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Rural and urban injection drug use in Puerto Rico: Network implications for human immunodeficiency virus and hepatitis C virus infection

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Abstract

Understanding the short- and long-term transmission dynamics of blood-borne illnesses in network contexts represents an important public health priority for people who inject drugs and the general population that surrounds them. The purpose of this article is to compare the risk networks of urban and rural people who inject drugs in Puerto Rico. In the current study, network characteristics are drawn from the sampling "trees" used to recruit participants to the study. We found that injection frequency is the only factor significantly related to clustering behavior among both urban and rural people who inject drugs.

Keywords

HCV; HIV; injection drug users; network affiliation; RDS

Background

Studies have documented significant prevalence rates of human immunodeficiency virus (HIV) and hepatitis C virus (HCV) among people who inject drugs (PWID) across the world (Bao & Liu, 2009; Rahimi-Movaghar, Razaghi, Sahimi-Izadian, & Amin-Esmaeili, 2010), yet research related to people who inject drugs remains limited due to the stigmatization of drug users and lack of a traditional sampling frame. One highly used and well-studied method that has been adopted to recruit members of hard-to-reach populations is respondent-driven sampling (Dombrowski, Khan, Moses, Channell, & Misshula, 2013; Wejnert, 2009). Pioneered in the 1990s by Heckathorn (1997, 2002) and extended since (Gile & Handcock, 2010), respondent-driven sampling (RDS) uses chain-referral sampling, where initial recruits (or "seeds") bring their social contacts into the study, to make use of social connections among hidden or hard-to-reach groups, with an emphasis on long referral chains and a rigorous analysis of recruitment biases to correct for common problems associated with "snowball" techniques. This recruitment method also allows us to map the risk networks of a sample.

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Risk networks are now widely recognized as critical factors in understanding the HIV and HCV infection patterns among PWID (Bell, Montoya, Atkinson, & Yang, 2002; Friedman et al., 2007; Goodreau, 2006; Young, Jonas, Mullins, Halgin, & Havens, 2012). Risk networks —graphs whose vertices are individuals and edges are social connections bearing disease transmission risk—necessarily shift our view of risk away from individual behaviors to collective, social bodies as the carriers and transmitters of infections (Dombrowski, 2013; Friedman, Curtis, Neaigus, Jose, & Jarlais, 2010; Kottiri, Friedman, Neaigus, Curtis, & Des Jarlais, 2002). They are the natural environments in which risk behaviors take place, through which infection propagates, and on which interventions are implemented. Even amid large changes in individual users' behaviors, risk networks may act as reservoirs of infection that perpetuate health risks for both PWID and the larger communities in which they live and interact (Christensen, Albert, Grenfell, & Albert, 2010; Doherty, Padian, Marlow, & Aral, 2005; Doherty, Pasquale, Liebman, Adimora, & Leone, 2011; Dombrowski, 2013). As a result, understanding the short- and long-term dynamics of infection transmission in network contexts represents an important public health priority for the PWID community and the general population that surrounds them.

Modeling risk networks as dynamic systems provides an opportunity to understand the long-term behavior of PWID risk networks—well beyond what can be seen by considering their constituent individuals in isolation (Khan, Dombrowski, & Saad, 2014). Critical to this task is an understanding of how individuals “mix” via patterns of injection equipment sharing. The basic building blocks for this include patterns of affiliation based on both drug use behaviors and user social factors (such as ordinary demographic variables). One method of understanding affiliation within risk networks is to examine homophily, or the tendency for actors to associate with similar others (McPherson, Smith-Lovin, & Cook, 2001). It has been shown that the potential for infection to spread across groups of people with similar behaviors or characteristics is limited in high homophily settings (Merli, Moody, Mendelsohn, & Gauthier, 2015); however, high homophily also provides an efficient vehicle for within-group diffusion if infection reaches the group (Del Valle, Hyman, Hethcote, & Eubank, 2007). A homophily score provides the researcher with an easily interpretable measure of within- versus across-group contact, which in turn can be used as a gauge for the disease risk potential of each group and the whole community.

The concept of within- and between-group affiliation is an extension of the concept of homophily, and both are estimated from recruitment patterns. *Affiliation* describes the recruitment patterns between all groups, adjusted for the number of in each group. Because it measures the recruitment patterns between all groups, affiliation can be used to measure homophily (the affiliation of a group with itself), or it can measure the extent of affiliation between one group and specific others. Groups have a strong affiliation with another if connections occur between them more frequently than expected on the basis of their numbers (and the number of people they recruit) alone. Heterosexual (male–female) equipment sharing is one possible example of cross-group affiliation; equipment sharing between people with nonconcordant infection statuses is another. Potential for infection across groups that partner with each other is increased in a setting defined by cross-group affiliation (Heckathorn, Broadhead, Anthony, & Weakliem, 1999).

Despite increasing recognition of rural drug use as a serious problem in the United States (Dombrowski, Crawford, Khan, & Tyler, 2016; Peters et al., 2016; Strathdee & Beyrer, 2015), there currently exists very little research making an explicit comparison between urban and rural risk networks. Traditionally, urban networks were thought to be more amenable to RDS in general because the networks of drug use are larger and focused around specific venues, but rural kinship networks are large and may also facilitate drug use (Keyes, Cerdá, Brady, Havens, & Galea, 2013). The purpose of this article is to compare the risk networks of urban versus rural PWID in Puerto Rico. This analysis is made possible by the collection of similar data across two areas—(a) San Juan metropolitan area and (b) the rural interior located in the mountainous center of the island—using similar research instruments and samples of PWID separated by less than 2 years. In the current study, network characteristics are drawn from the sampling "trees" used to recruit participants to the study. Here we follow prior work by Wejnert, Heckathorn, and others, including our research team (Dombrowski, Khan, Moses, Channell, & Dombrowski, 2014; Dombrowski et al., 2013; Wejnert, 2010; Wejnert, Heckathorn, Ramirez-Valles, & Diaz, 2008), that uses recruitment patterns to discern network topological features that have the potential to influence the spread of HIV and HCV among PWID. The success of this method depends in part on the underlying social network structure of the population of interest. The method performs best in social settings where people are densely connected to each other (Abdul-Quader, Heckathorn, Sabin, & Saidel, 2006) and where any pair of actors within the population of interest is potentially reachable through some chain of relationships (Salganik & Heckathorn, 2004). Urban networks conform more easily to these assumptions, as initial recruits (seeds) are more easily located and accessed (Draus & Carlson, 2006; Wang, Falck, Li, Rahman, & Carlson, 2007). However, the method is being applied successfully to a growing number of rural populations. Kinship networks in particular are thought to create a web of relationships that are larger and more densely connected than their urban counterparts. Recent studies of drug use in rural Ohio (Draus & Carlson, 2006; Wang et al., 2007), North Carolina (Kogan, Wejnert, Chen, Brody, & Slater, 2011), and Kentucky (Young et al., 2012; Young, Rudolph, Quillen, & Havens, 2014) have provided valuable insight into rural drug use. Of particular interest, racial, age, and behavioral homophily (Wang et al., 2007) have been found among drug users in Ohio, and HCV-status homophily was found among HCV-positive recruits in rural Kentucky (Young et al., 2012). These findings provide reassurance that rural networks are structured by homophily. We focus our comparison on patterns of interaction revealed among the recruitment sample and, in particular, how such patterns can cluster individuals in ways that confound the normal "random mixing" assumptions of classic SI models of disease spread.

