

Research Paper

Water, sanitation and hygiene insecurity predict abscess incidence among people who inject drugs in a binational US–Mexico metropolitan area: A longitudinal cohort study

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ABSTRACT

Introduction: People who inject drugs (PWID) are at high risk of developing injection-related infections, including abscesses. Access to water, sanitation, and hygiene (WASH) are key human rights and services; yet these services have been underexplored as predictors of abscesses among PWID.

Methods: Longitudinal analysis was employed among a cohort of PWID to determine if WASH insecurity (lack of access) was associated with abscess incidence in the Tijuana, Mexico and San Diego, United States metropolitan area during 24-months of follow-up survey data from 2020 to 2023. We calculated abscess prevalence at baseline and tracked the incidence of new abscesses among individuals without an abscess during the previous visit. Time dependent Cox regression modeling was employed with variance clustered by participant to characterize the relationship between WASH insecurity and abscess incidence.

Results: At baseline, hand hygiene insecurity, bathing insecurity in the previous six months and open defecation in the last week, were reported by 60 %, 54 % and 38 % of participants, respectively; 21 % reported an abscess in the last six months. The incidence of abscesses was 24.4 (95 %CI: 21.1–27.6) per 100 person-years. After adjusting for covariates, the hazard of developing an abscess remained significantly elevated among individuals using non-improved (with risk of contamination) water sources (e.g., surface water) for preparing drugs (adjusted HR [adjHR]: 1.49 [95 %CI: 1.01–2.21], experiencing bathing insecurity (adjHR: 1.59 [95 %CI: 1.12–2.24]) and open defecation (adjHR: 1.65 [95 %CI: 1.16–2.35]).

Conclusions: PWID in the Tijuana-San Diego metropolitan area reported facing high rates of insecurity accessing WASH services. Abscess incidence was higher (four to nine times) than observed rate among PWID cohorts in other settings. Access to continuously available toilet facilities, bathing infrastructure, and safe water sources for preparing drugs for injection could prevent abscesses among PWID. Accessible WASH infrastructure should be ensured among PWID communities and promoted as a key component of harm reduction infrastructure.

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Introduction

People who inject drugs are at high risk of developing infection-related diseases associated with increased morbidity and mortality (Kolla et al., 2020). Wounds and skin and soft tissue infections (SSTI) are common complications of injection drug use among people engaged in drug injection and are the most common cause of emergency department visits and medical care among this population (Calderón-Villarreal et al., 2022; Chambers, 2021; Colledge et al., 2020; Doran et al., 2020; Pollini et al., 2010; Sanchez et al., 2021). Abscesses, defined as a “collection of pus that has built up within the tissue of the body” or a “tender, fluctuant (compressible), palpable lesion with erythema” (i.e., fluctuant red nodule) (Lipsker, 2021), are the most common types of SSTI (Ozga et al., 2022; Pieper, 2019; Wright et al., 2020).

If not treated, SSTI can lead to life-threatening complications such as necrotizing fasciitis, gangrene, amyloid A amyloidosis, deep vein thrombosis, endocarditis, septic arthritis, septicemia and death (Colledge et al., 2020; Doran et al., 2020; Harris et al., 2020; Harris et al., 2018; Larney et al., 2017; Noroozi et al., 2019; Ozga et al., 2022; Wright et al., 2020). Abscesses can cause a significant level of pain, discomfort, scarring and disabilities, which negatively impact the capacity to work and also contribute to stigma (Calderón-Villarreal et al., 2022; Harris et al., 2020; Noroozi et al., 2019; Ozga et al., 2022; Wright et al., 2020). Further, wounds and abscesses can also contribute to increased use of substances, as individuals may seek to reduce SSTI-related pain (Sanchez et al., 2021).

People who inject drugs need water not only for drinking and handwashing, but also for preparing injection drugs, rinsing syringes and cleaning wounds and abscesses (Calderón-Villarreal et al., 2024b; Harris et al., 2020; Sanchez et al., 2021). Water sources can be ‘improved’ if they have the potential to deliver safe water by design (e.g., piped and bottled water) (WHO, 2020). Qualitative studies suggest that individuals engaged in drug injection tend to use the safest water available to them for preparing their drugs (Calderón-Villarreal et al., 2022; Gilbert et al., 2019). However, when improved water is not available or a person is experiencing withdrawal, individuals may use ‘non-improved’ (with high risk of contamination) water sources, such as surface water (e.g., river, canal, ditch), soda, alcoholic beverages, fruit juice, toilet water, saliva and puddle water (Calderón-Villarreal et al., 2024a; Baltes et al., 2020; Calderón-Villarreal et al., 2022; Harris et al., 2020; Otiashvili et al., 2016).

Lack of access to improved water, sanitation and hygiene services (i.e., WASH insecurity) and poor access to improved water for cleaning wounds is common among individuals who inject drugs—especially for those who are unhoused (Calderón-Villarreal et al., 2024a; Calderón-Villarreal et al., 2022; DeMyers et al., 2017; Leibler et al., 2019; Flanigan & Welsh, 2020; Sanchez et al., 2021) and who engage in sex work (Calderón-Villarreal et al., 2024b; Phillips-Howard et al., 2024; Wurcel et al., 2018). People who inject drugs in the Tijuana-San Diego region have lower WASH access than the national averages in Mexico and the US, and that is lower than international standards (Calderón-Villarreal et al., 2024b). Homelessness has been significantly associated with WASH insecurity among people who engage in substance use in the US–Mexico metropolitan area (Calderón-Villarreal et al., 2024b). Similarly, among people who inject drugs and who menstruate in the same cohort population, housing status and sex work status were associated with insecurity accessing hygiene services (water for handwashing, and handwashing facilities with soap and water) (Calderón-Villarreal et al., 2024a). Further, a study in Kenya reported sub-optimal WASH services in most female sex work venues (e.g., 34 % had no adequate WASH facilities) (Phillips-Howard et al., 2024).

