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BRIEF REPORT

Social Network Structure and HIV Infection Among Injecting Drug Users in Lithuania: Gatekeepers as Bridges of Infection

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Abstract The aim of the study was to assess—while controlling for individual risk characteristics—how certain social network structural characteristics (degree, eigenvector, and betweenness centrality) are related to HIV infections. Injecting drug users ($N = 299$) in Vilnius, Lithuania were recruited using incentivized chain referral sampling for a cross-sectional study. Sociometric social links were established between participants, and UCINET was used to calculate network measures. HIV prevalence was 10 %, and all except two knew they were infected. Of the five variables that remained significant in the final multivariate model, one showed temporal cumulative infection risk (more years since first drug injecting), three reflected informed altruism (always using condoms, less distributive syringe sharing and having not more than one sex partner), and one pointed to the importance of social network structure (betweenness centrality, indicating bridge populations). Loess regression indicates that betweenness may have the highest impact on HIV prevalence (about 60 vs. 20 % estimated HIV prevalence for the highest betweenness centrality values vs. highest age values). This analysis contributes to existing evidence showing both potential informed altruism (or maybe social desirability bias) in connection with HIV infection, and a link between HIV infection risk and the role of bridges within the social network of injecting drug user populations. These findings suggest the importance of harm reduction activities, including confidential testing and counseling, and of social network interventions.

Keywords HIV infection · Social network analysis · Centrality measures · Injecting drug users · Lithuania

Resumen El objetivo del estudio fue evaluar—controlando por las características individuales de riesgo—como ciertas características estructurales de la red social se relacionan con la infección por el VIH. La prevalencia del VIH era del 10 %, y todos excepto dos sabían que estaban infectados. De las cinco variables que permanecieron significativas en el modelo multivariado final, uno mostró riesgo de infección acumulada temporal (más años desde la primera drogas inyectables), tres refleja el altruismo informado (usando siempre condones, distribuir menos jeringas y tener más de una pareja sexual), y uno señaló la importancia de la estructura de red social (centralidad betweenness, lo que indica poblaciones puente). Regresión Loess indica que betweenness puede tener el mayor impacto en la prevalencia del VIH (alrededor del 60 frente a 20 % la prevalencia del VIH estimada para los más altos valores de centralidad betweenness contra los valores de mayor edad). Este análisis contribuye a la evidencia existente de altruismo informado (o tal de deseabilidad social) en relación con la infección por el VIH, y un vínculo entre el riesgo de infección por el VIH y el papel de los puentes en la red social de las poblaciones de consumidores de drogas. Estos hallazgos sugieren la importancia de las actividades de reducción de daños, incluyendo pruebas confidenciales y el asesoramiento, y de intervenciones de redes sociales.

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Introduction

Most HIV infections occurs in the context of actions that are related to social behaviors, such as having sex and using drugs. There is an increasing body of evidence indicating that social network characteristics (including structure, composition, and function) may play an even more important role in disease transmission than individual background or risk characteristics [1]. Bridge populations, for example, have been pinpointed as major contributors to both sexual [2] and drug injecting-related transmission of HIV [3]. In addition, other structural network characteristics, such as centralization [4], 2-core membership [5], or clustering [1] may also play an important role.

While many studies of injecting drug users (IDUs) have suggested the key role that networks play in HIV transmission, only few have linked sociometric network factors to HIV status. The goal of our analysis was to assess—while controlling for individual level risk attributes—how certain social network structural characteristics are related to HIV infections. We were interested in exploring the relationship with HIV infection of the following social network characteristics: (1) degree centrality (showing the number of people linked to a given person, that is, the number of egocentric network members, or the egocentric network size); (2) eigenvector centrality (indicating if someone is "well connected", that is, whether he or she is connected to many influential persons); and (3) betweenness centrality (showing the extent of being a "gate keeper", that is, being a connecting link or a bridge between groups within a network) [6].

Methods

Between March 2008 and May 2009, IDUs were recruited from the needle exchange program of the Lithuanian AIDS Centre in Vilnius, Lithuania (6 % of participants) or were brought in by other participants (94 % of participants, although many of them were also needle exchange clients) [7]. Of the 300 interviews conducted, one was removed from the data set because it was a duplicate person. Eligibility criteria were self-report of injecting drugs in the past 30 days and being 18 years old or older. Self-report of injecting drugs was confirmed by inspecting injecting marks. Participants were given food coupons for participation (worth LTL 20—about EUR 8) and for referring other participants (worth LTL 10). After signing an informed consent, eligible participants were administered a structured face-to-face survey. The questionnaire was originally written in English, translated into Lithuanian, back translated, and altered, if necessary. After the survey, participants were counselled about infectious disease prevention related to drug use, and provided blood samples. Abbott ELISA test Genscreen HIV1/2 (Biorad) confirmed by Western blot was used for HIV antibody testing. The Institutional Review Boards at the Johns Hopkins Bloomberg School of Public Health and the Lithuanian AIDS Centre approved all human subjects procedures for the study.

