs included multiple stimulants and benzodiazepines.
**Participants could select more than one response.
***Back-up plans included knowing where to buy safe drugs, having drugs tested, people being in the next room, telling someone before using, knowing one's tolerance, having an emergency application on one's phone, and carrying naloxone.

Oxygen Saturation Data

In our literature review, we found that there is substantial variation in how oxygen saturation data is analyzed. No conventional or accepted approaches or thresholds exist to define clinically meaningful desaturations or hypoxemia, nor consistent definitions of mild, moderate, and severe hypoxemia.

We obtained oxygen saturation levels and inhalation data from 352 observed inhalation events and excluded 247 observed inhalation events due to unusable data. We excluded observed inhalation events with no inhalation data and where inhalation data did not overlap with oxygen saturation data. All the observed inhalation event oxygen levels started in a physiological range. The median oxygen level in the first 1 minute of observation was 97.9% (IQR: 96.2 – 99.0]. While participating in the oximetry monitoring protocol, 36.9% of the observed inhalation events (N=93/352) experienced a drop in oxygen saturation to 90% or below at some point. We are in the process of further analyzing the relationship between the timing of these oxygen saturation drops and inhalation of opioids. While participating in our monitoring protocol, no participants experienced overdose or respiratory arrest. We are in the process of conducting more detailed analyses of changes in oxygen saturation levels in relation to inhalation events to better understand risk factors for drops in oxygen saturation.

Benefits of Continuous Pulse Oximetry

Effectiveness, Feasibility, and Acceptability Outcomes

We assessed the effectiveness, feasibility and acceptability of our continuous pulse oximetry monitoring protocol from the perspective of the overdose prevention service site staff and participants. We asked overdose prevention services staff and participants whether they thought remote monitoring is effective (e.g., allowed monitoring at a safe distance), feasible (e.g., equipment easy to work with), and acceptable (e.g., improved staff confidence in monitoring and responding to overdoses). Results for the effectiveness, feasibility, and acceptability outcomes are summarized below (Tables 1 & 2).

Table 1: Summary of Overdose Prevention Service Site Staff Outcomes

Effectiveness, Feasibility, and Acceptability Outcomes	Yes	No	Not answer
Easy to Use	17 (89.5%)	0 (0.0%)	2 (10.5%)
Would Use Again	16 (84.2%)	0 (0.0%)	3 (15.7%)
Allowed for Physical Distancing	16 (84.2%)	1 (5.2%)	2 (10.5%)
Felt Comfortable Monitoring and Responding to Participants	16 (84.2%)	1 (5.2%)	2 (10.5%)

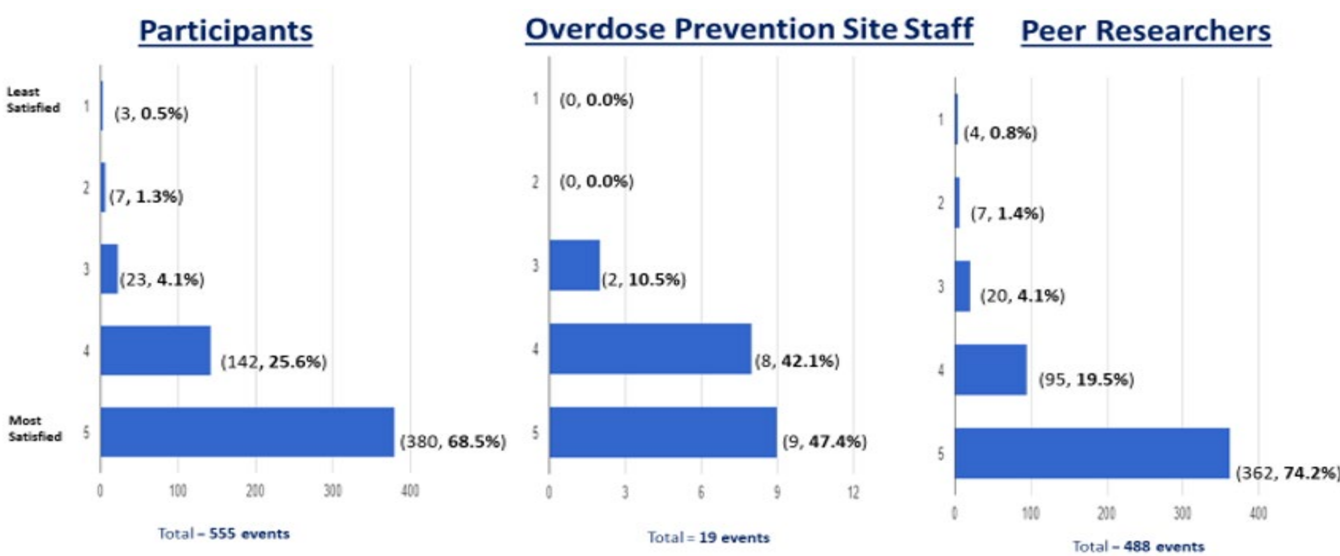
Table 2: Summary of Participant Outcomes