Insecurity accessing improved water sources and hand hygiene (water and soap for handwashing) are thought to be a common cause of skin irritation and can introduce infection when preparing the site of injection (Robertson et al., 2021; Sanchez et al., 2021). These experiences of WASH insecurity decrease quality of life, wellbeing and dignity,

and exacerbate social exclusion and health risks among vulnerable groups, including people engaged in substance use (Avelar Portillo et al., 2023; Avelar Portillo et al., 2024; Calderón-Villarreal et al., 2022; Neves-Silva et al., 2018; Uddin et al., 2016).

Securing WASH access is a core concern of public health, epidemiology and rural and urban planning, and is considered “the most crucial major urban environmental infrastructure necessary for human survival” (Calderón-Villarreal et al., 2022; Rosenberg, 1966). Access to WASH services is a human right that is interdependent and inseparable from other human rights; the violation of one affects all others, generating inequities and harm to health and wellbeing (Avelar Portillo et al., 2023; Avelar Portillo et al., 2024; Neves-Silva et al., 2018). The right to WASH is part of the right to quality of life and is directly linked to the right to food, health, and housing (Neves-Silva et al., 2018; UN General Assembly 2010). Likewise, WASH insecurity among people engaged in drug injection has been linked to environmental structural violence and increases the risk of infectious diseases, human rights violations, stigma, exclusion and discrimination, jeopardizing basic life needs (Calderón-Villarreal et al., 2022; Neves-Silva et al., 2018; WHO 2015). The development of abscesses represents a potent example of these deleterious outcomes.

Existing studies have estimated that between 7 % and 65 % of people who inject drugs have experienced SSTI in the past 12 months, with 40–67 % ever having reported an occurrence of prior SSTI (half of which led to hospitalization) (Doran et al., 2020; Dwyer et al., 2009; Harris et al., 2020; Harris et al., 2018; Noroozi et al., 2019; Ozga et al., 2022; Wright et al., 2020). SSTI incidence was estimated as 2.8 per 100 person-years (py) among a sample of 2444 people engaged in drug injection from the Swedish Prison and Probation Service in 2018 and 6.1 per 100 py among a sample of 1083 individuals engaged in drug injection randomly selected from an supervised injection facility in Vancouver, Canada (Dahlman et al., 2018; Lloyd-Smith et al., 2010). Abscess prevalence has been associated with a variety of factors, such as female sex, age, injection technique (e.g., intravenous vs intramuscular), injection site (e.g., neck, groin), sex work—particularly among women—and injection frequency (Baltes et al., 2020; Calderón-Villarreal et al., 2022; Chambers, 2021; Colledge et al., 2020; Lewer et al., 2020; Doran et al., 2020; Pieper, 2019; Pollini et al., 2010; Wright et al., 2020).

The United States (US)–Mexico border region of Tijuana and San Diego has a large population of people engaged in drug injection, many of whom experience additional vulnerabilities such as homelessness (West et al., 2020,40). An estimated 6400 to 10,000 people who inject drugs live in Tijuana (Fraser et al., 2021) and 21,800 to 35,000 live in San Diego (Lewis & Asmus, 2019). Previous studies have found that lifetime abscess prevalence is high among people who inject drugs in Tijuana (46 % in 2010) and San Diego (73 % in 2015) (Armenta et al., 2015; Pollini et al., 2010). In a previous study among the same study cohort, WASH insecurity was common and associated with housing status and city of residence (Calderón-Villarreal et al., 2024b). Access to basic WASH services in this cohort was lower than international standards and national averages for both countries (Calderón-Villarreal et al., 2024b). Also, among a study of Tijuana’s unhoused individuals who inject drugs who reside inside the Tijuana River canal, abscesses (cuerazos) or skin infections were the most common WASH-related condition reported in the previous week (47 %), and were significantly associated with use or contact with contaminated surface water (Calderón-Villarreal et al., 2022). Similarly, a study in San Diego found that among unhoused individuals living along the San Diego River (many of whom inject drugs), numerous health concerns were observed, including open sores and infections located at injection sites (Flanigan & Welsh, 2020).

Despite the high burden of disease from SSTI among people who inject drugs and the likely link to WASH practices, limited studies have focused on this critical set of risk factors, especially using longitudinal data (Summers et al., 2017; Wright et al., 2020). Few existing studies have examined cross-sectionally the intersection between substance use

and environmental health among individuals who inject drugs, and suggest there is an increased risk of wounds, abscesses, Hepatitis C complications, multidrug resistant bacterial infections, septic shock and myocarditis associated with WASH insecurity (Calderón-Villarreal et al., 2022; Leibler et al., 2019; Sanchez et al., 2021; Verbyla et al., 2021).

A better understanding of the relationship between WASH insecurity as a key driver of injection-related abscess incidence among people who inject drugs is critical for reducing harms associated with infectious disease and improving living conditions for these communities (Ballard et al., 2022; Calderón-Villarreal et al., 2022). Herein, we assessed whether WASH insecurity factors were associated with higher incidence of injection-related abscesses over a 24-month period among a binational cohort of people who inject drugs in the Tijuana and San Diego metropolitan area.

Methods

This study leveraged data from the *La Frontera* study and *LinkUp* sub-study to examine the association between WASH insecurity and incidence of injection-related abscesses over a 24-month period. *La Frontera* is a prospective cohort study designed to study incidence and predictors of HIV, HCV, and overdose among people who inject drugs who live in the binational metropolitan area of Tijuana, Baja California, Mexico and San Diego, California (CA), US (Strathdee et al., 2021). *LinkUp* is a *La Frontera*'s sub-study, which aimed to evaluate the impact of a peer-led behavioral intervention to improve COVID testing and vaccination among people who inject drugs in San Diego only. This analysis included data from the baseline, six, 12-, 18- and 24-month follow-up survey visits conducted between October 2020 to August 2023.

