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Associations Between Neighborhood Characteristics, Social Cohesion, and Perceived Sex Partner Risk among HIV-Seropositive and HIV-Seronegative Women in the Southern United States

Danielle F. Haley[1,2], **Gina M. Wingood**[3], **Michael R. Kramer**[4], **Regine Haardörfer**[2], **Adaora A. Adimora**[1,5], **Anna Rubtsova**[2], **Andrew Edmonds**[5], **Neela D. Goswami**[4,6], **Christina Ludema**[1], **DeMarc A. Hickson**[7], **Catalina Ramirez**[1], **Zev Ross**[8], **Hector Bolivar**[9], and **Hannah L. F. Cooper**[2]

[1]Institute for Global Health and Infectious Diseases, School of Medicine, University of North Carolina at Chapel Hill School of Medicine, 130 Mason Farm Road, Chapel Hill, NC, 27599, USA

[2]Department of Behavioral Sciences and Health Education, Rollins School of Public Health at Emory University, Atlanta, GA, USA

[3]Department of Sociomedical Sciences, Lerner Center for Public Health Promotion, Mailman School of Public Health at Columbia University, New York, NY, USA

[4]Department of Epidemiology, Rollins School of Public Health at Emory University, Atlanta, GA, USA

[5]Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

[6]Division of Infectious Diseases, Emory University School of Medicine, Atlanta, GA, USA

[7]Department of Epidemiology and Biostatistics, Jackson Jackson, MS, USA

[8]ZevRoss Spatial Analysis, Ithaca, NY, USA

[9]Division of Infectious Diseases, University of Miami Miller School of Medicine, Miami, FL, USA

Abstract

Neighborhood social and physical factors shape sexual network characteristics in HIV-seronegative adults in the United States. This multilevel analysis evaluated whether these relationships also exist in a predominantly HIV-seropositive cohort of women. This cross-sectional

Corresponding Author: Danielle F. Haley, Institute for Global Health and Infectious Diseases, University of North Carolina at Chapel Hill School of Medicine, 130 Mason Farm Road, Chapel Hill, NC USA 27599, T: 919-357-1045, danielle_haley@med.unc.edu.

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Compliance with Ethical Standards: Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Human and Animal Rights: This article does not contain any studies with animals performed by any of the authors.

Informed Consent: Informed consent was obtained from all individual participants included in the study. This secondary analysis is restricted to individual participants who provided written informed consent to collect and geocode their home address.

multilevel analysis included dm 734 women enrolled in the Women's Interagency HIV Study's sites in the U S South. Center track-level contextual data captured socioeconomic disadvantage (e.g., tract poverty), number of alcohol outlets, and number of nonprofits in the census tracts where women lived; participant-level data, including perceived neighborhood cohesion, were gathered via survey. We used hierarchical generalized linear models to evaluate relationships between tract characteristics and two outcomes: perceived main sex partner risk level (e.g., partner substance use) and perceived main sex partner non-monogamy. We tested whether these relationships varied by women's HIV. Greater tract-level socioeconomic disadvantage was associated with greater sex partner risk (*OR* = 1.29, 95 % *CI* = 1.06-1.58) among HIV-seropositive women and less partner non-monogamy among HIV-seronegative women (*OR* = 0.69, *95* % *CI* = 0.51-0.92). Perceived neighborhood trust and cohesion was associated with lower partner risk (*OR* = 0.83, 95 % *CI* = 0.69-1.00) for HIV-seropositive and HIV-seronegative women. The tract-level number of alcohol outlets and non-profits were not associated with partner risk characteristics. Neighborhood characteristics are associated with perceived sex partner risk and non-monogamy among women in the South; these relationships vary by HIV status. Future studies should examine causal relationships and explore the pathways through which neighborhoods influence partner selection and risk characteristics.

Keywords

HIV; Neighborhood Characteristics; Sexual Risk; Multilevel Analyses; Social Cohesion

Introduction

One in five newly identified HIV infections in the United States are among women; the vast majority of these infections are acquired through heterosexual transmission (Centers for Disease Control and Prevention, 2015). Although the HIV epidemic was initially concentrated in the northeastern and western regions of the U.S., it now has transitioned to the Southern U.S. (Adimora, Ramirez, Schoenbach, & Cohen, 2014; Centers for Disease Control and Prevention, 2015; Reif et al., 2014). The South has the highest rate of HIV diagnosis, and women living with HIV in this region experience higher rates of HIV-related morbidity and mortality (Adimora et al., 2014; Centers for Disease Control and Prevention, 2015; Reif et al., 2014, 2015).

An emerging line of evidence indicates that social and physical features of neighborhood environments influence the transmission of HIV and other sexually transmitted infections (STIs). In the U.S., geographic areas with high levels of socioeconomic disadvantage (e.g., high poverty rates) and social disorder (e.g., high violent crime rates) tend to have higher prevalences of STIs, including HIV (Chesson, Owusu-Edusei, Leichliter, & Aral, 2013; Cohen et al., 2000, 2006; Jennings, Woods, & Curriero, 2013; Theall et al., 2009; Thomas, Torrone, & Browning, 2010). Multilevel studies, which allow for exploration of relationships between neighborhood characteristics and sexual risk in individuals by controlling for potential neighborhood- and individual-level factors, have found that among HIV-seronegative populations, living in neighborhoods with low male:female sex ratios (i.e., fewer men than women), high incarceration rates, and prevalent poverty is associated with

more unprotected sexual intercourse, partner risk (i.e., non-monogamy, multiple sex partners, and risk discordant partnerships), and STIs (Adimora, et al., 2013b; Cooper et al., 2014, 2015; Ford & Browning, 2013; Green et al., 2012; Jennings, Glass, Parham, Adler, & Ellen, 2004; Jennings et al., 2010; Pouget, Kershaw, Niccolai, Ickovics, & Blankenship, 2010).