Effectiveness, Feasibility, and Acceptability Outcomes	Yes	No	Not answer
Easy to Use	483 (80.6%)	33 (5.5%)	83(13.8%)
Would Use Again	557 (93%)	18 (3.0%)	24 (4.0%)
Would Recommend to a Friend	544 (92.4%)	17 (2.8%)	38 (6.3%)
Felt Comfortable Being Monitored from a Distance	503 (84%)	76 (12.6%)	20 (3.3%)

Satisfaction with Continuous Pulse Oximetry Monitoring Protocol

Our findings indicate high satisfaction with the continuous pulse oximetry monitoring protocol among participants, overdose prevention service site staff and peer researchers. The interviewees' satisfaction with the continuous pulse oximetry monitoring protocol is summarized below (Figure 3).

Figure 3: Summary of Participants' Satisfaction with Continuous Pulse Oximetry Monitoring Protocol



Participants reported positive experiences with the continuous oximetry monitoring protocol and most commonly cited the utility of continuous pulse oximetry as the reason for high satisfaction (e.g., easy to use, efficient). They stated that it allowed closer overdose monitoring, and would enable timely overdose recognition and reversal.

Efficient in Monitoring Oxygen Saturation Levels

The overdose prevention service site staff noted that continuous pulse oximetry was efficient in monitoring oxygen saturation levels and provided greater efficiency in monitoring oxygen saturation levels compared to non-continuous pulse oximetry. This is because oxygen saturation levels were available to view on a remote monitor and an alarm signaled if an individual's oxygen saturation level fell to 90% or below for a sustained period of time.

Portable and Discrete

The participants and overdose prevention service site staff reported that the continuous pulse oximetry wrist and finger sensors and remote monitor were portable and discrete, which are beneficial when monitoring clients and responding to an overdose. One overdose prevention service site staff member stated that the remote monitor "Bluetooth feature and the [sensors'] compact size make it easy to use and carry in any environment." Furthermore, it allowed for client privacy without sacrificing the safety of observation. Participants reported that when wearing the sensor, it felt "like it wasn't there."

Easy to Use

Many overdose prevention service site staff and peer researchers reported that the continuous pulse oximetry equipment was easy to use, straightforward, user-friendly and easy to work with.

Provides Confidence in Monitoring and Responding to Overdoses

As the continuous pulse oximetry allowed for efficiency, accuracy, and timely response, many overdose prevention service site staff reported that it increased their confidence in monitoring and responding to overdoses. An overdose prevention service site staff member expressed that "the constant monitoring seems like it could be beneficial to earlier response and monitoring overdose risk." Overdose prevention service site staff highlighted that they felt "it provides a level of certainty that is not possible with simple observation and engagement."

Provides a Sense of Safety and Reassurance for Service Users

Many participants described that continuous pulse oximetry provided a sense of safety and reassurance when accessing harm reduction services at overdose prevention service sites. For example, one participant stated that continuous pulse oximetry "makes people feel safer" and "helps save lives." The feeling of increased safety was due to "knowing people are monitoring [them]."

The peer researchers also expressed that continuous pulse oximetry provided a sense of safety and reassurance for service users because it allowed them to be seen and not ignored when accessing harm reduction services at overdose prevention service sites. Peer researchers stated that service users will "feel so much better when they know people are watching and monitoring them; it provides a level of safety when [they] are using." The peer researchers also expressed that the "feedback… was positive. People felt safer when they had the oximeter on and it made them feel seen."

Challenges Associated with Continuous Pulse Oximetry

Technical and Usability Challenges

Many peer researchers, overdose prevention service site staff, and participants experienced challenges with the continuous pulse oximetry monitoring, mostly related to technical issues (e.g., inconsistent connection) or usability (e.g., restrictions in hand movement while applied and difficulties placing on hand).

The peer researchers noted that it became easier to use the continuous pulse oximetry and troubleshoot challenges through iterative learning. One peer researcher stated, "it is finicky at first but the more [we use it, we] become more confident in troubleshooting." Another peer researcher reported that the "process was difficult at first, but at 3 weeks it was a breeze" (see Appendix D for instructions developed by the peer researchers on how to use continuous pulse oximetry).

