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Identifying Which Place Characteristics are Associated with the Odds of Recent HIV Testing in a Large Sample of People Who Inject Drugs in 19 US Metropolitan Areas

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Abstract

This exploratory analysis investigates relationships of place characteristics to HIV testing among people who inject drugs (PWID). We used CDC's 2012 National HIV Behavioral Surveillance (NHBS) data among PWID from 19 US metropolitan statistical areas (MSAs); we restricted the analytic sample to PWID self-reporting being HIV negative (N = 7477). Administrative data were analyzed to describe the 1. Sociodemographic Composition; 2. Economic disadvantage; 3. Healthcare Service/Law enforcement; and 4. HIV burden of the ZIP codes, counties, and MSAs where PWID lived. Multilevel models tested associations of place characteristics with HIV testing. Fifty-eight percent of PWID reported past-year testing. MSA-level per capita correctional expenditures were positively associated with recent HIV testing among black PWID, but not white PWID. Higher MSA-level household income and imbalanced sex ratios (more women than men) in the MSA were associated with higher odds of testing. HIV screening for PWID is suboptimal (58%) and needs improvement. Identifying place characteristics associated with testing among

Compliance with Ethical Standards

Conflict of interest The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Ethical Approval Each author has contributed to the conception and design of the work, the acquisition of data or the analysis of the data in a manner substantial enough to take public responsibility for it. In addition, each author believes that the paper represents valid work and has reviewed the final version of the manuscript and approves it for publication. The findings in this paper have not been published and are not being considered elsewhere for publication.

Ethics Emory University's Institutional Review Board (IRB) approved this study's protocols; each NHBS site's IRB approved the NHBS protocol. CDC reviewed and approved the protocol as non-engaged research.

PWID can strengthen service allocation and interventions in areas of need to increase access to HIV testing.

Keywords

Place characteristics; HIV testing; People who inject drugs; National HIV Behavioral Surveillance; US metropolitan statistical areas

Introduction

HIV testing is the first step to enable persons who inject drugs (PWID) to know their HIV status, be linked to medical care and services that improve survival, and reduce the likelihood that they will transmit HIV to others [1–3]. CDC recommends persons at high risk of infection, including PWID, to be tested for HIV at least annually [4].

To date, almost all research into the determinants of HIV testing among PWID has examined individual-level covariates (e.g., age, gender, race/ethnicity, service utilization) [5–9]. The influence of *place-based* processes on HIV testing among PWID has been understudied. Understanding how place-based processes affect HIV testing rates may help us develop effective interventions and public policies to increase testing. Public health agencies, for example, could use place-based findings to direct enhanced HIV testing outreach efforts to high-need areas, and to develop interventions targeting place characteristics themselves or factors linking these characteristics to testing.

The research presented here *explores* which place characteristics are associated with recent HIV testing in a sample of PWID living in 19 large US metropolitan statistical areas (MSAs). Our selection of place-based constructs was guided by the Rhodes' Risk Environment Model (REM). Rhodes' REM highlights the situations, structures, and places that may influence drug-related harms and HIV-related health service use among PWID [10–17]. This framework hypothesizes that factors associated with HIV-related health and health service use operate at multiple levels, including those within geographic areas. Based on past literature [10–13, 15–21], we posit that the following domains of the risk environment will be associated with recent testing among PWID: 1. Sociodemographic Composition; 2. Economic Disadvantage; 3. Healthcare Service/Law Enforcement; and 4. HIV Burden. Based on past literature [22, 23], we adapted REM to include HIV Burden. Past research suggests that the magnitude of relationships between place characteristics and drug- and HIV-related outcomes among PWID might vary by individual race/ethnicity [15, 16, 19, 24–28]. We investigated that possibility in these analyses.

Methods

Sampling and Recruitment

Data were collected as part of the CDC's National HIV Behavioral Surveillance (NHBS), a CDC-funded multi-city annual cross-sectional survey designed to characterize HIV prevalence, behavioral risks among high-risk populations and extent and nature of these populations' contact with HIV related services [29]. Research presented here is based on

data from the 2012 NHBS cycle among PWID. NHBS's study design has been described in detail elsewhere [30, 31]. Briefly, in 2012, NHBS used respondent-driven sampling (RDS), a modified chain-referral method, to recruit PWID from 20 U.S. cities for a survey measuring HIV-related variables [30]. NHBS eligibility criteria for PWID were age ≥ 18 years; reported injection drug use in the past year; demonstrated evidence of injection (e.g., track marks); resided in an NHBS-eligible MSA; and provided oral consent. Collectively, the 20 NHBS MSAs represented 59% of all persons living with HIV infection in large MSAs in the US at the end of 2009 [29]. This analytic sample was limited to people who self-reported that they were HIV-negative. NHBS participants were excluded from analyses if they had an incomplete survey; lacked racial/ethnic information or ZIP code; or (because of small numbers) identified as transgender or non-Hispanic race other than white or black (alone or in combination). Individuals living in San Juan/Bayamon were also excluded because data on several place-based characteristics are not available for this MSA. A total of 7477 participants met eligibility criteria in the remaining 19 MSAs.

Measures

HIV testing in the past year—The dependent variable is the odds of an individual getting tested for HIV in the past year, and was drawn from NHBS.

Individual race/ethnicity—We analyzed NHBS participants' self-report data to create three mutually exclusive racial/ethnic groups: Latino, white, and black [15, 16].

Geographic scale—Participants reported the ZIP code and county where they lived. Homeless participants were assigned to ZIP codes and counties based on where they usually slept. Participants were linked to MSAs via data collection site.

Individual-level measures—Data about participant drug use behaviors (e.g., years since first injection), demographic characteristics, and other potential confounders were drawn from NHBS.

Place-based exposures—We analyzed place-based measures of sociodemographic, economic disadvantage, health care/law enforcement and HIV burden characteristics of the ZIP codes, counties, and MSAs where PWID lived (Table 1). REM typically includes a political environment domain, but we could not measure characteristics of that domain for all 19 MSAs. We added the healthcare/law enforcement intervention domain because of these interventions' potent effects on drug-related dependent variables [15, 17, 19–21, 24]. Thus, specific characteristics of each domain were selected based on past research about place and PWID risk environments among PWID, within the constraints of available place-based data. The geographic scale (i.e., ZIP code vs. county vs. MSA) at which we operationalized each place characteristic was determined by our conceptualization of the characteristic itself and data availability. For example, we assessed racial/ethnic residential segregation (measured using the Isolation Index[1]) within MSAs, and not within ZIP codes or counties, because segregation has been produced, in part, by the exodus of whites from

[1]The isolation index measures the extent to which minority members are exposed only to one another, and was calculated per Massey and Denton [32]. The isolation index varies from 0 (no isolation) to 100 (complete isolation).

central cities to suburbs (though white suburban workers continue to work in central cities) [32]. Unless otherwise noted in Table 1, we created measures capturing 2012 or the closest prior year.