Social organization models suggest that differential health outcomes across communities are a function of community cohesion and trust, and that neighborhood attributes (e.g., high poverty rates, high social disorder) may influence the ability of residents to develop cohesive relationships (Putnam, 2000; Sampson, Raudenbush, & Earls, 1997). More socially cohesive areas tend to have lower prevalences of STIs, including HIV (Holtgrave & Crosby, 2003; Theall et al., 2009). Theall et al. (2009) found that relationships between neighborhood alcohol availability and neighborhood gonorrhea rates were mediated by neighborhood trust and cohesion (i.e., social capital), suggesting that neighborhood social organizational factors may have both direct and indirect relationships to sexual health outcomes. However, the vast majority of research exploring relationships between neighborhood-level social capital and STIs has utilized ecologic designs (Holtgrave & Crosby, 2003; Theall et al., 2009). Studies using ecologic designs analyze relationships at a group level (e.g., census tracts), and as a result are unable to assess relationships between neighborhood characteristics and individual-level behaviors and to control for individual-level factors.

Sexual partner characteristics, including partner non-monogamy, can increase an individual's risk by creating overlapping sexual networks that facilitate the transmission of HIV and other STIs (Adimora et al., 2006; Cooper et al., 2015; Doherty et al., 2012). Notably, having a non-monogamous partner has been identified as a risk factor for HIV transmission among women who were otherwise low risk (Adimora et al., 2006a). Individuals living with and at increased risk of HIV tend to select sexual partners in closer proximity than lower risk populations (Cooper et al., 2016; Gindi et al., 2011). An understanding of whether and how neighborhood characteristics influence sex partner characteristics can inform the development of interventions to promote sexual health and reduce the transmission of STIs, including HIV. To date, no studies have explored whether relationships between neighborhood characteristics and sex partner risk vary by HIV status. It is possible that the magnitude and direction of relationships between place characteristics and sexual health are different for HIV-seropositive and HIV-seronegative women. For example, neighborhood characteristics may be less influential for women living with HIV because they have a stronger incentive to protect their health or that of their partner (Marks, Crepaz, Senterfitt, & Janssen, 2005).

The present study explored relationships between neighborhood characteristics, including social organizational factors, and perceived sex partner risk among a predominantly HIV-seropositive cohort of women living in the South. We sought to:

1. Examine relationships between neighborhood characteristics (e.g., socioeconomic disadvantage, trust and cohesion) and perceived sex partner risk.

2. Investigate whether the magnitudes and directions of relationships between neighborhood characteristics and perceived sex partner risk vary by women's HIV.

Methods

Participants

The Women's Interagency HIV Study (WIHS)is a multisite, prospective study designed to characterize the natural history, clinical, and behavioral impact of HIV among women living with HIV and among HIV-seronegative women at high risk of HIV infection in the U.S. (Bacon et al., 2005; Barkan et al., 1998). The WIHS includes HIV-seronegative women whose sociodemographic characteristics are similar to those of HIV-seropositive women in the cohort, who, in turn are representative of the race/ethnicity of HIV-seropositive U.S. women (Bacon et al., 2005; Hessol et al., 2000, 2001, 2009). Established in 1993, the WIHS cohort initially consisted of women living in the northeastern and western regions of the U.S. (Bacon et al., 2005; Barkan et al., 1998). Recognizing the shifting geography of the epidemic in U.S. women, the WIHS expanded to include sites in the Southern U.S. in 2013. This cross-sectional analysis utilized screening data from women who were enrolled at the WIHS sites in Alabama, Florida Georgia, Mississippi, and North Carolina between October 2013 and September 2015. Southern site WIHS participants were between 25-60 years old at enrollment. WIHS eligibility criteria at WIHS Southern sites stipulated that HIV-seropositive women were antiretroviral therapy (ART) naïve or started highly active antiretroviral therapy (HAART) after December 31, 2004; had never used didanosine, zalcitabine, or stavudine (unless during pregnancy or for pre- or post-exposure HIV prophylaxis); had never been on non-HAART ART, and had documented pre-HAART CD4 counts and HIV viral load. Eligible HIV-seronegative women reported at least one personal characteristic or male sexual partner characteristic associated with increased risk of HIV acquisition within past 5 years (e.g., clinical STI diagnosis). Participants were identified using diverse recruitment strategies, such as physician referrals and health fair contacts. Institutional Review Board approval was obtained at each of the collaborating institutions and written informed consent was obtained from each participant prior to initiation of study procedures. Methods are described in more detail elsewhere (Bacon et al., 2005; Barkan et al., 1998; Hessol et al., 2009). The secondary analyses described herein are restricted to WIHS participants who provided written informed consent to collect and geocode their home address.

Measures

WIHS collected demographic and behavioral data, including sexual partner characteristics, at the screening visit using structured interviewer-administered computer-assisted personal interviews. Participant home addresses were geocoded to 2010 census tract boundaries using ArcGIS. We used existing data sources (e.g., U.S. Census) to construct census tract variables that captured neighborhood social and physical environments.

Outcomes—We created two outcomes assessing perceived main sex partner characteristics: risk (ordinal) and non-monogamy (binary) (Wingood, Camp, Dunkle,

Cooper, & DiClemente, 2010;Wingood & DiClemente, 2000). Main sex partner was defined as “someone you have sex with and consider to be the most significant sexual partner in your life right now.”

Perceived Main Sex Partner Risk: For perceived main partner risk, we created an index that captured whether participants believed their main sexual partner definitely or probably: (1) had sex with someone else during the relationship; (2) ever injected any illegal drug; (3) ever spent more than 24 hours in jail, prison, or a detention center; (4) ever had sex with a man (male sexual partners only); (5) ever had a STI. Responses were summed across items (zero or one point for each item) to create a continuous score ranging from 0-5. We then created an ordinal measure (0 1 2 ≥3) based on the distribution of participant scores. Higher scores were indicative of greater risk.