Measures and Variables

Socio-demographic control variables included age, years since first drug injecting, gender, and Russian ethnicity. *Individual risk characteristics* were assessed for the past 30 days, and included receptive syringe sharing, distributive syringe sharing, sharing cookers or filters, always using condoms for sex, and having two or more sex partners.

Sociometric network data were collected as follows. Participants were asked using standard naming stimuli to provide us with the names of friends or family whom in the past 30 days they would go to for advice, asked a favor from, with whom they had sex or used non-injected or injected drugs. Ties among participants who were interviewed for the study were ascertained based on each participant's nominations, on reports of relationships of other participants about their network members, and on ethnographic methods [8]. We used UCINET [9] to create three social network measures based on this relationship data: degree centrality ("popularity": the number of direct or egocentric network members), eigenvector centrality ("well-connectedness", a measure of influence: it measures the amount of network flow that a given person within the network "controls"—high eigenvector centrality means reaching the most people within the shortest distance) and betweenness centrality (being a "gate keeper": it counts the number of paths that pass through a given person) [6].

Data Analysis

Univariate contingency tables to describe distribution and univariate logistic regressions with corresponding Wald Chi square *p* values to assess association were conducted. In addition, to visualize the relationship between HIV and the continuous variables, loess local regression [10, 11] smooth curve fit plots were created with the proc loess procedure in SAS V9.2. Loess is a nonparametric method for estimating regression surface especially suitable for situations where a reasonable parametric model for the regression surface cannot be specified. The loess curve plots the prevalence of the dependent variable estimated for the categories of the independent variable.

Analysis was conducted in two stages [12]: first, preliminary regression models were conducted for the socio-

Table 1 Sample discription, and univariate and multivariate associations with HIV infection. Injecting drug users ($N = 299$) Vilnius, Lithuania

Characteristic	Total	HIV infected		Univariate		Preliminary multivariate		Final multivariate	
	N (%) or mean (SD)	No *N* (%) or mean (SD)	Yes *N* (%) or mean (SD)	OR (95 % CI)	*p* value	aOR (95 % CI)	*p* value	aOR (95 % CI)	*p* value
Total	299 (100)	270 (90.3)	29 (9.7)	–		–		–	
Sociodemographic variables									
Age	29.8 (7.6)	29.5 (7.7)	32.6 (6.5)	1.0 (1.0–1.1)	0.05*	0.91 (0.81–1.0)	0.13	–	
Years since first drug injecting	10.2 (6.7)	9.7 (6.5)	14.4 (7.1)	1.1 (1.0–1.1)	<0.01*	1.2 (1.1–1.4)	<0.01*	1.1 (1.0–1.2)	0.05*
Male gender									
No	71 (23.7)	64 (90.1)	7 (9.9)	(Reference category)		(Reference category)			
Yes	228 (76.3)	206 (90.4)	22 (9.6)	1.0 (0.4–2.4)	0.96	1.0 (0.40–2.6)	0.97	–	
Russian ethnicity									
No	149 (49.8)	138 (92.6)	11 (7.4)	(Reference category)		(Reference category)			
Yes	150 (50.2)	132 (88.0)	18 (12.0)	1.7 (0.8–3.8)	0.18	1.9 (0.85–4.4)	0.12	–	
Individual risk characteristics									
Receptive syringe sharing									
No	98 (32.8)	90 (91.8)	8 (8.2)	(Reference category)		(Reference category)			
Yes	201 (67.2)	180 (89.6)	21 (10.4)	1.3 (0.6–3.1)	0.53	1.7 (0.63–4.4)	0.30	–	
Distributive syringe sharing									
No	9 (3.0)	5 (55.6)	4 (44.4)	(Reference category)		(Reference category)		(Reference category)	
Yes	290 (97.0)	265 (91.4)	25 (8.6)	0.1 (0.0–0.5)	<0.01*	0.13 (0.03–0.61)	<0.01*	0.15 (0.03–0.76)	0.02*
Sharing cookers and filters									
No	15 (5.0)	13 (86.7)	2 (13.3)	(Reference category)		(Reference category)			
Yes	284 (95.0)	257 (90.5)	27 (9.5)	0.7 (0.1–3.2)	0.63	0.85 (0.15–5,0)	0.86	–	
Always using condoms									
No	278 (93.0)	254 (91.4)	24 (8.6)	(Reference category)		(Reference category)		(Reference category)	
Yes	21 (7.0)	16 (76.2)	5 (23.8)	3.3 (1.1–9.8)	0.03*	2.4 (0.7–8.1)	0.15	4.8 (1.3–17.2)	0.02*
Two or more sex partners									
No	135 (45.2)	115 (85.2)	20 (14.8)	(Reference category)		(Reference category)		(Reference category)	
Yes	164 (54.8)	155 (94.5)	9 (5.5)	0.3 (0.1–0.8)	<0.01*	0.38 (0.16–0.88)	0.02*	0.42 (0.18–1.0)	0.05*
Sociocentric centrality measures									
Degree centrality	5.6 (3.1)	5.5 (3.0)	6.5 (3.5)	1.1 (1.0–1.2)	0.10	1.1 (0.89–1.3)	0.41	–	
Eigenvector centrality	4.1 (7.1)	4.1 (7.2)	4.3 (5.5)	1.0 (1.0–1.1)	0.93	0.97 (0.90–1.1)	0.49	–	
Betweenness	0.90 (1.56)	0.79 (1.31)	1.83 (2.89)	1.3 (1.1–1.6)*	<0.01*	1.3 (1.0–1.5)*	0.04*	1.3 (1.1–1.6)*	<0.01*