The interviewees provided several troubleshooting recommendations, summarized in Table 3 below:

Table 3: Summary of Challenges and Troubleshooting Recommendations

Technical Challenges	Troubleshooting Recommendations
• **The Remote Monitor Alarm Consistently Goes Off** • **Difficulties in Maintaining a Bluetooth Connection**	• Wash hands and nails. Dirt, grease, or nail polish on the nail bed can interfere with the readings. • If a wash station is not available, use alcohol swabs to clean hands and nails. • Place the sensor on a nail bed without nail polish, fake nails, or dirt. • Place the sensor so it lays flat and is tightly applied to the fingernail. The red light from the sensor should not be shining through the finger. • Move the individual closer to the remote monitor. • If the sensor did not work on one fingernail, change it to another. • Wait a few (~3) minutes to ensure the oxygen saturation reading comes through. If no reading, turn the remote monitor to the maximum setting. • Put the remote monitor on maximum setting. The setting has to be changed for each individual.
Inconsistent Function of The Continuous Pulse Oximetry Sensor	• A blue light appears on the Bluetooth adaptor when working. A red or white light indicates that the sensor is faulty and needs to be replaced. • If the continuous pulse oximetry sensor is faulty, replace the sensor.

Usability Challenges	Troubleshooting Recommendations
Individuals Not Able to Move Hands or Fingers	• Helpful to have the individual prepare their drugs before applying the continuous pulse oximetry sensor. • Ensure that the sensor is correctly positioned on the individual's nail bed. The sensor should lay flat and be tightly applied to the fingernail.
Difficulties Placing the Sensor on The Individual	• Place the white wrist band around the individual's wrist first. • Attach the sensor to the longest/widest nail bed (full nail bed) and wrap the adhesive tape around the fingernail for best placement. • Place the sensor so it lays flat and is tightly applied to the fingernail. The red light from the sensor should not be shining through the finger.

Environmental Challenges

The peer researchers and participants identified environmental challenges associated with outdoor inhalation sites, such as weather and lack of privacy. These are summarized in Table 4 below:

Table 4: Summary of Environmental Challenges and Recommendations

Environmental Challenges	Recommendations
Weather	• In the summer months, the outdoor inhalation sites can get too hot as there are no fans or proper ventilation available due to a lack of electrical outlets. Indoor sites with fans and proper ventilation would be ideal. • Too much wind can make it difficult for people to smoke opioids. At colder temperatures, pulse oximeters can be inaccurate because of decreased blood flow to cold hands. Canopy tent sidewalls or a wind blocker can assist with privacy and help to keep the wind out while people are smoking outside.
Lack of Privacy	• There is a need for inhalation sites to include enclosed spaces that allow clients to safely smoke opioids.

Additional Recommendations to Improve Overall Effectiveness, Feasibility, and Acceptability in Harm Reduction Services

Peer researchers made additional recommendations to improve the utility of continuous pulse oximetry as one component of a complement of harm reduction services.

Use Continuous Pulse Oximetry with Drug Testing

Peer researchers recommended that service providers offer both continuous pulse oximetry and drug testing. One peer researcher noted that often "benzos are mixed with fentanyl, [therefore] it is good to have oximeters with drug testing."

All Front-Line Workers Should have Access to and Training in Oximeter Use

The peer researchers recommended that training on the use of pulse oximeters be available to all front-line workers. One peer researcher recommended including pulse oximeter training in the "street degree curriculum [a peer-led program in overdose response][29]. Oximeter use and street training go hand in hand."

Expand Service Users' and Bystanders' Access to Oximeters Beyond Overdose Prevention Service Sites

The peer researchers stated that "oximeters are not easily accessible to service users," expressing the need to "provide oximeter training to service users and bystanders instead of just [overdose prevention service site] staff." Many peer researchers indicated that oximeter access and education should be provided to bystanders in a similar way that naloxone training is offered**.** A peer researcher stated that it could also assist with addressing stigma: everyone should be educated on how to respond to an overdose, and oximeters should be part of the training. People will feel more confident responding to an overdose with oximeters and naloxone. The peer researcher recommended having an "overdose kit similar to what people have for diabetes that included naloxone and [an] oximeter."

Pulse Oximetry Should be Used for People Who Inject Drugs

One peer researcher stated that continuous pulse oximetry would be beneficial to offer to people who inject drugs, in addition to those who smoke. They stated, "it's a great machine and should be available to all overdose prevention service sites for intravenous users too." They expressed concern that peoples' oxygen saturation levels may be more volatile when injecting, and therefore that continuous pulse oximetry would provide useful information for overdose prevention service site staff when responding to an overdose.

Project Impact and Evaluation

Community Building

Our study offers crucial lessons about engaging people with lived experience in participatory research on people who smoke opioids. The overdose prevention service site staff and peer researchers reported that the project was well-received and assisted with community building. An overdose prevention service site staff member reported that the project brought more people into the space, "facilitated harm reduction conversations, and helped build rapport" between staff and service users. A peer researcher and an overdose prevention service site manager reported that the project brought in a new group of people. They described their observation that more street youth came to use the overdose prevention service site to participate in the study. Also, the peer researcher stated they had been working in outreach for years and the project provided them with the opportunity to connect with people they had never met while also learning about the prevalence of smoking opioids in their community. Several overdose prevention service site staff echoed similar sentiments. One of the overdose prevention service site staff members stated, "the engagement of residents with the program has been an incredibly positive aspect of the study. That engagement is a powerful connection between staff and residents."