Methods

The rural sample discussed in this analysis consists of 315 injection drug users residing in four rural towns in the mountainous region of central Puerto Rico, about 40 miles from San Juan. The Injection Risk Networks in Rural Puerto Rico Project completed interviews with the sample between April 2015 and June 2015. Sample recruitment was managed using respondent-driven sampling (RDS) wherein participants who completed the survey were given three referral coupons they could pass out to other PWID they knew who had not previously participated in the study. Every eligible referral earned the recruiter an additional $10. Upon completion of the questionnaire, participants were given $25. These four towns were chosen due to the presence of a syringe exchange program operating in this rural region in Puerto Rico, collaboration with which facilitated seed selection—all eight seeds were identified by their participation in the rural syringe exchange program. Participants were 18 years of age or older, alert at the time of the interview, and active injection drug users (injected drugs within the past 30 days). The study received institutional review board (IRB) approval through the University of Nebraska-Lincoln (IRB# 20131113844FB) and the University of Puerto Rico School of Medicine (IRB# A8480115).

The urban sample consists of 512 injection drug users residing in San Juan, Puerto Rico, and the surrounding metropolitan area who participated in the Centers for Disease Control's (CDC's) National HIV Behavioral Surveillance (NHBS) Injection Drug User (IDU) Round 3 study. The NHBS IDU 3 study completed interviews between August 2012 and December 2012. Sample recruitment there was also managed using respondent-driven sampling with similar coupon and incentive structures, including $20 for the interview and $10 for each referral (up to 3). The urban and rural questionnaires were very similar—the Injection Risk Networks in Rural Puerto Rico project interview was based on the CDC NHBS IDU Round 3 Questionnaire version 13, which was used by the San Juan NHBS project. In addition to demographic variables, this questionnaire collected information about type and frequency of drug use as well as HIV and HCV risk behaviors such as sharing of needles, cookers, cotton, and water and utilization of prevention activities.

Measures

Gender was based on respondent report of whether they identified as male, female, or transgender. Given the overwhelmingly small number of transgender respondents, they were excluded from analyses of homophily and affiliation. *Income* was ascertained from the following question: “What was your household income last year from all sources before taxes?” Original response categories ranged from 1 = *$0–$4,999* to 13 = *$75,000 or more*. Given the large number of respondents who reported earning less than $5,000 in the previous year, responses were recoded into two categories to separate those who earned less than $5,000 dollars last year from those who earned $5,000 or more in the previous year. Respondents' age was originally coded in years. To simplify analyses, *age* was recoded into three categories: 1 = *20–39 years of age*; 2 = *40–49 years of age*; and 3 = *50–69 years of age*. *Unemployment status* was assessed by asking, “What best describes your employment status?” Responses included employed full time, employed part time, homemaker, full-time student, retired, unable to work for health reasons, and unemployed. The original response options were recoded into two categories: 1 = *unemployed* and 2 = *not unemployed* (which includes employed full time, employed part time, homemaker, full-time student, retired, and unable to work for health reasons). The “not unemployed” category was created to avoid small-cell-size issues because there were too few endorsements of any other category, aside from “unemployed.”

Believed HCV status was assessed by asking respondents whether they had ever had a blood test to check for HCV. Those who reported being tested for HCV and being informed of a positive test result were coded as "HCV positive." Those who reported being tested for HCV and being informed of a negative test result were coded as "HCV negative." Those who reported never being tested for HCV or being tested and never receiving any results were coded as "HCV unknown." *Drug treatment participation* is based on the question "have you ever participated in a drug treatment program?" with responses of 1 = *No* and 2 = *Yes*.

Speedball use (heroin and cocaine mixtures) was ascertained by asking respondents how often they injected the drug mixture in the past 12 months. Original response options ranged from 1 = *4 or more times per day* to 10 = *Never*. Since we were primarily interested in the use of speedballs, original response options were recoded into two categories: 1 = *any use of speedballs in the past 12 months* and 2 = *no use of speedballs in the past 12 months*. *Alcohol use in the past 12 months* measures whether respondents consumed an alcoholic beverage (such as beer, wine, or liquor) in the past 12 months. Response categories were 1 = *no* and 2 = *yes*. To further explore alcohol use, *binge drinking in the past 12 months* asked, "In the past 12 months, how often did you have 5 or more (4 or more for women) alcoholic beverages in one sitting?" Original response options ranged from 1 = *every day* to 7 = *never*. Response options were recoded for analysis into two categories: 1 = *any binge drinking in the past 12 months* (endorsements of the response categories "every day" to "less than once a month") and 2 = *no binge drinking in the past 12 months* (responses of "never"). *Injection frequency* comes from the question, "In the last 12 months, on average, how often did you inject drugs?" Original response categories ranged from 1 = *4 or more times per day* to 8 = *less than one time per month*. Given the large number of respondents who reported daily injection drug use, response options were recoded to 1 = *1 or more times per day* and 2 = *less than 1 time per day* for network analyses but remained in the original response form for sample comparisons (Table 1; 1 = *1 time per month*; 6 = *more than once per day*). To examine *shared needles in the past 12 months*, respondents were asked, "In the last 12 months, with how many people did you use a needle after they injected with it?" Respondents reported the total number of injection partners they shared needles with. Responses were recoded into two categories: 1 = *did not share needles with anyone in the past 12 months* and 2 = *shared needles with at least one person in the past 12 months*. In Table 1, frequency of sterile needle use, frequency of dirty needle use, frequency of shared cooker use, frequency of shared cotton use, and frequency of shared water use have responses ranging from 0 = *never* to 4 = *always*.

Analytic approach

Network structures in the two samples were discerned using the network recruiting data from each. RDS was used to collect a large sample via peer referral (Abdul-Quader et al., 2006; Heckathorn, 2002, 2007; Magnani, Sabin, Saidel, & Heckathorn, 2005). The RDS methodology has been used nationally and internationally in studies of PWID, commercial sex workers, and men who have sex with men (Abdul-Quader et al., 2006; Frost et al., 2006; Magnani et al., 2005; Simic et al., 2006) and continues to be important in HIV research (Huan et al., 2013; Rudolph, Crawford, Latkin, Fowler, & Fuller, 2013; Zohrabyan et al., 2013). Our research team has previously used RDS in a series of projects that have included commercially sexually exploited children, PWID, and individuals at high risk for HIV (Curtis, Terry, Dank, Dombrowski, & Khan, 2008; Dombrowski et al., 2012; Wendel et al., 2011). As is standard with RDS, measure of attribute homophily (the extent to which people cluster on the basis of similarities in individual characteristics or “attributes”) and degree homophily (the extent to which they cluster on the basis of size of individual network or “degree”) were used to correct for recruitment bias prior to statistical analysis of the samples (Gile, Johnston, & Salganik, 2015). However, these same analyses of the recruitment data also reflect clustering and social boundaries that can be discerned in the actual social networks of the population as a whole (Dombrowski et al., 2013). Here we follow Wejnert (2010) and others (Dombrowski et al., 2014; Dombrowski et al., 2013) who have argued that RDS analysis can be used for general social network analysis (labeled RDS-SN). As Wejnert notes, “RDS data provide a wealth of information and potential for social network analysis by shifting the unit of analysis from nodes to ties in the network” (Wejnert, 2010, p. 113). By examining patterns in these ties and comparing them to what we might expect from random distributions of the same data, we uncover systematic clustering and between-group social boundaries that potentially influence disease spread among PWID. In this effort, we seek to add to recent work that stresses the important of nonrandom (i.e., network) mixing patterns in the spread of HIV and related infections (Khan et al., 2014; Khan, Dombrowski, Saad, McLean, & Friedman, 2013).

