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Neighborhood Factors, Sexual Risk Behaviors, Sex Partner Risk, and Sexually Transmitted Infections among HIV-Infected and High Risk HIV-Uninfected Women in the Southern United States

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By

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MPH, University of North Carolina, Chapel Hill, 2006

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An abstract of
A dissertation submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
in Behavioral Sciences and Health Education
2016

Abstract

Neighborhood Factors, Sexual Risk Behaviors, Sex Partner Risk, and Sexually Transmitted Infections among HIV-Infected and High Risk HIV-Uninfected Women in the Southern United States

By Danielle Frances Haley

Introduction. Neighborhood characteristics shape sexual risk and sexually transmitted infections (STIs) in HIV-uninfected adults in the United States (US). This dissertation utilizes multilevel analyses to test relationships between census tract characteristics and sexual risk behaviors, sex partner risk, and testing positive for an STI in a predominantly HIV-infected cohort of women living in the southern US.

Methods. This cross-sectional multilevel study analyzed data from 737 HIV-infected and HIV-uninfected women enrolled at the Women's Interagency HIV Study's southern sites. Administrative data (e.g., US Census) captured characteristics of the census tracts where women lived; individual-level data were gathered via survey. We used principal components analysis to condense tract-level variables into two components: social disorder (e.g., violent crime rate) and social disadvantage (e.g., alcohol outlet density). We used hierarchical generalized linear models to test relationships between tract characteristics and (1) sexual risk behaviors (unprotected vaginal intercourse [UVI], anal intercourse [AI], unprotected anal intercourse [UAI]); (2) sex partner characteristics (risk-level [e.g., lifetime history of injection drug use], non-monogamy); and (3) testing positive for a current STI (Chlamydia, gonorrhea, trichomoniasis, syphilis) and to assess whether these relationships varied by HIV status.

Results. Greater tract-level social disorder was associated with less AI (OR=0.65, 95% CI=0.43, 0.96) and UAI (OR=0.50, 95% CI=0.31, 0.82), regardless of HIV status; less partner non-monogamy (OR=0.72, 95% CI=0.54, 0.96) among HIV-uninfected women; and greater partner non-monogamy (OR=1.20, 95% CI=0.96, 1.50) and partner risk (OR=1.41, 95% CI= 1.16, 1.72) among HIV-infected women. Greater tract-level social disorder was associated with more STIs (OR=1.34, 95% CI=0.99, 1.87), regardless of HIV status. Greater social disadvantage was associated with less partner non-monogamy (OR=0.73 95% CI=0.60, 0.96) and lower partner risk (OR=0.84, 95% CI=0.72, 0.97), but more STIs (OR=1.34, 95% CI=0.96, 1.86), regardless of HIV status. Perceived neighborhood cohesion was associated with lower partner risk (OR=0.84, 95% CI=0.70, 1.02), regardless of HIV status.

Conclusion. Findings suggest that neighborhood characteristics may be associated with sexual behaviors, partner characteristics, and STIs among HIV infected and HIV uninfected Southern women. Future research should establish the temporality of relationships and explore pathways through which neighborhoods create vulnerability to STIs.

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Acknowledgements

This dissertation is the product of the support and guidance of countless individuals, to whom I am sincerely grateful. I wish to extend special thanks to my dissertation dissertation committee chair, Hannah Cooper, and to my committee members, Regine Haardörfer, Michael Kramer, Adaora Adimora, and Gina Wingood. Hannah, you provide a superb example of what it means to be a leader in this field. Thank you for your patience, dedication, and superb mentorship as I explored new methods, scoured the literature, developed my research agenda, and learned to clearly communicate my methods and findings to the broader scientific community. Michael and Regine, thank you for your positive attitude, tireless support, and the countless emails and calls helping me to navigate new methods. Ada and Gina, thank you for always believing in me and providing the tools and resources needed to complete my dissertation. I feel so fortunate to have worked with all of you, and look forward to many future collaborations.