Importance of Meaningful Peer involvement in The Project

All groups valued that the project was facilitated by people with lived experience. Participants highlighted that they appreciated being interviewed by one of their peers. One peer researcher expressed that they felt individuals could open up and give them "real," as opposed to "fake," answers. They felt that they could connect with participants by creating a rapport and easily establishing trust. The participants felt comfortable with the peer researchers. Peer researchers felt that their involvement allowed people to "speak freely from the heart," and to obtain correct and accurate data.

Educational & Capacity Building

Peer researchers reported that their involvement in the project was educational and built community capacity for research. They stated that it was beneficial to learn how many people experienced overdoses while smoking opioids, as well as how prevalent smoking opioids was in their community. Overdose prevention service site staff witnessed that "the peers take a leadership role as research assistants" and the project was a "truly wonderful chance [for them] to gain more skills and confidence in a new field while also sharing their own knowledge and wisdom." Participants also stated that their experience with the project was educational, as it allowed them to learn how to use an oximeter and identify the correlation between oxygen saturation levels and overdoses.

Recommendations

Our project found that implementing a remote continuous oxygen monitoring protocol at overdose prevention service sites is was feasible (e.g., equipment was easy to work with), acceptable (e.g., improved OPS staff confidence in monitoring and responding to overdose), and promoted safety (e.g., allowed monitoring at a safe distance). Our findings support the need and demand for regional and provincial scale-up of continuous pulse oximetry monitoring protocols and remote oxygen saturation monitoring at overdose prevention service sites. Additionally, our study supports the following recommendations:

- Expand continuous oxygen monitoring protocols to additional overdose prevention service sites, service users (e.g., people who inject opioids), and other settings (e.g., private housing, apps for people who use opioids alone).

- Expand pulse oximeter training (facilitated by people with lived experience) to all staff at overdose prevention service sites to assist them in effectively responding to overdoses.
- Expand accessibility of pulse oximeters to all overdose prevention service site staff, service users, and bystanders.
- Expand observed inhalation spaces at overdose prevention service sites, and develop and create additional indoor inhalation sites.
- Develop appropriate safety protocols and mechanisms for indoor inhalation sites.
- Collaborate with people with lived experience of smoking opioids to co-develop innovations that improve harm reduction services and expand inhalation services specifically targeted towards the needs of people who smoke opioids (e.g., increase access to new inhalation devices and observed inhalation spaces).

Conclusion

Partnering overdose prevention service sites successfully implemented our continuous pulse oximetry monitoring protocol, and staff at these sites reported that our project improved their services. The project improved capacity and comfort levels of how to use continuous pulse oximetry among peer researchers, participants, and overdose prevention service site staff. Our data demonstrates that peers, staff, and participants found that continuous pulse oximetry was easy to use, allowed monitoring at a safe distance, and improved comfort levels of people who smoke drugs at overdose prevention service sites by imparting a sense of safety and reassurance when using drugs. Continuous pulse oximetry can improve overdose prevention service sites' capacity to safely monitor service users, specifically in the context of COVID physical distancing rules and outdoor inhalation sites. Given the increasing contamination of unregulated opioids with benzodiazepines, continuous pulse oximetry could assist overdose prevention service site staff assess whether to give naloxone to a person who is sedated (or unconscious) but not in respiratory failure. Furthermore, integrating our monitoring protocol into policies, monitoring guidelines, and harm reduction messaging could improve overdose monitoring and facilitate safer smoking at overdose prevention service sites and other settings, such as shared housing sites.