Sociodemographic composition characteristics captured demographic compositions of places, such as age structure, gender composition, and racial/ethnic composition.

Economic disadvantage characteristics measures included percent of households below the federal poverty line; percent of adults in labor force who were unemployed; and percent of adults without a high school diploma or general equivalency diploma.

Healthcare Service/Law Enforcement intervention characteristics are characteristics of the service and criminal justice environments that may facilitate or impede HIV healthcare utilization. Measures included spatial access to substance use disorder treatment programs, HIV testing sites, syringe service programs (SSPs) and methadone treatment programs (MTP); percent of adults living without health insurance; per capita expenditures on corrections and policing; and arrest rates for possessing any drug or for possessing hard drugs. As described in detail elsewhere [15], we used gravity-based methods to estimate spatial access to drug- and HIV-related health services for PWID. The measure was created using a 3-mile radius around each ZIP code's centroid. This method generates a unit-less measure, with higher values indicating better spatial access. Measures of spatial access to MTPs, SSPs, and HIV testing sites had many zero values, and so we dichotomized them (0 = no access vs. > 0 = some spatial access, according to the measure).

HIV burden characteristics are measured using epidemiological indicators such as the AIDS diagnosis rate among PWID in year 2008, and AIDS-related mortality rates in a community of PWID in year 2008.

Analysis Strategy

Variables describing place-based characteristics by domain (1. Sociodemographic Composition; 2. Economic Disadvantage; 3. Healthcare Service/Law Enforcement; and 4. HIV Burden) were merged with individual-level NHBS data. Descriptive statistics were used to characterize distributions of past-year testing, individual-level covariates, and each place-based covariate. Modeling progressed through the following *4 steps* to assess the relationships of each place characteristic to the odds of past-year testing:

Step 1—Some place-based measures were correlated with one another. To minimize multicollinearity in multivariable models, we used principal components analysis (PCA) with varimax rotation to combine correlated variables into uncorrelated components. PCAs were conducted for each domain within each geographic scale; resulting component scores were standardized.

Step 2: Bivariate Analyses—Bivariate hierarchical generalized linear models (HGLMs) were constructed to explore the relationship of each place characteristic to the dependent variable, and to determine whether individual race/ethnicity moderated this association. (The term "bivariate" is used here to also include models with a single place-based characteristics,

indicator variables for individual race/ethnicity, and the interactions of the place-based exposures with these indicator variables.) In all HGLMs, three-level models were constructed (individuals nested in ZIPs; ZIPs in counties; and counties in MSAs) with random intercepts for each scale. Place characteristics associated with the dependent variable at $p < 0.05$ (as main effects or interacted with race/ethnicity) were carried forward into Step 3.

Step 3: Geographic-Level-Specific Analyses—We next created geographic-specific models (one for MSA-level exposures, one for county-level exposures, and one for ZIP code-level exposures) to allow exposures to compete at the same level to be included in the final multivariable model. Each geographic-level-specific model started with all significant bivariate variables for that level from Stage 2 (cutpoint of $p < 0.05$), and eliminated exposures using backward stepwise selection (cutpoint of $p < 0.05$). The variables that remained were incorporated into the Step 4 model. Results for models by geographic-level are displayed in Appendix 1.

Step 4: Multilevel Multivariable Models—In this exploratory analysis, we constructed a multivariable HGLM that contained all significant (i.e., cutpoint of $p < 0.05$) place-based features (within ZIP codes, counties, and MSAs) from Step 3, individual-level race/ethnicity, and possible individual-level confounders (e.g., age, gender). Backward selection ($p < 0.05$ cutpoint) was used to create a more parsimonious final multivariable, multilevel model. Tests for race/ethnicity as a moderator generated three tests for each possible predictor: the test for odds ratio (OR) white = 1; the test for OR black/OR white ratio = 1 (or equivalently OR black = OR white), and a test for OR Latino/OR white ratio = 1 (or equivalently OR Latino = OR white). Thus there were *two tests for interaction*, or to determine if there were racial/ethnic differences in the association between the place-characteristic and the dependent variable. If these were significant, then *racial/ethnic-specific* ORs were examined: OR white was given, and black-specific and Latino-specific ORs were calculated respectively as OR black*OR white and OR Latino*OR white; significance tests of *racial/ethnic-specific* OR = 1 were generated using linear combinations of model estimates.

We re-ran this final multivariable model without select possible individual-level mediators of relationships between place characteristics and the outcome (e.g., health insurance, homelessness) to begin to explore whether they might mediate these relationships. ORs were compared across models, and a cutpoint (> 10%) was used to assess differences in OR magnitude for place characteristics across models. Results are displayed in models A and B.

Results

Sample Description

The distributions of characteristics of HIV-negative PWID participants included in the sample are presented in Table 2 (N = 7477). Fifty-eight percent of PWID reported past-year testing in 2012 (white = 55.6%; black = 58.1%; Latino = 59.5%). Approximately half (48.8%) of the PWID were black; 30.0% were white; and 21.2% were Latino. Slightly more than a quarter (29.6%) were female and the average age was 46.4 years (SD = 11.2). The great majority of participants were impoverished and 35.9% were currently homeless.

Participants had injected drugs for an average of 23.4 years (SD = 13.6); primarily injected heroin (66.0%); and most injected more than once a day (59.5%). Appendix 2 discusses in detail the distributions of characteristics of places where PWID live from the NHBS sample.

Multilevel Results

Table 3 (place covariates) and Table 4 (individual-level covariates) display the results of the bivariate analyses; Table 5 displays the final multivariable model (i.e., Stage 4 of our model.)

Sociodemographic composition domain—Multivariable model A indicates that the odds that PWID reported past-year HIV testing were 81% higher (OR = 1.56; p = 0.02; AOR = 1.81; p < 0.0005) in MSAs where there were ≥ 1.05 women for every man compared to MSAs with more equal ratios of women to men.

Economic disadvantage domain—Multivariable model A suggests that higher MSA-level median income was associated with a greater odds of past-year HIV testing. Specifically, PWID living in MSAs that had 1 SD higher median income (approx. $14,522 higher per year) had a 30% higher odds of reporting past-year HIV testing (OR = 1.24; p = 0.02; AOR = 1.30; p = 0.01).

Healthcare Service/Law Enforcement intervention domain—Associations of the relationship between MSA-level correctional expenditures and past-year testing varied by individual-level race/ethnicity (black*white interaction AOR = 1.15, p = 0.02; Latino*white interaction AOR = 1.30, p = 0.01). Racial/ethnic-specific AORs indicate that while there was no relationship between MSA-level correctional expenditures and the dependent variable among white PWID (AOR = 1.10, p=0.24; Table 6), among black PWID one SD higher correctional expenditures was associated with a 26% higher odds of reporting past-year testing (racial/ethnic-specific AOR = 1.26, p = 0.003). Among Latinos, one SD higher correctional expenditures was associated with 42% higher odds of past-year testing (racial/ethnic-specific AOR=1.42, p=0.002).

