Emergent properties of HIV risk among injection drug users in Tallinn, Estonia: synthesis of individual and neighbourhood-level factors

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ABSTRACT

Objectives HIV/AIDS risk is embodied within multiple levels including structural and social levels. The aim of this study was to assess the effects of neighbourhood characteristics on HIV prevalence among injection drug users (IDU) residing in the area of Tallinn, Estonia in 2007.

Methods A cross-sectional, multilevel design collecting individual-level data—a behaviour survey including data on self-reported residency and HIV antibody testing among 350 IDU and neighbourhood-level data—aggregate measures on socio-demo-economic residential characteristics from the 2000 Estonian census. Geocoding and multilevel modelling analysis was employed.

Results Among the 350 IDU recruited, earlier age at first injection, fentanyl as the main injection drug, receptive syringe sharing, main income source other than legal employment and ever attended a syringe exchange programme remained significantly associated with increased odds of anti-HIV positivity in the multivariable analysis involving individual effects with no predictors at the neighbourhood level. In the multilevel model, individual (earlier at IDU initiation AOR 1.86, 95% CI 1.01 to 3.44; injecting opioids AOR 4.43, 95% CI 2.74 to 7.18; receptive syringe sharing AOR 2.51, 95% CI 1.86 to 3.37; main income source other than work AOR 2.04, 95% CI 1.32 to 3.14; ever attended a syringe exchange programme AOR 2.58, 95% CI 1.83 to 3.61) and neighbourhood level (higher unemployment rate AOR 5.95, 95% CI 2.47 to 14.31; greater residential change AOR 1.89, 95% CI 1.09 to 3.26) emerged as significant predictors of individual HIV-positive status.

Conclusions Our results indicate that both individual-level and emergent neighbourhood-level factors contribute to HIV risk among IDU and are amenable for preventive interventions.

Research on the risk of injection-related HIV has largely focused on individual-level characteristics and behaviours. However, HIV/AIDS risk is embodied within multiple levels including structural and social levels. Cultural context, social networks, social capital and neighbourhood effects are proposed as categories of social-level factors impacting the epidemiology of HIV/AIDS.[1] Neighbourhoods represent the intersection of social networks and physical spatial locations, and thus constitute the structural conditions that shape individual lives and opportunities. Ignoring these factors can lead to an incomplete understanding of the relation between individual risk factors and disease.[2]

A recent international systematic review of HIV epidemics among injection drug users (IDU) highlighted the need for understanding both individual and risk environment characteristics that determine patterns of HIV among IDU. The review noted that delineating environmental risk factors and understanding the similarities and differences in relationships between individual and environmental factors across different national settings remain key challenges.[3] Several methodological approaches can be used to investigate neighbourhood effects on the injection-related risk of HIV/AIDS.[2] First, comparisons of a small number of well-defined neighbourhoods can be used. Buchanan *et al*[4] showed that IDU in more economically disadvantaged neighbourhoods were more likely to engage in higher risk injection behaviours than IDU from economically advantaged neighbourhoods. However, this research approach is limited in the number and range of neighbourhoods investigated and possibly in the generalisability of results.[2] The majority of research on neighbourhood-level effects has used an ecological approach and has focused on the roles of ethnic/racial segregation, poor socio-economic conditions, high unemployment and the proliferation of illicit drug markets.[1 5 6] Still, to be able to evaluate the role of individual-level factors as confounders, mediators, or modifiers of area effects, multilevel studies that include individuals nested within areas or neighbourhoods are required.[2] Yet, few studies have examined the associations between area characteristics and either HIV risk behaviour[7–13] or HIV infection among IDU.[8 14] In addition, combining qualitative and quantitative research has been used.[15]

Most of the studies referenced have been conducted in the USA. A recent study conducted in St Petersburg (Russia) focussing on IDU drug choice, spatial distribution and HIV risk using individual-level and aggregated neighbourhood-level data concluded that the neighbourhood of residence is an important covariate when studying the relationship between HIV prevalence and risk behaviours.[14]

To expand on previous work involving HIV risk factors among IDU, we studied the effects of individual and neighbourhood characteristics on HIV prevalence among IDU residing in the area of Tallinn, Estonia, in 2007.