Study population

La Frontera recruitment (cohort 1) began in 2020 and was re-opened in 2022 to accommodate a sub-study, *LinkUP* (cohort 2). The *La Frontera* cohort recruitment was open from October 2020 to September 2021, and recruitment for the *LinkUP* was open from March to June 2022. For both cohorts, data was collected by trained interviewers in the participants' language of preference (English or Spanish) using street outreach and mobile vans, as previously described (Bazzi et al., 2022; Strathdee et al., 2021). Cohort 1 included participants residing in Tijuana and San Diego whereas only participants residing in San Diego were included in the sub-study cohort 2. To reduce the risk of acquiring SARS-CoV-2, interviews were done outside in tents with plexiglass partitions and full personal protective equipment. All protocols were reviewed and approved by UCSD Risk Management. More details on recruitment protocols can be found in Strathdee et al. (2021). Recruitment interruptions due to COVID-19 outbreaks took place only for a two-week period.

In both cohorts, eligibility criteria were age ≥ 18 , report of injecting drugs within the last month—verified in limited instances by inspecting injection marks, and living in Tijuana or San Diego (Strathdee et al., 2021). A seven-minute screener survey programmed into a tablet enabled screening via computer-assisted programmable interviews (CAPI) to exclude ineligible participants. Of the $N = 720$ participants (cohort 1 = 612 and cohort 2 = 108) found to be eligible for *La Frontera*, $N = 647$ (89.9 %) participants completed at least two visits and were included in this study analysis (cohort 1 = 553, cohort 2 = 94). We had up to 3-month window periods where we allowed participants to be late for a visit, after which time they were recorded as having missed that visit. Longitudinal data included a baseline survey and five (2020–2023 – cohort 1) or four (2022–2023 – cohort 2) follow-up visits. Each survey took approximately 45 min and was enumerator administered. The baseline sample included $n = 647$ participants for visit #1, visit #2 (6-month) included $n = 601$, visit #3 (12-month) included $n = 573$, visit #4 (18-month) included $n = 488$ and visit #5 (24-month) included $n = 440$ participants, 69.6 % from San Diego, US and 30.4 % from Tijuana,

Mexico. Characteristics of excluded and included participants are described in Supplemental Table 1.

Health outcomes

In this analysis, the outcome was obtained via self-report of having at least one abscess (*cuerazo* in Spanish slang) at a location on their bodies where they inject drugs in the last six months. Abscesses were categorized dichotomously at the five follow-up time points: baseline, 6-month, 12-month, 18-month and 24-month visits.

WASH insecurity variables

Seven time-varying binary WASH insecurity variables were included as abscess incidence predictors: 1) use of non-improved water as the main water source for injecting drugs, 2) use of non-improved water as the main water source for cleaning wounds, 3) use of non-improved water as the main water source for handwashing, 4) basic hand hygiene insecurity 5) bathing insecurity, 6) basic sanitation insecurity and 7) open defecation practice. Variables were operationalized based on the WHO and UNICEF's Joint Monitoring Program (JMP) definitions (WHO, 2020).

The use of 'non-improved' water sources was defined according to the main (primary) water source for injecting drugs, cleaning wounds and handwashing reported by participants in the past six months. Non-improved water sources included bottled water taken from the trash, water treatment plant discharge into riverbeds, pet water bowls, water directly from a river, pond, stream or irrigation canal, *lloraderos* (i.e., unprotected water spring tubes next to the Tijuana River canal) (Calderón-Villarreal et al., 2022), and the use of 'no water' sources such as soda, alcohol beverages, wet wipes, hand sanitizer, ointments, or aloe vera instead of water (Calderón-Villarreal et al., 2024b; JMP, UNICEF, WHO 2023).

Basic hand hygiene insecurity was defined as not having a hand-washing facility with soap and water always available in the past six months (WHO, 2020). Bathing insecurity was defined as having less than five baths/showers per week and/or bathing using non-improved water sources in the past six months. The number of showers was described as a continuous variable.

Basic sanitation insecurity was defined as the use of 'non-improved' toilet facilities (e.g., bucket latrines, or not having access to toilet facilities/open defecation) as their main form of sanitation in the past six months (WHO, 2020). Open defecation was described as the disposal of human feces in fields, forests, bushes, open bodies of water, beaches, and other open spaces or with solid waste in the last week. Open defecation was described as dichotomous (at least once in the last week) and for those who reported open defecation, the number of times defecating in the open was described as a continuous variable.

Covariates

Demographic covariates of interest included city of residence (Tijuana/San Diego), gender identity, and housing status. Gender identity was classified as man, woman, trans men, trans women, and nonbinary. For statistical analysis, gender was classified as men (*cis*, trans men and nonbinary individuals who reported man as their sex at birth) and women (*cis*, trans women and nonbinary individuals who reported woman as their sex at birth). Housing status was a time varying variable based on the main places used for sleeping in the past six months. Permanent housing was defined as those sleeping at their parent's home, own apartment, with their spouse's/sex partner, or friends, whereas homelessness included sleeping in sheltered and unsheltered locations (Orange County 2022; US Department of Housing & Urban Development 2021). Sheltered homelessness was defined as those who reported living in shelters, temporary rented rooms, and other institutions (e.g., correctional institution, drug treatment center and

medical care facility). Unsheltered homelessness included sleeping in a car, bus, truck, or other vehicle, abandoned building, on the streets, beach, parks, canal, woods and shooting gallery.

Other fixed covariates included gender, years of education and cohort, and time varying variables age, engagement in sex work, days since last injection and most common site of the body used for injecting. Age and years of education were described as continuous and dichotomous variables (<45 vs 45+ years of age, <10 vs 10+ years of education, respectively). Sex work was defined as a source of income and described as 'prostitution or sex work' in the past six months. Number of days since last injecting drugs was described as a continuous and dichotomous variable (same day vs 1+ days). Most common body injection site included: 1) safest sites – arms, legs, hands, feet and between fingers and 2) most dangerous sites – neck, inguinal area, armpits and temple (Karimi et al., 2014; Robertson et al., 2021).