Throughout this article, we use the homophily index proposed by Heckathorn (Heckathorn, 2002). Here, homophily within groups is measured on a scale from −1 to 1 (Wejnert, 2010), with a score of H = 0 indicating no preference for in-group association, H = 1 indicating the highest possible preference for in-group association (implied, for example, if all men recruited to the project in turn recruited only other men), and a score of H = −1 indicating the highest possible preference to connect with those outside of the group (implied, for example, in a situation where all of the men recruited to the project in turn recruited only women). Homophily values exceeding ±0.3 are considered to be strong (Newman & Girvan, 2004).This provides an aggregate measure of contact between groups, the combined result of two processes. First, the baseline level of in-group contact is set by the number of social contacts people in each group have. If males have more contacts than females, more male–male ties can be expected by chance alone. This contribution to the homophily score is called *degree homophily* (H_d). Second, homophily may be generated by a biased preference for members of one's own group, beyond what is expected by their relative prevalence in the population. This bias is called *affiliation homophily* (H_a). The same scale can also be used to measure the level of association between groups (Dombrowski et al., 2014), although we focus on measuring within-group bias. Like homophily, in-group affiliation is scored on a scale of −1 to 1, with a positive score indicating a tendency for in-group association and a negative score indicating a tendency for intergroup association. We provide the full affiliation matrices in the Appendix, where out-group mixing rates are available. When evaluating the strength of cross-group affiliation, a positive score indicates intergroup association, and a negative score indicates intergroup disassociation (Heckathorn, 2002).

In interpreting these results, we assume that positive in-group affiliation represents boundaries to cross-group coinjection and thus soft barriers to infection. That is, while social contact remains between network members, consistent patterns of nonaffiliation decrease the likelihood of infection passing between those groups. This assumption finds support in both ethnographic and social network studies of PWID (Costenbader, Astone, & Latkin, 2006; Kottiri et al., 2002; Young et al., 2012).

Table 1 shows the unweighted sample means of 315 PWID in four communities in rural Puerto Rico in comparison with the 512 urban injectors from San Juan. We conducted *t* tests (for continuous variables) and oneway ANOVA tests (for categorical or dichotomous variables) to compare the means of participants from the rural sample to those of participants from the urban sample (Table 1), and significant differences (where $p < .05$) are denoted with an asterisk.

Results

Gender

Significantly more female PWID were included in the urban sample (17.5%) than in the rural sample (9.2%). Male respondents in both urban and rural Puerto Rico showed no gender preference ($H_x = 0.000$) when recruiting others for participation in the study (Table 2). By contrast, the recruiting patterns of female PWID differed by social context. Among urban respondents, females showed a slight preference for recruiting other female PWID to the study ($H_x = 0.137$). Among rural respondents, however, females showed a marked preference for recruiting male PWID to the study ($H_x = -0.601$). While female PWID in urban Puerto Rico showed an affinity for other female PWID ($H_a = 0.116$), those in rural Puerto Rico showed a greater preference for male PWID ($H_a = -0.578$). Female PWID in rural Puerto Rico may recruit more male PWID because females are less likely to use injection drugs.

Income

Most respondents in both the urban (91%) and the rural (80%) samples reported earning less than $5,000 annually. There is some evidence of clustering in the urban Puerto Rico sample based on income. Both respondents who reported earning less than $5,000 in the past year and those who reported earning $5,000 or more in the past year preferentially recruited others who reported earning less than $5,000 ($H_x = 0.209$ and $H_x = -0.222$, respectively). This preferential recruitment appears to be the result of differences in the degree distributions of those who earn less than $5,000 a year and those who earn $5,000 or more a year ($H_d = 0.210$ and $H_d = -0.210$, respectively). There is no evidence of preferential recruitment based on income in the rural sample.

Age

Both the rural and urban samples have the same average age, but there is some evidence of preferential recruitment patterns around age in the urban sample of injection drug users. Those between the ages of 20 and 39 were more likely to recruit others in the same age category ($H_x = 0.230$). In addition, those between the ages of 50 and 69 were slightly more likely to recruit others in the same age category ($H_x = 0.163$). These preferential recruitment patterns appear to largely be the result of affiliation homophily (0.169 and 0.138) and preference for affiliating with other PWID of a similar age. There is no evidence of preferential recruitment based on age in the rural sample.

Unemployment status

Over 85% of both urban and rural respondents reported being unemployed at the time of the survey. Unemployed respondents in the rural sample preferentially recruited unemployed PWID (H_x = 0.249). This appears to be driven by differences in the degree distributions of those who are unemployed and those who are not. There is no evidence of preferential recruitment based on unemployment status in the urban sample.

Believed HCV status

Approximately 50% of both urban and rural respondents reported that they believed they were HCV positive (48% and 50%, respectively). In the rural sample, those who reported a positive HCV status were more likely to recruit others with a similar HCV status (H_x = 0.249). By contrast, those who reported an unknown or negative HCV status showed no preferential recruitment based on believed HCV status. According to the affiliation matrix, rural participants who believed they were HCV positive were less likely to recruit those with an unknown HCV status (−0.129) and those with a negative HCV status (−0.335). There is no evidence of preferential recruitment based on believed HCV status in the urban sample.

Drug treatment participation

Participation in drug treatment programs showed evidence of significant clustering behavior among rural respondents in Puerto Rico, but not among urban respondents. Approximately 81% of the rural sample and 67% of the urban sample reported lifetime participation in a drug treatment program. Drug treatment participation provides substantial clustering in the social lives of PWID living in rural Puerto Rico (H_x = 0.423), and this clustering appears to be largely driven by differences in the degree distributions of those who have attended drug treatment programs and those who have not. By contrast, the urban sample provides little evidence of drug treatment participation as a cause of clustering in the lives of PWID (H_x = 0.116).

Speedball use

More than 90% of respondents in both urban and rural Puerto Rico reported significant use of speedballs (mixtures of cocaine and heroin). However, speedball use appears to influence clustering behavior in the social networks of PWID in rural Puerto Rico only (H_x = 0.446). This clustering appears to be driven by differences in both the degree distributions of those who do and do not use speedballs (H_d = 0.270) and the tendency to cluster based entirely on similarity of drug choice (H_a = 0.251), in this case, speedballs.

Alcohol use in the past 12 months

More rural (71%) than urban (51%) respondents reported alcohol use in the past 12 months. In the urban sample, respondents who reported no alcohol use showed preferential recruitment for other non–alcohol users (H_x = 0.218). This appears to be the result of both affiliation (H_a = 0.101) and degree (H_d = 0.131) homophily. By contrast, those who reported alcohol use showed no preferential recruitment for others based on alcohol use. There is little evidence of preferential recruitment based on alcohol use in the rural sample.

Binge drinking in the past 12 months

Rural respondents were much more likely than urban respondents to report that they engaged in binge drinking in the past 12 months (57% and 37%, respectively). Urban respondents who reported no binge drinking behavior in the past 12 months were more likely to be recruited by those who also reported that they did not binge drink (H_x = 0.269). There is little evidence of preferential recruitment based on binge drinking in the rural sample.

Injection frequency

A majority of respondents in both urban (92.7%) and rural (84.8%) Puerto Rico reported injecting drugs at least once a day. Injection frequency appears to influence clustering in the social networks of PWID in urban Puerto Rico. Urban respondents who reported injection at least once a day showed preferential recruitment for others who reported similar injection frequencies (H_x = 0.481). This preferential recruitment appears to be the result of differences in the degree distributions of those who inject drugs at least once a day and those who inject drugs less frequently. Those who inject less frequently show no preferential recruitment patterns based on injection frequency. While a similar pattern emerges in the rural sample, people who inject drugs at least once a day show less preferential recruitment of frequent injectors (H_x = 0.247) than the urban sample.