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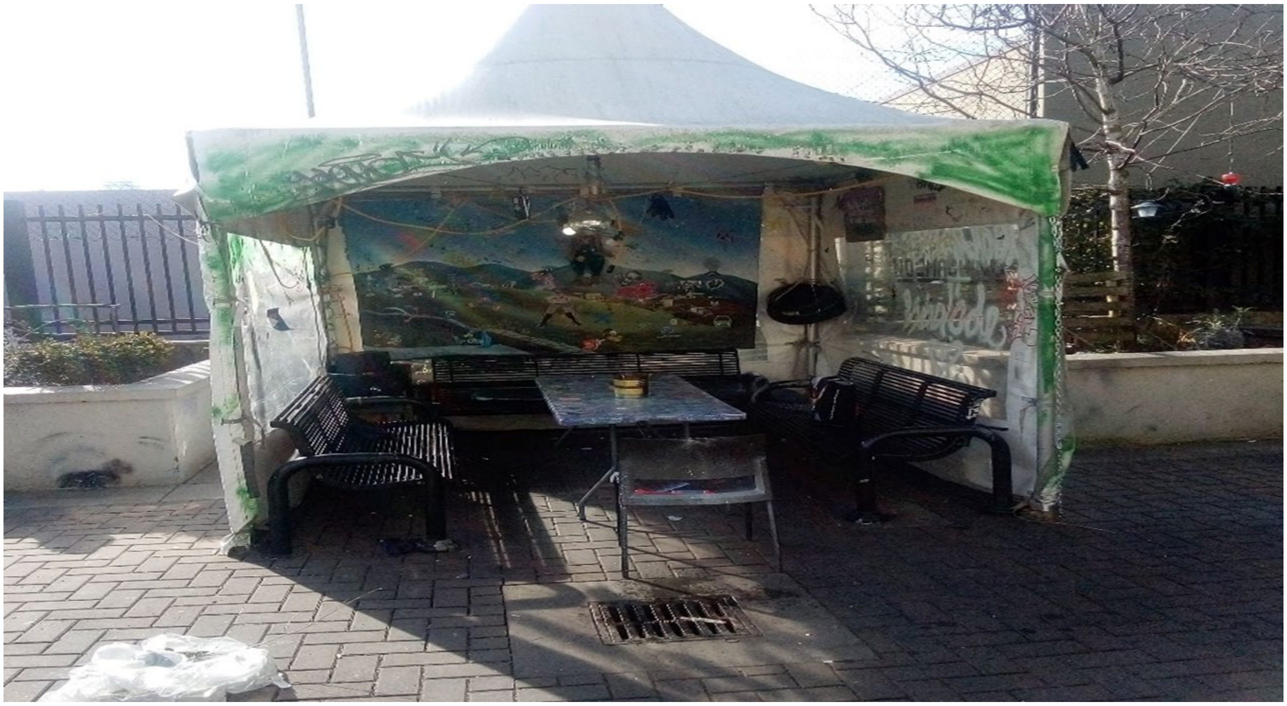
Appendix A: Pictures of Inhalation Services at Participating Overdose Prevention Service Sites