Variables capturing arrest rates did not meet statistical screening criteria for inclusion in the final model. In bivariate models, county-level arrests for drug possession were associated with higher odds of being HIV tested (OR = 1.24; p = 0.02), and the MSA-level component for police expenditures was positively associated with HIV testing (OR = 1.22; p=0.03).

Bivariate models indicated that spatial access to HIV testing sites, substance use disorder treatment, and SSPs were associated with higher odds of past-year testing in the full sample, and, in models with interactions by individual race/ethnicity, mainly for Latino compared to white PWID. For substance use disorder treatment, the relationship was also significant for white PWID, but lost significance in Step 4. The interaction effects for access to SSPs and HIV testing lost significance in Step 3, when other ZIP-level variables were included in the model, and were dropped from multivariable models.

While our multivariable model suggests that the relationship between the percent of county residents without health insurance and past-year testing might vary across racial/ethnic groups (black*white interaction AOR = 1.16, p = 0.08), further probing of this interaction

found that this place-based exposure was unrelated to testing in all racial/ethnic groups (Table 6).

As noted, some individual-level variables included in Model A might have mediated relationships between place characteristics and past-year testing (e.g., employment status, injection frequency). Notably, however, AORs for relationships between place characteristics and past-year testing did not change > 10% when individual-level mediators were removed from the final model (Table 5, Model B).

Discussion

This multilevel analysis found that several characteristics of the 19 MSAs in this study where PWID live are associated with past-year HIV testing. To our knowledge, this is the first analysis to assess which place characteristics are associated with recent HIV testing in a sample of (HIV-negative) PWID, and to explore potential covariates operating at *multiple* geographic scales. The following important findings were observed in these analyses: (1) PWID living in MSAs with a higher median household income were more likely to be tested for HIV; (2) PWID living in MSAs with more women than men were more likely to get tested; and (3) higher MSA-level correctional expenditures were associated with a greater likelihood of HIV testing for black and Latino PWID, but not white PWID.

Prior research documents that place-based economic conditions are related to a variety of health and social outcomes [21, 33, 35–43], however the influence of economic conditions on HIV testing among PWID has been understudied. Notably, place-based economic conditions may be an important determinate of HIV and HIV morbidity. The few studies on this topic in the general population suggest that this is a promising line of inquiry. Setia et al. [44] for example, found that men and women living in the most materially deprived neighborhoods in Canada were less likely to report HIV testing than those living in the least deprived neighborhoods. This present study likewise found that MSA-level median household income was positively related to the likelihood of being tested for HIV among PWID. Future research regarding testing initiatives for PWID should potentially prioritize MSAs with lower household incomes, and explore pathways linking MSA median income to testing.

Within the criminal justice domain, the positive relationship of per capita MSA-level correctional expenditures to the odds of past-year testing among black and Latino PWID may be the result of higher rates of incarceration among black and Latino PWID, spurred by racialized policing and the war on drugs [15–17, 19, 21, 42, 45]. In 2010, black men had an incarceration rate that was nearly six times that of White men, and almost two and a half times that of Latino men [46]. While incarceration has multiple adverse effects for PWID, their families, and social networks, the correctional setting is often the first place PWID might be diagnosed with HIV [47–49], making it an important avenue for HIV testing and linkage to care [47–50]. As such, it may be that MSAs with higher correctional expenditures invest more in health services (including HIV testing) for inmates interacting with the system [50–52].

The association between correctional expenditures and HIV testing may highlight the importance of HIV testing and linkage to care programs in jails and prisons, as well as being an effective setting in which to initiate risk reduction intervention and maintain HIV-positive PWID on ART [49–52], thereby placing a greater emphasis on health and health care for those incarcerated. In addition, correction centers are increasingly seen as a place to assist persons with HIV-positive partners in accessing needed services, including HIV testing [52].

This study found that PWID living in MSAs with a higher ratio of women versus men had higher odds of reporting past-year HIV testing. The association between imbalanced sex ratios (specifically, more women relative to men) and past-year testing may be attributable to the criminal justice system. Mass incarceration disproportionately removes men from the community, creating imbalanced sex ratios [53–55]. Thus, our sex ratio finding may simply be an echo of the incarceration rate finding, discussed above. Future research on the relationship of sex ratios to testing behaviors is warranted, and if associations are found, mediators of the relationship between the presence of more women relative to men and testing should be explored.

Our bivariate models found associations between past-year HIV testing and spatial access to HIV testing, substance use disorder treatment programs, and SSPs, both for the sample overall and, in models with interactions with individual race/ethnicity, for Latinos versus white PWID. Most measures of spatial access to health services dropped out during the modeling process, when other covariates were included. The interaction of spatial access to substance use disorder treatment with individual race/ethnicity was carried forward from Step 3, in which the ZIP-level model indicated a positive relationship between spatial access to substance use treatment and past-year testing for each racial/ethnic group. This substance use treatment by race/ethnicity interaction dropped out during the backward selection process in Step 4, suggesting that this relationship was confounded by characteristics of individuals (e.g., age) and/or of other geographic scales (MSA-median income).

Lastly, and importantly, current HIV screening for PWID is suboptimal (58%) and needs to be improved. Approaches to improve screening rates might include expanding harm reduction services which provide ‘user friendly services’ and work to reduce HIV-related stigma and discrimination while stressing the importance of confidentiality [21, 56–63]. Likewise, increased state and local funding for community-based programs (including SSPs) which provide multiple services including access to substance use disorder treatment programs, MTP and access to mental health services for both PWID clients and family might improve HIV testing rates especially in low-resource settings [9, 63–68].

Limitations

This research has several limitations to consider. First some participants (about 4%) lived in ZIP code areas that crossed county boundaries. In these cases we assigned participants to the county where most other participants in that ZIP code lived. This may result in some misclassification of county-level exposures for these participants. Given the small number of affected participants it is unlikely that our main conclusions were affected. Secondly, our measures of place only capture PWID residential environments. These data do not capture

places where PWID purchase and use drugs, have sex, work, or engage in other daily activities. The extent to which PWID engage in these behaviors outside of their home ZIP code area, county or MSA may vary across racial/ethnic groups in unknown ways. Additionally, census-derived place-based measures used ZIP Code Tabulation Areas rather than ZIP codes, potentially generating mis-classification of exposure. The resulting exposure mis-classification likely biased effect estimates to the null.

