AIDS and Behavior
https://doi.org/10.1007/s10461-022-03783-6

ORIGINAL PAPER

Network-level HIV risk norms are associated with individual-level HIV risk and harm reduction behaviors among people who inject drugs: a latent profile analysis

Cho-Hee Shrader[1] · Annick Borquez[2] · Tetyana I. Vasylyeva[2] · Antoine Chaillon[2] · Irina Artamanova[2] · Alicia Harvey-Vera[2,3,4] · Carlos F. Vera[2] · Gudelia Rangel[4,5] · Steffanie A. Strathdee[2] · Britt Skaathun[2]

Accepted: 30 June 2022
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2022

Abstract

The COVID-19 related U.S.-Mexico border-crossing restrictions disrupted social networks and HIV harm reduction services among people who inject drugs (PWID) in San Diego and Tijuana. We assessed associations of descriptive network norms on PWID's HIV vulnerability during this period. Between 10/2020 and 10/2021, 399 PWID completed a behavioral and egocentric questionnaire. We used Latent Profile Analysis to categorize PWID into network norm risk profiles based on proportions of their network (n = 924 drug use alters) who injected drugs and engaged in cross-border drug use (CBDU), among other vulnerabilities. We used logistic and linear regressions to assess network profile associations with individual-level index of HIV vulnerability and harm reduction behaviors. Fit indices specified a 4-latent profile solution of descriptive network risk norms: lower (n = 178), moderate with (n = 34) and without (n = 94) CBDU and obtainment, and higher (n = 93). Participants in higher risk profiles reported more HIV vulnerability behaviors and fewer harm reduction behaviors. PWID's gradient of HIV risk was associated with network norms, warranting intervention on high-vulnerability networks when services are limited.

Keywords Drug users · HIV infections · Latent class analysis · Social Networks · Mexico

Introduction

Among people who inject drugs (PWID), social norms are an important environmental convention which can influence individual-level HIV vulnerability and harm reduction behaviors [1–6], as posited by Bandura's Social Cognitive Theory [7]. Alternatively, in accordance with the theory of homophily and differential association, individuals are attracted to similar others; thus, they engage in HIV risk behaviors endorsed by their social networks [8, 9]. Both theories posit that social network norms can predict future HIV risk behaviors such as sharing injection equipment (i.e., needles, cookers, or cottons; or back/front loading) [10, 11]. Peers not only establish social norms, but can also serve as a source of injection equipment, drugs, and healthy or harm reduction behaviors [10, 12]. To better understand the association between social norms and individual behavior, two types of social norms have been identified: *injunctive norms*, individual-level perceptions of what is acceptable by others, and *descriptive norms*, the actual observed behaviors within a network [13–15]. Much of previous research has focused on the influences of network-level injunctive norms on individual-level HIV vulnerability [1, 16, 17] and there is a dearth of research surrounding descriptive norms at the

✉ Cho-Hee Shrader
Cs4138@cumc.columbia.edu

1 ICAP at Columbia University, New York, NY, United States of America

2 Division of Infectious Diseases and Global Public Health, Department of Medicine, University of California, San Diego, La Jolla, CA, United States of America

3 Facultad de Medicina, Universidad Xochicalco Campus Tijuana, Tijuana, Baja California, Mexico

4 Mexican Section, United States-Mexico Border Health Commission, Tijuana, Baja California, Mexico

5 Departmento de Estudios de Población, El Colegio de la Frontera Norte, Tijuana, Baja California, Mexico

Published online: 08 August 2022

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

network- and individual-level, and the relationship of social norms with HIV risk behaviors among PWID [1, 2, 4, 6].

Research surrounding social network HIV risk norms among PWID has predominantly focused on PWID communities along the East Coast of the United States (U.S) [1, 2, 10, 16, 18]. However, since norms can be unique to geographic regions, information is needed outside of the context of the East Coast, in injection drug use hubs such as those along the U.S.-Mexico border [19]. Prior to the emergence of COVID-19 as a global pandemic, a large body of research established that PWID along the U.S.-Mexico border were already at elevated risk of HIV relative to other populations [20]. The San Ysidro Port of Entry separates the border between San Diego County, California, U.S. and Tijuana Municipality, Baja California, Mexico. It is the 4th busiest border crossing in the world and a major drug trafficking route [21–24]. Travel restrictions northbound at the San Ysidro Port of Entry during the COVID-19 pandemic might have exacerbated HIV vulnerability, as they prevented cross-border mobility, and disrupted established social networks [21, 22, 25, 26]. The latter may have forced PWID to join new drug use networks, potentially increasing exposure to HIV [27]. In addition, access to harm reduction services may have been affected as a result of physical distance protocols and as health system resources shifted towards the COVID-19 response [28–30]. Despite a political border separating these two cities, they merge to form a "melting pot" of overlapping key populations with high HIV vulnerability [31]. In 2019, HIV incidence among the general population was 13 per 100,000 in San Diego [32] and 10.3 per 100,000 in Tijuana [33]. However, HIV incidence is estimated to be much higher among PWID and preliminary research carried out after the border closure suggests that HIV incidence rate was 4-fold among a sample of PWID living in Tijuana, relative to PWID living in San Diego who engage in cross-border drug use (CBDU) [34].

CBDU and cross-border drug obtainment (CBDO) on the San Diego and Tijuana border have been increasing over the past decade [35, 36]. Drugs are generally cheaper and easier to obtain in Tijuana relative to neighboring San Diego given both drug production and supply (predominantly to the U.S.) occur in Tijuana. Differences in currency and drug policies between Mexico and the U.S., and lower exposure to police harassment in Mexico make CBDU/CBDO attractive for U.S. PWID [35, 36]. In 2009, Mexico decriminalized drug possession for personal consumption for a selection of drugs and under a specified threshold, which may also be contributing to these trends, although studies from our research group suggest limited implementation of these reforms [37]. Thus, people who engage in CBDU or CBDO are often San Diego residents who travel to Tijuana, instead of Tijuana residents who travel to San Diego, to obtain and/or use drugs. Black-tar heroin and methamphetamine use, often in combination, have been consistently reported in both Tijuana and San Diego over the past decade [38–41]. However, the picture has been changing recently, as cartels have shifted from black tar to fentanyl production and supply as this is much more profitable than heroin [42]. California experienced one of the highest increases (> 45%) in overdose deaths across the U.S. between 2020 and 2021 [43, 44]. Over this same period, there was a 61% increase in overdose deaths in San Diego County (871 overdose versus 528), and ≥ 60% were fentanyl-related [45]. In 2022, 16% of PWID in San Diego had an overdose in the prior 6 months, which has doubled since 2014 [46, 47]. Between 2011 and 2013 in Tijuana, 17.4% of PWID had an overdose within the last 6 months [48]. Overdose deaths are poorly monitored in Tijuana but increases in the use of powder heroin and fentanyl presence in drug samples along the Mexican side of the border have been confirmed [49]. In addition to increasing fatal overdose risk, fentanyl use is associated with greater risk of HIV infection as, unlike black-tar heroin use, its use does not require heating or rinsing of syringes in order to prevent clogging, a harm reduction strategy to inactivate HIV [50–52]. Additionally, fentanyl's short half-life has also been shown to lead to more frequent injecting and by extension, to more frequent syringe sharing [50, 53].