Statistical analysis

Descriptive statistics were calculated for potential confounders and WASH insecurity variables at baseline. For categorical variables we reported frequencies and proportions. For continuous variables we reported mean and standard deviation (SD) or medians and IQR according to their distributions.

Longitudinal imputation methods were implemented to manage missing values. WASH insecurity indicators with missing values were imputed using the last value carried forward/backwards method, utilizing the previous or following value by participant (mostly to fill missing from skip logic errors) (Twisk, 2013). The frequency of missing values by WASH insecurity variable is shown before and after imputation Supplemental Table 2. This process was limited to 12 months, so values were not extended past 12 months from their collection date. Imputation for missing values of abscess status were calculated using the mode of all 0 (absent) and 1 (present) value across all available time-points for a given individual. In rare instances when the average value for an individual was exactly 0.5 (in a 0–1 range), the imputed value was assigned the population average.

Abscesses were described by frequency and incidence rate. Abscess frequency (prevalence) was described at baseline and as a recurrent event. To calculate incidence rate (reflecting only new-onset symptoms) only participants who did not have an abscess in the previous visit were included for each period of incidence calculation. Given that abscesses may persist for long periods of time, this method helped ensure that the measured incidence rate values only reflect de-novo infections and that we did not misclassify past abscesses that persisted as being incident cases. To compute incidence rate, we defined person-time at risk, which served as the denominator, as all six-month windows of time during which the individual did not have an abscess during the previous visit. All participants' time at risk were summarized to obtain cumulative person-time at risk. The abscess incidence rate was estimated as the number of participants experiencing new-onset abscesses in the prior six-month period divided by the cumulative person-time at risk.

We used time-varying Cox regression models to estimate the effect of WASH insecurity variables on abscess incidence. We first conducted bivariate Cox regressions, reporting hazard ratios (HR) and used the results to inform the multivariable model. We included demographic variables previously shown to be associated with abscesses and/or WASH insecurity from existing literature (Avelar Portillo et al., 2024; Baltes et al., 2020; Calderón-Villarreal et al., 2022; Lewer et al., 2020; Doran et al., 2020; Pieper, 2019; Pollini et al., 2010; Wright et al., 2020; Wurcel et al., 2018). Only WASH insecurity and abscess-related covariables with significant values ($p < 0.05$) in bivariate time-varying Cox analyses were chosen to be included in the final model. No other method to remove predictors was employed. Five of the seven WASH variables, days since last injection and injects in more dangerous body areas had the strongest association with abscess incidence and were included in the adjusted hazard regression model. The association between the

aforementioned variables and the abscess incidence rate was reported as adjusted hazard ratios (adjHR) (Therneau et al., 2023). All Cox models included robust variance clustered—by ID—on study subject (i.e., multiple outcome events were potentially included per person) (Therneau et al., 2023). We assessed collinearity among WASH variables and homelessness (Supplementary Fig. 1) as well as the assumption of proportionality in the final Cox model (Supplemental Table 3). Associations were reported as HRs with 95 % confidence interval (95 % CI). All data analyses were performed using R (Version 4.3.1).

Ethics statement

The study protocols received ethics approval from the institutional review boards at the University of California, San Diego (UCSD) (IRB# 191390) and Xochicalco University in Mexico. Only participants that consented were enrolled in the study. Study activities were carried out in accordance with IRB guidelines. Monetary reimbursements (\$20 USD) were provided to enrolled participants at each visit.

Results

A total of 2749 participant visits and 784 py at risk were included in this analysis (median: three visits per person; inter quartile range [IQR]: 2–4). Of 647 participants who completed at least two visits, at baseline 448 resided in San Diego and 196 in Tijuana. The median age was 43 years (IQR=35–52 years), and participants had a median of 11 years of education (IQR=8–12). Seventy-one percent were cis men, 28 % cis women and 1 % identified as transgender or nonbinary. Most had experienced homelessness at least once in the last six months (72 %). At baseline 33 % reported living in permanent housing, 21 % experienced sheltered homelessness, and 46 % experienced unsheltered homelessness. Eight percent of sample reported having a source of income related to sex work in the past six months. Participant characteristics are included in Table 1.

At baseline, 64 % of participants had injected drugs on the day of the survey. Most common body sites used for injecting in the last six months were 'safer sites' (82 %), such as arms (65 %) and legs (11 %), but 15 % used 'more dangerous' sites, such as the neck (13 %).

WASH insecurity

In terms of WASH insecurity at baseline, the use of non-improved water in the past six months was reported by 8 % for injecting drugs, 6 % for cleaning wounds and 5 % for handwashing. Basic hand hygiene insecurity was reported by 59 %. Bathing insecurity (i.e., <5 showers in the last week and/or using non-improved water sources) was reported by 54 %, with an average of four (± 3) showers in the last week. Basic sanitation insecurity, defined as the use of non-improved main toilet facilities in the past six months, was reported by 17 % of participants. Open defecation during the previous week was practiced by 38 %. Of those practicing open defecation, median frequency was four times/week (IQR=2–7), ranging from one to 24 times. Frequency of WASH insecurity at baseline and follow-up visits are reported in Table 2.

Abscess frequency, incidence and predictors of incident abscesses

At baseline, 21 % of participants reported having an abscess in the last six months. Over the 24-month follow-up period, the abscess incidence rate was 24.4 (95 %CI: 21.1–27.6) per 100 py and the cumulative incidence was 31.7 per 100 participants, representing 191 new abscesses. Among participants residing in Tijuana the incidence rate was 23.6 (95 %CI: 19.7–27.4) new abscesses and in those residing in San Diego 26.1 (95 %CI: 20.1–32.2) new abscesses per 100 py.