Injecting drug use is driving HIV epidemics in many areas of eastern Europe, central Asia and southeast Asia. Estonia is confronted with an HIV epidemic driven by injection drug use that has led

to the highest incidence of HIV infection in Europe (with numbers of new cases diagnosed increasing from 7.2 per million in 1998 to 472 per million in 2007).[16] Recent studies among IDU conducted in the capital city of Tallinn have revealed a high prevalence of HIV (~50%)[17–19] and an estimated HIV incidence of more than 20/100 person-years at risk.[20] HIV infection has been associated with injection risk behaviours, types of drugs injected and ethnicity.[17 19 21] The size of the IDU population in Tallinn is estimated to be approximately 10 000, which translates into an injection drug use prevalence of 4.3% among people aged 15–44 years (Tallinn area population: 522 147; population aged 15–44 years: 230 318).[19]

METHODS

Study subjects

In May and June 2007, respondent-driven sampling methods[22 23] were employed to recruit IDU in Tallinn for a risk behaviour survey and biological sample collection for HIV testing. Briefly, respondent-driven sampling is a chain referral sampling method designed to reduce bias generally associated with such methods. Although sampling is initiated by purposively selected recruits ('seeds'), the composition of the ultimate sample is independent of those initial subjects and may be considered representative of the target population.[22 23] For the current study seeds were selected among syringe exchange programme clients. Eligibility criteria included injection drug use within the past 2 months, age of 18 years or older and the ability to provide written informed consent. To ensure IDU status, subjects were checked for injection marks and/or asked to describe the process of preparing drugs for injection.

Study procedures

Study participants completed an interviewer-administered questionnaire conducted privately by trained staff. After the interview, participants were offered HIV counselling and testing and referrals for medical and social services. After 2 weeks, at the HIV test result visit, participants were provided additional counselling and referrals. Coupons for grocery store purchases were used to compensate respondents' effort, time and travel costs associated with participation (primary incentive with the value of US$10) and recruitment of peers (secondary incentive with the value of US$5). Study participation was anonymous.

Measures

Individual-level variables (level 1)

Behavioural data were collected using a structured questionnaire developed from the WHO Drug Injecting Study Phase II survey (version 2b).[24] In addition to sociodemographic variables, data were collected on past and recent drug use, sexual behaviour, contacts with police and imprisonment, drug treatment history and contacts with HIV prevention and harm-reduction services. We also enquired on the self-reported residency of participants ('the nearest bus stop to the location where the respondent had mostly lived during the last 6 months').

Venous blood was collected from participants and tested with commercially available kits for HIV antibodies—Abbott IMx HIV-1/HIV-2 III Plus (Abbott Laboratories, Abbott Park, Illinois, USA) with immunobloting assay INNI LIA HIV I/II Score Western blot conformation (Microgen Bioproducts Ltd, Surrey, UK). This HIV testing procedure has high sensitivity and specificity (>99%).[25 26] The testing was conducted at the State HIV/AIDS reference laboratory in Tallinn.

Neighbourhood-level variables (level 2)

Using data from the 2000 Estonian Census (traditional census, conducted by the method of face-to-face interviews) we obtained data on variables representing sociodemographic and economic characteristics of 15 habitats in the Tallinn area with self-reported IDU residencies. Habitats represent districts that closely match the description of neighbourhoods. For each of the habitats the following aggregate characteristics were evaluated: age (percentage of residents aged 16–30 years; the overwhelming majority of IDU in Estonia are of age <30 years[17–21]), gender (percentage of men), residential instability (percentage having different residence in 1989), mother tongue (percentage non-Estonian), marital status (percentage married), source of income (percentage other than regular—salary, pension—income), employment (percentage unemployed), type of buildings (percentage living in apartment buildings vs private/small houses), mean income (per habitat) and dwelling infrastructure (percentage without plumbing).

Data analysis

Univariate statistics of frequency, central tendency and dispersion were used to describe the sample at the individual level on sociodemographics, sexual behaviour, drug use, HIV status and network characteristics; and on habitat-level attributes pertaining to sex and age distribution, ethnicity, language, socioeconomic indicators and housing.