Perceived Main Sex Partner Non-Monogamy: We assessed perceived partner non-monogamy independently due to the strong relationship between partner non-monogamy and STIs, including HIV (Adimora et al., 2006).Consistent with past work by Adimora et al. (2013a), women were classified as having a non-monogamous main sex partner if they responded “definitely yes”to the question “Do you think your current/most recent main partner had sex with someone else during your relationship?”

Participant-level predictors—Perceived neighborhood cohesion was measured using a four-item scale developed by Sampson et al. (1997) that captured how strongly participants believed that their neighborhood was close-knit and whether people in the neighborhood were willing to help each other, could be trusted, got along with each other, and shared common values. We created a mean score across the four items, which ranged from 1 to 5. Higher scores were indicative of more cohesive neighborhoods.

WIHS classified women as HIV-seropositive if they had a reactive serologic enzyme-linked immunosorbent assay test and a confirmed positive western blot or detectable plasma HIV-1 ribonucleic acid.

We also included data on participant-level characteristics that might confound or modify relationships between tract-level characteristics and sex partner risk and non-monogamy by including variables classically included in analyses exploring associations of participant-level and sexual network characteristics (Adimora, et al., 2013a; Justman et al., 2015; Rudolph, Linton, Dyer, & Latkin, 2013). Covariates captured behaviors in the past six months and were binary unless otherwise noted: age in years (continuous), married or cohabitating, non-Hispanic African American race/ethnicity, annual household income ≤$18 000 intimate partner violence (any emotional, physical, or sexual violence or feeling unsafe), problem drinking (defined as a score of ≥ 8 on the Alcohol Use Disorders Identification Text [Bohn, Babor, & Kranzler, 1995]), and social support (four-item scale assessing whether participants had people with whom they could share social events, get advice, be themselves when upset, or feel loved [Brandt & Weinert, 1981]). We averaged responses across social support items, creating a mean score ranging from 1 to 4, with higher scores indicative of greater social support

Census tract-level predictors—Census tract measures were constructed as follows: The 2013 American Community Survey 5-year tract estimates were used to calculate the percentage of residents living in poverty, percentage of unemployed residents, and percentage of residents without a high school diploma or equivalent (e.g., GED). The percentage of vacant housing units was obtained from the Vacant Address Database, a collaboration by the U.S. Postal Services and the U.S. Department of Housing and Urban Development (U.S. Department of Housing and Urban Development, 2015). The locations of Type 1 violent crimes (i.e., murder, non-negligent manslaughter, forcible rape, robbery, and aggravated assault) in 2013 were obtained from law enforcement agencies, geocoded, and used to calculate the violent crime rate per 1,000 residents for each tract. The number of businesses with a license to sell alcohol for off-premise consumption per 1,000 residents was created by geocoding 2014 address data obtained from state licensing agencies. In Mississippi, off-premise liquor licensing data were available (liquor can only be purchased at package/liquor stores), but licensing data for sale of beer and wine off-premise were not publically available. As a proxy, we used non-restaurant businesses with permits to sell eggs or milk (e.g., convenience stores, pharmacies) under the oversight of the Mississippi Department of Agriculture and Commerce because these types of businesses would have refrigerated display cases and likely have the capacity to sell beer and wine.

Place-based measures (e.g., voting records) used in past research exploring relationships between social capital, sexual risk, and HIV/STIs are not readily available at the census tract-level (Holtgrave & Crosby, 2003; Theall et al., 2009). For this study, tract-level social capital was measured as the number of non-profit institutions providing community services in a census tract (e.g., religious institutions, health and human service organizations) per 1,000 tract residents. We selected this measure because tax records are publicly available for non-profit institutions and because the number of non-profits has been included in past indices measuring state-level social capital (Putnam, 2000). This measure was created using the Internal Revenue Service (IRS) Business Master File (BMF), obtained from the National Center for Charitable Statistics (2014). The IRS BMF contains descriptive information on all active tax-exempt organizations, including physical address and major function (e.g., human services, health care). The physical addresses of organizations were geocoded to tracts and were used to create the count of non-profit organizations per 1,000 tract residents. Organizations with unknown major functions or functions unlikely to benefit tract residents (e.g., international development organizations, insurance providers, and pension management institutions) were excluded from the calculation.

We were unable to group census tract measures a priori because a number of these tract-level measures were correlated (Pearson's $r \geq 0.6$). We used principal component analysis (PCA) with orthogonal rotation (varimax) to capture underlying constructs and to avoid multicollinearity in multivariable models. The PCA produced one component (i.e., percentage poverty, percentage unemployment, percentage high school drop out, percentage vacant housing units, and violent crime rate) with eigenvalue > 1 and Cronbach's $\alpha = 0.85$. These variables have been used as markers of neighborhood social and economic disadvantage in past research (Bauermeister, Zimmerman, & Caldwell, 2011; Cooper et al., 2015; Sampson et al., 1997).Continuous component scores were extracted for each

participant and included in final multivariable models. Higher scores were indicative of greater socioeconomic disadvantage relative to the sample average.

The tract-level number of alcohol outlets and number of non-profit organizations were not correlated with other neighborhood measure (Pearson's $r < 0.6$). These measures were not included in the PCA so that we could independently explore relationships between neighborhood social services and alcohol access and perceived main sex partner characteristics.

Analysis

We used descriptive statistics to characterize distributions of tract- and participant-level factors. All bivariate and multivariable relationships were modeled with hierarchical generalized linear models (HGLMs), using a multinomial distribution and cumulative probability link for perceived partner risk and a binomial distribution and logit link for perceived partner non-monogamy. All HGLMs had two levels: participants (Level 1) were nested in census tracts (Level 2). The modeling process for each outcome had four phases.

In Phase 1, we used an unconditional model with random effects to evaluate the proportion of variance in each outcome due to clustering within census tracts.

In Phase 2 (Bivariate Model), we modeled bivariate relationships between each tract- and participant-level characteristic and each outcome.