A study of PWID living in Mexico found that nearly 20% of PWID in Tijuana recently injected with U.S. PWID who engaged in CBDU, suggesting that CBDU can enable cross-border HIV transmission [54]. While historically, cross-border HIV transmission primarily occurred from the U.S. to Mexico, for the first time, cross-border transmission is now occurring from Mexico to the U.S. [31]. Consequently, CBDU and CBDO as a phenomenon warrants further investigation. Harm reduction strategies to reduce HIV vulnerability from injection drug use have been implemented differentially across the two countries [55, 56]. The uptake of harm reduction services is not only impacted by service availability, but also may also be influenced by social network norms. Access restrictions to harm reduction strategies during the COVID-19 pandemic [26] and previous needle sharing norms might have exacerbated HIV risk among PWID who live along the U.S.-Mexico border. It is therefore important to characterize social network norms relevant to specific communities highly vulnerable to HIV, as norms are diverse across different environments, continuously evolve, and rapidly disseminate throughout networks [4].

The aim of the present study was to examine the influence of PWID's descriptive network norms from a person-centered perspective on HIV-related risk and harm reduction behaviors during the COVID-19 pandemic (post-implementation of border crossing restrictions) [26, 57]. We

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

used Latent Profile Analysis (LPA) to categorize PWID into person-centered descriptive network risk norms profiles. LPA was used due to its ability to identify unique subgroups based on social network norms that variable-centered analyses alone cannot elucidate. We examined the relationship between descriptive network risk-norms profiles and individual-level HIV risk and harm reduction behaviors during the previous 6 months.

Methods

Setting and sample description- The parent study, *La Frontera*, is a longitudinal study among PWID in which researchers aim to characterize trends in incidence of HIV, Viral Hepatitis C and drug overdose associated with binational drug markets and CBDU between San Diego, US, and Tijuana, Mexico. Data for the present study were baseline and supplemental visit data of *La Frontera.* Additional study information can be found elsewhere [58]. Participants were PWID aged ≥ 18 from 3 groups: (1) PWID who live in San Diego but engaged in CBDU in Tijuana in the past 2 years, (2) PWID who live in San Diego and had not been to Mexico in at least 2 years or (3) PWID who live in Tijuana and had not been to the U.S. in at least 2 years. We operationalized PWID who did not engage in CBDU as PWID who have not used illicit drugs across the border from where they reside in the past 2 years. Participants were recruited through street outreach between October 2020 and October 2021. Trained interviewers obtained written informed consent then administered a computer-assisted sociodemographic and behavioral questionnaire. Within two weeks of the initial visit, interviewers administered a computer-assisted supplemental questionnaire which assessed participants' social network and HIV-related risk factors.

Sociodemographic characteristics- We collected data on participants' sociodemographic characteristics such as age, ethnic identity (Non-Hispanic or Hispanic), race (Black, White, Mixed, Asian, Native American, or other), sex assigned at birth (male or female), and country of birth (U.S., Mexico, or other).

HIV status and serology- Samples underwent HIV serology at baseline. Rapid HIV tests were conducted using the Miriad® HIV Antibody InTec Rapid Anti-HCV Test (Avantor, Radnor, PA) [59]. Reactive and indeterminate tests underwent a second rapid test with Oraquick® HIV (Orasure, Bethlehem, PA) [60].

Network risk variables- Social network information was collected by asking participants to name up to 20 people they had seen in the past 30 days and who they talked to about things that are important to them (alters). Network risk information was collected for the first five alters that participants named. Only alters that used drugs were included for analyses. Based on previously established HIV risk factors, participants indicated whether each alter (1) used drugs by injection or (2) by non-injection (i.e., "*Does [ALTER] use drugs by injection, by non-injection, or sometimes one and sometimes the other?*"), (3) lived in Mexico at the time of the study (i.e., "*Where does [ALTER] live*?"), (4) ever crossed the border to buy or obtain drugs (i.e., "*In the past 6 months, had [ALTER] traveled to Mexico/U.S. to buy or obtain drugs?*" i.e., CBDO), (5) shared injection equipment with the participant (i.e., "*Have you ever used a needle, water, cooker or cotton that had already been used by [ALTER]?")*, (6) offered to share drugs with the participant (i.e., "*Has [ALTER] ever offered to share or encouraged you to use drugs?*"), and (7) either used more than or double their usual dose of drugs (i.e., "*Consider [ALTER] usual daily drug use, does [ALTER] ever use double the amount or mix with other drugs?*"). Then, for each network risk variable we calculated the proportion of participants' drug use networks that engaged in the network risk variable.

HIV behavioral risk and harm reduction variables- Participants' HIV risk was assessed through self-reports of 4 risk behaviors and 2 harm reduction behaviors. Risk behaviors in the past 6 months included consistency of (1) giving, renting, or lending a syringe the participant already used to someone else; (2) using a syringe that participant knew or suspected had been used before by someone else; (3) dividing up drugs with somebody else by using a syringe (i.e., back loading, piggybacking or splitting drugs wet); and/or (4) using a cooker, cotton, or water with someone or after someone else. Responses were collected in Likert scale form (1 = never; 2 = less than half the time; 3 = about half of the time; 4 = more than half the time; and 5 = always). We created an index to measure HIV risk, which was calculated by finding the mean score of participants' responses to the aforementioned items. The index had excellent internal consistency (Cronbach's $\alpha = 0.908$).

HIV harm reduction behaviors included (1) consistency of injecting with a new, sterile syringe in the past 6 months and (2) having ever been tested for HIV. Injecting with a new, sterile syringe was assessed as a Likert scale for consistency in the past 6 months (1 = never; 2 = less than half the time; 3 = about half of the time; 4 = more than half the time; and 5 = always). Having ever been tested for HIV was measured dichotomously (1 = no; 2 = yes).

Statistical analysis- LPA was used to categorize PWID into empirically-based network risk-norms profiles based on the proportion of their network which engaged in specific risk behaviors, using a person-centered approach [57]. The indicators for LPA included information about alters who used injection and non-injection drugs, engaged in CBDO, lived in Mexico, shared a needle with the participant, offered

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

the participant drugs, and either doubled their daily use or mixed drugs, as mentioned above. The network risk-norms latent variables were itemized and constructed as continuous measures based on the proportion of their network who engaged in each behavior, with higher values indicating higher network norm of that variable.

The outcomes of interest were the HIV risk index, and the two harm reduction variables. To assess significant differences between network risk-norms profiles by sociodemographic and HIV risk and harm reduction behaviors, we used chi-square goodness-of-fit tests and Analysis of Variance (ANOVA). Lastly, we identified associations profile membership using post-hoc linear and binomial logistic regression to identify associations with HIV behavioral risk and harm reduction outcomes. We tested five assumptions of linear regression: linearity, homoscedasticity, multicollinearity, independence, and normality [61]. Basic assumptions that were met for logistic regression include independence of errors, linearity in the logit for continuous variables, absence of multicollinearity, and lack of strongly influential outliers [62]. We observed the distribution and outliers of our data through visualizations (i.e., histogram) and by measuring the skewness and kurtosis of each numerical variable. Additionally, we looked at the correlation of variables and the VIF of models. All assumptions of linear and logistic regressions were met. The R environment was used to conduct the LPA (*tidyLPA*) and the regressions (*lm* for linear regression and *glm* for logistic regression).

The University of California San Diego ethics committee provided ethical approval for this study.

Results

Of 612 participants who were recruited and enrolled in the parent longitudinal study, 399 PWID (n = 150 San Diego residents who engage in CBDU, n = 90 San Diego residents who did not engage in CBDU, n = 159 Tijuana residents who did not engage in CBDU; 65% of entire sample) provided additional social network data (n = 1,226 alters) and only those network members who participants indicated drug use for in the past year (n = 924 alters who used drugs within the past year) were included in the LPA. Participants' mean age was 44 years and 26% were assigned female sex at birth. All participants identified as cis gender. Additional information about participants can be found in Table 1, by latent profile.