Shared needles in the past 12 months

More than 30% of respondents in the rural and urban Puerto Rico samples reported sharing a needle with another injector in the past 12 months. Rural respondents who reported no sharing of needles with other injectors in the past 12 months showed preferential recruitment of others who also reported no sharing of needles with other injectors (H_x = 0.298). By contrast, rural respondents who reported sharing needles with at least one other person in the past 12 months showed lower levels of homophily and within-group preference (H_x = 0.215). In the urban sample, respondents showed little evidence of preferential within-group recruitment.

Factors unrelated to clustering

Other variables that did not influence clustering among social groups of PWID in either the rural or the urban sample were (a) noninjection drug use, (b) number of sex partners in the past 12 months, (c) sharing of works (i.e., cookers, cotton, water) in the past 12 months, and (d) back-/frontloading in the past 12 months.

Discussion and conclusion

In this article, we aimed to understand more about risk networks based on the affiliation tendencies for two separate samples—one rural and one urban—in Puerto Rico. The existence of two separate data sets, one exclusively urban and one exclusively rural, both collected with the same RDS methods and survey instruments in the same geographic area, at timepoints 2 years apart, presents a unique opportunity to understand how risk networks may differ by urbanity.

Factors related to clustering in urban and rural Puerto Rico

Injection frequency is related to clustering behavior among both urban and rural PWID. High-frequency users tend to cluster with other high-frequently users in both settings, yet high-frequency PWID in metropolitan San Juan cluster only with other high-frequency users while in rural PWID, high-frequency PWID also cluster with users that inject with lower frequency. This finding suggests different social network dynamics between the two areas. This difference might be attributed to the fact that in rural Puerto Rico PWID know each other, having attended school together, as neighbors or even relatives, and maintain strong personal ties that bring them together regardless of drug frequency. On the contrary, urban PWID might lack these kinds of bonds by living in a more impersonal and anonymous environment. This could explain the tendency for high-frequency users to actively cluster with other high-frequency users with whom they can acquire and use drugs or enter into other kinds of arrangements based on similar injection habits. Injection frequency was the only factor significantly related to clustering for both the urban and the rural samples.

Factors related to clustering in rural Puerto Rico only

Female PWID in rural Puerto Rico show a strong preference for the recruitment of male PWID. Results indicate that the population size of female PWID in rural Puerto Rico is quite small (less than 10% of the PWID population). Therefore, female PWID may be less likely to recruit other females simply because they are difficult to find. However, this cannot account for the full extent of female–male association because we found positive affiliation homophily that accounts for differences in relative group size and differential degree. In addition, female PWID may be introduced to injection drug use by their male partners. However, we do not see evidence of this same phenomenon in the urban sample as evidenced by the low level of cross-group affiliation.

Perceived HCV status also appears to affect the recruitment and affiliation patterns of rural PWID. Those who believe they are HCV positive show preferential recruitment for others with a similar status. Similarly, individuals who believe they are HCV positive are significantly less likely to recruit those who have an unknown HCV status or believe that they are HCV negative. Those who have an unknown or negative HCV status do not show preferential recruitment or affiliation patterns based on HCV status. Therefore, it appears that HCV-positive individuals act as a sort of "gatekeeper" to help prevent the spread of disease throughout the social network. There is a general perception in rural Puerto Rico that most PWID have or will acquire HCV. This may account for why individuals with an unknown or negative HCV status make little effort to avoid HCV-positive individuals. On the other hand, those who are HCV positive may have larger social networks and more risk partners, which may explain why they are more likely to recruit those with a similar status and why those with an unknown or negative status recruit them. This pattern is not evident in the urban sample of PWID.

Results for speedball (heroin and cocaine mixtures) use indicate differences in the ways IDUs cluster in rural and urban Puerto Rico. Among the rural sample, those who inject speedballs are more likely to recruit and associate with others who inject the same mixture, which provides evidence for a phenomenon locally known as *caballo*, the process of two or more IDUs collectively pooling resources to purchase both the heroin and cocaine needed to inject speedball. By contrast, speedball use is unrelated to clustering within the urban sample of PWID. We also found clustering related to unemployment status, drug treatment participation, and sharing needles in the past year among rural PWID, but not urban PWID.

Factors related to clustering in urban Puerto Rico Only

Factors that were related to clustering among urban PWID only included income, age, any alcohol use, and past-year binge-drinking frequency. These were unrelated to clustering in the rural sample.

This analysis applies a novel method for discovering features of social structure among PWID, which in turn can prompt novel and important questions about injection-related risk. These findings are limited by the use of recruitment patterns as stand-ins for risk network patterns. In the next phase of research, direct ethnographic observation of the risk networks will allow us to evaluate the extent to which this is true. Those results will help further explore and contextualize the patterns observed here, at least in terms of contextualizing the results of clustering among the rural sample. The findings are further limited due to the time difference of the two data sets. The urban data set was collected almost 2 years before the rural data set. We realize that a rapidly changing economy, which likely affects migration patterns as well as drug use patterns, could have influenced the different clustering and homophily trends seen here. Future research should attempt data collection of rural and urban network data sets simultaneously.

Despite these limits and the formative nature of the results shown here, RDS has been shown to be a vital method in recruiting PWID. This analysis is one of the first to address recruitment patterns and social network characteristics among injectors living in rural and in urban areas of the same geographic area (in this case, Puerto Rico). The analysis of this recruitment process provides evidence of social clustering based on several characteristics, although by and large these characteristics were different for the rural and the urban sample. The only factor we found to be significantly related to clustering in both rural and urban areas was frequency of injection. Frequency of injection has important implications for disease transmission as each injection event is an opportunity for HIV or HCV transmission between network actors, depending on the precautions taken. This analysis not only informs future use of RDS for the recruitment of PWID, but also provides valuable insight on the social network characteristics for those attempting to implement interventions for such populations.

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Appendix

Table A1

RDS sample and social network characteristics by gender.

	Urban sample			Rural sample		
	Male	**Female**	**Total**	**Male**	**Female**	**Total**
Distribution of recruits	400	85	485	278	28	306
Estimated pop. prop.	0.847	0.153	1.0	0.904	0.096	1.0
Sample prop.	0.825	0.175	1.0	0.908	0.092	1.0
Homophily	0.0	0.137		0.000	−0.601	
Affiliation homophily	0.116	0.116		−0.006	−0.578	
Degree homophily	−0.024	0.024		0.054	−0.055	
Recruitment matrix						
Male	332	60		253	27	
Female	68	25		25	1	
Affiliation matrix						
Male	0.0	0.0		0.0	0.0	
Female	−0.137	0.137		0.601	−0.601	

Table A2

RDS sample and social network characteristics by income.

	Urban sample			Rural sample		
	≤ $4,999	**≥ $5,000**	**Total**	**≤ $4,999**	**≥ $5,000**	**Total**
Distribution of recruits	403	39	442	244	57	301
Estimated pop. prop.	0.888	0.112	1.0	0.823	0.177	1.0
Sample prop.	0.914	0.086	1.0	0.802	0.198	1.0
Homophily	0.209	−0.222		0.035	0.081	
Affiliation homophily	0.000	−0.015		0.073	0.073	
Degree homophily	0.210	−0.210		−0.009	0.009	
Recruitment matrix						
≥ $4,999	361	35		185	38	
< $5,000	42	4		59	19	
Affiliation matrix						
≥ $4,999	0.209	−0.209		0.035	−0.035	
< $5,000	0.222	−0.222		−0.081	0.081	

Table A3

RDS sample and social network characteristics by age.