In Phase 3, we modeled multivariable associations between tract-level characteristics (i.e., socioeconomic disadvantage component, number of alcohol outlets, number of non-profits), perceived neighborhood cohesion, and perceived partner risk characteristics, controlling for potential participant-level covariates. A primary aim of our analyses was to evaluate whether relationships between tract-level characteristics and partner risk characteristics were dependent on a woman's HIV status. In Phase 3A, we tested whether the magnitudes and directions of relationships between tract characteristics and partner risk varied by HIV status (i.e., interaction on the multiplicative scale) by entering cross-level interaction terms for HIV status and tract-level variables (e.g., HIV status * socioeconomic disadvantage), retaining interaction terms with $p < .05$ in the multivariable model (Full Model). In Phase 3B, we assessed whether the combined effect of tract characteristics and HIV status exceeded the effect of each factor independently (i.e., interaction on the additive scale) by fitting separate linear models using a multinomial distribution and cumulative probability link for partner risk and a binomial distribution and identity link for partner non-monogamy (Bauer & Sterba, 2011; Spiegelman & Hertzmark, 2005; VanderWeele, 2015). We entered cross-level interaction terms for HIV status and tract-level variables (e.g., HIV status * socioeconomic disadvantage) stepwise, interaction terms with $p < .05$ were considered statistically significant on the additive scale.

Participant-level covariates (e.g., problem drinking) traditionally included in models evaluating partner risk and measures of social capital may lie in the causal pathway between tract-level characteristics and our outcomes (Adimora, et al., 2013a; Crosby, Holtgrave, DiClemente, Wingood, & Gayle, 2003; Holtgrave & Crosby, 2003; Justman et al., 2015;

Rudolph et al., 2013; Sampson et al., 1997; Theall et al., 2011). In Phase 4 (Reduced Model), we excluded variables that might lie on the causal pathway between neighborhood characteristics and perceived sex partner risk characteristics in two separate Reduced Models excluding: (1) income, intimate partner violence, problem drinking, and social support; and (2) perceived neighborhood cohesion. Because including these variables in the full model would attenuate relationships between tract-level characteristics and outcomes if they did indeed lie on the causal pathway, we compared odds ratio (*OR*) estimates for all tract-level variables and perceived neighborhood cohesion in the Full vs. Reduced Model. Differences in magnitude of the *OR* ± 10 % suggested that excluded variables may lie in the causal pathway.

HGLMs were fit using PROC GLIMMIX using Newton Raphson optimization and Gauss-Hermite quadrature approximation in SAS 9.4 (SAS Institute Inc., Cary, NC). Census tract-level characteristics, perceived neighborhood cohesion, and HIV status were retained in all models in order to assess study aims.

Results

A total of 845 women were enrolled at the WIHS sites in Alabama, Florida, Georgia, North Carolina, and Mississippi; 841 women completed the behavioral screening questionnaire. Of these, 734 women (87.3 %) consented to the geocoding protocol and provided geocodable address information. Eighty-seven percent of women who did not have geocoded address data reported annual household incomes of ≤ $18 000,as compared to 75 % of participants with geocoded address data *(p* = .01). We included household income in full multivariable models in order to minimize potential confounding. Participants with and without geocoded address data were comparable for all other variables included in these analyses, including the outcomes (i.e., *p*-value > .05 in chi-square and *t*-test comparisons).

In the analytic sample (N = 734), participants were on average 43 years old *(SD* = 9.31), most identified as non-Hispanic African American (82.8 %), and 71.5 % were HIV-seropositive. The mean perceived neighborhood cohesion score was 3.13 *(SD* = 0.8). Participants on average lived in census tracts with 29.1 % *(SD* = 13.6) of residents living in poverty, 13.7 *(SD* = 13.4) violent crimes per 1,000 residents annually, and three non-profit organizations per 1,000 residents. As compared to HIV-seropositive women, a greater proportion *(p* < .05) of HIV-seronegative participants reported having a non-monogamous main partner (39.4 % vs. 29.3 %*)* or a main sex partner with two or more risk factors (66.3 % vs. 51.2 %*).* In addition, HIV-seronegative women lived in neighborhoods with greater relative socioeconomic disdvantage *(p* < .05). Participants lived in 492 distinct census tracts, and the number of participants per census tract (cluster size) ranged from 1 to 8 participants. The cluster size was one for majority of tracts (n = 347, 70 %); two for 17 % (n = 83) of tracts, and three or more for 13 % (n = 62) of tracts. Work by Bell Morgan, Kromrey, & Ferron (2010) has demonstrated that the proportion of singleton tracts has little effect on confidence interval coverage or Type 1 error rates in multilevel models with a large number of clusters (e.g., census tracts).

Relationships Between Census Tract-Level Characteristics, Perceived Social Cohesion, and Perceived Main Sex Partner Risk by HIV Status

In bivariate analyses, greater tract-level socioeconomic disadvantage was associated with greater percieved main sex partner risk (*OR* = 1.16, 95 % Confidence Interval [*CI*] = 0.99-1.35). Tract-level number of alcohol outlets (*OR* = 1.03, 95 % *CI* = 0.91-1.17) and number of nonprofits (*OR* = 1.02, 95 % *CI* = 0.99-1.05) were not associated with perceived main sex partner risk. Living with HIV (*OR* = 0.54, 95 % CI = 0.40-0.74) and perceived neighborhood cohesion (*OR* = 0.81, 95 % *CI* = 0.68-0.96) were associated with lower main sex partner risk.

In multivariable models, the direction of relationships between socioeconomic disadvantage and perceived sex partner risk varied by HIV status. For HIV-seropositive women, one SD higher socioeconomic disadvantage was associated with 27 % greater perceived sex partner risk (*OR* = 1.27, 95 % *CI* = 1.04-1.55). In contrast, for HIV-seronegative women, tract-level socioeconomic disadvantage was not associated with perceived partner risk (*OR* = 0.85, 95 % *CI* = 0.66-1.09). In models assessing additive effects on relationships between socioeconomic disadvantage and perceived partner risk by HIV status, for each one-unit increase in the socioeconomic disadvantage component, the absolute perceived partner risk was 24 % greater for HIV-seropositive women, but was not associated with partner risk for HIV-seronegative women (additive risk = 0).