Many thanks to the Kimberly Jacob-Arriola and the many Department of Behavioral Sciences and Health Education faculty and staff, for creating an environment supporting learning and collaboration. Brandi Harper, Ashley Mastin, Brittani Magee, and Gary Huskey: thank you for all you do to support the doctoral program and for making it possible to complete my dissertation from North Carolina.

Thank you to Sabriya Linton and my fellow doctoral students, especially Rebecca Woodruff, Umed Ibragimov, Juan Rodriquez, Katherine Krause, and Illana Raskind: your knowledge and support have been invaluable. I look forward to new opportunities to collaborate with you throughout your undoubtedly impressive careers.

To my many colleagues and mentors throughout the years, who have shaped my understandings of the social determinants of health and provided a superb grounding in research. Special thanks to Carol Golin for introducing me to the field of behavioral health and for always encouraging me to pursue my dreams. I am so fortunate to count you as a mentor and friend.

This dissertation would not be possible without the support and love of my family. To my parents, Daniel and Connie Haley, thank you for encouraging me to ask the tough questions and for giving me the tools to venture forth into the world. To my sister, Brooke Haley; my grandfather, Richard Duell; my aunt, uncle, and cousin, Michael, Kathy, and Emily Camire: thank you for your constant encouragement and positive attitude. To my partner, Peter Balvanz, thank you for your constant support and calm as I ventured through this process. I could not have done it without you.

I extend my sincere gratitude to the Women's Interagency HIV Study (WIHS) participants for sharing their time and experiences and to the WIHS study staff, with special thanks to Ighovwerha Ofotokun, Anna Rubtsova, Neela Goswami, Sarah Sanford, Deja Er, Rachael Farah-Abraham, Christina Ludema, Catalina Ramirez, Andrew Edmonds, Carrigan Parrish, Zenoria Causey, Venetra McKinney, and Lisa Rohn.

I also wish to thank the state health departments, state licensing agencies, and law enforcement agencies that provided data needed to construct census tract predictors.

This work was supported by the National Institute of Mental Health of the National Institutes of Health under Award Number F31MH105238, the Surgeon General C. Everett Koop HIV/AIDS Research Grant, and the George W. Woodruff Fellowship of the Laney Graduate School, and Laney Graduate School Professional Development Funds. Participant data in this manuscript were collected by the Women's Interagency HIV Study (WIHS): UAB-MS WIHS (PIs: Michael Saag, Mirjam-Colette Kempf, and Deborah Konkle-Parker), U01-AI-103401; Atlanta WIHS (PIs: Ighovwerha Ofotokun and Gina Wingood), U01-AI-103408; Miami WIHS (PIs: Margaret Fischl and Lisa Metsch), U01-AI-103397; UNC WIHS (PI: Adaora Adimora); WIHS Data Management and Analysis Center (PIs: Stephen Gange and Elizabeth Golub). The WIHS is funded primarily by the National Institute of Allergy and Infectious Diseases (NIAID), with additional co-funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD), the National Cancer Institute (NCI), the National Institute on Drug Abuse (NIDA), and the National Institute on Mental Health (NIMH). Targeted supplemental funding for specific projects is also provided by the National Institute of Dental and Craniofacial Research (NIDCR), the National Institute on Alcohol Abuse and Alcoholism (NIAAA), the National Institute on Deafness and other Communication Disorders (NIDCD), and the NIH Office of Research on Women's Health. WIHS data collection is also supported by UL1-TR000004 (UCSF CTSA) and UL1-TR000454 (Atlanta CTSA).

The contents of this publication are solely the responsibility of the authors and do not represent the official views of the National Institutes of Health (NIH) or the Florida Department of Health. The NC Department of Health and Human Services does not take responsibility for the scientific validity or accuracy of methodology, results, statistical analyses, or conclusions presented.