The abscess incidence rate by WASH variables is described in Fig. 1 and covariates are described in Supplemental Table 4. Abscess incidence was higher among those who used non-improved water sources for

Table 1

Baseline characteristics of people who inject drugs by baseline abscess status, *La Frontera* cohort study, Tijuana-San Diego metropolitan area 2020–2023 ($N = 644$).

Variable	With Abscess ($N = 134$)	Without Abscess ($N = 510$)	Overall ($N = 644$)
Age			
Mean (SD)	43.1 (10.8)	43.5 (10.7)	43.4 (10.7)
Median [IQR]	41.0 [35.0, 51.0]	43.0 [35.0, 52.0]	43.0 [35.0, 52.0]
45+ years	50 (37.3 %)	237 (46.5 %)	287 (44.6 %)
<45 years	84 (62.7 %)	273 (53.5 %)	357 (55.4 %)
Years of Education			
Mean (SD)	10.0 (3.4)	10.0 (3.1)	10.0 (3.2)
Median [IQR]	11.0 [8.0, 12.0]	11.0 [8.0, 12.0]	11.0 [8.0, 12.0]
<10 years	48 (36.1 %)	204 (40.5 %)	252 (39.6 %)
10+ years	85 (63.9 %)	300 (59.5 %)	385 (60.4 %)
City of Residence			
Tijuana	44 (32.8 %)	152 (29.8 %)	196 (30.4 %)
San Diego	90 (67.2 %)	358 (70.2 %)	448 (69.6 %)
Gender			
Cis men	106 (79.1 %)	354 (69.4 %)	460 (71.4 %)
Cis women	28 (20.9 %)	150 (29.4 %)	178 (27.6 %)
Trans gender or nonbinary	0 (0 %)	6 (0.9 %)	6 (0.9 %)
Housing Status			
Permanent housing	36 (26.9 %)	178 (34.9 %)	214 (33.2 %)
Homelessness			
Sheltered	15 (11.2 %)	121 (23.7 %)	136 (21.1 %)
Unsheltered	83 (61.9 %)	211 (41.4 %)	294 (45.7 %)
Sex Work Status			
No sex work	122 (91.0 %)	469 (92.0 %)	591 (91.8 %)
Sex work	12 (9.0 %)	41 (8.0 %)	53 (8.2 %)
Days Since Last Injection			
Mean (SD)	1.2 (3.8)	1.7 (4.2)	1.6 (4.1)
Median [IQR]	0 [0, 1.0]	0 [0, 1.0]	0 [0, 1.0]
Most Common Site of Injection			
Safer Sites			
Arms	93 (72.7 %)	326 (65.9 %)	419 (67.3 %)
Feet	2 (1.6 %)	10 (2.0 %)	12 (1.9 %)
hands	6 (4.7 %)	19 (3.8 %)	25 (4.0 %)
Legs	14 (10.9 %)	54 (10.9 %)	68 (10.9 %)
Between Fingers	0 (0 %)	2 (0.4 %)	2 (0.3 %)
More Dangerous Sites			
Neck	13 (10.2 %)	71 (14.3 %)	84 (13.5 %)
Armpits	0 (0 %)	2 (0.4 %)	2 (0.3 %)
Inguinal Area	0 (0 %)	2 (0.4 %)	2 (0.3 %)
Temple	0 (0 %)	10 (2.0 %)	10 (1.6 %)
Water Insecurity			
Use of non-improved water as main water source for:			
Injecting drugs	9 (6.8 %)	40 (8.0 %)	49 (7.7 %)
Cleaning wounds	9 (6.8 %)	32 (6.5 %)	41 (6.5 %)
Handwashing	7 (5.3 %)	27 (5.3 %)	34 (5.3 %)
Hygiene Insecurity			
Basic hand hygiene insecurity	85 (63.9 %)	299 (58.9 %)	384 (59.9 %)
Bathing insecurity (<5 showers in the last week)	80 (60.2 %)	264 (52.0 %)	346 (53.7 %)
Number of showers in the last week			
Mean (SD)	4.1 (2.6)	4.5 (2.6)	4.4 (2.6)

Table 1 (continued)

Variable	With Abscess ($N = 134$)	Without Abscess ($N = 510$)	Overall ($N = 644$)
Median [IQR]	3.0 [2.0, 7.0]	4.0 [2.0, 7.0]	4.0 [2.0, 7.0]
Sanitation Insecurity			
Basic sanitation insecurity (non-improved toilet facilities)			
No facility/open defecation	28 (21.1 %)	67 (13.1 %)	95 (14.8 %)
Unimproved toilet	4 (3.0 %)	12 (2.4 %)	16 (2.5 %)
Open defecated at least once in the last week	65 (48.9 %)	179 (35.1 %)	244 (37.9 %)
Times defecating in the open in the last week			
Mean (SD)	5.63 (5.34)	5.22 (4.28)	5.3 (4.6)
Median [IQR]	4.0 [2.0, 7.0]	4.0 [2.0, 7.0]	4.0 [2.0, 7.0]

Table 1 summarizes demographic and WASH insecurity variables among study participants at baseline, stratified by if an abscess was present during the baseline visit. Note that $n = 3$ individuals were missing abscess information at baseline, $n = 7$ values were missing for years of education and $n = 21$ values were missing for the most common site of injection.

preparing drugs for injection (incidence rate: 49.6 [95 %CI: 34.2–65.0] vs those who used improved water sources: 22.6 [95 %CI: 19.3–25.8]), those who experienced bathing insecurity (incidence rate: 29.4 [95 %CI: 24.3–34.6] vs those who had bathing access: 20.0 [95 %CI: 15.9–24.1]) and those who practiced open defecation (incidence rate: 42.6 [95 %CI: 35.4–49.9] vs those who did not practice open defecation: 16.1 [95 %CI: 12.9–19.4]). The abscess incidence rates did not significantly differ by age, years of education, city of residence, gender identity, housing status and reported sex work.