Using GIS software, reported IDU residences were geocoded to a point location and corresponding habitat. Habitat-level demographic and socioeconomic variables were linked with individual attribute data to create the final multilevel dataset. Multilevel modelling analysis was employed to identify individual-level and emergent structural-level factors, as well as cross-level interactions, associated with IDU-related HIV risk.[27] Multilevel random intercept logistic regression was employed to test bivariate and multivariable models regarding individual-level and habitat-level predictors of HIV infection among IDU. Multilevel models were fit using Mplus (version 5.2) statistical software. The significance level was set at 0.05.

Multilevel analysis combines the effects of variables at different levels (in this case, individual IDU and habitat-level effects) while accounting for the interdependence among individuals (level 1) nested within habitats (level 2).[28] There are two primary advantages of using multilevel modelling in the present analysis. First, given heterogeneity across habitats, individuals within habitats may give correlated responses (a violation of the assumption of data independence, which can lead to inflated type 1 errors) and multilevel modelling corrects for this clustering effect. Second, risk factors can be estimated at both the individual and habitat levels. Multilevel modelling thus permits testing hypotheses regarding the effects of habitat-level characteristics on outcomes, an important source of information for planning structural interventions.

None of the level 1 or level 2 variables were centred because they were either dichotomous or had a meaningful value for zero. Bivariate multilevel logistic regression models were used to examine the effects of risk factors on HIV serostatus. In multivariable analysis, a hierarchical technique was used to specify the final model.[29] First, an unconditional or 'empty' multilevel model was specified to examine the effects of habitat clustering on the outcome. Next, individual-level predictors were added to the model followed by habitat-level predictors. Non-significant terms were then removed from the two-level saturated model while retaining significant main effects to produce

the final model. This permitted an investigation of the ways in which individual and habitat factors are independently associated with HIV infection.

RESULTS

The majority of the 350 IDU recruited were men (84%), Russian-speaking (82%) and had stable living conditions (living in a house/flat, 91%). More than one-third (38.6%) was less than 25 years old, and approximately half (53%) had less than 9 years of education. Half of the sample (53%) was employed (full/part time), and one-third (32%) named theft, robbing, or stealing as a main source of income.

The mean age at first drug injection among participants was 18.7 years (SD 5.6) and the mean number of years injecting was 7.9 (SD 4.4). Sixty-two per cent reported injecting daily in the past 4 weeks. The majority (72%) injected mainly opioids (namely fentanyl, an illicitly manufactured synthetic opioid), followed by amphetamine (26%). Approximately one-third (35.4%) of the IDU reported injecting with a used needle/syringe in the past 6 months. Over two-thirds were never married (71%). Nearly half (45%) reported having two or more sex partners in the past 12 months. Fifty-eight per cent reported ever having been in prison; 82% reported ever having used the needle/syringe exchange and 39% reported a history of drug treatment.

In the bivariate analysis of individual-level risk factors with no predictors at level 2, increased odds of anti-HIV positivity were associated with mainly injecting opioids (OR 4.6, 95% CI 2.9 to 7.4), sharing needles in the past 6 months (OR 2.6, 95% CI 1.9 to 3.5), reporting other than work as a main income source (OR 2.4, 95% CI 1.7 to 3.3), ever having attended a needle/syringe exchange (OR 4.2, 95% CI 3.1 to 5.8), injecting daily (OR 1.7, 95% CI 1.1 to 2.6), ever receiving drug treatment (OR 1.7, 95% CI 1.2 to 2.5) and being less than 18 years of age at first injection (OR 2.4, 95% CI 1.4 to 4.2; table 1).