Table of Contents

Chapter 5: Summary and Conclusion

List of Figures

List of Tables

Chapter 1: Introductory Literature Review

Introduction

The burden of HIV/AIDS in women in the United States (US) has grown substantially since the beginning of the epidemic: rising from 8% of all newly diagnosed AIDS cases in 1983 to more than 19% of all newly diagnosed HIV infections in 2014.[1,2] Although the HIV epidemic was initially concentrated in the northeastern and western regions of the US, the South now bears a significant burden of the epidemic.[3-5] Roughly half of individuals living with HIV in 2010 were diagnosed in the South, though only 37% of the US population lives in this region.[5] Moreover, HIV-infected individuals living in this region experience the highest rates of morbidity and mortality in the US.[3-5] The South also experiences persistently high prevalences of other sexually transmitted infections (STIs).[3,4] STIs can cause infertility, sexual dysfunction, and increased morbidity. Co-infection with STIs is common in people living with HIV.[6,7 8] For women living with HIV, co-infection with another STI may facilitate HIV transmission to sexual partners and reduce HIV treatment gains.[6,9,10] The National HIV/AIDS Strategy, Healthy People 2020, and the Centers for Disease Control and Prevention have identified the improvement of prevention and treatment of HIV and STIs for people living with HIV as priority areas.[11-13]

Neighborhood-Level Determinants of Sexual Behavior and HIV/STIs

An emerging line of evidence indicates that several features of the social and built environment influence the transmission of HIV and other STIs in *HIV-uninfected populations*. Geographic areas with high levels of poverty, social disorder (e.g., high violent crime rate), incarceration, or racial/ethnic residential segregation tend to have higher prevalences of HIV/AIDS and other STIs.[14-24] Multilevel studies, which allow for exploration of relationships between neighborhood characteristics and sexual health in individuals by controlling for potential neighborhood- and individual-level confounders, have expanded neighborhood-based predictors to include neighborhood STI prevalence and the ratio of men to women, and outcomes to include individual-level sexual behaviors (e.g., unprotected sexual intercourse) and attributes of sexual partnership characteristics (e.g., non-monogamy, sexual network turnover).[25-38] Collectively, this line of multilevel research has found that living in neighborhoods with low male:female sex ratios (i.e., fewer men than women), high incarceration rates, high densities of alcohol outlets, prevalent neighborhood poverty, and prevalent STIs is associated with more unprotected sexual intercourse, partner risk (i.e., non-monogamy, multiple sex partners, risk discordant partnerships, sex partners in close proximity), sexual network turnover, and STIs in *HIV-uninfected* populations.[25-38]

Potential Mechanisms thorough which Neighborhood-Level Determinants Influence Sexual Behavior and HIV/STIs

Larger social and physical factors, including neighborhood environment and attributes of sexual networks, are thought to contribute to sexual risk behaviors and resulting disparities in HIV/STIs. Conceptualizing neighborhoods as opportunity structures, residents of neighborhoods with comparatively greater economic disadvantage (e.g., high poverty rates) or social disorder (e.g., vacant houses, violent crime) may have less access to social and structural resources needed to engage in healthful behaviors (e.g., employment opportunities), and greater exposure to hazards associated with negative health outcomes.[39,40] For example, a high density of liquor stores in a neighborhood may contribute to greater community-level alcohol consumption and sexual risk behaviors.[39,40] Similarly, neighborhood attributes may shape sexual partner availability and sexual network characteristics. For instance, low male to female sex ratios may increase the dyadic power of men and ultimately reduce women's ability to negotiate lower risk sexual behaviors, such as monogamy and condom use.[25,32-34,41,42]

Limitations in our Understanding of Whether and How Neighborhood-Level Determinants Influence Sexual Behavior and Risk of Acquisition of HIV/STIs among *HIV-Infected Women*

Our ability to understand whether and how neighborhood-level characteristics influence sexual risk behaviors, sexual networks, and STIs among *HIV-infected women* is subject to the following major limitations:

1) The vast majority of studies of neighborhoods and sexual health among HIV uninfected populations have used ecologic designs.

Numerous ecologic studies have found associations between neighborhood characteristics and the prevalence of STIs (e.g., county-level incarceration rates and county STI prevalence) in predominately HIV-uninfected populations.[14-17,19-24] Futhermore, neighborhood economic deprivation has been associated with AIDS incidence.[18] However, ecologic designs are unable to assess relationships between neighborhood characteristics and individual-level outcomes (e.g., sexual behaviors) and to control for individual-level factors.[43,44]

2) No studies have explored relationships of neighborhoods and sexual health among HIV-infected women.