Tract-level number of alcohol outlets (*OR* = 0.96, 95 % CI = 0.83-1.10) and tract-level number of non-profits (*OR* = 1.02, 95 % *CI* = 0.99-1.04) were not associated with perceived main sex partner risk among the sample. There were no significant interactions between either tract-level variable and perceived partner risk by HIV status on the additive or multiplicative scale ($p > .05$). Perceived neighborhood cohesion was not associated with perceived partner risk (*OR* = 0.86, 95 % *CI* = 0.71-1.05).

As a final step, we compared *OR* estimates for all tract-level variables and perceived neighborhood cohesion in the Full vs. Reduced Model. The Reduced Model excluded income, intimate partner violence, problem drinking, and social support, each of which might lie in the causal pathway connecting neighborhood exposures and perceived partner risk. Estimates were within 5 % for all comparisons, suggesting that excluded variables did not lie in the causal pathway. However, the confidence intervals for perceived neighborhood cohesion were more precise, reaching statistical significance in the Reduced Model (*OR* = 0.83, 95 % *CI* = 0.69-1.00; $p = .05$). Odds ratio estimates for all tract-level variables in the Full Model as compared to the Reduced Model excluding perceived neighborhood cohesion were within 2 % for all comparisons (results not presented), suggesting that perceived neighborhood cohesion did not lie in the causal pathway between tract-level variables and partner risk.

Relationships Between Census Tract Characteristics, Perceived Social Cohesion, and Perceived Main Sex Partner Non-Monogamy by HIV Status

In bivariate analyses, tract-level socioeconomic disadvantage (*OR* = 0.90, 95 *% CI* =0.76-1.06), number of alcohol of alcohol outlets (*OR* = 0.99, 95 % *CI* = 0.87-1.13), number

of non-profits (*OR* = 1.00, 95 % *CI* = 0.97-1.03), and perceived neighborhood cohesion (*OR* = 1.04, 95 % *CI* = 0.85-1.28) were not associated with reporting a perceived non-monogamous main sex partner. Living with HIV was associated with lower odds of reporting a perceived non-monogamous main sex partner (*OR* = 0.62, 95 % *CI* = 0.43-0.88).

In multivariable models, the direction of relationships between socioeconomic disadvantage and reporting a perceived non-monogamous main sex partner varied by HIV status. For HIV-seronegative women, tract-level socioeconomic disadvantage (*OR* = 0.65, 95 % *CI* = 0.47-0.88) was associated with a lower odds of reporting a non-monogamous main sex partner. In contrast, for HIV-seropositive women, tract-level socioeconomic disadvantage was not associated with reporting a non-monogamous main sex partner (*OR* = 1.01, 95 % *CI* = 0.80-1.28). In models assessing additive effects on relationships between socioeconomic disadvantage and having a perceived non-monogamous main sex partner by HIV status, for each one unit increase in the socioeconomic disadvantage component, the absolute risk of having a perceived non-monogamous main partner was 2 % greater for HIV-seropositive women, but 10 % lower for HIV-seronegative women.

Tract-level number of alcohol outlets (*OR* = 0.99, 95 % *CI* = 0.84-1.16) and tract-level number of non-profits (*OR* = 0.99, 95 % *CI* = 0.96-1.02) were not associated with having a perceived non-monogamous main partner. There were no significant interactions between either tract-level variable and perceived partner non-monogamy by HIV status on the additive or multiplicative scale ($p > .05$). Perceived neighborhood cohesion was not associated with perceived partner non-monogamy (*OR* = 1.05, 95 % *CI* = 0.83-1.32).

As a final step, we compared *OR* estimates for all tract-level variables and perceived neighborhood cohesion in the Full vs. Reduced Model. The Reduced Model excluded income, intimate partner violence, problem drinking, and social support, each of which might lie in the causal pathway connecting neighborhood exposures and partner non-monogamy. Estimates were within 5 % for all comparisons, suggesting that excluded variables did not lie in the causal pathway. Odds ratio estimates for all tract-level variables in the Full Model as compared to a Reduced Model excluding perceived neighborhood cohesion were within 2 % for all comparisons (results not presented), suggesting that perceived neighborhood cohesion did not lie in the causal pathway between tract-level variables and partner non-monogamy.

Discussion

Our analyses showed that neighborhood characteristics were associated with perceived sex partner risk behaviors among women living in the South, and that these relationships varied by HIV status. HIV-seronegative women reported more perceived sex partner risk and perceived partner non-mongamy than HIV-seropositive women. However, greater tract-level socioeconomic disadvantage (i.e., more poverty, unemployment, high school drop out, vacant housing, and violent crime) was associated with greater perceived sex partner risk among HIV-seropositive women and less perceived sex partner non-monogamy among HIV-seronegative women. In addition, perceived neighborhood cohesion was associated with lower perceived partner risk, regardless of HIV status.

Greater socioeconomic disadvantage was associated with greater sex partner risk among HIV-seropositive women. Women living with HIV are more likely to have HIV-seropositive sexual partners (Liu et al., 2011). The partner sexual risk measures, which included partner's lifetime histories of injection drug use, incarceration, and STIs, may be serving as a proxy for having a sexual partner living with HIV. Past studies have found that individuals living with or at increased risk of HIV tend to select sexual partners in closer proximity than lower risk populations (Cooper et al., 2016; Gindi et al., 2011). Neighborhoods with greater socioeconomic disadvantage tend to have higher prevalences of HIV (Hixson, Omer, del Rio, & Frew, 2011; Song et al., 2011). It is possible that HIV-seropositive women living in more disadvantaged areas are more likely to live in areas where the HIV prevalence among potential partners is higher.