In addition, NHBS intentionally sampled MSAs that had high AIDS burden; findings may thus not be generalizable to MSAs with lower AIDS burden or to non-urban areas. As is the case with most studies of PWID, the NHBS sample may not reflect the underlying population of PWID in the study areas (here, the 19 MSAs). For example, NHBS may have under-sampled young PWID who lived in the suburbs or rural areas, and these and perhaps other under-sampled PWID may differ systematically from those sampled by NHBS in ways that affect the relationships studied here. NHBS used RDS to generate the PWID sample; we were not able to adjust for within-chain dependence because we were accounting for four other levels (individuals, ZIPs, counties, and MSAs). Confidence intervals for some effect estimates may thus be artificially narrow. Lastly, recent initiatives to provide ART to all HIV-positive persons have become recommended policy. Thus, it is possible that relationships between place and testing may have changed because ART policies have changed. Finally, these analyses are limited to cross-sectional associations.

Conclusions

The research presented here investigated which place characteristics are associated with recent HIV testing in a large sample of PWID in 19 large US metropolitan statistical areas. This paper found that specific MSA-level characteristics of the places where PWID live, (i.e., MSAs with a higher median household income; MSAs with more women than men; and higher MSA-level correctional expenditures) are associated with past-year HIV testing; some relationships varied by race/ethnicity. *Our study was exploratory*. If future research confirms our conclusions, these findings may support the development of new place-based interventions to increase HIV testing among PWID. Identifying place characteristics associated with the odds of HIV testing is potentially important to public health agencies, which can use these insights to direct enhanced HIV-testing outreach efforts to areas of high need. Likewise, understanding how place-based processes affect PWID utilization of, and access to, HIV testing services may help us develop effective health and social interventions to increase testing among this high-risk population. These findings contribute a growing body of literature on the influence of place-based characteristics on injection-related risk environments [15–17, 25–28, 69, 70].

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Appendix 1

See Table 7.

Appendix 2: Characteristics Among Self-Reported HIV-Negative PWID (N = 7477), Drawn from the 2012 Centers for Disease Control and Prevention's National HIV Behavioral Surveillance

Description of the Places Where PWID Lived

Sociodemographic composition characteristics

On average, PWID lived in ZIP codes where 26.7% (SD = 23.4) of PWID are white, 38.9% (SD = 31.7) black and 24.8% (SD = 23.9) Latino. MSA-level average black residential isolation index was 44.8% (SD = 20.6) and the average Latino isolation index was 37.3% (SD = 16.8) (Appendix A).

Economic disadvantage characteristics

The mean ZIP code poverty rate for PWID was 28.4% (SD = 11.4); in comparison, the mean county-level poverty rate was 18.8% (SD = 5.2), and the mean MSA-level poverty rate 14.4% (SD = 4.3). On average PWID lived in ZIP codes with a median household income of $40,909.00, in counties where the median income was $54,817.00, and in MSAs where the median income was $66,668.00.

Healthcare Service/Law Enforcement intervention characteristics

In this sample, the mean ZIP code distance (i.e., 3 mile radius) for spatial access to substance use disorder treatment facilities was 1.8 (SD = 2.2). On our dichotomous measures of spatial access to other health services for PWID, we found that 77.4% of PWID lived in ZIP codes where spatial access to HIV testing sites > 0 (i.e., there was ≥ 1 testing site within 3 miles of the ZIP's centroid), 63% had some spatial access to an MTP, and 48.8% had some spatial access to an SSP.

On average, PWID lived in counties where 22.0% (SD = 8.7) of residents were without health insurance, and where 16.9% (SD = 21.1) of residents lived in medically underserved areas. On average, PWID were located in counties where arrest rates for hard drug possession were 3.6 per 1000 population (SD = 3.1), and in MSAs where arrest rates were 2.8 per 1000 population (SD = 1.4).

On average, PWID lived in MSAs that spent $333.60 per capita on police (SD = 95.1), $97.60 per capita on corrections (SD = 44.7), and $163.60 per capita on health care (SD = 170.0).

HIV burden characteristics

On average, PWID lived in MSAs where annual AIDS-related mortality rates among PWID were 1.37 per 1000 PWID (SD = 1.8) and where annual AIDS diagnoses among PWID were 0.89 per 1000 PWID (SD = 0.9).

See Table 8.

Table 1

Place-based constructs, variables studied and data sources

Domain	Place construct	Variables (geographic scale)	Data source(s)
Sociodemographic composition	Availability of sex partners (male:female sex ratios)	Male:female sex ratio for adults (18–64 years; ZIP, county, MSA)[a]	2010 Decennial Census[b,c]
	Racial/ethnic composition	Percent of total population who are non-Hispanic white, non-Hispanic black/African-American, or Hispanic/Latino (ZIP)	American Community Survey (ACS) 5-year Estimates (2007–2011)[b]
	Racial/ethnic residential segregation	Black isolation index (MSA)[d]	2010 US Decennial Census
		Latino isolation index (MSA)[d]	2010 US Decennial Census
Economic disadvantage	Exposure to economic disadvantage	Median household income (ZIP; county; MSA)	ACS 5-year Estimates (2007–2011)[b]
		Percent of households below federal poverty line (ZIP; county; MSA)	ACS 5-year estimates (2007–2011)[b]
		Percent of adults (≥ 16 years) in labor force who are unemployed (ZIP; county; MSA)	ACS 5-year estimates (2007–2011)[b]
		Percent of adults (≥ 25 years) without a high school diploma or general equivalency diploma (ZIP; county; MSA)	ACS 5-year estimates (2007–2011)[b]
	Income inequality	Gini coefficient (MSA)	2010 Decennial Census
Health and law enforcement interventions	Spatial access to substance use disorder treatment- and HIV-related programs	Density of HIV testing sites per square mile (ZIP)	Numerator (testing sites): CDC's 2009 National HIV Prevention Program Monitoring & Evaluation database Denominator (square miles): US Census TIGER Files[e] This variable was dichotomized (0 vs. > 0) in analyses because of its skewed distribution
		Spatial access to substance use disorder treatment programs, (a) overall; (b) methadone treatment programs (MTPs) and; (3) Syringe service programs (SSP) (ZIP)	Gravity-based methods were used to measure spatial access to treatment sites; data on treatment site location were available in SAMHSA's National Directory of Drug and Alcohol Abuse Treatment Programs The MTP access variable was dichotomized (0 vs. > 0) in analyses because of its skewed distribution.
		Access to syringe service programs (SSP), (a) overall, and as classified by whether they (b) limit participants to one-for-one exchange, and (c) cap the number of syringes one can get in a single visit (ZIP)	Gravity-based methods were used to measure spatial access to treatment sites; data on treatment site location were available from Des Jarlais' annual SSP survey This variable was dichotomized (0. vs. > 0) in analyses because of its skewed distribution.
	Access to general health care	Percent of adults (18–64 years) who are uninsured (county)	2012–2013 Area Health Resource File[f]
		Percent of residents living in a medically underserved area (county)	2013 Health Professional Shortage Area Dataset[e]