Little is known about whether or how neighborhood characteristics shape sexual risk for women living with HIV infection. To our knowledge, only one multilevel study has explored relationships between neighborhoods and sexual behaviors in HIV-infected adults. This study found no association between neighborhood poverty rates, racial/ethnic composition, unemployment rates, and unprotected sexual intercourse among a predominantly *male* clinic-based population in the Midwestern US.[45] It is possible that the magnitudes and directions of relationships between neighborhood characteristics and sexual health are different for HIV-infected versus HIV-uninfected women. For example, neighborhood characteristics may be less influential for HIV-infected women because they have a stronger incentive to protect their health or that of their partner.[46] Notably, however, neighborhood characteristics have been found to predict some HIV-related outcomes among HIV-infected women: neighborhood poverty has been linked to higher HIV-related mortality, lower CD4 counts, and late or no ART.[45,47,48]

3) Few studies have explored the roles of neighborhood social organizational factors in the relationships between neighborhoods and sexual health.

Social organization models suggest that differential health outcomes across communities are a function of community cohesion and trust (e.g., social capital).[49,50] Neighborhood social organizational factors (e.g., social cohesion, social control) have been found to mediate the relationships between neighborhood social disorder and violent crime[49,51] and to moderate relationships between social disorder and self-rated health.[52] Natural experiments have found inverse relationships between increased social capital and STIs.[17] However, the vast majority of research exploring relationships of neighborhood-level social capital to STIs have utilized ecologic designs,[17,53] which are unable to assess relationships between neighborhood-level social capital and individual-level sexual behaviors or STI status and to control for individual-level factors.[43,44] Notably, individual-level social capital is associated with condom use in adolescents.[54,55]

Significance of the Research

This dissertation addresses gaps in the literature and advances research on the relationships between neighborhood characteristics and women's sexual health by using multilevel approaches to investigate associations of neighborhood characteristics with sexual risk behavior, sex partner risk, and STIs among a predominately HIV-infected cohort of women living in the Southern US. This dissertation research will be the first study to explore whether and how neighborhood-level characteristics (e.g., social disorder) influence sexual risk behavior (e.g., unprotected vaginal intercourse), sexual network characteristics (e.g., sex partner non-monogamy), and current STI status among *HIV-infected* women. An understanding of whether and how neighborhood environments contribute to the sexual health of women living with HIV can inform the development of future multilevel interventions designed to improve women's sexual health and reduce HIV/STI transmission.

The specific aims of this study are:

Aim 1. Examine relationships between neighborhood characteristics and *sex partner risk*, and investigate whether the magnitudes and directions of these relationships vary by HIV status.

Subaim 1. Examine relationships between social organizational factors (e.g., neighborhood trust and cohesion) and *sex partner risk*, and explore the role of neighborhood trust and cohesion in the relationships between social disorder and sex partner risk.