In contrast to past research supporting positive associations between socioeconomic disadvantage and partner non-monogamy in HIV-seronegative populations (Adimora et al., 2013b; Cooper et al., 2015), greater socioeconomic disadvantage was associated with less perceived partner non-monogamy among HIV-seronegative women in this sample. The mechanisms supporting this finding are unclear and warrant further exploration. Partner non-monogamy confers risk of HIV/STI transmission for both individuals and sexual networks (Adimora et al., 2006a; Doherty et al., 2012). HIV-seronegative women living in more disadvantaged neighborhoods may have perceived that having a non-mongamous partner placed them at enhanced risk of HIV infection and might have ended partnerships with partners who they perceived had other sexual partners (Cooper et al., 2015). Alternatively, neighborhood socioeconomic disadvantage may promote having multiple sexual partnerships (Green et al., 2012; Pouget et al., 2010) and sex partner assessments captured perceived risk characteristics of main sex partners only. HIV-seronegative women are more likely to have multiple sexual partners than HIV-seropositive women (Liu et al., 2011). If HIV-seronegative women had multiple sex partners, it is possible that they did not identify sex partners with other sexual partner as the “most significant sexual partner” (Dauria et al., 2015). Neighborhood conditions may not directly influence the partner non-monogamy of HIV-seropositive women because they have a stronger incentive to protect their own health or others within the sexual network (Marks et al., 2005).

Perceived neighborhood cohesion was associated with lower perceived partner risk, regardless of HIV status. Women who perceived their neighborhoods to be more socially cohesive may be engaged in social networks with prosocial norms that discourage behaviors captured in the index (e.g., substance use, criminal activity) and may select partners who share these norms (Adimora et al., 2001; Kerrigan, Witt, Glass, Chung, & Ellen, 2006; Lang et al., 2011; Sampson et al., 1997).

The number of non-profit organizations was not associated with partner non-monogamy nor partner risk. In post hoc analyses, we explored alternative operationalizations of this measure that may more closely capture the presence of non-profit organizations likely to foster a local sense of community, including advocacy and coalition-building and religious insitutions (Lewis, Macgregor, & Putnam, 2013; Tempalski et al., 2007). These alternative measures were also not associated with our outcomes. Due to the nature of the dataset, we

were unable to quantify the breadth and reach of services provided by each institution, including whether these institutions provided services locally.

The number of alcohol outlets in the tract was not associated with partner non-monogamy nor partner risk. Although ecologic studies have found relationships between alcohol outlets and STIs (Cohen et al., 2006; Theall et al., 2009), findings of multilevel studies assessing relationships between alcohol outlets and sexual partnerships in adults have been mixed (Cooper et al., 2015; Linton et al., 2017). It is possible that alcohol outlets indirectly impact women's sexual health by promoting alcohol use and subsequently, higher sexual risk behaviors (Campbell et al., 2009; Cooper et al., 2013; Linton et al., 2017; Linton, Haley, Hunter-Jones, Ross, & Cooper, 2017; Seth, Wingood, & DiClemente, 2008).

Past multilevel studies have detected relationships between shortages of men and greater partner risk, including non-monogamy (Adimora, et al., 2013b; Green et al., 2012; Pouget et al., 2010). The vast majority (83%) of women in our sample lived in tracts with sex ratios well below one (i.e, shortages of men relative to women). We thus did not have sufficient numbers of women living in tracts with equitable or excess ratios of men relative to women needed to test relationships between sex ratios and partner risk (Adimora et al., 2006b; Dauria et al., 2015). Past research has cited the challenges of exploring relationships between sex ratios and sexual network characteristics in predominantly African American populations in light of persistent social inequities (e.g., incarceration, excess mortality) contributing to a shortage of male partners (Adimora, et al., 2013b; Pouget et al., 2010).

Our findings are subject to limitations. Although WIHS provides a high quality sample of women who are living with or are at increased risk of HIV infection in the southern U.S., study participants agreed to long-term follow-up and may not be representative of the general population of women living with HIV or high risk HIV-seronegative women. The majority of participants living with HIV were recruited from clinic-based populations and, as a result, findings may not extend to women living with HIV who are not connected to HIV care and treatment. WIHS did not geocode address information for participants who self-identified as living on the street or in residential drug treatment. These women may live in qualitatively different neighborhoods as result of their housing circumstances. Residential census tracts may fail to capture the boundaries from which women meet and select sexual partners. However, studies have found that individuals living with and at increased risk of HIV tend to have sexual partners living in closer proximity than lower risk populations (Cooper et al., 2016; Gindi et al., 2011). Although this research provides new insight on relationships between neighborhood characteristics and perceived sexual partner risk, WIHS does not collect data on either the HIV status of each woman's main sexual partner or the types of sexual behaviors that a woman engaged in with her main partner. Similarly, participant-reported measures may not accurately reflect sex partner behaviors and risk. In addition, the cross-sectional multilevel design does not permit us to draw conclusions regarding the causality of these relationships.

This multilevel study is among the first to test relationships between neighborhoods and perceived sex partner risk and non-monogamy by HIV status. Collectively, these findings support past research on the importance of neighborhood environments in shaping sexual

risk among women living in the South, highlight that these relationships may vary by HIV status, and indicate that research on neighborhoods and sexual networks generated using HIV-seronegative populations cannot simply be generalized to HIV-seropositive populations. Additional longitudinal, network, and qualitative research is needed to establish the causality of these relationships, better understand the pathways through which neighborhood characteristics shape partner selection differentially across HIV-seropositive and -seronegative women, and inform the development of future multilevel interventions designed to improve women's sexual health and reduce HIV/STI transmission.