Additional information about CBDU group

Among the group of participants who engaged in CBDU (n = 150), participants were either interviewed in San Diego or Tijuana. Participants who were interviewed in San Diego reported having gone to Mexico a mean of 2.6 months ago. Participants interviewed in Tijuana reported that the previous time that they travelled to Mexico before the day of the interview was a mean of 1.1 months ago. Participants reported going to Mexico a mean of 30.7 times in the last 6 months (min = 1; max = 180 times). The mean length of time that participants reported staying in Tijuana was 16 days (min = 0.05, max = 279 days). Of participants who engaged in CBDU, 90% reported using or obtaining drugs or drug paraphernalia, 49% reported visiting friends, and 37% reported visiting family. Of participants who reported CBDU, the most commonly used drugs in Mexico included heroin (91%; of which 69% reported using primarily black tar heroin), methamphetamine or crystal meth (71%), marijuana (56%), and the combined use of heroin and methamphetamine or crystal meth (43%). Additional information about participants who engaged in CBDU can be found in **Appendix 1**.

Selection of latent profile model of most parsimonious fit

To assess which model of the five profiles best fit the data, we considered several fit criteria as described in in Table 2 [63]. We first assessed Akaike's information criterion (AIC) and Bayes information criterion (BIC) for lower values as these indicate a more parsimonious fit of the data [64–66]. We then considered the models with an Entropy value greater than 0.8 as this indicates the model's ability to discriminate between profiles [67]. In considering AIC, BIC, and Entropy, the four- and five-profile models fit the data best. We then considered the Lo-Mendell-Rubin likelihood ratio test (LMR-LRT) and Bootstrap likelihood ratio test (BSLRT) as this indicates if a given model fits the data better than the model with one profile less [68, 69]. The BSLRT suggested that only the six-profile model did not fit the data better than the model with one profile less (BSLRT value = 316.92; p = 0.99). Lastly, we considered the smallest sample size of each profile, as models which include profiles that are less than or equal to 25 members could indicate a spurious profile [70]. The Prob. Min (minimum of the diagonal of the average latent profile probabilities for most likely profile membership, by assigned profile) and Prob. Max (maximum of the diagonal of the average latent profile probabilities for most likely profile membership, by assigned profile) signify greater classification as values increase, and should be as high as possible [71]. For this, we chose the four-profile model, which had the most parsimonious fit to the data. Figure 1 visualizes the mean probability of being included in social norm risk profiles for each network risk variable.

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Table 1 Associations between network HIV risk norms profile and background characteristics

	Lower risk network norm profile (N = 178)	Moderate risk with CBDO network norm profile (N = 34)	Moderate risk without CBDO network norm profile (N = 94)	Higher risk network norm profile (N = 93)	Total (N = 399)	Test statistic value‡
Study group**						$\chi^2 = 63.36$
Engaged in CBDU	62 (34.8%)	27 (79.4%)	43 (45.7%)	18 (19.4%)	150 (37.6%)	
San Diego No CBDU	55 (30.9%)	3 (8.82%)	19 (20.2%)	13 (14.0%)	90 (22.6%)	
Tijuana No CBDU	61 (34.3%)	4 (11.8%)	32 (34.0%)	62 (66.7%)	159 (39.8%)	
Age						F = 1.80
Mean (SD)	44.3 (11.1)	46.0 (11.2)	43.1 (9.79)	41.8 (9.65)	43.6 (10.5)	
Median [Min, Max]	46.0 [20.0, 69.0]	46.5 [24.0, 64.0]	43.0 [20.0, 65.0]	42.0 [24.0, 67.0]	44.0 [20.0, 69.0]	
Race						$\chi^2 = 25.91$
Hispanic	112 (62.9%)	20 (58.8%)	70 (74.5%)	75 (81.5%)	277 (69.6%)	
Multiracial	18 (10.1%)	3 (8.82%)	9 (9.57%)	11 (12.0%)	41 (10.3%)	
Not Hispanic other	5 (2.81%)	1 (2.94%)	0 (0%)	0 (0%)	6 (1.51%)	
Not Hispanic Black	11 (6.18%)	1 (2.94%)	1 (1.06%)	2 (2.17%)	15 (3.77%)	
Not Hispanic White	32 (18.0%)	9 (26.5%)	14 (14.9%)	4 (4.35%)	59 (14.8%)	
Sex at birth						$\chi2 = 5.466$
Male	121 (68.0%)	26 (76.5%)	74 (78.7%)	73 (78.5%)	294 (73.7%)	
Female	57 (32.0%)	8 (23.5%)	20 (21.3%)	20 (21.5%)	105 (26.3%)	
Birth country***						$\chi2 = 25.52$
United States	84 (47.2%)	19 (55.9%)	42 (44.7%)	18 (19.4%)	163 (40.9%)	
Mexico	91 (51.1%)	15 (44.1%)	51 (54.3%)	74 (79.6%)	231 (57.9%)	
Other‡	3 (1.69%)	0 (0%)	1 (1.06%)	1 (1.08%)	5 (1.25%)	
HIV sero-status						$\chi2 = 5.24$
HIV Negative	167 (93.8%)	32 (94.1%)	84 (89.4%)	80 (86.0%)	363 (91.0%)	
HIV Positive	11 (15.18%)	2 (5.88%)	10 (10.64%)	13 (13.98%)	39 (9%)	
Last day injected (0 = day of assessment)						F-value = 0.92
Mean (SD)	1.35 (3.43)	0.559 (1.48)	1.09 (3.37)	0.796 (3.44)	1.09 (3.30)	
Median [Min, Max]	0 [0, 29.0]	0 [0, 8.00]	0 [0, 21.0]	0 [0, 24.0]	0 [0, 29.0]	
Number of alters						F-value = 1.65
Mean (SD)	3.13 (1.31)	2.71 (1.27)	2.95 (1.43)	3.22 (1.24)	3.07 (1.32)	
Median [Min, Max]		3.00 [1.00, 5.00]	2.00 [1.00, 5.00]	3.00 [1.00, 5.00]	3.00 [1.00, 5.00]	
HIV Risk Index***						
Mean (SD)		1.79 (1.03)	2.01 (1.11)	1.97 (0.965)	2.59 (1.02)	2.04 (1.06)	F-value: 12.8
Median [Min, Max]		1.25 [1.00, 5.00]	1.75 [1.00, 5.00]	2.00 [1.00, 4.50]	2.50 [1.00, 5.00]	1.75 [1.00, 5.00]	
Ever been tested for HIV***						$\chi2 = 16.35$

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Table 1 (continued)

	Lower risk network norm profile (N = 178)	Moderate risk with CBDO network norm profile (N = 34)	Moderate risk without CBDO network norm profile (N = 94)	Higher risk network norm profile (N = 93)	Total (N = 399)	Test statistic value‡
No	41 (23.2%)	18 (52.9%)	36 (38.3%)	24 (25.8%)	119 (29.9%)	
Yes	136 (76.8%)	16 (47.1%)	58 (61.7%)	69 (74.2%)	279 (70.1%)	
In the last 6 months injected with a new, sterile syringe*****						F-value = 3.97
Mean (SD)	4.00 (1.22)	3.62 (1.23)	3.70 (1.26)	3.51 (1.08)	3.78 (1.21)	
Median [Min, Max]	4.00 [1.00, 5.00]	4.00 [1.00, 5.00]	4.00 [1.00, 5.00]	4.00 [2.00, 5.00]	4.00 [1.00, 5.00]	

Using tests of significance, * indicates p<0.05; ** indicates p<0.01; *** indicates p<0.001; †Tests include Chi−Square tests of significance ($\chi 2$) and ANOVA (F−value); ‡ Other countries of birth include Australia, El Salvador, Japan, and Puerto Rico

Network norm latent profile profile description

As the fit indices suggested a 4-latent profile solution, network norm profiles were classified as (1) lower risk network norm profile (n = 178), (2) moderate risk with CBDO network norm profile (n = 34), moderate risk without CBDO network norm profile (n = 94), and 4) higher risk network norm profile (n = 93), as observed in Fig. 1. Figure 1 demonstrates that higher risk network norm profiles have networks in which the majority of alters participated in high HIV risk behaviors. The moderate risk network norm profiles were composed of network with alters who had similar HIV risk behaviors, with two exceptions: (1) proportion of alters who engaged in CBDO and (2) proportion of alters who lived in Mexico. The lower risk network norm risk profile was composed of networks in which the majority of alters did not practice high HIV vulnerability behaviors. Table 1 describes sociodemographic characteristics of participants, stratified by network norm HIV risk profile membership, with significant relations examined by bivariate associations. There were differences in profile membership based on Hispanic ethnicity, race and ethnicity, and birth country.