* $p < 0.05$

demographic, centrality, and individual risk characteristic measures. Second, variables whose Wald Chi square p values were under 0.2 ($p < 0.2$) in the preliminary regression models were entered into one logistic regression model, and only variables that had statistically significant Wald Chi square p values ($p < 0.05$) were retained in the final model. Univariate odds ratios (OR), multivariate adjusted odds ratios (aOR), and their corresponding 95 % confidence intervals (95 % CI) are reported.

Results

The average age of participants was 30 years, and they had been injecting drugs for a mean of 10 years (Table 1). Table 1 also shows that most were male, half were Russian ethnicity, and that HIV risk characteristics—especially injecting equipment sharing—was very common. The overall prevalence of HIV infection was 9.7 %. Of the 29 people who were HIV infected, almost all ($n = 27$) reported they were aware of being infected (data not shown in table). The final sample of 299 individuals reported altogether 1,672 connections (Fig. 1)—participants were directly linked to between 0 ($n = 3$) and 16 ($n = 2$) other study participants (mean = 5.6, SD = 3.1)—with an overall network density of 0.0188 (meaning that 1.88 % of all possible connections among all participants were present in the network). There were altogether 14 components: one large component with 249 individuals (83 % of the sample), and 13 smaller components with 1–12 individuals (17 % of the sample).

In *univariate analysis*, older age, a higher number of years since first drug injecting, always using condoms and

Fig. 1 Sociometric graph showing HIV infected individuals (*black*) in relation to betweenness centrality (*larger sized nodes* depicting higher betweenness)

higher betweenness were significantly ($p < 0.05$) associated with HIV infection—distributive syringe sharing and having two or more sex partners showed a significant reverse association (Table 1). Loess regression fit plots showed that the highest estimated HIV prevalence value for the highest measured betweenness centrality was over 60 %, while the highest estimated prevalence values for both age and years since first drug injecting were around 20 % or under (Fig. 2).

In *multivariate analysis*, a higher number of years since first drug injecting, always using condoms, and betweenness centrality remained significantly ($p < 0.05$) associated with HIV prevalence, while distributive syringe sharing and having two or more sex partners showed a significant but reverse association.

Discussion

In this study we found moderate levels of HIV infection among IDUs in Vilnius, Lithuania. Of the five variables that remained significant in the final multivariate model, one showed temporal cumulative infection risk, three reflected potential informed altruism (or maybe social desirability bias), and one pointed to the importance of social network structure.

The association of years of injecting with HIV infection shows the cumulative risk during the lifetime of IDUs. The loess curve in this study showing the relationship between the estimated HIV prevalence and years of injecting is similar to the HIV population dynamics curves shown in IDU populations [13]. In both cases, HIV prevalence increased initially (at the beginning of the HIV epidemic in the overall IDU population, and in a naïve population of new injectors in our sample), then the prevalence became steady (a combination of new infections offset by loss due to death, with a background of low transmission due to preventive behavior). These infection dynamics highlight the importance of harm reduction efforts both within populations of IDUs and during the lifetime of individual people who inject drugs [14].