	Urban sample				Rural sample			
	20–39	40–49	50–69	Total	20–39	40–49	50–69	Total
Distribution of recruits	222	178	89	489	137	97	73	307
Estimated pop. prop.	0.425	0.426	0.148	1.0	0.475	0.291	0.233	1.0
Sample prop.	0.462	0.358	0.180	1.0	0.444	0.317	0.238	1.0
Homophily	0.230	−0.091	0.163		−0.020	0.050	0.009	
Affiliation homophily	0.169	0.044	0.138		0.034	0.017	0.002	
Degree homophily	0.070	−0.157	0.031		−0.060	0.033	0.006	
Recruitment matrix								
20–39	107	63	22		61	37	33	
40–49	82	76	38		46	33	22	
50–69	33	39	29		30	27	18	
Affiliation matrix								
20–39	0.230	−0.238	−0.207		−0.020	0.015	−0.003	
40–49	−0.006	−0.091	0.049		−0.099	0.050	0.015	
50–69	−0.251	−0.075	0.163		−0.083	0.046	0.009	

Table A4

RDS sample and social network characteristics by unemployment status.

	Urban sample			Rural sample		
	Unemployed	Not unemployed	Total	Unemployed	Not unemployed	Total
Distribution of recruits	385	48	433	260	42	302
Estimated pop. prop.	0.884	0.116	1.0	0.819	0.181	1.0
Sample prop.	0.889	0.111	1.0	0.859	0.141	1.0
Homophily	0.052	0.002		0.249	−0.120	
Affiliation homophily	0.008	0.008		0.023	0.023	
Degree homophily	0.044	−0.045		0.231	−0.231	
Recruitment matrix						
Unemployed	45	6		223	35	
Not unemployed	340	42		37	7	
Affiliation matrix						
Unemployed	−0.002	0.002		0.249	−0.249	
Not unemployed	0.052	−0.052		0.12	−0.12	

Table A5

RDS sample and social network characteristics by believed HCV status.

	Urban sample				Rural sample			
	Unknown	Negative	Positive	Total	Unknown	Negative	Positive	Total
Distribution of recruits	128	99	203	430	67	76	144	287
Estimated pop. prop.	0.294	0.220	0.486	1.0	0.243	0.341	0.416	1.0
Sample prop.	0.298	0.224	0.478	1.0	0.228	0.271	0.502	1.0
Homophily	−0.029	0.058	−0.002		0.041	−0.038	0.249	
Affiliation homophily	−0.039	0.045	0.024		0.049	0.084	0.129	
Degree homophily	0.004	0.013	−0.027		−0.026	−0.217	0.140	
Recruitment matrix								
Unknown	36	27	63		17	16	29	
Negative	33	27	42		19	23	28	
Positive	59	45	98		31	37	87	
Affiliation matrix								
Unknown	−0.029	0.016	−0.008		0.041	−0.173	0.047	
Negative	0.009	0.058	−0.105		0.009	−0.038	0.010	
Positive	0.013	−0.037	−0.002		−0.129	−0.335	0.249	

Table A6

RDS sample and social network characteristics by drug treatment participation.

	Urban sample			Rural sample		
	No	Yes	Total	No	Yes	Total
Distribution of recruits	142	301	443	58	249	307
Estimated pop. prop.	0.357	0.643	1.0	0.279	0.721	1.0
Sample prop.	0.326	0.674	1.0	0.187	0.813	1.0
Homophily	−0.074	0.116		0.018	0.423	
Affiliation homophily	0.015	0.015		0.131	0.131	
Degree homophily	−0.102	0.103		−0.336	0.331	
Recruitment matrix						
No treatment	45	91		19	46	
Yes treatment	97	210		39	203	
Affiliation matrix						
No treatment	−0.074	0.074		0.018	−0.018	
Yes treatment	−0.116	0.116		−0.423	0.423	

Table A7

RDS sample and social network characteristics by speedball use.

	Urban sample			Rural sample		
	No	**Yes**	**Total**	**No**	**Yes**	**Total**
Distribution of recruits	35	408	443	26	280	306
Estimated pop. prop.	0.077	0.923	1.0	0.121	0.879	1.0
Sample prop.	0.077	0.923	1.0	0.089	0.911	1.0
Homophily	0.195	0.192		0.225	0.446	
Affiliation homophily	0.195	0.192		0.251	0.251	
Degree homophily	0.0	0.0		−0.260	0.270	
Recruitment matrix						
No	10	29		7	15	
Yes	25	379		19	265	
Affiliation matrix						
No	0.195	−0.195		0.225	−0.225	
Yes	−0.192	0.192		−0.446	0.446	

Table A8

RDS sample and social network characteristics by alcohol use.

	Urban sample			Rural sample		
	No	**Yes**	**Total**	**No**	**Yes**	**Total**
Distribution of recruits	212	231	443	90	217	307
Estimated pop. prop.	0.398	0.602	1.0	0.279	0.721	1.0
Sample prop.	0.489	0.511	1.0	0.292	0.708	1.0
Homophily	0.218	−0.05		0.115	0.038	
Affiliation homophily	0.101	0.101		0.094	0.094	
Degree homophily	0.131	−0.131		0.023	−0.024	
Recruitment matrix						
No	116	103		29	51	
Yes	96	128		61	166	
Affiliation matrix						
No	0.218	−0.218		0.115	−0.115	
Yes	0.05	−0.05		−0.038	0.038	

Table A9

RDS sample and social network characteristics by binge drinking.

	Urban sample			Rural sample		
	No	Yes	Total	No	Yes	Total
Distribution of recruits	277	166	443	91	216	307
Estimated pop. prop.	0.539	0.461	1.0	0.308	0.692	1.0
Sample prop.	0.632	0.368	1.0	0.295	0.705	1.0
Homophily	0.269	−0.064		0.097	0.128	
Affiliation homophily	0.095	0.095		0.106	0.106	
Degree homophily	0.191	−0.193		−0.024	0.024	
Recruitment matrix						
No	177	90		30	50	
Yes	100	76		61	166	
Affiliation matrix						
No	0.269	−0.269		0.097	−0.097	
Yes	0.064	−0.064		−0.128	0.128	

Table A10

RDS sample and social network characteristics by injection frequency.

	Urban sample			Rural sample		
	≥1×/day	<1×/day	Total	≥1×/day	<1×/day	Total
Distribution of recruits	410	33	443	259	48	307
Estimated pop. prop.	0.868	0.132	1.0	0.798	0.202	1.0
Sample prop.	0.927	0.073	1.0	0.848	0.152	1.0
Homophily	0.481	0.012		0.247	0.008	
Affiliation homophily	0.074	0.074		0.056	0.056	
Degree homophily	0.438	−0.44		0.208	−0.202	
Recruitment matrix						
≥ 1×/day	380	28		240	43	
< 1×/day	30	5		19	5	
Affiliation matrix						
≥ 1×/day	0.481	−0.481		0.247	−0.247	
< 1×/day	−0.012	0.012		−0.008	0.008	

Table A11

RDS sample and social network characteristics by number of sex partners.