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Table 1

Alabama, Florida, Georgia, Mississippi, and North Carolina census tract measure, definition, data source, and year

Measure	Definition	Data Source	Year
Socioeconomic disadvantage component			
Percentage poverty	Percentage residents with annual income below poverty level	American Community Survey (ACS)	2008-2013
Percentage unemployed	Percentage unemployed residents ≥ 16 old	ACS	2008-2013
Percentage high school drop out	Percentage of residents > 25 years old without a high school diploma or GED	ACS	2008-2013
Percentage vacant housing units	Percentage vacant residential housing units	Housing and Urban Development and United States Postal Service	2013
Violent crime rate	Total murder, non-negligent manslaughter, forcible rape, robbery, and aggravated assaults per 1,000 tract residents[a]	Law Enforcement Agencies (i.e., police department, Sheriff's Office)	2013
Number of alcohol outlets	Number of businesses with a license to sell beverages containing alcohol (e.g., liquor, beer, wine) for off-premise consumption per 1,000 tract residents[a,b]	State Licensing Agencies (e.g., Department of Revenue, Alcoholic Beverage Control Commission)	2014
Number of non-profit institutions	Number of tax-exempt institutions per 1,000 tract residents	National Center for Charitable Statistics Internal Revenue Service Business Master File	2013

[a]Addresses were obtained from state agencies and geocoded to tracts; addresses within a 100-foot buffer of the track boundry were includes in the track's calculation.

[b]In Mississippi, off-premise liquor licensing data were available (liquor can only be purchased at package/liquor stores), but licensing data for sale of beer and wine off-premise were not publically available. As a proxy, we used non-restaurant businesses with permits to sell eggs or milk (e.g., convenience stores, pharmacies) under the oversight of the Mississippi Department of Agriculture and Commerce because these types of businesses would have refrigerated display cases and likely have the capacity to sell beer and wine.

Table 2

Distributions of individual and census tract characteristics among 734 women enrolled in the Women's Interagency HIV Study's Southern sites[a]

Characteristics of participants and census tracts	HIV-seropositive n (%) or M (*SD*)	HIV-seronegative n (%) or M (*SD*)
Outcomes		
Perceived non-monogamous main sex partner[b]	154 (29.3)	82 (39.4)
Perceived partner risk score[c]	1.65 (1.3)	2.03 (1.2)
Perceived partner risk score category[b,c,d]		
0	113 (21.5)	19 (9.1)
1	143 (27.2)	51 (24.5)
2	134 (25.5)	66 (31.7)
≥3	135 (25.7)	72 (34.6)
Census tract-level characteristics		
Socioeconomic disadvantage component[b]	-0.05 (0.9)	0.13 (1.1)
Percentage poverty	28.53 (13.3)	30.42 (14.5)
Percentage unemployed	15.72 (7.7)	16.92 (8.5)
Percentage high school drop out	19.65 (10.0)	20.03 (10.5)
Percentage vacant housing units	7.56 (6.3)	8.36 (6.3)
Violent crime rate per 1,000 residents[b]	12.70 (11.7)	16.12 (16.0)
Number of alcohol outlets per 1,000 residents	1.17 (1.2)	1.17 (1.1)
Number of non-profit organizations per 1,000 residents[b]	2.76 (3.9)	4.3 (8.6)
Participant-level characteristics		
Perceived neighborhood cohesion[1]	3.17 (0.8)	3.03 (0.9)
Age in years	43.68 (9.1)	42.09 (9.7)
Married or living as married	146 (27.8)	57 (27.5)
Non-Hispanic African American	433 (82.3)	175 (84.1)
Intimate partner violence[b]	89 (16.9)	74 (35.6)
Annual household income of $18,000 or less	404 (76.8)	145 (70.4)
Problem drinking[b]	48 (9.1)	47 (22.6)
Social support	4.13 (0.7)	4.14 (0.7)

[a] This cross-sectional analysis utilizes screening data from women who were enrolled at the Women's Interagency HIV Study sites in Alabama, Florida, Georgia, Mississippi, and North Carolina between October 2013 and September 2015.

[b] Comparison by HIV status, $p > .05$;

[c] Partner risk score captured whether participants believed their main sexual partner definitely or probably: (1) had sex with someone else during the relationship; (2) ever injected any illegal drug; (3) ever spent more than 24 hours in jail, prison, or a detention center, (4) ever had sex with a man (male sexual partners only); (5)ever had a STI.

[d] Ordinal measures (0 1 2 ≥3) based on the distribution of participants risk score, higher scores are indicative of greater risk.

Table 3

Bivariate and multivariable relationships of census tract characteristics to perceived main sex partner risk at screening among women enrolled in the Women's Interagency HIV Study's Southern sites (n = 733)[a, b]

Characteristics of participants and census tracts	Bivariate *OR* (95 % *CI*)	Final Model *aOR* (95 % *CI*)[c]	Reduced Model *aOR* (95 % *CI*)[c]
Census tract-level characteristics			
Socioeconomic disadvantage component	1.16 (0.99-1.35)	--	--
HIV-seropositive * greater socioeconomic disadvantage (ref: HIV-seropositive participants in tracts with average disadvantage)	--	1.27 (1.04-1.55)[d]	1.29 (1.06-1.58)[d]
HIV-seronegative*greater socioeconomic disadvantage (ref: HIV-seronegative participants in tracts with average disadvantage)	--	0.85 (0.66-1.09)	0.90 (0.70-1.15)
Number of alcohol outlets	1.03 (0.91-1.17)	0.96 (0.83-1.10)	0.96 (0.84-1.10)
Number of non-profits	1.02 (0.99-1.05)	1.01 (0.98-1.04)	1.01 (0.99-1.04)
Participant-level characteristics			
Perceived neighborhood cohesion	0.81 (0.68-0.96)[d]	0.86 (0.71-1.05)	0.83 (0.69-1.00)[d]
HIV-seropositive	0.54 (0.40-0.74)[d]	0.60 (0.43-0.83)[d]	0.52 (0.38-0.72)[d]
Age in years	1.00 (0.99-1.02)	1.01 (0.99-1.02)	1.00 (0.99-1.02)
Married or cohabitating	0.84 (0.61-1.14)	0.89 (0.64-1.23)	0.87 (0.63-1.20)
Non-Hispanic African American	0.76 (0.52-1.10)	0.74 (0.50-1.08)	0.71 (0.48-1.05)
Annual household income of $18,000 or less	1.19 (0.86-1.64)	1.12 (0.80-1.57)	--
Intimate partner violence	2.37 (1.68-3.35)	2.09 (1.44-3.01)	--
Problem drinking	1.63 (1.06-2.50)	1.21 (0.77-1.90)	--
Social support	0.90 (0.75-1.08)	1.08 (0.88-1.33)	--
Model Fit			
Random intercept variance (*p*-value)	--	0.15 (.27)	0.18 (.23)
-2 Log Likelihood (*-2LL*)	--	1824.67	1843.47
Akaike Information Criterion (*AIC)*	--	1858.67	1869.47
Bayesian Information Criterion (*BIC)*	--	1928.38	1922.77

aThis cross-sectional multilevel analysis utilizes screening data from women who were enrolled at the Women's Interagency HIV Study sites in Alabama, Florida, Georgia, Mississippi, and North Carolina between October 2013 and September 2015.