Bivariate associations between network norm profile and HIV risk and harm reduction behaviors

There were statistically significant differences between network norm profiles and study groups, our HIV risk index, and the harm reduction strategies examined. There were significant differences in distribution of profile membership by network norm profiles ($\chi 2 = 63.36$, $p < 0.01$). The lower risk network norm profile consisted of an equal distribution of study groups (~ 33%), the moderate risk with CBDO network norm profile consisted of a majority of participants who engaged in CBDU (81%), the moderate risk without CBDO network profile consisted of approximately equal distributions of participants who engaged in CBDU (44%) and Tijuana group (40%), and the higher risk network norm profile consisted of a majority of participants from the Tijuana group (71%). PWID in the higher network-risk norms profile reported more HIV vulnerability behaviors relative to the lower network-risk norms profile (2.59 vs. 1.79; F-value: 12.8, $p < 0.001$) and PWID in the two moderate network risk norms profile reported a similar number of behaviors (2.01 vs. 1.97). Interestingly, a higher proportion of PWID in both the higher (74.2%) and the lower (76.8%) network risk norms profiles had ever tested for HIV compared to the two moderate risk profiles (with CBDO = 47.1%; without CBDO = 61.7%; $\chi 2 = 16.35$, $p < 0.001$). Mean Likert scale value of consistency of injecting with a new, sterile syringe in the past 6 months varied by network profile, with the lower network risk norm

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Table 2 Fit indices for network norm HIV risk latent profile analysis

Profiles	AIC	BIC	Entropy	Prob. Min.*	Prob. Max.**	N Min.†	N Max. ‡	BSLRT p-value	BSLRT p-value
2	2017.95	2093.74	0.94	0.97	0.99	0.47	0.53	2095.75	0.01
3	2365.77	2485.44	0.87	0.89	0.99	0.25	0.48	855.67	0.01
4	1983.60	2135.18	0.91	0.90	0.99	0.08	0.47	951.35	0.01
5	1588.55	1772.04	0.92	0.86	1	0.07	0.40	232.193	0.01
6	1827.99	2043.40	0.84	0.04	1	0.01	0.36	316.92	0.99

*Prob. Min: Minimum of the diagonal of the average latent profile probabilities for most likely profile membership, by assigned profile; **Prob. Max: Maximum of the diagonal of the average latent profile probabilities for most likely profile membership, by assigned profile; †N Min.: Proportion of the sample assigned to the smallest profile (based on most likely profile membership); ‡N Max.: Proportion of the sample assigned to the largest profile (based on most likely profile membership)

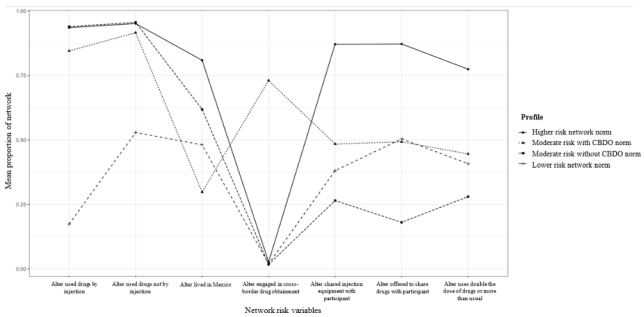

Fig. 1 Four profile LPA plot of network HIV risk norms within the social networks of PWID

profile reporting the highest consistency (mean = 4) and higher network risk norm reporting the lowest consistency (mean = 3.51; F-value = 3.97, p < 0.001).

Adjusted multivariate linear regression: HIV risk outcome

Relative to participants in the lower risk network norm profile, the HIV risk index score increased for participants in the moderate risk (with CBDO) network norm profile (β = 0.4; 95% CI: 0.02–0.78; p = 0.04) and higher risk network norm profile (β = 0.65; 95% CI: 0.38–0.91; p < 0.001). In addition, the HIV risk index score increased for those in the Tijuana study group who did not engage in CBDO (β = 0.64; 95% CI: 0.40–0.89; p < 0.001) relative to the CBDU study group. Full model specifications can be found in Table 3: **Model A**.

Table 3 Multivariate adjusted regression models examining associations between network norm profiles and HIV risk and harm reduction behaviors

	Model A: HIV Risk*			Model B: Injected with a new, sterile syringe*			Model C: Ever tested for HIV**		
Predictors	*Estimates*	*CI*	*p*	*Estimates*	*CI*	*p*	*Odds Ratios*	*CI*	*p*
(Intercept)	1.85	1.31–2.39	**< 0.001**	3.6	2.95–4.25	**< 0.001**	0.57	0.16–2.03	0.38
Study group									
(Ref: PWID who engage in CBDU)									
San, Diego (no CBDU)	0.13	-0.15–0.41	0.354	-0.09	-0.43–0.24	0.586	3.17	1.59–6.61	**0.001**
Tijuana (no CBDU)	0.64	0.40–0.89	**< 0.001**	-0.41	-0.70 – -0.12	**0.006**	1.48	0.86–2.55	0.154
Age	-0.00	-0.01–0.00	0.308	0	-0.01–0.01	0.61	1.02	1.00–1.04	0.083
Female sex assigned at birth	0.20	-0.02–0.42	0.08	-0.24	-0.51–0.03	0.079	1.43	0.84–2.49	0.192
(Ref: male)									
Hispanic identity	-0.11	-0.38–0.16	0.434	0.4	0.08–0.72	**0.015**	0.72	0.37–1.36	0.315
(Ref: not Hispanic)									
HIV sero-status	0.02	-0.33–0.37	0.916	0.1	-0.32–0.52	0.648	2.1	0.90–5.52	0.104
(ref = HIV negative)									
Alters	-0.03	-0.10–0.05	0.45	0.07	-0.02–0.16	0.119	1.21	1.01–1.45	**0.036**
Network risk norm profile									
Ref = Lower risk									
Moderate risk with CBDO	0.40	0.02–0.78	**0.04**	-0.47	-0.93 – -0.02	**0.041**	0.36	0.16–0.80	**0.013**
Moderate risk without CBDO	0.21	-0.04–0.47	0.096	-0.36	-0.66 – -0.06	**0.019**	0.56	0.32–1.00	**0.048**
Higher risk	0.65	0.38–0.91	**< 0.001**	-0.48	-0.79 – -0.17	**0.003**	0.94	0.51–1.77	0.847
Observations	399			399			398		
R^2 Tjur	0.162 / 0.141			0.076 / 0.052			0.1		

*Models A and B are linear regression models; **Model C is a logistic regression model

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Adjusted multivariate linear regression: injected with a new syringe harm reduction outcome

Participants in the moderate risk (with CBDO) network norm profile (β=-0.47; 95% CI: -0.93 – -0.02; p = 0.041), moderate risk (without CBDO) network norm profile (β=-0.36; 95% CI: -0.66 – -0.06; p = 0.019), and higher risk network norm profile (β=-0.48; 95% CI: -0.79 – -0.17; p = 0.003), relative to participants in the lower risk network norm profile, had significantly lower consistency of injecting with a new, sterile syringe. Participants who were in the Tijuana group (relative to CBDU; β=-0.41; 95% CI: -0.70 – -0.12; p = 0.006) also experienced decreased consistency in having used sterile syringes. However, participants who identified as Hispanic (relative to not Hispanic; β = 0.40; 95% CI: 0.08–0.72; p = 0.015) were more likely to inject with a new, sterile syringe in the past 6 months. Full model specifications are included in Table 3: **Model B**.