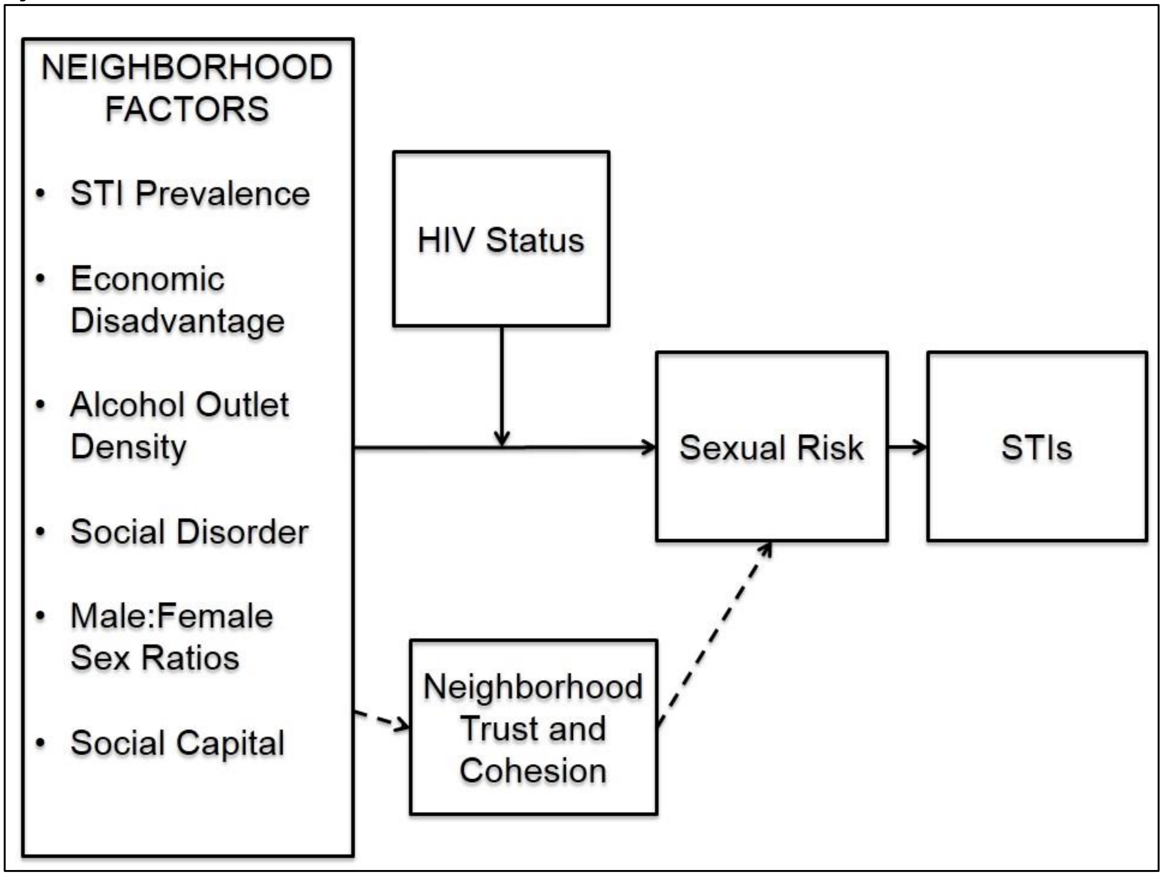
Aim 2. Examine relationships between neighborhood characteristics and *sexual risk behaviors*, and investigate whether the magnitudes and directions of these relationships vary by HIV status.

Aim 3. Examine relationships between neighborhood characteristics and *current STI status*, and investigate whether the magnitudes and directions of these relationships vary by HIV status.

This research is guided by the Socioecologic Framework (SEF) and social organization models (i.e., Social Disorganization Theory, Social Capital) (Figure 1.1).[49,50,56,57] We hypothesized that the relationship between neighborhood factors and sexual risk would be moderated by HIV status. The SEF provides a valuable framework through which to conceptualize the multilevel determinants of sexual risk and STIs, and acknowledges that health behaviors and related outcomes are influenced by multiple facets of the physical and social environment, which are multidimensional and multilevel. The SEF allows for the integration of other theoretical constructs, which can refine research on different levels' impacts on health behavior. Social organization theories, which posit that differential health outcomes across communities are a function of community cohesion and trust, were used to inform the selection of constructs to explore the role of neighborhood social organization and sex parter risk (described further in Chapter 2).

Findings of this research provide an ideal opportunity to advance our understanding of whether and how neighborhood-level characteristics influence sexual risk behavior, sex partner characteristics, and testing positive for a current STI among HIV-infected and high-risk HIV-uninfected women living in the South. The remainder of this dissertation is presented in four chapters. Chapter 2 tests the associations between neighborhood characteristics, including social organizational factors, and *sex partner risk*, and examines whether the magnitudes and directions of these relationships vary by HIV status. Chapter 3 tests the associations between neighborhood characteristics and *sexual risk behaviors*, and examines whether the magnitudes and directions of these relationships vary by HIV status. Chapter 4 tests the associations between neighborhood characteristics and *current STI status*, and examines whether the magnitudes and directions of these relationships vary by HIV status. Chapter 5 presents an integrative summary of findings, strengths, limitations, and discusses implications for future research.