Domain	Place construct	Variables (geographic scale)	Data source(s)
	Exposure to law enforcement	Arrest rate for hard drug possession[g], per 1000 adults, by race/ethnicity (18–64 years; county, MSA)	Numerator (possession arrests by race/ethnicity): 2009 ICPSR county-level detailed arrest and offense data); Denominator (adults 18–64 years, by race/ethnicity): ACS 5-year estimates (2007–2011)
		Arrest rate for possession of any drug, per 1000 adults, by race/ethnicity (18–64 years; county, MSA)	Numerator (possession arrests, by race/ethnicity): 2009 ICPSR county-level detailed arrest and offense data Denominator (adults 18–64 years, by race/ethnicity): ACS 5-year estimates (2007–2011)
		Jail incarceration rate, per 1000 adults by race/ethnicity (18–64 years; MSA)	Numerator (jail inmates by race/ethnicity): 2010 Decennial census Denominator (adults 18–64 years by race/ethnicity): 2010 Decennial Census
	Health and Law enforcement expenditures	Per capita expenditures on police (MSA)	Numerator (expenditures in USD): 2007 Census of Governments County Area Finances File
		Per capita expenditures on health (MSA)	Denominator (total population): US Census Bureau Population
		Per capita expenditures on corrections (MSA)	Estimates Program
HIV burden	Loss of PWID population to AIDS during the HAART era	AIDS-related mortality rates for PWID during the HAART era, by race/ethnicity (MSA)	Numerator (total AIDS-related deaths from 1998–2008, by race/ethnicity): CDC Surveillance data; Denominator (total number of PWID in 1998, by race/ethnicity): CVAR study[h]
	AIDS diagnosis rates per PWID	AIDS diagnosis rates for PWID by race/ethnicity (MSA)	Numerator (total AIDS diagnosis from 1998–2008, by race/ethnicity): CDC Surveillance data; Denominator (total number of PWID in 1998, by race/ethnicity)[h]

[a] Male:female sex ratios were initially categorized into 3 levels: equal sex ratios (commonly defined as ranging from 0.95–1.05), more males (> 1.05), and more females (< 0.95); equity was used as the reference category to assess whether sex ratios were imbalanced. There were, however, no MSAs that had sex ratios indicating more males, thus in the end the measure included only 2 categories: more females and equity

[b] People who were institutionalized (e.g., incarcerated) were excluded from calculations

[c] When we used data from the Census Bureau to calculate ZIP-code level variables we used ZIP code tabulation areas instead of ZIP code areas. ZIP code tabulation areas are Census approximations of ZIP code areas

[d] The isolation index measures the extent to which minority members are exposed only to one another, and was calculated per Massey and Denton [32]. The isolation index varies from 0 (no isolation) to 100 (complete isolation)

[e] Topologically Integrated Geographic Encoding and Referencing system (TIGER) data, produced by the US Census Bureau. The TIGER/Line files are extracts of selected geographic information, including roads, boundaries, and hydrography features

[f] This database contained historical data and so it was possible to capture conditions for 2009

[g] Friedman et al. [19]. “Hard” drugs included opiates, cocaine, and “truly addicting” synthetic or other dangerous non-narcotic drugs

[h] Tempalski et al. [34]

Table 2

Characteristics of self-reported HIV-negative people who inject drugs (PWID; N = 7477), drawn from the 2012 Centers for Disease Control and Prevention's National HIV Behavioral Surveillance

Characteristic	% (No.) or mean (SD)
Past year HIV testing	58.0% (4306)
Age (years)	46.4 (11.2)
Gender	
Male	70.4% (5262)
Female	29.6% (2215)
Race/ethnicity composition	
Non-Hispanic white	30.0% (2244)
Non-Hispanic black/African-American	48.8% (3646)
Latino/Hispanic	21.2% (1587)
Annual household income (USD)	
≤ $4999	32.2% (2389)
$5000–$9999	24.4% (1812)
$10,000–$14,999	19.7% (1464)
$15,000–$19,999	6.1% (451)
≥ $20,000	17.6% (1303)
High-school graduate/general equivalency diploma	66.9% (5001)
Employed full-time	4.0% (295)
Currently homeless	35.9% (2681)
Drug primarily injected	
Heroin	66.0% (4908)
Cocaine	3.3% (247)
Speedball	6.2% (464)
Combination of heroin, cocaine, speedball	13.5% (1005)
Other	11.3% (846)
Injection frequency	
> 1/day	59.5% (4448)
1/day	13.5% (1011)
> 1/week	14.8% (1101)
1/week	3.0% (221)
> 1/month	5.3% (394)
1/month	4.0% (294)
Number of years since first injection	23.4 (13.6)
Geographic region	
Northeast	23.7% (1771)
South	38.9% (2910)
Midwest	9.0% (676)
West	28.4% (2120)
Number of years living in the MSA	

Characteristic	% (No.) or mean (SD)
Overall	32.3 (19.77)
White PWID	21.8 (17.02)
Black PWID	41.1 (17.9)
Latino PWID	27.9 (18.0)
Total geographic area in sample	
Metropolitan statistical area (MSA)	N = 19
County	N = 55
ZIP code area	N = 930

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Table 3

Bivariate associations between place covariates and the odds of past-year HIV testing among self-reported HIV-negative PWID (N = 7477), drawn from the 2012 Centers for Disease Control and Prevention's National HIV Behavioral Surveillance

Place-based exposures by geographic scale	Models with place characteristic only		Models with individual race/ethnicity as moderator of the effect of place characteristic						
			Effects in Whites		Interaction: difference of effect in black/whites		Interaction: difference of effect in Latino/whites		1 SD difference
	OR	p value	OR	p value	OR	p value	OR	p value	
Sociodemographic composition									
Male:female sex ratios: more females versus equity (%)[a]									
ZIP	1.25	0.09	1.01	0.91	1.33	0.08	1.38	0.08	–
County	1.41	0.04	1.21	0.31	1.17	0.25	1.40	0.03	–
MSA	1.56	0.02	1.45	0.07	1.04	0.76	1.21	0.18	–
Racial/ethnic composition (ZIP)									
% White	0.99	0.64	0.99	0.89	1.06	0.39	0.95	0.53	23.89
% Black	1.07	0.06	1.09	0.20	0.94	0.49	1.11	0.34	32.42
% Latino	0.96	0.21	0.96	0.45	0.97	0.68	0.96	0.63	23.45
Residential isolation (MSA)									
Black	1.16	0.16	1.11	0.34	1.05	0.49	1.05	0.53	20.64
Latino	0.96	0.74	0.97	0.81	1.04	0.57	0.89	0.12	16.81
Principal component analysis (PCA)									
MSA									
Social component[b]	1.14	0.22	1.10	0.40	1.01	0.93	1.16	0.10	–
Economic disadvantage									
Median income (USD)									
ZIP	0.99	0.65	0.98	0.65	1.10	0.17	0.91	0.23	18,869
County	0.96	0.07	0.87	0.96	0.92	0.18	1.07	0.40	13,636
MSA	1.24	0.02	1.32	0.02	0.88	0.07	1.17	0.08	14,522
Poverty rate (%)									
ZIP	1.03	0.39	1.04	0.42	0.91	0.16	1.09	0.25	11.41
County	1.05	0.55	0.99	0.96	1.09	0.12	1.04	0.61	5.19
MSA	0.88	0.21	0.85	0.16	1.08	0.31	0.92	0.34	4.26