Results of adjusted multivariate logistic regression: ever tested for HIV harm reduction outcome

Participants who were in the moderate risk with CBDO network norm profile (OR = 0.36; 95% CI: 0.16–0.80; p = 0.013) and in the moderate risk without CBDO network norm profile (OR = 0.56; 95% CI: 0.32–1.00; p = 0.048) were less likely than participants in the lower risk network norm profile to have ever been tested for HIV. Relative to participants who engaged in CBDU, participants who were in the San Diego study group (OR = 3.17; 95% CI: 1.59–6.61; p = 0.001) were more likely to have had an HIV test. Those who reported more alters (OR = 1.21; 95% CI: 1.01–1.45; p = 0.036) were also more likely to have had an HIV test. Additional model specifications are included in Table 3: **Model C**.

Discussion

This study aimed to identify descriptive network-level risk norm profiles among three PWID groups who live along the US-Mexico border, and then identify associations between these profiles and individual-level HIV risk and harm reduction behaviors. We found that network descriptive norms could be categorized into distinct profiles and these profiles were associated with HIV risk and harm reduction behaviors. We identified four distinct profiles which described network norms: a lower risk network norm profile, a moderate risk network norm profile composed of alters who engaged in CBDO, a moderate risk network norm profile composed of alters who did not engage in CBDO, and a higher risk network norm profile. We found that PWID who were classified into moderate and higher risk network norm profiles (relative to the lower risk network norm profile) were significantly more likely to engage in individual-level HIV risk behaviors and significantly less likely to engage in HIV harm reduction behaviors.

Our findings suggest that CBDU, CBDO, and place of residency play a role in access to harm reduction strategies. For example, Tijuana-based PWID may have reduced access to sterile syringes as they are less likely to inject with a clean syringe relative to San Diego-based PWID who engage in CBDU. In addition, PWID who live in San Diego and do not engage in CBDU were more likely to have received an HIV test relative to PWID who live in San Diego and engaged in CBDU. These service gaps could have been compounded by the COVID-19 pandemic, which resulted in further cuts to the already meagre and irregular harm reduction budget in Tijuana and the disruption of health and harm reduction services in San Diego [29, 30]. The moderate risk profile with CBDO engaged in higher risk behaviors that the other moderate risk profile without CBDO and the lower risk profile, indicating that socializing with people who engage in CBDU is associated with higher individual-level HIV risk behaviors. Participants in the CBDU study group were defined as those who reported being a resident of San Diego who crossed the border to inject drugs in Tijuana within the 2 years prior to baseline. Thus, participants were different from their alters in the sense that participants did not specifically travel across the border to use, buy, or obtain drugs-they may have crossed the border for different reasons such as visiting family and then engaged in CBDU because they had already crossed the border into Mexico. If PWID who do not engage in CBDU have exposure to CBDU and CBDO norms and behaviors, they may have increased exposure to HIV within these drug use networks. PWID who engage in CBDU and CBDO may serve as a bridge between injection networks. Additionally access restrictions to harm reduction strategies and previous syringe sharing norms likely exacerbated HIV risk among PWID in Tijuana and our analysis indicates that engaging in CBDU and having people who engage in CBDU or CBDO in one's social network was associated with higher risk behaviors, and potentially amplified HIV vulnerability. Thus, interventions should take a social network approach and strive to change the network's norms of injection drug use.

Social network interventions provide an opportunity to decrease HIV risk network norms, decrease individual-level risk behaviors, and increase individual-level harm reduction behaviors [43]. A systematic review published in 2017 identified 58 studies which tested various social network strategies to increase HIV prevention among people who use substances [72]. Relevant to our priority population of PWID, social network interventions can leverage

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

social diffusion interventions and peer change agents; a peer change agent intervention could include PWID peers referring PWID to harm reduction services [18]. Another opportunity to intervene could be to distribute and facilitate access to syringes in settings such as Tijuana where harm reduction services are insufficient, but syringes are sold at pharmacies. Peer educators may also influence social norms by engaging in HIV harm reduction behaviors which can potentially change the descriptive norms or communication norms of a social network [18]. Bouchard et al. (2018) found that although a network may be saturated with people who practice some harm reduction behaviors, only a minority of networks consisted of PWID who were champions of harm reduction strategies [12]. We also found that more expansive social networks (i.e., higher number of alters named) was associated with ever testing for HIV, a harm reduction behavior. This suggests that increasing PWID's social network characteristics, such as network size could increase exposure to harm reduction services within networks and serve as an intervention component.

For social network interventions to be effective in eliciting the desired behavioral change (i.e., reducing HIV risk behaviors and increasing harm reduction behaviors), conversations must highlight network-level health promotion social norms so individuals are aware of their social network member's health behaviors [10]. Future interventions can consider including CBDU or CBDO reduction components; as networks with people who engage in CBDO may increase individual-level HIV vulnerability, or focusing on reducing risk behaviors among people who engage in CBDU, as these may be influential members in networks on both sides of the border. Previous research suggests that reducing the number of people within a network who inject could also decrease drug use by injection [73]. Another social network intervention could be to train PWID with large networks in buying syringes for themselves and others within their networks. Future studies and intervention research should also consider the multilevel and larger social contexts that PWID live in: violence, fear of withdrawal, and fear of police, among other issues, could serve as barriers to the harm reduction strategy of needle exchange.

Our study is unique because previous studies focus on injunctive norms instead of descriptive norms [1, 2, 11, 74, 75]. Our operationalization of social norms focuses on descriptive norms, which are observed, instead of injunctive norms, which are perceived. In addition, those studies that did include measures of descriptive norms did not use LPA, which can be powerful in identifying person-centered patterns of risk [1, 17]. However, our study is not without limitations. Our first limitation is the lack of social network data collected. Of a total of 612 participants, only 399 were included in our secondary analysis due to a lack of participant familiarity with network data collection, participants' loyalty and protection of their social networks, and potential mistrust with researchers. Some participants clearly stated during assessments that they would not share their network information with our study team. This may be due to police falsely impersonating researchers to gain access to drug use related information: in our San Diego site, study participants relayed stories of undercover police presence on the streets and infiltrating their networks. Significant police presence was observed in the surroundings of some of the recruitment spots in the community. However, addressing fear of police could be beneficial for harm reduction interventions. Previous interventions found that law enforcement officers could provide syringe exchange site referrals to PWID [76]; thus, improving the relationships between law enforcements officers and PWID could facilitate better data for future studies. Second, due to the retrospective self-report items in our questionnaire, we may have introduced recall bias. In addition, despite our data being longitudinal, we opted to use cross-sectional data for the present analyses and we did not examine change in risk profile or behaviors relative to prior to the COVID-19 related border closure. A future study will incorporate a longitudinal approach. Finally, we used an egocentric approach. A sociocentric approach, which includes the recruitment of an entire network, could have made our approach stronger. Examples of sociometric networks would include groups of people who inject together or who may engage in CBDU or CBDO together.