The majority (73%) of IDU participating in the study reported living in only three neighbourhoods out of the total 15 in the Tallinn area: 42% in Lasnamäe; 20% in North-Tallinn and 11% in Mustamäe (figure 1).[4]

In table 2, we present multivariable individual and multilevel predictors of the sociodemographic characteristics of the neighbourhoods of IDU that were associated with HIV-positive status among study participants. In the multivariable analysis involving individual effects with no predictors at level 2, five variables remained significantly associated with increased odds of anti-HIV positivity—earlier age of IDU initiation, injecting opioid (fentanyl) as main injection drug, receptive syringe sharing in previous 6 months, main income source other than legal employment, and ever attended a syringe exchange programme. The adjusted odds ratios and 95% confidence intervals were only slightly altered with the addition of habitat-level predictors to the model. This indicates the likely absence of cross-level interactions. Two habitat characteristics were significantly associated with individual HIV-positive status. Namely, for a 10% increase in the unemployment rate by habitat an individual's odds of being HIV positive increase by nearly six times (AOR 5.95, 95% CI 2.5 to 14.3) and in resident change since 1989 by habitat by 89% (AOR 1.9, 95% CI 1.09 to 3.3). Across habitats, the median unemployment rate was 11% with a range of 4–17%; the median resident change from 1989 was 73% with a range of 19–84%.

Comparison of the −2 log likelihood, Akaike's information criterion (AIC), and adjusted Bayesian information criterion (BIC) model fit measures between the two nested models (see table 2) indicate that the addition of the two habitat-level predictors to the model improved model fit. Two nested models were compared using the likelihood ratio test: a full model containing both individual and habitat level predictors and a 'restricted' model containing only individual level predictors. The restricted model yielded a −2 log likelihood of 3.88.33, whereas the full model produced a −2 log likelihood of 343.29 (difference −2 log likelihood 45.04, 2 df, $p<0.001$). AIC and sample size adjusted BIC model fit indices also improved substantially with the addition of the habitat-level variables to the model.

The random effect variance component of the multilevel model was very small and not significantly different from zero (σu <0.001, p=0.93), indicating very little if any variance in the outcome left to be accounted for by level 2 predictors.

Table 1 Characteristics of IDU in Tallinn, 2007 associated with HIV positive status

	HIV+/total	%HIV+	OR	95% CI	p Value
Characteristic					
HIV serostatus	193/350	55.1	NA		
Sociodemographic					
Age (years)					
24 or less	72/135	53.3	1		
25+	121/215	56.3	0.67	0.41 to 1.1	0.1
Gender					
Male	157/294	53.4	1		
Female	36/56	64.3	1.60	0.87 to 2.84	0.1
Main source of income in past 4 weeks					
Full/part-time work	83/187	44.4	1		
Other	110/163	67.5	2.60	1.68 to 4.02	0.000
Ethnicity					
Estonian	24/53	45.3	1		
Russian, other Russian speaking	169/297	56.9	1.60	0.89 to 2.87	0.1
Injecting drug use characteristics					
Age at beginning to inject (years)					
17 or less	105/163	64.4	2.39	1.35 to 4.32	0.001
18+	88/187	47.1	1		
Frequency of injection (past 4 weeks)					
Less than daily	62/136	45.6	1		
Daily	131/210	62.4	1.98	1.28 to 3.07	0.020
Main drug injected in past 4 weeks					
Amphetamine	24/90	26.7	1		
Opioids (fentanyl)	161/248	64.9	5.09	2.98 to 8.69	0.000
Shared needles or syringes during past 6 months					
No	107/223	48.0	1		
Yes	85/124	68.6	2.36	1.49 to 3.74	0.000
Sexual risk behaviours					
No of sexual partners in past 12 months					
0/1	108/191	56.5	1		
2+	8/159	53.5	0.88	0.58 to 1.35	0.563
Environmental factors					
Ever been in prison?					
No	75/146	51.4	1		
Yes	118/204	57.8	1.30	0.85 to 2.0	0.200
Ever received drug treatment?					
No	108/214	50.5	1		
Yes	85/136	62.5	1.64	1.06 to 2.54	0.028
Ever attended needle exchange?					
No	27/76	35.5	1.0		
Yes	162/269	60.2	2.75	1.62 to 4.67	0.000

IDU, injection drug user.