Figure 1.1. Conceptual model of the pathways between neighborhood characteristics, sexual risk, and sexually transmitted infections (STIs), as moderated by HIV status



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Chapter 2: Associations between Neighborhood Characteristics and Perceived Sex Partner Risk among HIV-infected and HIV-uninfected Women in the Southern United States

ABSTRACT

Introduction. Research suggests that neighborhood social and physical factors shape sexual network characteristics in HIV-uninfected adults in the United States (US). This multilevel analysis tests relationships between census tract characteristics and sex partner risk in a predominantly HIV-infected cohort of women living in the Southern US.

Methods. This cross-sectional multilevel analysis included data from 734 women enrolled in the Women's Interagency HIV Study's southern sites. Administrative data captured social disorder (e.g., violent crime rate), social disadvantage (e.g., alcohol outlet density), and social capital (e.g., prevalence of non-profits) of the census tracts where women lived; participant-level data, including perceived neighborhood trust and cohesion, were gathered via survey. We used hierarchical generalized linear models to evaluate relationships between tracts, perceived main sex partner risk level (e.g., partner illicit drug use, incarceration) and main sex partner non-monogamy. We tested whether these relationships varied by HIV status.

Results. Greater social disorder was associated with less partner non-monogamy among HIV-uninfected women (OR=0.72, 95% CI=0.54, 0.96) and more partner non-monogamy (OR=1.20, 95% CI=0.96, 1.50) and more sex partner risk (OR=1.41, 95% CI= 1.16, 1.72) among HIV-infected women. Greater social disadvantage was associated with less partner non-monogamy (OR=0.73 95% CI=0.60, 0.96) and lower sex partner risk

(OR=0.84, 95% CI=0.72, 0.97) among both HIV-infected and HIV-uninfected women. Perceived neighborhood trust and cohesion was borderline statistically significantly associated with lower partner risk (OR=0.84, 95% CI=0.70, 1.02).

Conclusion. Study findings reveal that neighborhood characteristics are associated with sex partner risk characteristics among women living in the South, and that relationships vary by HIV status. Future studies should examine causality of these relationships and explore the causal pathways through which neighborhoods influence partner selection and risk characteristics.

Introduction

One in five newly identified HIV infections in the United States (US) are among women- the vast majority of which are acquired through heterosexual transmission.[1] Although the HIV epidemic was initially concentrated in the northeastern and western regions of the US, it now has transitioned to the Southern US.[2-4] The South has the highest rate of HIV diagnoses, and HIV-infected women in this region experience higher rates of HIV-related morbidity and mortality.[2-5] Furthermore, nine states in the South (Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Texas) have higher proportions than other regions of individuals diagnosed with HIV who are Black, female, and living in suburban and rural areas.[5]

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 US. Geographic areas with high levels of socioeconomic disadvantage (e.g., high poverty rate) and social disorder (e.g., high violent crime rate) tend to have higher prevalences of STIs, including HIV.[6-14] Multilevel studies, which allow for exploration of relationships between neighborhood characteristics and sexual risk in individuals by controlling for potential neighborhood- and individual-level confounders, have found that living in neighborhoods with low male:female sex ratios (i.e., fewer men than women), high incarceration rates, and prevalent neighborhood poverty is associated with more unprotected sexual intercourse, partner risk (i.e., non-monogamy, multiple sex partners, and risk discordant partnerships), and STIs in *HIV-uninfected* populations.[15-26] 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-infected versus HIV-uninfected women. For example, neighborhood characteristics may be less influential for HIV-infected women because they have a stronger incentive to protect their health or that of their partner.[27]

Sexual network characteristics, including partner non-monogamy, can increase an individual's risk by creating overlapping sexual networks which facilitate the transmission of HIV and other STIs.[25,28,29] Notably, having a non-monogamous partner has been identified as a risk factor for HIV transmission among women who were otherwise low risk.[28] An understanding of whether and how neighborhood characteristics influence sex partner characteristics can inform the development of interventions designed to promote sexual health and reduce the transmission of STIs, including HIV.