Place-based exposures by geographic scale	Models with place characteristic only		Models with individual race/ethnicity as moderator of the effect of place characteristic						
			Effects in Whites		Interaction: difference of effect in black/whites		Interaction: difference of effect in Latino/whites		1 SD difference
	OR	p value	OR	p value	OR	p value	OR	p value	
Economic disadvantage									
Unemployment (%)									
ZIP	1.00	0.99	1.00	0.96	0.97	0.67	1.04	0.68	6.97
County	1.08	0.84	0.98	0.84	1.05	0.53	1.07	0.49	2.89
MSA	0.88	0.28	0.84	0.20	1.06	0.50	0.97	0.81	2.60
No high-school diploma or general equivalency diploma (%)									
ZIP	0.99	0.68	0.99	0.88	0.93	0.29	1.01	0.84	11.27
County	1.08	0.34	1.06	0.55	1.05	0.49	1.01	0.89	5.08
MSA	0.94	0.60	0.91	0.45	1.10	0.15	0.98	0.79	4.21
Gini coefficient of income inequality (MSA) (%)	1.03	0.77	0.93	0.52	1.16	0.04	1.16	0.07	2.40
Principal component analysis (PCA)									
ZIP									
Economic disadvantage component[c]	0.93	0.07	1.02	0.70	0.92	0.22	1.07	0.40	–
County									
Economic disadvantage component[c]	1.05	0.60	1.01	0.93	1.10	0.22	1.01	0.89	–
MSA									
Economic disadvantage component[c]	0.86	0.15	0.80	0.08	1.12	0.14	0.92	0.37	–
Health and law enforcement interventions									
Spatial access to HIV testing sites (y/n) (ZIP) (%)	1.20	0.01	1.18	0.12	1.16	0.23	1.39	0.04	–
Spatial access to substance use disorder treatment programs (ZIP)[d]	1.30	<0.0005	1.15	0.01	1.07	0.32	1.27	0.002	2.20
Spatial access to MTPs (y/n/) (ZIP) (%)	1.14	0.06	1.05	0.65	1.50	0.71	1.33	0.06	–
Health and law enforcement interventions									
Spatial access to SSPs (y/n) (ZIP) (%)	1.32	<0.0005	1.11	0.32	1.16	0.23	1.60	0.001	–
Percent of residents living in a medically underserved area (County) (%)	1.10	0.37	0.99	0.95	1.15	0.03	1.32	0.03	24.30
Percent of residents without health insurance (County) (%)	0.88	0.14	0.88	0.20	1.06	0.40	0.83	0.01	8.70

Place-based exposures by geographic scale	Models with place characteristic only		Models with individual race/ethnicity as moderator of the effect of place characteristic						
			Effects in Whites		Interaction: difference of effect in black/whites		Interaction: difference of effect in Latino/whites		1 SD difference
	OR	p value	OR	p value	OR	p value	OR	p value	
Per capita expenditures on health (MSA) (USD)	1.09	0.44	1.09	0.43	0.97	0.52	1.08	0.29	170.02
Arrest rate for hard drug possession, per 1000									
County	1.17	0.10	1.28	0.03	0.88	0.14	0.88	0.31	3.09
MSA	1.05	0.68	1.09	0.48	0.95	0.53	0.93	0.30	1.41
Arrest rate for possession of any drug, per 1000									
County	1.24	0.02	1.26	0.02	0.95	0.51	1.01	0.93	6.04
MSA	1.21	0.06	1.23	0.06	0.98	0.74	0.96	0.59	2.82
Jail incarceration rate, per 1000 (MSA)									
Overall	0.99	0.96	0.95	0.65	1.10	0.09	0.91	0.32	0.16
Black	0.96	0.72	0.93	0.55	1.09	0.28	0.96	0.72	0.44
White	0.88	0.22	0.86	0.20	1.07	0.34	0.83	0.04	0.08
Latino	1.02	0.84	1.03	0.80	1.01	0.84	0.96	0.11	0.25
Per capita expenditures on police (MSA) (USD)	1.22	0.03	1.20	0.06	0.99	0.84	1.11	0.15	95.0
Per capita expenditures on corrections (MSA) (USD)	1.15	0.17	1.03	0.80	1.15	0.01	1.38	0.001	44.0
Principal component analysis (PCA)									
County									
Poor access to general healthcare[e]	0.96	0.66	0.91	0.40	1.15	0.04	0.88	0.19	–
Criminal justice component[f]	1.23	0.04	1.15	0.22	1.08	0.25	1.20	0.02	–
HIV burden									
AIDS diagnosis per 1000 PWID (MSA)	1.04	0.24	0.92	0.77	1.07	0.77	1.78	0.05	0.91
AIDS-related mortality rates for PWID during the HAART era, (MSA)	1.04	0.31	0.82	0.68	1.20	0.67	1.89	0.17	1.81

We use the term “bivariate” here to describe models that include a single place-based covariate, indicator variables for individual race/ethnicity, and the interactions of the place-based exposures with these indicator variables. All bivariate models were hierarchical generalized linear models with three levels (individual nested in ZIP code, ZIP code nested in county, and county nested in MSA) When independent variables are continuous, the odds ratio (OR) is calculated for a 1 standard deviation difference in that variable *USD* United States Dollar; *MTPs* Methadone Treatment Programs; *SSPs* Syringe Service Programs

[a]Male:female sex ratios were initially categorized into 3 levels: equal sex ratios (commonly defined as ranging from 0.95–1.05), more males (>1.05), and more females (<0.95); equity was used as the reference category to assess whether sex ratios were imbalanced. There were, however, no MSAs that had sex ratios indicating more males, thus in the end the measure included only 2 categories: more females and equity

[b] Component variables: black isolation; Latino isolation

[c] Component variables: Median income; Percent in poverty; Percent unemployed; Percent of adults without a high-school degree/GED