DISCUSSION

On a macrosocial level, neighbourhood characteristics have been found to be associated with the prevalence of HIV and other

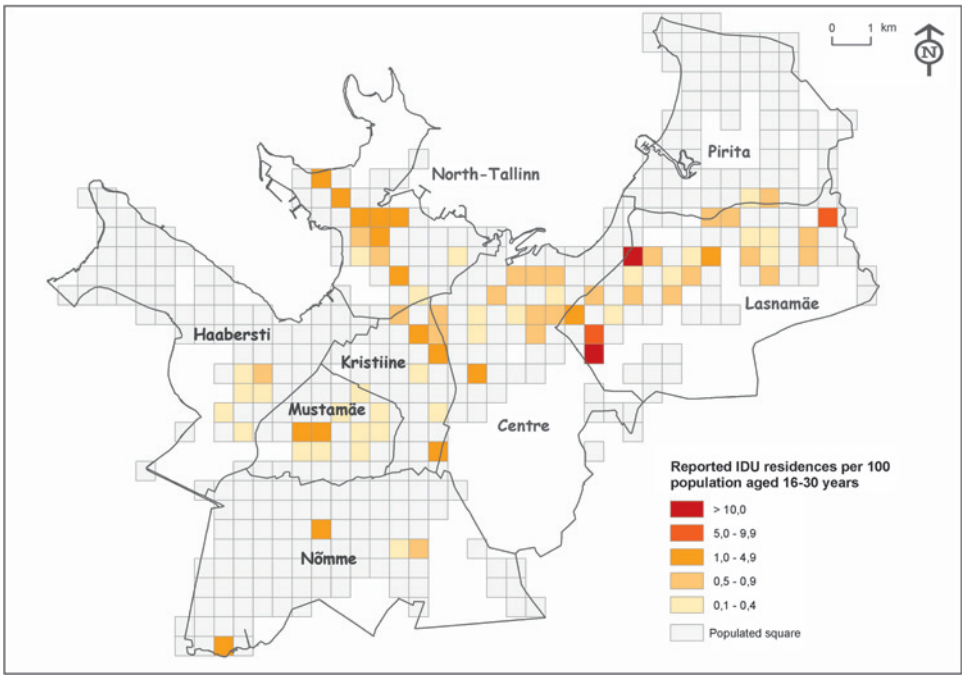

Figure 1 Map of the Tallinn neighbourhoods (N=8) and reported injection drug user (IDU) residences per 100 population aged 15–30 years in the neighbourhoods, 2007.

blood-borne and sexually transmitted infections.[1 11] In a number of studies among non-IDU populations, neighbourhood-level effects together with individual-level characteristics were jointly examined as predictors of HIV serostatus.[30 31] Relatively few studies have examined neighbourhood and individual-level effects together on HIV seroprevalence among current IDU.[14] Our findings highlight the importance of neighbourhood socioeconomic conditions on injection-related HIV risk.

Table 2 Multivariable individual and multilevel predictors of HIV-positive status among IDU in Tallinn, 2007

Variable	Individual-level effects adjusted OR (95% CI)*	Individual and habitat-level effects adjusted OR (95% CI)†
Individual-level		
Earlier age of IDU initiation (1=less than 18 years; 0=18 years or older)	1.94 (1.19 to 3.16)	1.86 (1.01 to 3.44)
Opioid (fentanyl) as main injection drug‡	4.01 (2.31 to 6.96)	4.43 (2.74 to 7.18)
Receptive sharing in past 6 months‡	2.30 (1.36 to 3.88)	2.51 (1.86 to 3.37)
Main income source of other than work‡	2.11 (1.30 to 3.43)	2.04 (1.32 to 3.14)
Ever attended syringe exchange programme‡	2.75 (1.43 to 5.30)	2.58 (1.83 to 3.61)
Habitat-level		
Employment (unemployment rate, 10% unit)	NA	5.95 (2.47 to 14.31)
Residential change (10% different from 1989)	NA	1.89 (1.09 to 3.26)
Tests of model fit		
−2 Log likelihood	388.33	343.29
AIC	400.33	361.29
Sample size adjusted BIC	404.29	366.44

*Adjusted for individual-level effects only, by multiple logistic regression.
†Adjusted for both individual and neighborhood-level effects by multilevel modelling techniques.
‡Unit of measurement: yes=1; no=0.
AIC, Akaike's information criterion; BIC, Bayesian information criterion; IDU, injection drug user.