Unadjusted and adjusted HR and 95 %CI are described in Fig. 2 and Supplemental Table 4. The unadjusted hazard of developing new abscesses was significantly associated with the use of non-improved water sources for preparing drugs for injection (HR: 1.85 [95 %CI: 1.28–2.68]), basic hand hygiene insecurity (HR: 1.83 [95 %CI: 1.33–2.51]), bathing insecurity (HR: 2.16 [95 %CI: 1.58–2.93]), basic sanitation insecurity (HR: 1.64 [95 %CI: 1.04–2.57]), open defecation (HR: 2.22 [95 %CI: 1.67–2.97]), days since last time of injection (HR: 0.72 [95 %CI: 0.55–0.94]), and injecting in more dangerous body areas (HR: 1.76 [95 %CI: 1.29–2.40]).

After adjusting for potential confounders, the hazard of developing a new abscess remained significantly associated with insecurity accessing improved water sources for preparing drugs for injection (adjHR: 1.49 [95 %CI: 1.01–2.21]), bathing insecurity (adjHR: 1.59 [95 %CI: 1.12–2.24]) and open defecation (adjHR: 1.65 [95 %CI: 1.16–2.35]). The cohort variable (cohort 1 vs cohort 2) had no significant association in bivariate analyses and controlling for cohort in multivariable analyses did not change the direction or significance of other associations. We ran a series of sensitivity analyses using 1) a complete case approach and 2) imputing only WASH variables. In each case, the magnitude and direction of all coefficients for the WASH insecurity variables remained unchanged. In both sensitivity analyses the overall estimated abscess incidence remained almost unchanged at 23.7 versus 24.4 per 100 person-years.

Discussion

In this study, as previously reported (Calderón-Villarreal et al., 2024b), we found that WASH insecurity was frequent, abscess prevalence and incidence were high, and open defecation, bathing insecurity and the use of non-improved water sources for preparing drugs were predictors of abscess incidence among a binational cohort of people who inject drugs in the Tijuana-San Diego metropolitan area. The risk of developing injection-site abscesses was high regardless of housing status and city of residence. Homelessness had positive, albeit weak

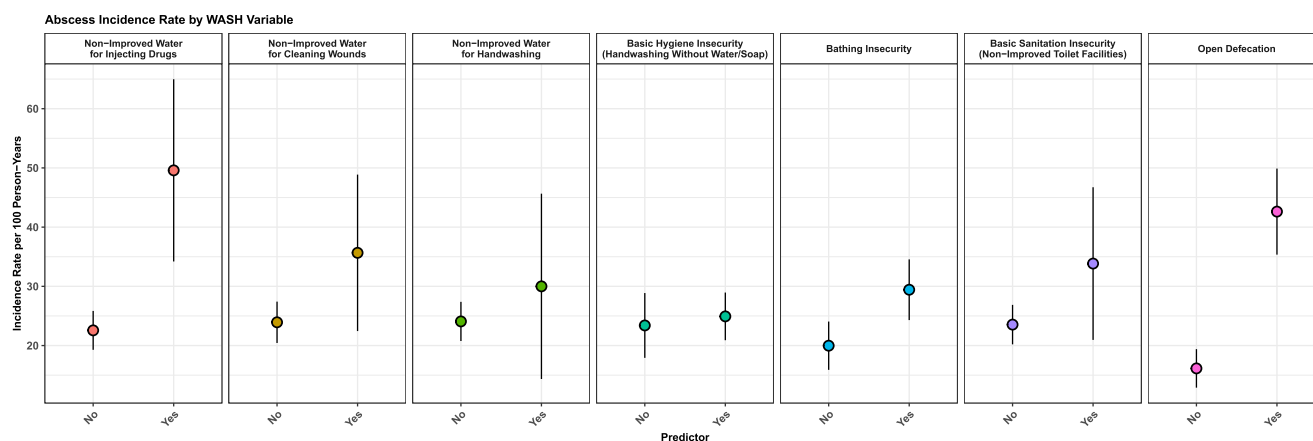


Fig. 1. Crude abscess incidence rate per 100 person-years by WASH insecurity variables among people who inject drugs in the Tijuana-San Diego metropolitan area, *La Frontera* cohort study, 2020–2023 ($N = 647$).

Fig. 1 summarizes abscess incidence rates per 100 person-years stratified by key WASH variables. The incidence rates are crude, not adjusted for the effect of other variables. All points are shown with 95 % confidence intervals. The significance of each WASH variable can be assessed using the unadjusted hazard ratios shown in Fig. 2.