	Urban sample			Rural sample		
	None	**Any**	**Total**	**None**	**Any**	**Total**
Distribution of recruits	70	369	439	58	241	299
Estimated pop. prop.	0.163	0.837	1.0	0.217	0.783	1.0
Sample prop.	0.162	0.838	1.0	0.194	0.806	1.0
Homophily	0.033	0.059		0.018	0.142	
Affiliation homophily	0.038	0.038		0.045	0.045	
Degree homophily	−0.022	0.022		−0.102	0.102	
Recruitment matrix						
None	13	55		12	40	
Any	57	314		46	201	
Affiliation matrix						
None	0.033	−0.033		0.018	−0.018	
Any	−0.059	0.059		−0.142	0.142	

Table A12

RDS sample and social network characteristics by noninjection drug use.

	Urban sample			Rural sample		
	No	**Yes**	**Total**	**No**	**Yes**	**Total**
Distribution of recruits	237	206	443	116	189	305
Estimated pop. prop.	0.472	0.528	1.0	0.389	0.611	1.0
Sample prop.	0.535	0.465	1.0	0.376	0.624	1.0
Homophily	0.189	−0.053		−0.035	0.013	
Affiliation homophily	0.072	0.072		−0.014	−0.005	
Degree homophily	0.125	−0.126		−0.021	0.021	
Recruitment matrix						
No	123	92		42	70	
Yes	114	114		74	119	
Affiliation matrix						
No	0.189	−0.189		−0.035	0.035	
Yes	0.053	−0.053		−0.013	0.013	

Table A13

RDS sample and social network characteristics by shared needle.

	Urban sample			Rural sample		
	No	**Yes**	**Total**	**No**	**Yes**	**Total**
Distribution of recruits	273	166	439	201	106	307
Estimated pop. prop.	0.653	0.347	1.0	0.625	0.375	1.0
Sample prop.	0.627	0.373	1.0	0.663	0.337	1.0
Homophily	0.006	0.162		0.298	0.215	
Affiliation homophily	0.108	0.108		0.246	0.246	
Degree homophily	−0.061	0.059		0.070	−0.069	
Recruitment matrix						
No	198	104		151	54	
Yes	75	62		50	52	
Affiliation matrix						
No	0.006	−0.006		0.298	−0.298	
Yes	−0.162	0.162		−0.215	0.215	

Table A14

RDS sample and social network characteristics by shared works.

	Urban sample			Rural sample		
	No	**Yes**	**Total**	**No**	**Yes**	**Total**
Distribution of recruits	163	247	410	125	182	307
Estimated pop. prop.	0.401	0.599	1.0	0.421	0.579	1.0
Sample prop.	0.394	0.606	1.0	0.400	0.600	1.0
Homophily	0.038	0.058		0.084	0.105	
Affiliation homophily	0.046	0.046		0.093	0.093	
Degree homophily	−0.012	0.012		−0.013	0.014	
Recruitment matrix						
No	75	102		47	53	
Yes	88	145		78	129	
Affiliation matrix						
No	0.038	−0.038		0.084	−0.084	
Yes	−0.058	0.058		−0.105	0.105	

Table A15

RDS sample and social network characteristics by back-/frontloading.

	Urban sample			Rural sample		
	No	Yes	Total	No	Yes	Total
Distribution of recruits	214	218	432	201	106	307
Estimated pop. prop.	0.505	0.495	1.0	0.673	0.327	1.0
Sample prop.	0.501	0.499	1.0	0.660	0.340	1.0
Homophily	0.008	0.048		−0.031	0.020	
Affiliation homophily	0.028	0.028		−0.004	−0.014	
Degree homophily	−0.020	0.020		−0.027	0.027	
Recruitment matrix						
No	115	111		137	73	
Yes	99	107		64	33	
Affiliation matrix						
No	0.008	−0.008		−0.031	0.031	
Yes	−0.048	0.048		−0.020	0.020	

References

Abdul-Quader AS, Heckathorn DD, Sabin K, Saidel T. Implementation and analysis of respondent driven sampling: Lessons learned from the field. Journal of Urban Health: Bulletin of the New York Academy of Medicine. 2006; 83(1):1–5. DOI: 10.1007/s11524-006-9108-8 [PubMed: 16736349]

Bao YP, Liu ZM. Systematic review of HIV and HCV infection among drug users in China. International Journal of STD & AIDS. 2009; 20(6):399–405. DOI: 10.1258/ijsa.2008.008362 [PubMed: 19451325]

Bell DC, Montoya ID, Atkinson JS, Yang SJ. Social networks and forecasting the spread of HIV infection. Journal of Acquired Immune Deficiency Syndromes (1999). 2002; 31(2):218–229. DOI: 10.1097/00126334-200210010-00013 [PubMed: 12394801]

Christensen C, Albert I, Grenfell B, Albert R. Disease dynamics in a dynamic social network. Physica A: Statistical Mechanics and Its Applications. 2010; 389(13):2663–74. DOI: 10.1016/j.physa. 2010.02.034 [PubMed: 20563303]

Costenbader EC, Astone NM, Latkin CA. The dynamics of injection drug users' personal networks and HIV risk behaviors. Addiction (Abingdon, England). 2006; 101(7):1003–1013. DOI: 10.1111/j. 1360-0443.2006.01431.x

Curtis, R., Terry, K., Dank, M., Dombrowski, K., Khan, B. The commercial sexual exploitation of children in New York city, Volume 1: The CSEC population in New York City: Size, characteristics, and needs. Washington, DC: Bureau of Justice Statistics. Final Report Submitted to the National Institute of Justice; New York, NY: Center for Court Innovation and John Jay College of Criminal Justice; 2008. NCJ Publication No. 225083Retrieved January, 12, 2012

Del Valle SY, Hyman JM, Hethcote HW, Eubank SG. Mixing patterns between age groups in social networks. Social Networks. 2007; 29(4):539–554. DOI: 10.1016/j.socnet.2007.04.005

Doherty I, Pasquale D, Liebman A, Adimora A, Leone P. P1-S5. 39 Triple jeopardy? Sexual networks of syphilis & HIV infection among heterosexuals, MSM, and bisexual men in North Carolina. Sexually Transmitted Infections. 2011; 87(1):A192–A193. DOI: 10.1136/sextrans-2011-050108.217

Doherty IA, Padian NS, Marlow C, Aral SO. Determinants and consequences of sexual networks as they affect the spread of sexually transmitted infections. The Journal of Infectious Diseases. 2005; 191(1):S42–S54. DOI: 10.1086/425277 [PubMed: 15627230]

Dombrowski K. Topological and historical considerations for infectious disease transmission among injecting drug users in Bushwick, Brooklyn (USA). World Journal of AIDS. 2013; 03(01):1–9. DOI: 10.4236/wja.2013.31001

Dombrowski K, Crawford D, Khan B, Tyler K. Current rural drug use in the US Midwest. Journal of Drug Abuse. 2016; 2(3):22. Retrieved from http://drugabuse.imedpub.com/abstract/current-rural-drug-use-in-the-us-midwest-11072.html.