In this study population, HIV infected participants reported significantly less likely than non-infected participants that they gave away their used syringes or had sex with two or more partners, and more likely that they used condoms. While this relationship may sound counterintuitive, it is not a product of lower-risk behavior leading to infection but infection leading to (reported) lower-risk behavior. Almost all HIV infected study participants were aware of being infected. Therefore, the reverse association between HIV infection and risk behaviors may reflect either the adoption of informed altruism of those individuals who know they are HIV infected [15], or social desirability bias where individuals who know they are HIV infected underreport risk behaviors. While there is no way to disentangle informed altruism from social desirability

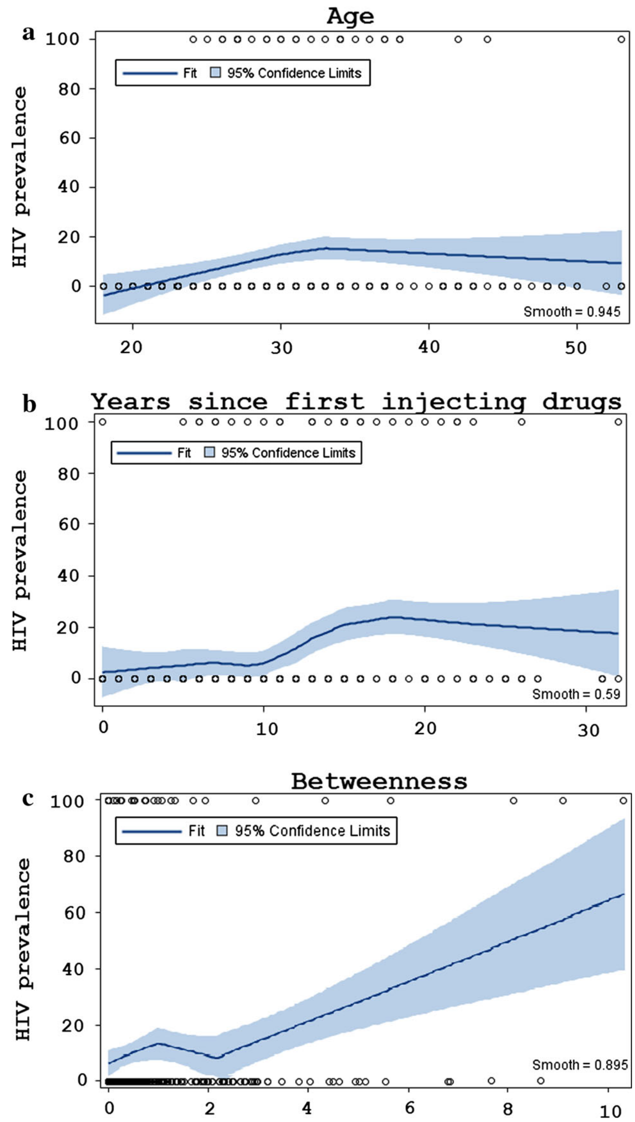

Fig. 2 Loess fit plots showing the relationship between HIV infection and **a** age, **b** years since first injecting and **c** betweenness centrality

bias based on self report, both are based on awareness. Therefore, they both point not only to the importance of harm reduction activities including the provision of information and the maintenance of social norms supporting the value of being uninfected, but also the necessity of confidential testing and counseling, with a special emphasis on ensuring that those who were tested receive their test results in a timely manner. These public health measures, however, are effective only if IDUs have access to harm reduction material and police do not arrest them for carrying risk reduction materials.

In addition to individual characteristics, HIV prevalence in this study was both significantly and considerably associated with betweenness centrality (a structural social network characteristic). While we intended to use loess curves to visualize the relationship between the assessed continuous variables and HIV infection, this visualization led us to one of the major results. The loess curves showing HIV prevalence estimates for the continuous variables indicate that—while age, years since first drug injecting and betweenness are all highly statistically significant in univariate analysis—betweenness may have the highest impact on HIV prevalence. This highlights something of an “occupational hazard” of gatekeepers who, given their connecting roles in the population, may act as bridges of infections. This finding not only shows the importance of the sociocentric social network, but also highlights a potential for prevention. Highly central individuals have been targeted with prevention campaigns in network prevention interventions to become peer leaders. As part of these preventions, these central peers had the role of spreading messages about how to prevent HIV infection. It has been found that peer leaders themselves exhibited the most risk reduction behaviors [16]. Our result, therefore, highlights the potential dual importance of people with high betweenness centrality. First, they can be used as effective peer educators in network prevention interventions to reach various at-risk populations, and second, since as peer leaders they are very likely to reduce their risk profile, they may therefore reduce the flow of HIV infection within the IDU population and among segments of sub-populations that they connect.

Limitations of the study include that linkages may have changed during the duration of the study, and self-report of links may not have captured all existing links, or certain links may not have been reported. Therefore, relations may have been under- or over-reported. Another limitation is that participants were initially recruited from the needle exchange. However, most participants were recruited through other participants, which probably reduced the initial recruitment bias. Social desirability, which may explain some of the findings, was not specifically assessed in this study.

This analysis contributes to existing evidence showing both informed altruism in connection with HIV infection, and a link between HIV infection risk and the social network structure of injecting drug user populations. Our findings point to the importance of harm reduction activities including confidential testing and counseling (in relation to informed altruism), and of social network interventions (in relation to centrality) in connection with HIV prevention among IDUs.

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Conflict of interest The authors declare no conflict of interest.

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