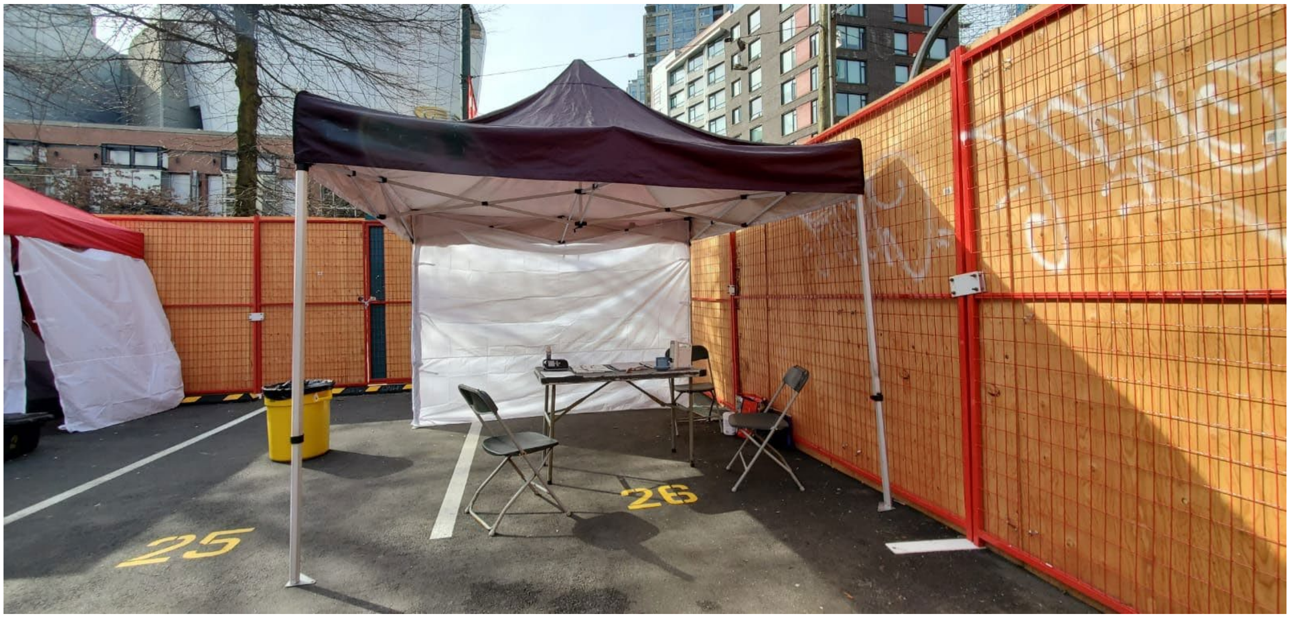
SOLID Outreach Society, Victoria BC

Rock Bay Landing, run by Victoria Cool Aid Society, Victoria BC



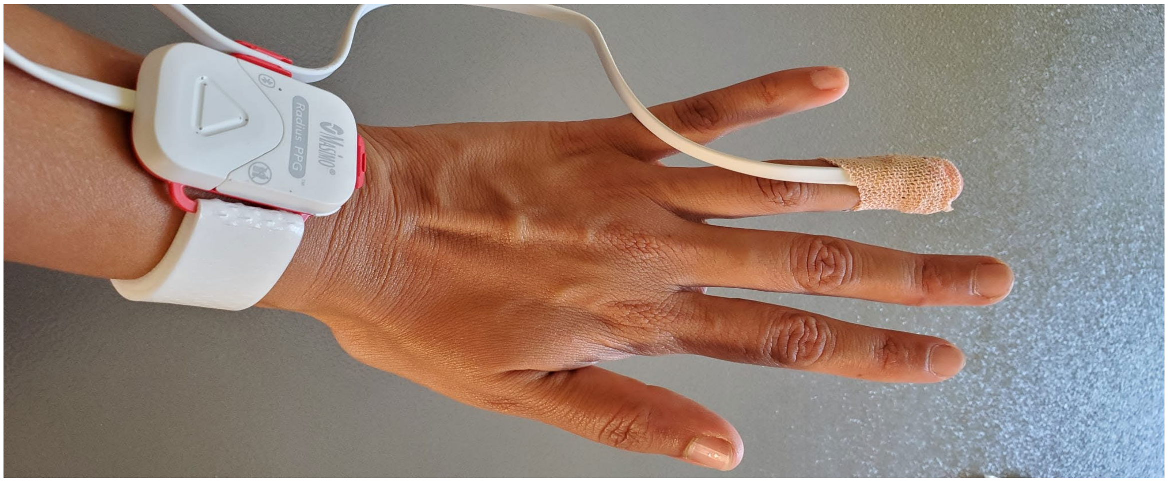
Travelodge run by AIDS Vancouver Island Health & Community Services, Victoria BC

Overdose Prevention Society, Vancouver BC



Appendix B: Continuous Pulse Oximetry Monitoring Devices

Masimo Radius PPG ™ Tetherless Pulse Oximeter



Masimo Rad-97 ™ Remote Patient Monitor

OCTOBER 2020

Funding received, developed study materials, and received ethics approval

- Awarded CIHR funding for the study.
- Obtained UBC Human Research Ethics Board and health authority approvals including COVID-19 specific protocols on October 28, 2020.

NOVEMBER 2020

Co-developed study materials with peer advisory committee, connected with partnering overdose prevention service sites, and ordered continuous pulse oximetry equipment

- Co-developed and pilot tested study procedures and instruments with our peer advisory committee (Professionals for Ethical Engagement of Peers) and partnering overdose prevention service sites.
- Discussed project background, suggestions, and concerns with study procedures and instruments (e.g., consent form, data collection form, study survey, and project information sheet).
- Connected with partnering overdose prevention service sites in Victoria and Vancouver and discussed the feasibility of project implementation.
- Rolled out initial planning stages of study protocol at partnering overdose prevention service site in Vancouver (Overdose Prevention Society), and assessed initial feasibility.
- BC Provincial COVID-19 restrictions were implemented restricting travel outside of ones' community/health authority. Therefore, project implementation plans with Victoria partnering overdose prevention service sites were delayed.
- Ordered continuous pulse oximetry equipment.

DECEMBER 2020

Visited partnering overdose prevention service site and hired peer researchers

- Visited Overdose Prevention Society in Vancouver and identified site-specific resources and needs to facilitate project implementation, such as layout, space for smoking, and peer researcher candidates.
- Hired peer researchers for the Vancouver project via a teleconference meeting, in which we discussed the project background and peer researcher role.
- Trained peer researchers in a hybrid manner, including virtual and in-person sessions, in order to follow physical distancing recommendations.
- Received input from peer researchers on study procedures and instruments (e.g., consent form, data collection sheet, study survey and project information sheet).
- Due to COVID-19, experienced delays in the shipment of continuous pulse oximetry equipment.

JANUARY 2021

Trialed continuous pulse oximetry equipment and planned project logistics in Vancouver

- Met with Overdose Prevention Society staff and discussed study protocols and project logistics.
- Received and trialed continuous pulse oximetry equipment with the study team and assessed if the equipment was appropriate for the project.
- Identified issues with the continuous pulse oximetry equipment. The study team noticed that blood oxygen level monitoring was lost with the slightest

movement. As well, the wireless connection was easily lost between the remote tablet and the continuous pulse oximetry monitoring devices.
- Identified the need for continuous pulse oximetry equipment that can be used in a low barrier setting (i.e., user-friendly, not reliant on Wi-Fi for monitoring, designed for hand movement and provides reliable oxygen saturation level readings in a range of environmental conditions).
- Met with Vancouver peer researchers in-person and discussed study protocols and project logistics.
- Consulted with several continuous pulse oximetry manufacturing companies, trialed continuous pulse oximetry equipment and placed a pilot order.
- Consulted with peer advisory committee to obtain feedback on the wording of questions on the data collection sheet.