Dombrowski K, Khan B, Moses J, Channell E, Dombrowski N. Network sampling of social divisions in a rural Inuit community. Identities. 2014; 21(2):134–151. DOI: 10.1080/1070289X.2013.854718

Dombrowski K, Khan B, Moses J, Channell E, Misshula E. Assessing respondent driven sampling for network studies in ethnographic contexts. Advances in Anthropology. 2013; 03(01):1–9. DOI: 10.4236/aa.2013.31001

Dombrowski K, Khan B, Wendel T, McLean K, Misshula E, Curtis R. Estimating the size of the methamphetamine-using population in New York City using network sampling techniques. Advances in Applied Sociology. 2012; 2(4):245–252. DOI: 10.4236/aasoci.2012.24032 [PubMed: 24672746]

Draus PJ, Carlson RG. Needles in the haystacks: The social context of initiation to heroin injection in rural Ohio. Substance Use & Misuse. 2006; 41(8):1111–1124. DOI: 10.1080/10826080500411577 [PubMed: 16798679]

Friedman, SR., Curtis, R., Neaigus, A., Jose, B., Jarlais, DCD. Social networks, drug injectors' lives, and HIV/AIDS. Springer; 2010. 1st ed Softcover of orig ed 1999

Friedman SR, Mateu-Gelabert P, Curtis R, Maslow C, Bolyard M, Sandoval M, Flom PL. Social capital or networks, negotiations, and norms? A neighborhood case study. American Journal of Preventive Medicine. 2007; 32(6):S160–S170. DOI: 10.1016/j.amepre.2007.02.005 [PubMed: 17543707]

Frost SDW, Brouwer KC, Firestone Cruz MA, Ramos R, Ramos ME, Lozada RM, et al. Strathdee SA. Respondent-driven sampling of injection drug users in two U.S.-Mexico border cities: Recruitment dynamics and impact on estimates of HIV and syphilis prevalence. Journal of Urban Health: Bulletin of the New York Academy of Medicine. 2006; 83(6):83–97. DOI: 10.1007/s11524-006-9104-z

Gile KJ, Handcock MS. Respondent-driven sampling: An assessment of current methodology. Sociological Methodology. 2010; 40(1):285–327. DOI: 10.1111/j.1467-9531.2010.01223.x [PubMed: 22969167]

Gile KJ, Johnston LG, Salganik MJ. Diagnostics for respondent-driven sampling. Journal of the Royal Statistical Society: Series A (Statistics in Society). 2015; 178(1):241–269. DOI: 10.1111/rssa.12059

Goodreau SM. Assessing the effects of human mixing patterns on human immunodeficiency virus-1 interhost phylogenetics through social network simulation. Genetics. 2006; 172(4):2033–2045. DOI: 10.1534/genetics.103.024612 [PubMed: 16636112]

Heckathorn DD. Respondent-driven sampling: A new approach to the study of hidden populations. Social Problems. 1997; 44(2):174–199. DOI: 10.2307/3096941

Heckathorn DD. Respondent-driven sampling II: Deriving valid population estimates from chain-referral samples of hidden populations. Social Problems. 2002; 49(1):11–34. DOI: 10.1525/sp.2002.49.1.11

Heckathorn DD. Extensions of respondent-driven sampling: Analyzing continuous variables and controlling for differential recruitment. Sociological Methodology. 2007; 37(1):151–207. DOI: 10.1111/j.1467-9531.2007.00188.x

Heckathorn DD, Broadhead RS, Anthony DL, Weakliem DL. AIDS and social networks: HIV prevention through network mobilization. Sociological Focus. 1999; 32(2):159–179. DOI: 10.1080/00380237.1999.10571133

Huan X, Hao C, Yan H, Guan W, Xu X, Yang H, et al. Lau JTF. High prevalence of HIV and syphilis among men who have sex with men recruited by respondent-driven sampling in a city in Eastern China. Asia-Pacific Journal of Public Health / Asia-Pacific Academic Consortium for Public Health. 2013; 27(2):NP854–NP865. DOI: 10.1177/1010539513480230

Keyes KM, Cerdá M, Brady JE, Havens JR, Galea S. Understanding the rural–urban differences in nonmedical prescription opioid use and abuse in the United States. American Journal of Public Health. 2013; 104(2):e52–e59. DOI: 10.2105/AJPH.2013.301709 [PubMed: 24328642]

Khan B, Dombrowski K, Saad M. A stochastic agent-based model of pathogen propagation in dynamic multi-relational social networks. Simulation: Transactions of the Society for Modeling and Simulation International. 2014; 90(4):460–484. DOI: 10.1177/0037549714526947 [PubMed: 25859056]

Khan B, Dombrowski K, Saad M, McLean K, Friedman S. Network firewall dynamics and the subsaturation stabilization of HIV. Discrete Dynamics in Nature and Society. 2013; 2013:1–16. DOI: 10.1155/2013/720818

Kogan SM, Wejnert C, Chen Y, Brody GH, Slater LM. Respondent-driven sampling with hard-to-reach emerging adults: An introduction and case study with rural African Americans. Journal of Adolescent Research. 2011; 26(1):30–60. DOI: 10.1177/0743558410384734

Kottiri BJ, Friedman SR, Neaigus A, Curtis R, Des Jarlais DC. Risk networks and racial/ethnic differences in the prevalence of HIV infection among injection drug users. Journal of Acquired Immune Deficiency Syndromes (1999). 2002; 30(1):95–104. DOI: 10.1097/00042560-200205010-00013 [PubMed: 12048369]

Magnani R, Sabin K, Saidel T, Heckathorn D. Review of sampling hard-to-reach and hidden populations for HIV surveillance. AIDS. 2005; 19:S67–S72. DOI: 10.1097/01.aids.0000172879.20628.e1

McPherson M, Smith-Lovin L, Cook JM. Birds of a feather: Homophily in social networks. Annual Review of Sociology. 2001; 27(1):415–444. DOI: 10.1146/annurev.soc.27.1.415

Merli MG, Moody J, Mendelsohn J, Gauthier R. Sexual mixing in Shanghai: Are heterosexual contact patterns compatible with an HIV/AIDS epidemic? Demography. 2015; 52(3):919–942. DOI: 10.1007/s13524-015-0383-4 [PubMed: 25904346]

Newman MEJ, Girvan M. Finding and evaluating community structure in networks. Physical Review E. 2004; 69(2):026113.doi: 10.1103/PhysRevE.69.026113

Peters PJ, Pontones P, Hoover KW, Patel MR, Galang RR, Shields J, et al. Duwve JM. HIV infection linked to injection use of oxymorphone in Indiana, 2014–2015. New England Journal of Medicine. 2016; 375(3):229–239. DOI: 10.1056/NEJMoa1515195 [PubMed: 27468059]

Rahimi-Movaghar A, Razaghi EM, Sahimi-Izadian E, Amin-Esmaeili M. HIV, hepatitis C virus, and hepatitis B virus co-infections among injecting drug users in Tehran, Iran. International Journal of Infectious Diseases. 2010; 14(1):e28–e33. DOI: 10.1016/j.ijid.2009.03.002 [PubMed: 19464218]

Rudolph AE, Crawford ND, Latkin C, Fowler JH, Fuller CM. Individual and neighborhood correlates of membership in drug using networks with a higher prevalence of HIV in New York City (2006–2009). Annals of Epidemiology. 2013; doi: 10.1016/j.annepidem.2013.02.006

Salganik MJ, Heckathorn DD. Sampling and estimation in hidden populations using respondent-driven sampling. Sociological Methodology. 2004; 34(1):193–240. DOI: 10.1111/j.0081-1750.2004.00152.x

Simic M, Johnston LG, Platt L, Baros S, Andjelkovic V, Novotny T, Rhodes T. Exploring barriers to "respondent driven sampling" in sex worker and drug-injecting sex worker populations in Eastern Europe. Journal of Urban Health: Bulletin of the New York Academy of Medicine. 2006; 83(1):6–15. DOI: 10.1007/s11524-006-9098-6