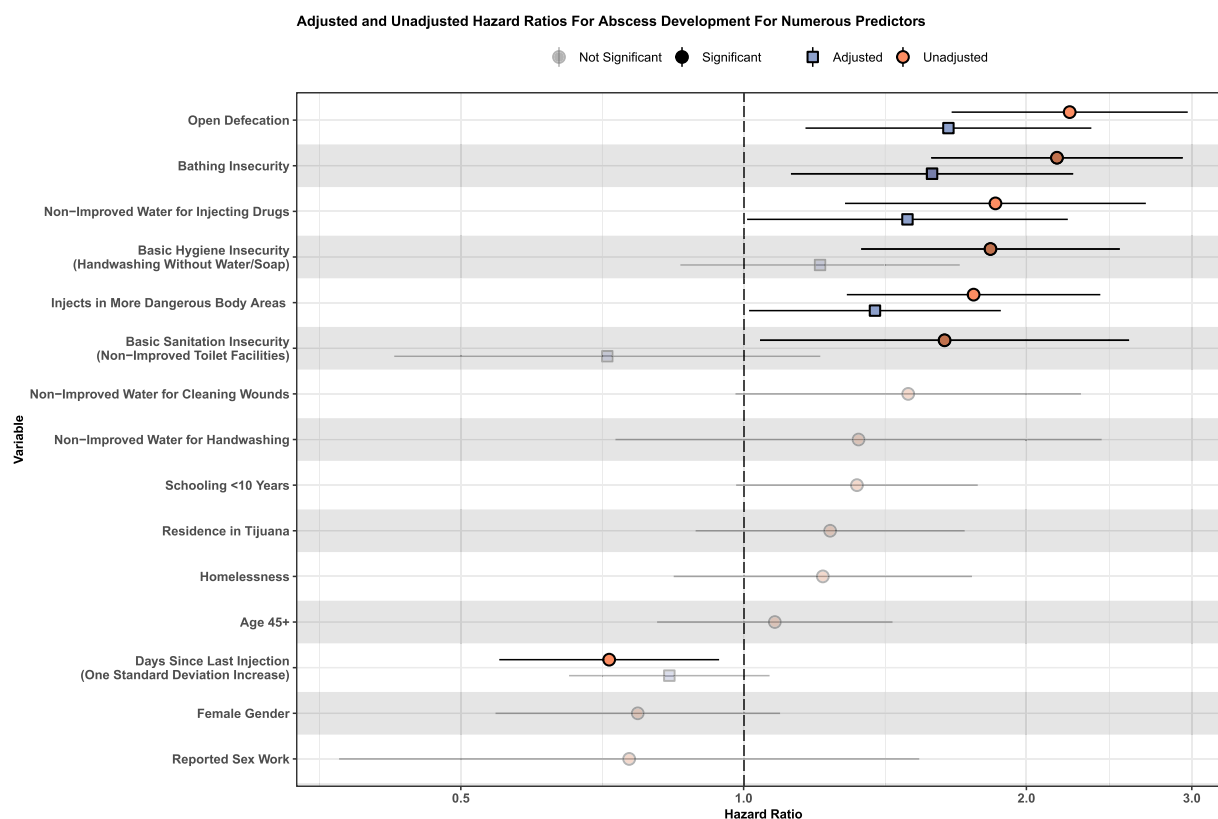


Fig. 2. Hazard Ratios from Cox Models for Abscess Development in Past Six Months for All Considered Predictors among people who inject drugs in the Tijuana-San Diego metropolitan area, *La Frontera* cohort study, 2020–2023 ($N = 647$).

Figure 2 summarizes all Cox models used to assess predictors of abscess formation. Unadjusted models were employed first, assessing the association of each variable with abscess formation. A single adjusted model was subsequently used, including all variables found to be statistically significant in the first round of models. Adjusted vs. unadjusted HRs are shown with point shape and fill color. Statistically significant vs not statistically significant at the 0.05 level was shown with the intensity of the point color. 95 % CI are shown for all HRs, and a vertical line shows 1.0, the point of non-significance.

correlations with the WASH insecurity variables included in our study, but it cannot fully explain WASH insecurity or abscess incidence. Other studies of WASH and SSTI have been cross-sectional in nature and focused on more limited sets of WASH indicators. We provide the most comprehensive, and first longitudinal evidence, that WASH access represents a key set of determinants of abscess incidence among people who inject drugs.

Prevalence and incidence of abscesses among individuals who inject drugs appears to vary depending on the context and period studied, and is likely influenced by a myriad of environmental and individual factors (Fink et al., 2013; Larney et al., 2017). At baseline, we found that one in five participants reported having an abscess in the prior six months, which was similar to that observed in a study among people who inject drugs in Canada (21.5 %) in 2005 (Lloyd-Smith et al., 2005). However,

the incidence of abscesses in our study (24.4/100 py) was about four to nine times higher than rates observed in other cohorts of individuals engaged in drug injection in Canada in 2010 (6.1/100 py) (Lloyd-Smith et al., 2010) and Sweden in 2017 (2.8/100 py) (Dahlman et al., 2018). In our study, participants were recruited using targeted sampling not linked with public or private services (Strathdee et al., 2021), while other cohort studies enrolled participants based on their participation in institutions (public prison) or formal programs (supervised injection facilities) (Dahlman et al., 2018; Lloyd-Smith et al., 2010). Drug policies, criminalization of substance use and availability of harm reduction programs and supervised injection facilities in study locations could influence differences in incidence rates. Additionally, our study was conducted during the COVID-19 pandemic, and in the years since those studies were published, a housing crisis in California may be increasing rates of homelessness broadly among individuals engaged in substance use, which may be worsening WASH access and abscess incidence.

Limited studies have described—or assessed associations with—the use of non-improved water sources for preparing drugs, such as surface water or saliva (Calderón-Villarreal et al., 2024b; Baltes et al., 2020; Calderón-Villarreal et al., 2022; Harris et al., 2020; Otiashvili et al., 2016). We found that individuals using non-improved water sources for preparing drugs for injection (one in every 12 participants) had the highest incidence of abscesses and this practice was a robust predictor of abscess incidence. Water sources used for preparing drugs for injection has been associated with abscess prevalence (Baltes et al., 2020), but in our knowledge, no previous study has explored its relationship with abscess incidence. Although the use of non-improved water sources is not preferred or common among people who inject drugs, multiple factors such as environmental structural violence and insecurity accessing sterile/improved water sources for injection can render it an unfortunate necessity (Calderón-Villarreal et al., 2022; Harris et al., 2020). People use water in the preparation of a wide range of drugs for injection (e.g., heroin, fentanyl, methamphetamine) (Harris et al., 2020). For instance, individuals who injected heroin and crack cocaine together usually add water (or an alternative to water) in two distinct moments during the drug preparation: 1) water to mix heroin, which is heated and 2) cold water used before mixing with crack cocaine. Therefore, in the context of rapidly rising polysubstance use (especially of fentanyl, xylazine and stimulants) (Friedman & Shover, 2023; Friedman et al., 2022), more research on the specific water types and quality used during drug preparation is needed.

There is a large research gap related to bathing insecurity (e.g., frequency and facilities access/functionality/safety) among people who inject drugs, particularly important among those experiencing housing instability. We found that lack of access to body hygiene (bathing insecurity) was an independent predictor of abscess incidence. Similarly, open defecation and sanitation insecurity have been unexplored as predictors of abscesses. We found open defecation was independently associated with abscess incidence. Broader infectious disease and substance use-related research and policies focused on open defecation and continuously available toilet facilities is needed among communities of people engaged in substance use—and those who experience housing instability.