Conclusions

PWID had a gradient of HIV risk within their networks, based on network norms. PWID in social networks in which descriptive norms included higher risk HIV behaviors, such as CBDU/CBDO social norms, were more likely to engage in behaviors which increased behavioral vulnerability to HIV. Longitudinal research is needed to understand long term effects of border closure on network risk norms and HIV risk outcomes. Interventions should focus on reducing HIV risk among PWID with higher risk networks, particularly when services are limited and networks are PWID's main source of influence.

APPENDIX 1

Appendix 1 Drug use among PWID who engaged in CBDU

	Overall (N = 150)
Marijuana	

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Appendix 1 Drug use among PWID who engaged in CBDU

	Overall (N = 150)
No	66 (44.0%)
Yes	84 (56.0%)
Any black tar/heroin	
No	13 (8.7%)
Yes	137 (91.3%)
Primarily used Black tar heroin	
No	47 (31.3%)
Yes	103 (68.7%)
Primarily used brown powder heroin	
No	135 (90.0%)
Yes	15 (10.0%)
Methamphetamine/crystal meth	
No	44 (29.3%)
Yes	106 (70.7%)
Snorted methamphetamine/crystal meth	
No	79 (52.7%)
Yes	71 (47.3%)
Injected methamphetamine/crystal meth	
No	99 (66.0%)
Yes	51 (34.0%)
Injected heroin and methamphetamine/crystal meth together	
No	86 (57.3%)
Yes	64 (42.7%)
Fentanyl	
No	129 (86.0%)
Yes	21 (14.0%)

Acknowledgements We would like to acknowledge our mentors, and the men and women who shared their stories with us.

Authors' contributions Conceived and designed the analysis: CS, AB, SS, BS. Collected the data: AH, CV, GR. Contribute data or analysis tools: AB, TV, AC, IA, AH, CV, GR, SS. Performed the analysis: CS, BS. Wrote the paper: CS, BS, AB, TV, AC, IA, AH, CV, GR, SS. Edited the paper: CS, BS, AB, TV, AC, IA, AH, CV, GR, SS.

Funding This work was supported by the National Institute on Drug Abuse (Strathdee, Skaathun, Borquez, Vasylyeva, Chaillon: R01DA1049644; Skaathun: K01DA049665; Borquez: DP2 DA049295; Shrader: R25DA026401; Shrader: P30DA011041), the National Institute of Allergy and Infectious Diseases (Shrader: T32AI114398; Skaathun: P30AI036214; Vasylyeva: R01AI135992; Chaillon: R01AI145555; Chaillon: R24AI106039), the National Institute of Minority Health and Health Disparities (Shrader: F31MD015988), the National Institute of Mental Health (Chaillon: R01MH128153), the National Cancer Institute (Chaillon: DP2 CA051915) the San Diego Center for AIDS Research (Chaillon: AI306214; Chaillon: AI100665), the Branco Weiss Fellowship (Vasylyeva), the Department of Veterans Affairs (Chaillon), the John and Mary Tu Foundation (Chaillon), and the James B. Pendleton Charitable Trust (Chaillon).

Data Availability (data transparency) Data can be made available on a case by case basis by requesting permission from the senior author.

Code Availability The code can be made available on a case by case basis by requesting permission from the first author.

Declarations

Conflict of interest The authors declare no conflicts of interests or competing interests.

Ethics approval The University of California San Diego provided ethical approval for this project. Written informed consent was obtained from all participants to participate in the study. Participants were reimbursed for their time and transport costs.

Consent Written informed consent was obtained from all participants to participate in the study to participate.

Consent to participate Not applicable.

Consent for publication Not applicable.

References

1. Latkin C, Kuramoto S, Davey-Rothwell M, Tobin K. Social norms, social networks, and HIV risk behavior among injection drug users. AIDS Behav. 2010;14(5):1159–68.
2. Latkin CA, Forman V, Knowlton A, Sherman S. Norms, social networks, and HIV-related risk behaviors among urban disadvantaged drug users. Soc Sci Med. 2003;56(3):465–76.
3. Centers for Disease Control and Prevention. Surveillance Report HIV. 2019; vol 32 2021 [Available from: https://www.cdc.gov/hiv/pdf/library/reports/surveillance/cdc-hiv-surveillance-report-2018-updated-vol-32.pdf.
4. Bandura A. Social cognitive theory and exercise of control over HIV infection. PreventingS: Springer; 1994. pp. 25–59.
5. De P, Cox J, Boivin JF, Platt RW, Jolly AM. The importance of social networks in their association to drug equipment sharing among injection drug users: a review. Addiction. 2007;102(11):1730–9.
6. Sheehan DM, Miller RP, Trepka MJ, Smith LR, Latkin C. Role of Social Network Sexual Norms and Behaviors on the HIV Sexual Risk Behaviors of People Who Inject Drugs in HPTN 037. AIDS Behav. 2019;23(6):1604–11.
7. Bandura A. Social Cognitive Theory: An Agentic Perspective. Ann Rev Psychol. 2001;52(1):1–26.
8. McPherson M, Smith-Lovin L, Cook JM. Birds of a feather: Homophily in social networks. Ann Rev Sociol. 2001;27(1):415–44.
9. Latkin CA, Knowlton AR, Sherman S. Routes of drug administration, differential affiliation, and lifestyle stability among cocaine and opiate users: implications to HIV prevention. J Subst Abuse. 2001;13(1–2):89–102.
10. Latkin C, Donnell D, Liu TY, Davey-Rothwell M, Celentano D, Metzger D. The dynamic relationship between social norms and behaviors: the results of an HIV prevention network intervention for injection drug users. Addiction. 2013;108(5):934–43.
11. Andía JF, Deren S, Robles RR, Kang SY, Colón HM. Peer norms and sharing of injection paraphernalia among Puerto Rican injection drug users in New York and Puerto Rico. AIDS Educ Prev. 2008;20(3):249–57.
12. Bouchard M, Hashimi S, Tsai K, Lampkin H, Jozaghi E. Back to the core: A network approach to bolster harm reduction among persons who inject drugs. Int J Drug Policy. 2018;51:95–104.
13. Encyclopedia of Social Psychology. 2007 2022/02/14. Thousand Oaks Thousand Oaks, California: SAGE Publications, Inc. Available from: https://sk.sagepub.com/reference/socialpsychology.