FEBRUARY 2021

Trialed continuous pulse oximetry equipment at Overdose Prevention Society in Vancouver

- Experienced delays in piloting project at Overdose Prevention Society site because of a lack of long-term funding, forcing the site to relocate.
- Received pilot order of continuous pulse oximetry equipment.
- Visited Overdose Prevention Society's new location in Vancouver and identified site-specific needs to facilitate the project, such as layout and space for smoking. Trialed continuous pulse oximetry equipment on site.
- Received input from overdose prevention staff in Vancouver on study procedures and instruments (e.g., consent form, data collection sheet, study survey, and project information sheet).
- Set a start date with Overdose Prevention Society to pilot the project.
- Connected with partnering overdose prevention service sites in Victoria and discussed site visit dates and feasibility of project implementation.

MARCH 2021

Piloted project at Overdose Prevention Society in Vancouver

- Facilitated in-person training with peer researchers in Vancouver.
- Piloted project at Overdose Prevention Society in Vancouver, March 10, 2021 (began enrollment and data collection).
- Visited partnering overdose prevention service sites in Victoria (Rock Bay Landing, SOLID Outreach Society and Travelodge run by AIDS Vancouver Island Health & Community Services) and identified site-specific project needs, such as layout and space for smoking. Trialed continuous pulse oximetry equipment on-site.
- Received input from overdose prevention staff in Victoria on study procedures and instruments (e.g., consent form, data collection form, study survey, and project information sheet).

APRIL 2021

Preparation for project implementation in Victoria

- Hired peer researchers for Rock Bay Landing, Travelodge, and SOLID Outreach Society via a teleconference meeting, in which we discussed the project background and peer researcher role.
- Received input from peer researchers on study procedures and instruments (e.g., consent form, data collection sheet, study survey, and project information sheet).
- Set a start date with Rock Bay Landing to pilot the project in Victoria.
- Set a start date for Travelodge and SOLID Outreach Society.

- Facilitated in-person training with peer researchers at Rock Bay Landing in Victoria.
- The study team visited Vancouver weekly, checked in with peer researchers and overdose prevention service site staff and assisted with troubleshooting.
- Trained data entry clerks to input data into REDCap.

MAY 2021

Piloted project at partnering overdose prevention service sites in Victoria

- Piloted project at Rock Bay Landing in Victoria, May 3, 2021 (began enrollment and data collection).
- Facilitated in-person training with peer researchers at Travelodge, and SOLID Outreach Society in Victoria.
- Project rollout at SOLID Outreach Society in Victoria on May 25, 2021 (began enrollment and data collection).
- Project rollout at Travelodge in Victoria on May 31, 2021 (began enrollment and data collection).

JUNE 2021

Project implemented in Vancouver and Victoria

- Project implemented and enrolled participants at the four overdose prevention service sites in Victoria and Vancouver.
- The study team visited each site weekly, checked in with peer researchers and overdose prevention staff, and assisted with troubleshooting.

JULY 2021

Project implemented in Vancouver and Victoria

- Project implemented and enrolled participants at the four overdose prevention service sites in Victoria and Vancouver.
- The study team visited each site weekly, checked in with peer researchers and overdose prevention staff, and assisted with troubleshooting.
- Set an end date of the project with partnering overdose prevention service sites.
- Completed literature review to inform our approach to the oxygen saturation data analysis.

AUGUST 2021

Wrap up of the project in Vancouver and Victoria

- Project enrollment and data collection ended on August 6, 2021, at the four overdose prevention service sites in Victoria and Vancouver.
- Completed data input (data collection forms, post-monitoring surveys, and blood oxygen level data).
    - Total participants: 93 from the Overdose Prevention Society in Vancouver, 91 from Rock Bay Landing, 185 from Travelodge, and 230 from SOLID Outreach Society in Victoria
    - 599 data collection sheets and post-monitoring surveys from participants
    - 511 post-monitoring surveys from peer researchers
    - 19 post-monitoring surveys from overdose prevention service site staff
- Data cleaned.
- Shared preliminary results including demographics of participants and infographics summarizing survey responses with the peer advisory committee.
- Discussed preliminary results including demographics of participants and infographics summarizing survey responses with peer researchers and partnering overdose prevention service site staff for data validation.

SEPTEMBER 2021

Data analysis

- Started qualitative analysis. Analyzed the data from the post-monitoring surveys using a thematic deductive process that informed the coding framework, which we inputted into NVivo 12.
- Consulted with other BCCDC research coordinators on qualitative analysis process and coding framework.
- Started quantitative analysis of oxygen saturation and inhalation data.

OCTOBER 2021

Completion of qualitative analysis

- Completed qualitative analysis and shared with the study team and other BCCDC research coordinators.
- Presented project background and preliminary findings at BCCDC Research Week via a virtual poster presentation.
- Quantitative analysis: study team, which includes a clinician, an epidemiologist, and a statistician, evaluated data and made key decisions on an optimal analytic plan.