[d] We used gravity-based methods to estimate spatial access to drug- and HIV-related health services for PWID. The measure was created using a 3-mile radius around each ZIP code's centroid. This method generates a unit-less measure, with higher values indicating better spatial access. Measures of spatial access to MTPs, SSPs, and HIV testing sites had many zero values, and so we dichotomized them (0 = *no access* vs. >0 = *some spatial access*, according to the measure)

[e] Component variable: Percent of residents who are uninsured; Percent of residents living in a medically underserved area

[f] Component variables: Expenditures on policing per capita; Expenditures on corrections per capita; Hard drug arrest rates, per 1000 adults

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Table 4

Bivariate associations between participant characteristics and the odds of past-year HIV testing among self-reported HIV-negative PWID (N = 7477), drawn from the 2012 Centers for Disease Control and Prevention's National HIV Behavioral Surveillance

Individual-level characteristics	OR	p value
Age (SD = 11.2 years)	0.81	< 0.0005
Gender (ref = female)	0.99	0.87
Race/ethnicity		
Ratio black/white	1.11	0.06
Ratio Latino/white	1.19	0.008
Annual household income (USD) (1 SD = $15,000)	1	0.97
High-school graduate//general equivalency diploma (ref: no diploma/GED)	1.03	0.54
Employed full time (ref: not employed full time)	0.99	0.94
Currently homeless (ref: not currently homeless)	1.26	< 0.0005
Injection daily	0.95	0.02
Years since first injection (1 SD = 13.6 years)	0.84	< 0.0005

Table 5

Final multivariable multilevel logistic models regressing individual and place covariates on the odds of having an HIV test (past year) in a sample of self-reported HIV-negative PWID (N = 7477), drawn from the 2012 Centers for Disease Control and Prevention's National HIV Behavioral Surveillance

Individual- and place-level characteristics	Model A: full final model, including possible individual-level mediators		Model B: full final model, with age gender only	
	AOR	p value	AOR	p value
Individual-level				
Age (1 SD = 11.2 years)	0.78	< 0.0005	0.76	< 0.0005
Gender (ref = female)	0.93	0.21	0.91	0.10
Annual household Income (1 SD = $15,000)	1.03	0.23		
High-school graduate/General equivalency diploma (ref: no diploma/GED)	1.13	0.03		
Employed full time (ref: not employed full time)	0.93	0.61		
Currently homeless (ref: not currently homeless)	1.20	0.001		
Injection daily (ref: less than daily)	1.11	0.08		
Years since first injection (1 SD = 13.6 years)	0.98	0.59		
Race/ethnicity				
Black/white	0.65	0.14	0.67	0.17
Latino/White	0.89	0.77	0.88	0.73
Place-level				
Metropolitan statistical area (MSA)				
Social				
Male:female sex ratio:more females versus equity	1.81	< 0.0005	1.78	< 0.0005
Economic				
Median Income (USD)(1 SD = $14,522)	1.30	0.01	1.30	0.01
Health and law enforcement interventions				
Per capita expenditures corrections (USD) (1 SD = $44.7)				
Interaction effects				
White (ref)	1.09	0.28	1.10	0.24
Black/white	1.15	0.02	1.14	0.02
Latino/White	1.30	0.01	1.28	0.02
County				
Health and law enforcement interventions				
Percent of residents without health insurance (1 SD = 8.7%)				
Interaction effects				
White (ref)	1.04	0.79	1.04	0.77
Black/white	1.16	0.08	1.14	0.11
Latino/White	0.89	0.19	0.89	0.19

Individual- and place-level characteristics	**Model A: full final model, including possible individual-level mediators**		**Model B: full final model, with age gender only**	
	AOR	**p value**	**AOR**	**p value**
Random intercept	Estimate	SE (Est)	Estimate	SE (Est)
MSA	0.01	0.06	0.02	0.05
County	0.07	0.06	0.06	0.06
Zip code	0.02	0.02	0.03	0.02

Hierarchical generalized linear models were applied to account for place-based clustering

Table 6

Racial/ethnic-specific effect estimates, calculated from Model B (Table 5) when relationships between place characteristics and HIV test (past year) in a sample of self-reported HIV-negative PWID (N = 7477) varied by individual race/ethnicity in a sample of people who inject drugs daily in the 2012 National HIV Behavioral Surveillance

Place-based characteristic	AOR (p value)
MSA-level, per capita expenditures corrections (USD) (1 SD = $44.7)	
White	1.10(0.24)
Black	1.26(0.003)
Latino	1.42(0.002)
County-level, percent of residents without health insurance (1 SD = 8.7%)	
White	1.01(0.77)
Black	1.18(0.17)
Latino	0.92(0.54)

Table 7

Results of three geographic-scale specific, multivariable multilevel models regressing the odds of past-year HIV testing on individual race/ethnicity and place-based covariates in a sample of self-reported HIV-negative people who inject drugs (PWID; N = 7477), drawn from the 2012 National HIV Behavioral Surveillance. Hierarchical generalized linear models were applied to account for place-based clustering

Geographic scale	Place exposure	OR	p value
ZIP code	Race/ethnicity		
	Ratio black/white	1.04	0.67
	Ratio Latino/white	0.92	0.37
	Spatial access to substance abuse treatment programs (1 SD = 2.2 units)		
	Interaction effects		
	Ratio black/white	1.07	0.32
	Ratio Latino/white	1.27	0.002
	Race specific effects		
	White	1.16	0.01
	Black	1.23	< 0.0005
	Latino	1.47	< 0.0005
		Estimate	SE(Est)
	Random intercept	0.21	0.04
County	Race/ethnicity		
	Ratio black/white	0.88	0.53
	Ratio Latino/white	1.55	0.05
	Arrest rate for possession for any drug, per 1000 (1 SD = 6)	1.28	0.006
	Percent of residents without health insurance (1 SD = 8.7%)		
	Interaction effects		
	Ratio black/white	1.04	0.62
	Ratio Latino/White	0.83	0.02
	Race-specific effects		
	White	0.84	0.05
	Black	0.87	0.12
	Latino	0.70	< 0.0005
	Percent of residents living in a medically underserved area (1 SD = 21.1%)		
	Ratio black/white	1.13	0.02
	Ratio Latino/white	1.22	0.07
	Race-specific effects		
	White	0.95	0.58
	Black	1.07	0.40
	Latino	1.16	0.25
		Estimate	SE (Est)
	Random intercept	0.15	0.05
MSA	Race/ethnicity		
	Ratio black/white	0.74	0.04

Geographic scale	Place exposure	OR	p value
	Ratio Latino/white	0.50	0.002
	Per capita expenditures corrections (USD) (1 SD = $44.7)		
	Interaction effects		
	Ratio black/white	1.16	0.01
	Ratio Latino/white	1.38	0.001
	Race specific estimates		
	White	1.04	0.59
	Black	1.20	0.01
	Latino	1.43	0.001
	Male:female sex ratio: more females vs equity	1.62	0.001
	Median income (USD) (1SD=$14,522)	1.24	0.001
		Estimate	SE (Est)
	Random intercept	0.07	0.03