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

14. Cialdini RB, Reno RR, Kallgren CA. A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places. J Personal Soc Psychol. 1990;58(6):1015.
15. Kincaid DL. From innovation to social norm: Bounded normative influence. J health communication. 2004;9(S1):37–57.
16. Latkin C, Donnell D, Celentano DD, Aramrattna A, Liu T-Y, Vongchak T, et al. Relationships between social norms, social network characteristics, and HIV risk behaviors in Thailand and the United States. Health Psychol. 2009;28(3):323–9.
17. Hadjikou A, Pavlopoulou ID, Pantavou K, Georgiou A, Williams LD, Christaki E, et al. Drug injection-related norms and high-risk behaviors of people who inject drugs in Athens, Greece. AIDS Res Hum Retroviruses. 2021;37(2):130–8.
18. Latkin CA, Knowlton AR. Social network assessments and interventions for health behavior change: a critical review. Behav Med. 2015;41(3):90–7.
19. Strathdee SA, Fraga WD, Case P, Firestone M, Brouwer KC, Perez SG, et al. "Vivo para consumirla y la consumo para vivir" ["I live to inject and inject to live"]: High-Risk Injection Behaviors in Tijuana, Mexico. J Urb Health. 2005;82(4):iv58–73.
20. Brouwer KC, Case P, Ramos R, Magis-Rodríguez C, Bucardo J, Patterson TL, et al. Trends in production, trafficking, and consumption of methamphetamine and cocaine in Mexico. Subst Use Misuse. 2006;41(5):707–27.
21. Rachlis B, Brouwer KC, Mills EJ, Hayes M, Kerr T, Hogg RS. Migration and transmission of blood-borne infections among injection drug users: understanding the epidemiologic bridge. Drug Alcohol Depend. 2007;90(2–3):107–19.
22. Strathdee SA, van Ameijden EJ, Mesquita F, Wodak A, Rana S, Vlahov D. Can HIV epidemics among injection drug users be prevented? Aids. 1998;12(Suppl A):71-9.
23. US Census Bureau. Quick Facts: San Diego County, California; California 2020 [Available from: https://www.census.gov/quickfacts/fact/table/sandiegocountycalifornia,CA/PST045219.
24. Data Mexico Beta. Tijuana: Municipality of Baja California [.
25. Russell C, Ali F, Nafeh F, Rehm J, LeBlanc S, Elton-Marshall T. Identifying the impacts of the COVID-19 pandemic on service access for people who use drugs (PWUD): A national qualitative study. J Subst Abuse Treat. 2021;129:108374.
26. Vasylyeva TI, Smyrnov P, Strathdee S, Friedman SR. Challenges posed by COVID-19 to people who inject drugs and lessons from other outbreaks. J Int AIDS Soc. 2020;23(7):e25583.
27. Costenbader EC, Astone NM, Latkin CA. The dynamics of injection drug users' personal networks and HIV risk behaviors. Addiction. 2006;101(7):1003–13.
28. Frost MC, Sweek EW, Austin EJ, Corcorran MA, Juarez AM, Frank ND, et al. Program Adaptations to Provide Harm Reduction Services During the COVID-19 Pandemic: A Qualitative Study of Syringe Services Programs in the U.S. AIDS Behav. 2022;26(1):57–68.
29. Department of Homeland Security. Fact Sheet: DHS Measures on the Border to Limit the Further Spread of Coronavirus. 2020.
30. Strathdee SA, Magis-Rodriguez C, Mays VM, Jimenez R, Patterson TL. The Emerging HIV Epidemic on the Mexico-U.S. Border: An International Case Study Characterizing the Role of Epidemiology in Surveillance and Response. Ann Epidemiol. 2012;22(6):426–38.
31. Mehta SR, Wertheim JO, Brouwer KC, Wagner KD, Chaillon A, Strathdee S, et al. HIV Transmission Networks in the San Diego–Tijuana Border Region. EBioMedicine. 2015;2(10):1456–63.
32. AidsVu. Local Data: San Diego County, CA 2022 [Available from: https://aidsvu.org/local-data/united-states/west/california/san-diego-county/#new-hiv-diagnoses.
33. Gobierno de Mexico S, de Salud. Direccion de Vigilancia Epidemiologica de Enfermedades Transmisisbles. Sistema de Vigilancia Epidemiologica de VIH: Informe Historico VIH-SIDA Cierre 2019 2010 [Available from: https://www.gob.mx/cms/uploads/attachment/file/578477/Informe_Hist_rico_2020_DVEET_VIH-Sida_Cierre_2019.pdf.
34. Skaathun B, Shrader C-H, Borquez A, Chaillon A, Vasylyeva T, Artamanova I et al, editors. High HIV Incidence among PWID on the US/Mexico Border during the COVID-19 Pandemic. CROI; 2022. February 12–16; Denver, Colorado.
35. Wagner KD, Moynihan MJ, Strathdee SA, Cuevas-Mota J, Clark M, Zuniga ML, et al. The social and environmental context of cross-border drug use in Mexico: findings from a mixed methods study of young injection drug users living in San Diego, CA. J Ethn Subst Abuse. 2012;11(4):362–78.
36. Wood EF, Werb D, Beletsky L, Rangel G, Cuevas Mota J, Garfein RS, et al. Differential experiences of Mexican policing by people who inject drugs residing in Tijuana and San Diego. Int J Drug Policy. 2017;41:132–9.
37. Arredondo J, Gaines T, Manian S, Vilalta C, Bañuelos A, Strathdee SA, et al. The law on the streets: Evaluating the impact of Mexico's drug decriminalization reform on drug possession arrests in Tijuana, Mexico. Int J Drug Policy. 2018;54:1–8.
38. Meacham MC, Roesch SC, Strathdee SA, Lindsay S, Gonzalez-Zuniga P, Gaines TL. Latent classes of polydrug and polyroute use and associations with human immunodeficiency virus risk behaviours and overdose among people who inject drugs in Tijuana, Baja California, Mexico. Drug Alcohol Rev. 2018;37(1):128–36.
39. Meacham MC, Strathdee SA, Rangel G, Armenta RF, Gaines TL, Garfein RS. Prevalence and Correlates of Heroin-Methamphetamine Co-Injection Among Persons Who Inject Drugs in San Diego, California, and Tijuana, Baja California, Mexico. J Stud Alcohol Drugs. 2016;77(5):774–81.
40. Rusch ML, Lozada R, Pollini RA, Vera A, Patterson TL, Case P, et al. Polydrug use among IDUs in Tijuana, Mexico: correlates of methamphetamine use and route of administration by gender. J Urban Health. 2009;86(5):760–75.
41. Meacham MC, Rudolph AE, Strathdee SA, Rusch ML, Brouwer KC, Patterson TL, et al. Polydrug Use and HIV Risk Among People Who Inject Heroin in Tijuana, Mexico: A Latent Class Analysis. Subst Use Misuse. 2015;50(10):1351–9.
42. Pergolizzi J, Magnusson P, LeQuang JAK, Breve F. Illicitly Manufactured Fentanyl Entering the United States. Cureus. 2021;13(8):e17496-e.
43. Yamanis TJ, Dervisevic E, Mulawa M, Conserve DF, Barrington C, Kajula LJ, et al. Social Network Influence on HIV Testing Among Urban Men in Tanzania. AIDS Behav. 2017;21(4):1171–82.
44. Drug Overdose Deaths in the U.S. Top 100,000 Annually [press release]. Atlanta, GA; 2021. November 17.
45. California Department of Public Health. California Overdose Surveillance Dashboard 2022 [Available from: https://skylab.cdph.ca.gov/ODdash/.
46. Wagner KD, Liu L, Davidson PJ, Cuevas-Mota J, Armenta RF, Garfein RS. Association between non-fatal opioid overdose and encounters with healthcare and criminal justice systems: identifying opportunities for intervention. Drug Alcohol Depend. 2015;153:215–20.
47. Yeager S, Abramovitz D, Harvey-Vera A, Vera CF, Algarin AB, Smith LR, et al. Factors Associated with COVID-19 Testing among People who Inject Drugs. medRxiv: Missed Opportunities for Reaching those Most at Risk; 2022.
48. Rivera Saldana CD, Abramovitz D, Meacham MC, Gonzalez-Zuniga P, Rafful C, Rangel G, et al. Risk of non-fatal overdose and polysubstance use in a longitudinal study with people who inject drugs in Tijuana, Mexico. Drug Alcohol Rev. 2021;40(7):1340–8.
49. Fleiz C, Arredondo J, Chavez A, Pacheco L, Segovia LA, Villatoro JA, et al. Fentanyl is used in Mexico's northern border: current challenges for drug health policies. Addiction. 2020;115(4):778–81.