Our results on individual-level factors associated with HIV seropositivity are in accordance with earlier studies in that predictors included earlier age of IDU initiation,[32 33] type of drug injected,[16 20] receptive syringe sharing,[34 35] unemployment[36] and syringe exchange programme usage.[37 38] A recent analysis by Vorobiov *et al*[39] concluded that IDU utilising syringe exchange programme services are further along in their injection career (longer time of injecting, injecting more frequently) and thus are more likely to be HIV infected than those IDU who mainly obtain syringes from pharmacies[39] and thus do have access to sterile syringes.

Our analysis showed that adding habitat-level predictors of HIV seropositivity improved model fit, but has little influence on individual-level predictors in the model. In contrast, a recent analysis from Russia found that individual-level behaviours were associated with HIV seropositivity only after control for neighbourhood characteristics.[14]

The major finding of this study was that features of the social environment, specifically neighbourhood unemployment level and residential instability are important in predicting HIV seropositivity among IDU. Unemployment level is an indicator of neighbourhood disadvantage. An increased risk of contracting HIV in economically disadvantaged urban neighborhoods has been described previously.[10] Interestingly, residential instability (measured as proportion of households who have lived in their current home for less than 10 years) was associated with increased odds of HIV seropositivity. Previously, higher levels of residential instability have been associated with child maltreatment,[40 41] life-time alcohol use in children[42] and mental health in adolescents.[43] In addition, higher residential instability (as an aggregate measure) has been associated with decreased access to HIV-related services in Toronto, Canada.[44]

Our study has several limitations. The study design does not allow us to establish a causal relationship or a direction of causality. Second, we used a non-probability sample that may have implications for the representativeness and generalisability of study findings. However, it is important to underline that we used a social network sampling strategy (respondent-driven sampling) that has been shown to produce representative samples of hidden populations, including IDU.[22 23] Individual

Key messages

- Neighbourhood of residence is an important covariate for the relationship between HIV prevalence and risk behaviours.
- Research on the effect of neighbourhood on HIV and related risk behaviours is needed.
- Standardisation on the measures of the effect of neighbourhood is needed.

and habitat-level data for the analysis presented were collected in 2007 and 2000, respectively. Comparing the distribution of key habitat-level factors at the city level revealed close correspondence of 2000 census data with the routinely collected statistics in 2007:[45] there were no changes in the age or gender distribution (data not shown).

Despite marked differences in culture, economic factors and drug use, our results were similar to earlier studies at both the individual and neighbourhood level. We observed that neighbourhood economic disadvantage (high unemployment) and residential instability were associated with higher HIV seropositivity. Given the high rate of transiency among IDU in many urban settings throughout the world, our finding justifies additional research on this topic, including the implications for locating HIV prevention services in areas with high residential change.

The implications of our results might be relevant to HIV prevention practice and research. HIV/AIDS among IDU is a truly global public health problem, and understanding similarities and differences at both individual and neighbourhood levels can contribute to understanding how HIV prevention interventions at multiple levels may function in different settings. Individual-level characteristics of IDU-related HIV risk have been the most commonly studied predictors. However, a potential limitation of this approach is that the individualistic interventions it informs may not adequately address the underlying forces driving the prevalence and distribution of risk factors for injection drug use in the population.

Further research on the effect of neighbourhood/risk environment on HIV and related risk behaviours is needed, including research towards standardisation on the measures to be used. In designing and implementing targeted interventions for IDU in Tallinn, Estonia, it will be important to focus on specific risk behaviours and the social and structural contexts in which these are practised. Integrating and directing economic, social and health policies towards decreasing neighbourhood disparities involving economic disadvantage and residential instability may have a significant impact on curbing the growing HIV epidemic in urban areas of Estonia.

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Competing interests None declared.

Patient consent Obtained.

Ethics approval This study was conducted with the approval of the the Ethics Review Board at the University of Tartu.

Contributors AU, KAO, AT, KR and DCDJ designed the individual-level data collection study and KAO, AT, KR supervised the data collection. RA and SS compiled the neighbourhood-level data. AU and JMM planned the analysis; MR organised the data and JMM conducted the statistical analysis. AU wrote the first draft of the manuscript. All authors contributed to revising the manuscript and have approved the final manuscript.

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