Strathdee SA, Beyrer C. Threading the needle — How to stop the HIV outbreak in rural Indiana. New England Journal of Medicine. 2015; 373(5):397–399. DOI: 10.1056/NEJMp1507252 [PubMed: 26106947]

Wang J, Falck RS, Li L, Rahman A, Carlson RG. Respondent-driven sampling in the recruitment of illicit stimulant drug users in a rural setting: Findings and technical issues. Addictive Behaviors. 2007; 32:924–937. DOI: 10.1016/j.addbeh.2006.06.031 [PubMed: 16901654]

Wejnert C. An empirical test of respondent-driven sampling: Point estimates, variance, degree measures, and out-of-equilibrium data. Sociological Methodology. 2009; 39(1):73–116. DOI: 10.1111/j.1467-9531.2009.01216.x [PubMed: 20161130]

Wejnert C. Social network analysis with respondent-driven sampling data: A study of racial integration on campus. Social Networks. 2010; 32(2):112–124. DOI: 10.1016/j.socnet.2009.09.002 [PubMed: 20383316]

Wejnert, C., Heckathorn, DD., Ramirez-Valles, J., Diaz, RM. The dual homophily model: Disentangling the effects of affiliation preference and differential degree on homophily. Conference Papers – American Sociological Association; 2008. p. 1

Wendel T, Khan B, Dombrowski K, Curtis R, McLean K, Misshula E, et al. Marshall IV D. Dynamics of Methamphetamine Markets in New York City: Final Technical Report to the National Institute of Justice (Vol. NIJ Document 236122): A Report to the National Institute of Justice(Award # 2007-IJ-CX-0110). 2011

Young AM, Jonas AB, Mullins UL, Halgin DS, Havens JR. Network structure and the risk for HIV transmission among rural drug users. AIDS and Behavior. 2012; 17(7):2341–2351. DOI: 10.1007/s10461-012-0371-2

Young AM, Rudolph AE, Quillen D, Havens JR. Spatial, temporal and relational patterns in respondent-driven sampling: evidence from a social network study of rural drug users. Journal of Epidemiology and Community Health. 2014; 68(8):792–798. DOI: 10.1136/jech-2014-203935 [PubMed: 24692631]

Zohrabyan L, Johnston LG, Scutelniciuc O, Iovita A, Todirascu L, Costin T, et al. Ionascu G. Determinants of HIV infection among female sex workers in two cities in the Republic of Moldova: The role of injection drug use and sexual risk. AIDS and Behavior. 2013; 17(8):2588–2596. DOI: 10.1007/s10461-013-0460-x [PubMed: 23539186]

Table 1

Descriptive Statistics.

	Urban sample (512)	Rural sample (315)	Urban NHBS national aggregate
Demographics and health			
Age	41.1	41.8	
Gender (% female)	19% *	10% *	
Mean per capita income	$4,918 *	$4,451 *	
HIV + Status	13.4% *	6.0% *	11.00%
Been tested for HCV and HCV + Status	48.0%	49.0%	
Have health insurance coverage	52.0% *	82.0% *	61.20%
Have a usual source of health care	71.0% *	90.0% *	
Past year visited a health care provider	55.0% *	68.0% *	78.60%
Unable to access health care due to cost	26.0% *	12.0 *%	
No visit to health care in past 5 years	12.0% *	8.0% *	
Ever tested for HIV	87.00%	90.00%	91.30%
Ever tested for HCV	65.0% *	77.0% *	78.00%
Injection drug use behaviors			
Age at first injection	20.6 *	21.9 *	
# of years spent injecting	20.1	19.9	
# of people used needles after	2.7 *	1.2 *	
# of people used works after	6.3	4.5	
# of people divided drugs with	4.3 *	1.4 *	
Past year average frequency of injection	5.8 *	5.5 *	
Frequency used a sterile needle	3.0 *	2.7 *	
Frequency used a dirty needle after someone	0.7 *	0.4 *	
Receptive sharing of syringes	36.90%	32.40%	33.00%
Receptive sharing of injection equipment	45.90%	59.00%	57.00%
Frequency shared a cooker with someone	1.0	1.1	
Frequency shared cotton with someone	0.9	0.7	
Frequency shared water with someone	0.8 *	0.7 *	

* $p < .05$.

Table 2

Comparisons of homophily between the Puerto Rico urban and rural samples.

	Urban sample			Rural sample		
	Total in-group contact homophily (H)	Affiliation homophily (H_x)	Degree homophily (H_d)	Total in-group contact homophily (H)	Affiliation homophily (H_x)	Degree homophily (H_d)
Gender						
Male	0.000	0.116	−0.024	0.000	−0.006	0.054
Female	0.137	0.116	0.024	−0.601	−0.578	−0.055
Income						
≥ $4,999	0.209	0.000	0.210	0.035	0.073	−0.009
< $5,000	−0.222	−0.015	−0.210	0.081	0.073	0.009
Age						
20–39	0.230	0.169	0.070	−0.020	0.034	−0.060
40–49	−0.091	0.044	−0.157	0.050	0.017	0.033
50–69	0.163	0.138	0.031	0.009	0.002	0.006
Unemployment state						
Unemployed	0.052	0.008	0.044	0.249	0.023	0.231
Not unemployed	0.002	0.008	−0.045	−0.120	0.023	−0.231
Believed HCV status						
Unknown	−0.029	−0.039	0.004	0.041	0.049	−0.026
Negative	0.058	0.045	0.013	−0.038	0.084	−0.217
Positive	−0.002	0.013	−0.027	0.249	0.129	0.140
Drug treatment participation						
No	−0.074	0.015	−0.102	0.018	0.131	−0.336
Yes	0.116	0.015	0.103	0.423	0.131	0.331
Speedball use						
No	0.195	0.195	0.000	0.225	0.251	−0.260
Yes	0.192	0.192	0.000	0.446	0.251	0.270
Alcohol use in the past 12 months						
No	0.218	0.101	0.131	0.115	0.094	0.023
Yes	−0.050	0.101	−0.131	0.038	0.094	−0.024

	Urban sample			Rural sample		
	Total in-group contact homophily (H)	**Affiliation homophily (H_x)**	**Degree homophily (H_d)**	**Total in-group contact homophily (H)**	**Affiliation homophily (H_x)**	**Degree homophily (H_d)**
Binge drinking in the past 12 months						
No	0.269	0.095	0.191	0.102	0.089	0.015
Yes	−0.064	0.095	−0.193	0.069	0.089	−0.015
Injection frequency						
≥ 1×/day	0.481	0.074	0.438	0.247	0.056	0.208
< 1×/day	0.012	0.074	−0.440	0.008	0.056	−0.202
Number of sex partners in the past 12 months						
None	0.033	0.038	−0.022	0.018	0.045	−0.102
Any	0.059	0.038	0.022	0.142	0.045	0.102
Noninjection drug use in the past 12 months						
No	0.189	0.072	0.125	−0.035	−0.014	−0.021
Yes	−0.053	0.072	−0.126	0.013	−0.005	0.021
Shared needles in the past 12 months						
No	0.006	0.108	−0.061	0.298	0.246	0.070
Yes	0.162	0.108	0.059	0.215	0.246	−0.069
Shared works in the past 12 months						
No	0.038	0.046	−0.012	0.084	0.093	−0.013
Yes	0.058	0.046	0.012	0.105	0.093	0.014
Back-/frontloading in the past 12 months						
No	0.008	0.028	−0.020	−0.031	−0.004	−0.027
Yes	0.048	0.028	0.020	0.020	−0.014	0.027