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

50. Poklis A. Fentanyl: a review for clinical and analytical toxicologists. J Toxicology: Clin Toxicol. 1995;33(5):439–47.
51. Bourgois P, Bourgois PI, Schonberg J. Righteous dopefiend: Univ of California Press; 2009.
52. Ciccarone D, Bourgois P. Explaining the geographical variation of HIV among injection drug users in the United States. Subst Use Misuse. 2003;38(14):2049–63.
53. Talu A, Rajaleid K, Abel-Ollo K, Ruutel K, Rahu M, Rhodes T, et al. HIV infection and risk behaviour of primary fentanyl and amphetamine injectors in Tallinn, Estonia: implications for intervention. Int J Drug Policy. 2010;21(1):56–63.
54. Bórquez A, Garfein RS, Abramovitz D, Liu L, Beletsky L, Werb D, et al. Prevalence and Correlates of Injecting with Visitors from the United States Among People Who Inject Drugs in Tijuana, Mexico. J Immigr Minor Health. 2019;21(6):1200–7.
55. Ball AL. HIV, injecting drug use and harm reduction: a public health response. Addiction. 2007;102(5):684–90.
56. Iversen J, Wand H, Topp L, Kaldor J, Maher L. Extremely low and sustained HIV incidence among people who inject drugs in a setting of harm reduction. AIDS. 2014;28(2).
57. Fergusson DM, Horwood LJ, Ridder EM, Beautrais AL. Sexual orientation and mental health in a birth cohort of young adults. Psychol Med. 2005;35(7):971–81.
58. Strathdee SA, Abramovitz D, Harvey-Vera A, Vera CF, Rangel G, Artamonova I, et al. Prevalence and correlates of SARS-CoV-2 seropositivity among people who inject drugs in the San Diego-Tijuana border region. PLoS ONE. 2021;16(11):e0260286.
59. MedMira Laboratories Inc. Miriad: Rapid HCV/HIV antibody test [Available from: https://medmira.com/wp-content/uploads/2020/01/815311005954.pdf.
60. Reynolds SJ, Muwonga J. OraQuick® ADVANCE Rapid HIV-1/2 antibody test. Expert Rev Mol Diagn. 2004;4(5):587–91.
61. Weisberg S. Applied linear regression. John Wiley & Sons; 2005.
62. Stoltzfus JC. Logistic regression: a brief primer. Acad Emerg Med. 2011;18(10):1099–104.
63. Pastor DA, Barron KE, Miller BJ, Davis SL. A latent profile analysis of college students' achievement goal orientation. Contemp Educ Psychol. 2007;32(1):8–47.
64. Schwarz G. Estimating the Dimension of a Model. Ann Statist. 1978;6(2):461–4.
65. Akaike H. A new look at the statistical model identification. IEEE Trans Autom Control. 1974;19(6):716–23.
66. Akaike H. Likelihood and the Bayes procedure, in "Bayesian Statistics", ed. by JM Bernardo, MH DeGroot, DV Lindley, and AFM Smith. University Press, Valencia; 1980.
67. Celeux G, Soromenho G. An entropy criterion for assessing the number of clusters in a mixture model. J Classif. 1996;13(2):195–212.
68. Lo Y, Mendell NR, Rubin DB. Testing the number of components in a normal mixture. Biometrika. 2001;88(3):767–78.
69. McLachlan GJ, Peel D. Finite mixture models: John Wiley & Sons; 2004.
70. Lubke G, Neale MC. Distinguishing between latent classes and continuous factors: Resolution by maximum likelihood? Multivar Behav Res. 2006;41(4):499–532.
71. Jung T, Wickrama KA. An introduction to latent class growth analysis and growth mixture modeling. Soc Pers Psychol Compass. 2008;2(1):302–17.
72. Ghosh D, Krishnan A, Gibson B, Brown S-E, Latkin CA, Altice FL. Social Network Strategies to Address HIV Prevention and Treatment Continuum of Care Among At-risk and HIV-infected Substance Users: A Systematic Scoping Review. AIDS Behav. 2017;21(4):1183–207.
73. Rudolph AE, Upton E, Young AM, Havens JR. Social network predictors of recent and sustained injection drug use cessation: findings from a longitudinal cohort study. Addiction. 2021;116(4):856–64.
74. Davey-Rothwell MA, Siconolfi DE, Tobin KE, Latkin CA. The role of neighborhoods in shaping perceived norms: An exploration of neighborhood disorder and norms among injection drug users in Baltimore, MD. Health Place. 2015;33:181–6.
75. Davey-Rothwell MA, Latkin CA. Gender differences in social network influence among injection drug users: Perceived norms and needle sharing. J Urb Health. 2007;84(5):691–703.
76. Olgin GK, Bórquez A, Baker P, Clairgue E, Morales M, Bañuelos A, et al. Preferences and acceptability of law enforcement initiated referrals for people who inject drugs: a mixed methods analysis. Substance Abuse Treatment, Prevention, and Policy. 2020;15(1):75.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Content courtesy of Springer Nature, terms of use apply. Rights reserved.

Terms and Conditions

Springer Nature journal content, brought to you courtesy of Springer Nature Customer Service Center GmbH (“Springer Nature”).
Springer Nature supports a reasonable amount of sharing of research papers by authors, subscribers and authorised users (“Users”), for small-scale personal, non-commercial use provided that all copyright, trade and service marks and other proprietary notices are maintained. By accessing, sharing, receiving or otherwise using the Springer Nature journal content you agree to these terms of use (“Terms”). For these purposes, Springer Nature considers academic use (by researchers and students) to be non-commercial.
These Terms are supplementary and will apply in addition to any applicable website terms and conditions, a relevant site licence or a personal subscription. These Terms will prevail over any conflict or ambiguity with regards to the relevant terms, a site licence or a personal subscription (to the extent of the conflict or ambiguity only). For Creative Commons-licensed articles, the terms of the Creative Commons license used will apply.
We collect and use personal data to provide access to the Springer Nature journal content. We may also use these personal data internally within ResearchGate and Springer Nature and as agreed share it, in an anonymised way, for purposes of tracking, analysis and reporting. We will not otherwise disclose your personal data outside the ResearchGate or the Springer Nature group of companies unless we have your permission as detailed in the Privacy Policy.
While Users may use the Springer Nature journal content for small scale, personal non-commercial use, it is important to note that Users may not:

1. use such content for the purpose of providing other users with access on a regular or large scale basis or as a means to circumvent access control;
2. use such content where to do so would be considered a criminal or statutory offence in any jurisdiction, or gives rise to civil liability, or is otherwise unlawful;
3. falsely or misleadingly imply or suggest endorsement, approval , sponsorship, or association unless explicitly agreed to by Springer Nature in writing;
4. use bots or other automated methods to access the content or redirect messages
5. override any security feature or exclusionary protocol; or
6. share the content in order to create substitute for Springer Nature products or services or a systematic database of Springer Nature journal content.

In line with the restriction against commercial use, Springer Nature does not permit the creation of a product or service that creates revenue, royalties, rent or income from our content or its inclusion as part of a paid for service or for other commercial gain. Springer Nature journal content cannot be used for inter-library loans and librarians may not upload Springer Nature journal content on a large scale into their, or any other, institutional repository.
These terms of use are reviewed regularly and may be amended at any time. Springer Nature is not obligated to publish any information or content on this website and may remove it or features or functionality at our sole discretion, at any time with or without notice. Springer Nature may revoke this licence to you at any time and remove access to any copies of the Springer Nature journal content which have been saved.
To the fullest extent permitted by law, Springer Nature makes no warranties, representations or guarantees to Users, either express or implied with respect to the Springer nature journal content and all parties disclaim and waive any implied warranties or warranties imposed by law, including merchantability or fitness for any particular purpose.
Please note that these rights do not automatically extend to content, data or other material published by Springer Nature that may be licensed from third parties.
If you would like to use or distribute our Springer Nature journal content to a wider audience or on a regular basis or in any other manner not expressly permitted by these Terms, please contact Springer Nature at

onlineservice@springernature.com