Table 8

Characteristics among self-reported HIV-negative PWID (N = 7477), drawn from the 2012 Centers for Disease Control and Prevention's National HIV Behavioral Surveillance

Place-based exposures by geographic scale	White		Black		Latino		Total	
	Mean or %	SD or N	Mean or %	SD or N	Mean or %	SD or N	Mean or %	SD or N
Sociodemographic composition								
Male:female sex ratios (%)[a]								
ZIP								
Roughly equal	35.3	792	25.2	918	33.6	533	30.0	2243
More females	23.5	528	49.8	1815	33.1	525	38.4	2858
More males	41.2	924	25.0	913	33.3	529	31.6	2366
County								
Roughly equal	56.1	1259	41.5	1512	48.0	762	47.3	3533
More females	36.2	813	53.6	1955	49.0	777	47.4	3545
More males	7.7	172	4.9	179	3.0	48	5.3	399
MSA								
Roughly equal	61.3	1374	41.2	1501	47.5	754	48.6	3631
More females	38.7	868	58.8	2145	52.5	833	51.4	3846
More males	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Racial/ethnic composition (ZIP) (%)								
White	42.6	23.0	19.4	18.9	21.9	21.5	26.7	23.4
Black	20.8	21.9	56.6	30.4	24.3	22.8	38.9	31.7
Latino	23.7	20.5	17.0	20.5	44.2	24.8	24.8	23.9
Residential isolation (MSA)								
Black	36.3	20.2	51.6	19.2	41.2	19.1	44.8	20.6
Latino	36.1	17.1	33.2	15.1	48.4	15.1	37.3	16.8
Economic disadvantage								
Median income (USD)[b]								
ZIP	47886.0	20772.0	37242.0	17187.0	39468.0	16952.0	40909.0	18870.0
County	58297.0	15142.0	53252.0	13119.0	53491.0	11498.0	54817.0	13637.0
MSA	68170.0	12255.0	66253.0	16689.0	65498.0	11685.0	66668.0	14522.0

Place-based exposures by geographic scale	White		Black		Latino		Total	
	Mean or %	SD or N	Mean or %	SD or N	Mean or %	SD or N	Mean or %	SD or N
Poverty rate (%)								
ZIP	24.2	11.8	31.0	10.5	28.8	11.1	28.4	11.4
County	17.3	5.8	19.7	4.6	18.7	4.9	18.8	5.2
MSA	13.6	3.4	14.7	4.9	15.1	3.4	14.4	4.3
Unemployment (%)								
ZIP	11.8	5.7	17.2	7.5	14.5	5.3	15.0	6.9
County	10.3	2.6	11.8	3.1	11.3	2.3	11.3	2.9
MSA	9.4	1.6	10.2	3.3	10.2	1.3	9.9	2.6
No high-school diploma or general equivalency diploma (%)								
ZIP	18.8	10.9	22.7	10.9	27.6	11.7	22.6	11.3
County	15.0	5.1	16.2	4.65	18.6	5.3	16.3	5.1
MSA	13.0	4.5	13.9	3.53	15.9	4.6	14.0	4.2
Gini coefficient of income inequality (MSA) (%)	47.3	2.1	46.6	2.48	48.5	2.2	47.2	2.4
Health and law enforcement interventions								
Density of HIV testing sites per square mile[c] (y/n) (ZIP)) (%)	64.3	1443	84.9	3097	78.6	579	77.4	5787
Spatial access to substance use disorder treatment programs (ZIP)	1.9	2.1	1.5	1.9	2.1	2.6	1.8	2.2
Spatial access to MTPs[d] (y/n/) (ZIP) (%)	68.1	1529	59.6	2174	63.5	1008	63.0	4711
Spatial access to SSPs[e] (y/n) (ZIP) (%)	55.1	1236	41.1	1499	57.4	911	48.8	3646
Percent of residents living in a medically underserved area (County) (%)	13.0	23.7	19.7	21.5	11.8	13.5	16.9	21.1
Percent of residents without health insurance (County) (%)	20.5	8.7	22.1	8.7	24.1	8.16	22.0	8.7
Per capita expenditures on health (MSA) (USD)	189.9	196.0	150.9	159.1	155.4	149.4	163.6	170.0
Arrest rate for hard drug possession, per 1000								
County	2.9	2.3	3.7	3.8	4.3	1.7	3.6	3.1
MSA	2.5	1.4	2.5	1.2	3.6	1.4	2.8	1.4
Arrest rate for possession of any drug, per 1000								
County	5.4	4.7	7.6	7.1	7.8	4.6	7.0	6.0
MSA	4.6	2.9	5.4	2.2	6.7	3.4	5.5	2.8
Jail incarceration rate, per 1000 (MSA)								
Overall	0.3	0.2	0.3	0.2	0.3	0.1	0.3	0.2

Place-based exposures by geographic scale	White		Black		Latino		Total	
	Mean or %	SD or N	Mean or %	SD or N	Mean or %	SD or N	Mean or %	SD or N
Black	1.1	0.4	0.9	0.5	0.9	0.3	0.9	0.4
White	0.2	0.1	0.2	0.1	0.1	0.1	0.2	0.1
Latino	0.4	0.3	0.3	0.2	0.3	0.2	0.3	0.2
Per capita expenditures on police (MSA) (USD)	320.5	93.9	321.5	83.7	380.0	106.2	333.6	95.1
Per capita expenditures on corrections (MSA) (USD)	105.4	47.8	92.6	46.7	99.6	31.9	97.6	44.7
HIV burden								
AIDS diagnosis rates for PWID (MSA)	0.2	0.2	1.5	0.9	0.5	0.4	0.9	0.9
AIDS-related mortality rates for PWID during the HAART era, (MSA)	0.3	0.3	2.2	2.2	0.9	0.9	1.4	1.8

[a] Male:female sex ratios were initially categorized into 3 levels: equal sex ratios (commonly defined as ranging from 0.95–1.05), more males (>1.05), and more females (<0.95); equity was used as the reference category to assess whether sex ratios were imbalanced. There were, however, no MSAs that had sex ratios indicating more males, thus in the end the measure included only 2 categories: more females and equity.

[b] *USD* United States Dollar

[c] We used gravity-based methods to estimate spatial access to drug- and HIV-related health services for PWID. The measure was created using a 3-mile radius around each ZIP code's centroid. This method generates a unit-less measure, with higher values indicating better spatial access. Measures of spatial access to MTPs, SSPs, and HIV testing sites had many zero values, and so we dichotomized them (0 = *no access* vs. >0 = *some spatial access*, according to the measure)

[d] *MTPs* Methadone Treatment Programs

[e] *SSPs* Syringe Service Programs