In our study, water used for cleaning wounds, handwashing and basic hand hygiene insecurity were not found to be significant predictors for abscess incidence. However, literature has reported contradictory results regarding of water sources use or contact and skin cleaning prior injection associations with SSTI/abscesses prevalence. In a study conducted by some of the authors in our study (ACV, SAS and GLK) among 84 unhoused individuals who inject drugs and lived in the Tijuana River canal in Tijuana, Mexico, we found that people who used or were in contact with surface water were two times more likely to have SSTI than those who did not (Calderón-Villarreal et al., 2022). Similarly, in San Francisco, Dahlman et al.'s (2015) study among 201 people who inject drugs reported an association between infrequent skin cleaning before injection and SSTI prevalence (Dahlman et al., 2017). While these

studies identified an association between forms of WASH insecurity and prevalence of SSTI, Larney et al. (2017) conducted a systematic review that included 29 cross-sectional studies of SSTI prevalence among individuals engaged in drug injection in different contexts, reporting no significant association between SSTI and skin cleaning prior to injection or handwashing prior to injection (Larney et al., 2017). This remains an important area for further study to parse out the contradictory results.

There are limitations to this study, including attrition due to challenges in following participants that are experiencing homelessness or incarceration, which could attenuate some associations. It is possible that some WASH outcomes, such as open defecation, were influenced by COVID-19 related measures, for example, if public restrooms were less available than outside of the pandemic period. On the other hand, our decision to limit incidence calculations to individuals who did not have an abscess in the prior 6-month period—although necessary to avoid overcounting—may have led to underestimating the true incidence rate. There is also a possibility of misclassification bias since participants self-reported having abscesses and some could represent other types of SSTI, such as a wound without a collection of pus (e.g., cellulitis) (Lipsker, 2021). Further, we classified water sources according to the JMP definitions for drinking water; however, this classification is not tailored for people who inject drugs or who experience homelessness. We also used and defined water insecurity based on the JMP definitions instead of other scales to measure water insecurity (Strathdee et al., 2012), as these have been tested globally. However, we did expand them to dimensions such as shower frequency and water for drug preparation and injection—which we argue are critical for the study population and to similar populations across the globe. We did not test the quality of the water people reported using, thus we cannot determine if the water people used was safe or continuity (continuously available 24-h per day).

More than half of individuals experiencing SSTI will have at least one recurrent infection in their lifetime impacting their quality of life and limiting their mobility (McNeil & Fritz, 2019). SSTI-related healthcare has financial implications for both the patient and health care systems (~190 million USD per year) (Chambers, 2021; Cross, 2013). Further, about half of people who inject drugs experience more than one injection related injury and disease at a time (Colledge et al., 2020), increasing complications and costs.

WASH infrastructure that provides access to improved water sources, showers, handwashing, and 24-h sanitation facilities is needed to prevent the incidence of abscesses and related complications for people who inject drugs. Local governments and civil society play an important role as actors that can potentially modify the structural barriers that limit people who use drugs' access to continuously available WASH services. We argue that WASH should be considered a key component of harm reduction infrastructure, research, and policy. For instance, water provided by harm reduction services often is the only improved water source for drinking, preparing drugs and cleaning wounds among communities of people who inject drugs. Harm reduction strategies and other local/state level programs integrating WASH services, may decrease abscesses (Chambers, 2021). Also, public WASH facilities should be continuously open and functional for everyone. Further, among those who inject drugs and who experience housing instability, transitional housing (such as shelters), 'Housing First' programs (affordable housing not conditioned on behavioral change) (O'Sullivan et al., 2021) and mobile hygiene services could reduce WASH insecurity. Mobile hygiene services can hold up the principle of 'Radical Hospitality'—the idea to "treat those who often feel invisible and dehumanized with an extraordinary level of respect and care to restore dignity and unlock the opportunities that come with being clean" (LavaMae 2022; Zelayandia & Leon, 2020). This is highly compatible with the existing ethos of many harm reduction programs: receiving people as they are and helping them improve their quality of life as much as possible.

Conclusions

In this cohort study of people who inject drugs in the Tijuana-San Diego metropolitan area, we document high incidence of insecurity accessing WASH services. Abscess incidence was about four to nine times higher than rates observed among individuals who inject drugs in other contexts and was independently associated with the WASH insecurity variables of open defecation, body hygiene insecurity, and the use of non-improved water sources for preparing drugs. Our findings demonstrate that WASH insecurity variables are important and understudied predictors of abscess incidence that should be incorporated into further infectious disease studies among people who inject drugs. Access to basic WASH infrastructure should be ensured and championed as a key component of harm reduction infrastructure to prevent the incidence of abscesses and infectious diseases, to decrease stigma, and address environmental injustices among communities of people who inject drugs.

Ethics approval

The study protocols received ethics approval from the institutional review boards at the University of California, San Diego (UCSD) (IRB# 191390) and Xochicalco University in Mexico.

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CRedit authorship contribution statement

Alhelí Calderón-Villarreal: Writing – review & editing, Writing – original draft, Visualization, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Daniela Abramovitz:** Writing – review & editing, Data curation. **Lourdes Johanna Avelar Portillo:** Writing – review & editing, Methodology, Conceptualization. **Shira Goldenberg:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Shawn Flanigan:** Writing – review & editing, Supervision, Conceptualization. **Penelope J.E. Quintana:** Writing – review & editing, Supervision. **Alicia Harvey-Vera:** Resources, Project administration, Investigation. **Carlos F. Vera:** Project administration, Investigation. **Gudelia Rangel:** Resources, Funding acquisition. **Stefanie A. Strathdee:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Investigation, Funding acquisition, Conceptualization. **Georgia L. Kayser:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.drugpo.2024.104485.

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