NOVEMBER 2021

Data validation and report outline

- Facilitated data validation focus groups, where the project coordinator and peer researchers discussed key themes and findings from the qualitative data analysis (5 focus groups in total).
- Drafted project report outline and consulted with other BCCDC research coordinators.
- Ongoing quantitative analysis: study team, which includes a clinician, an epidemiologist, and a statistician, evaluated data and made key decisions on an optimal analytic plan.

DECEMBER 2021

Completion of the project report outline

- Facilitated final data validation via focus groups, where the project coordinator and peer researchers discussed themes and findings from the qualitative data analysis (December 8, 2021).
- Developed a knowledge translation plan.
- Completed data report outline and collated all project information in preparation for drafting project report.

JANUARY 2022

Completion of the first draft of the project report

- Completed the first draft of the project report and shared it with the study team.
- Developed and prepared presentation slides with a peer researcher.
- Ongoing quantitative analysis: study team, which includes a clinician, an epidemiologist, and a statistician, evaluated data and made key decisions on an optimal analytic plan.

FEBRUARY 2022

Presented project qualitative findings

- The research coordinator and peer researcher presented qualitative findings to the peer advisory committee and received feedback on the findings and presentation.
- The research coordinator and peer researcher presented qualitative findings to BC Drug Overdose and Alert Partnership.
- Shared qualitative findings presentation with partnering overdose prevention service site staff.
- Ongoing quantitative analysis: study team, which includes a clinician, an epidemiologist, and a statistician, evaluated data and made key decisions on an optimal analytic plan.

MARCH 2022

Completion of project report

- Completion of project report and knowledge translation products.
- The research coordinator and peer researcher presented qualitative findings to the Vancouver Coastal Health Overdose Community of Practice Group.
- Ongoing quantitative analysis: study team, which includes a clinician, an epidemiologist, and a statistician, evaluated data and made key decisions on an optimal analytic plan.

APRIL 2022

Completion of knowledge translation products

- Completion of knowledge translation products.
- The research coordinator and peer researcher presented qualitative findings to the Overdose Prevention Strategies Working Group.
- The research coordinator presented qualitative findings at UBC Emergency Medicine Research Day 2022.
- Ongoing quantitative analysis: study team, which includes a clinician, an epidemiologist, and a statistician, evaluated data and made key decisions on an optimal analytic plan.
- The study team presented project findings and discussed the next steps

Appendix D: A step-by-step guide for how to use and troubleshoot continuous pulse oximetry, created by peer researchers. (N.B. this guide applies to the specific continuous oximeter make and model used in this study.)

Get started

• Turn on the remote monitor by pressing the round button on the screen.
• Ask the person to wash their hands and nails. Make sure there is no grease or dirt on the nail. If sink and water are not available, use disinfectant wipes.
• Ensure that the monitor is on the correct sensitivity mode for blood oxygen level reading (normal to maximum sensitivity mode). TIP: *If the person's nails are dirty or have nail polish, place the monitor on maximum sensitivity mode to increase blood oxygen level reading signal.*
• Ask the person to start preparing their drugs.

Attach the sensor

• Open a new pack of disposable oximeter sensors and place the wrist band around the person's wrist.
• Attach the sensor to the nail that has the longest and widest nail bed. *TIP: Typically, this is the thumb, middle or ring finger.* Ensure that the sensor is as close to the nail bed as possible and wrap the sensor tape tightly around the finger. *TIP: When attaching the sensor, try to keep the person's hand as steady as possible. Make sure that the red light from the sensor is not shining through the finger.*
• Take the Bluetooth chip from the monitor holder and tap it onto the Bluetooth adaptor. Next, place the Bluetooth chip in the red holder on the person's wristband. A blue light will appear on the Bluetooth adaptor. *TIP: If a red or white light appears on the Bluetooth adaptor this means that the sensor is faulty and needs to be replaced.*
• Blood oxygen level and heart rate readings should appear on the monitor screen within one minute. *TIP: If no reading is visible, switch the monitor to the maximum sensitivity mode to increase the blood oxygen level reading signal.*
• If the connection becomes lost, check on the person to ensure that the sensor is still correctly placed on the person's finger, and advise them to limit hand movement if possible.

Monitor for low blood oxygen levels

• The alarm will sound if the person's blood oxygen levels fall to 90% or below for 15 consecutive seconds.
• If the alarm goes off, assess the individual. They are potentially at risk for overdose.
• Respond as promptly as possible to a person experiencing a potential overdose using a step-wise approach to assessment and interventions (e.g., verbal or tactile stimulation if minimally responsive; supplemental oxygen and/or naloxone if level of responsiveness and blood oxygen levels remain low).

End monitoring session

• Return the Bluetooth chip to staff for cleaning. Place the Bluetooth chip back on the remote monitor holder.
• Dispose of the wristband and oximeter sensor.