[b] 1 participant missing outcome

[c] Multivariable analyses restricted to participants with no missing predictors (n = 686)

[d] $p \leq .05$

Table 4

Bivariate and multivariable relationships of census tract characteristics to the odds of having a perceived non-monogamous main sex partner at screening among women enrolled in the Women's Interagency HIV Study's clinical research sites in Alabama, Florida, Georgia, Mississippi, and North Carolina, 2013-2015 (n = 733)[a,b]

Characteristics of participants and census tracts	Bivariate OR (95 % CI)	Final Model aOR (95 % CI)[c]	Reduced Model aOR (95 % CI)[c]
Census tract-level characteristics			
Socioeconomic disadvantage component	0.90 (0.76-1.06)	--	--
HIV-seropositive * greater socioeconomic disadvantage (ref: HIV-seropositive participants living in tracts with average disadvantage)	--	1.01 (0.80-1.28)	1.02 (0.81-1.28)
HIV-seronegative * greater socioeconomic disadvantage (ref: HIV-seronegative participants living in tracts with average disadvantage)		0.65 (0.47-0.88)[d]	0.69 (0.51-0.92)[d]
Number of alcohol outlets	0.99 (0.87-1.13)	0.99 (0.84-1.16)	0.99 (0.85-1.14)
Number of non-profits	1.00 (0.97-1.03)	0.99 (0.96-1.02)	0.99 (0.97-1.02)
Participant-level characteristics			
Perceived neighborhood cohesion	1.04 (0.85-1.28)	1.05 (0.83-1.32)	0.99 (0.80-1.22)
HIV-seropositive	0.62 (0.43-0.88)[d]	0.65 (0.44-0.96)[d]	0.60 (0.41-0.87)[d]
Age in years	1.01 (0.99-1.03)	1.01 (0.99-1.03)	1.01 (0.99-1.03)
Married or cohabitating	0.39 (0.26-0.60)[d]	0.39 (0.25-0.60)[d]	0.39 (0.25-0.59)[d]
Non-Hispanic African American	0.89 (0.58-1.35)	0.82 (0.52-1.30)	0.80 (0.51-1.25)
Annual household income of $18,000 or less	1.14 (0.78-1.65)	1.10 (0.73-1.67)	--
Intimate partner violence	1.72 (1.16-2.54)[d]	1.64 (1.06-2.53)[d]	--
Problem drinking	1.35 (0.85-2.15)	1.03 (0.61-1.74)	--
Social support	0.87 (0.70-1.08)	0.93 (0.72-1.20)	--
Model Fit			
Random intercept variance (*p*-value)	--	0.09 (.37)	0 (.49)
-2 Log Likelihood (*-2LL*)	--	818.97	825.43
Akaike Information Criterion (*AIC)*	--	848.97	847.43
Bayesian Information Criterion (*BIC)*	--	910.47	892.53

[a] This cross-sectional multilevel analysis utilizes screening data from women who were enrolled at the Women's Interagency HIV Study sites in Alabama, Florida, Georgia, Mississippi, and North Carolina between October 2013 and September 2015.

[b] 1 participant missing outcome

[c] Multivariable analyses restricted to participants with no missing predictors (n = 686)

[d] $p \leq 05$

Table 5

Associations between census tract characteristics, neighborhood cohesion, and perceived main sex partner risk and non-monogamy among women enrolled in the Women's Interagency HIV Study's clinical research sites in Alabama, Florida, Georgia, Mississippi, and North Carolina between 2013-2015, by HIV status

	Partner risk		Partner non-monogamy	
	HIV+ aOR (95 % CI)[a]	HIV-aOR (95 % CI)[a]	HIV+ aOR (95 % CI)[b]	HIV-aOR (95 % CI)[b]
Census-tract level characteristics				
Socioeconomic disadvantag	↑1.29 (1.06-1.58)	**n.a.** 0.69 (0.51-0.92)	**n.a.** 1.02 (0.81-1.28)	↑0.69 (0.51-0.92)
Number of alcohol outlets	**n.a.** 0.99 (0.85-1.14)	**n.a.** 0.99 (0.97-1.02)	**n.a.** 0.99 (0.85-1.14)	**n.a.** 0.99 (0.85-1.14)
Number of non-profit organizations	**n.a.** 1.01 (0.99-1.04)	**n.a.** 1.01 (0.99-1.04)	**n.a.** 0.99 (0.97-1.02)	**n.a.** 0.99 (0.97-1.02)
Participant-level characteristics				
Neighborhood cohesion	↓0.99 (0.80-1.22)	↓0.99 (0.80-1.22)	**n.a.** 0.99 (0.80-1.22)	**n.a.** 0.99 (0.80-1.22)

↑=positive association

n. a. =not associated

↓=inverse assocation

[a]Multivariable models examining relationships between census-tract level characteristics, participant-level perceived neighborhood cohesion, and perceived main sex partner risk, controlling for HIV status, age in years, marital status, and race/ethnicity.

[b]Multivariable models examining relationships between census-tract level characteristics, participant-level perceived neighborhood cohesion, and perceived main sex partner non-monogamy, controlling for HIV status, age in years, marital status, and race/ethnicity.