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.[30,31] More socially cohesive areas tend to have lower prevalences of STIs, including HIV.[8,32] Theall and colleagues found that relationships between neighborhood alcohol availability and neighborhood gonorrhea rates were mediated by neighborhood social capital, suggesting that neighborhood social organizational factors may have both direct and indirect relationships to sexual health outcomes.[8] However, the vast majority of research exploring relationships of neighborhood-level social capital to STIs has utilized ecologic designs,[8,32] which are unable to assess relationships between neighborhood social capital and individual-level behaviors and to control for individual-level factors.[33,34]

The present analysis explores relationships between neighborhood characteristics and sex partner risk among a predominantly HIV-infected cohort of women living in the Southern US. We seek to:

1) Examine relationships between neighborhood characteristics (e.g., social disorder, trust and cohesion) and sex partner risk.
2) Investigate whether the magnitudes and directions of relationships between neighborhood characteristics and sex partner risk vary by HIV status.

Methods

Study Sample

The Women's Interagency HIV Study (WIHS) is a multisite, prospective study designed to investigate the impact and progression of HIV among HIV-infected women and among HIV-uninfected women who are at high risk of HIV infection in the US.[35,36] This cross-sectional analysis utilizes screening data from women who were enrolled at the newly added WIHS clinical research sites in Alabama, Georgia, Mississippi, Florida, and North Carolina between October 2013 and September 2015. WIHS participants were women between 25-60 years old. Eligible HIV-infected 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-uninfected women reported at least one personal characteristic or male sex 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, including 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.[35-37] The analyses described herein are restricted to WIHS participants who provided written informed consent to collect and geocode their home address.

Data Collection and Measures

WIHS collected demographic and behavioral data at screening using Computer-Assisted Personal Interview (CAPI). Participant home addresses were geocoded to 2010 census tract boundaries. We used existing data sources to construct census tract variables that captured neighborhood social and physical environments (e.g., US Census).

Outcomes

We created two outcomes assessing main sex partner characteristics, including risk (ordinal) and non-monogamy (binary). 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.”

<u>Perceived Main Sex Partner Risk:</u> For main partner risk, we created an index that captured whether participants believed their main sexual partner definitely or probably: a) had sex with someone else during the relationship; b) ever injected any illegal drug; c) ever spent more than 24 hours in jail, prison, or a detention center, d) ever had sex with a man (male sexual partners only); e) ever had a STI. Responses were summed across

items to create a continuous score ranging from 0-5. We then created an ordinal measure (0, 1, 2, $\geq$3) based on the distribution of participant scores. Higher scores are indicative of greater risk.

Perceived Main Sex Partner Non-Monogamy: We assessed partner non-monogamy independently due to the strong relationship between partner non-monogamy and STIs, including HIV.[28] 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?".[38] Women who responded "probably yes," "probably no," "definitely no," or "don't know" were categorized as not having a non-monogamous main sex partner.

Census Tract-Level Predictors

Census tract measures (Table 2.1) were constructed as follows:

The 2013 American Community Survey (ACS) 5-year tract estimates were used to calculate the percentage of residents living in poverty, percentage of unemployed residents, and percentage of renter-occupied housing units. The percentage of vacant housing units was obtained from the Vacant Address Database, a collaboration by the United States Postal Services and the Office of Housing and Urban Development.[39]

State Health Department counts of newly identified STIs (i.e., primary and secondary syphilis, gonorrhea, Chlamydia) were used to calculate the STI prevalence per 1,000 residents aged 15-64 for each tract in 2013.

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 to census tract boundaries, and used to calculate the violent crime rate per 1000 residents for each tract. Addresses within a 100-foot buffer of the tract boundary were included in the tract's calculation. Alcohol outlet density (i.e., the number of businesses with a license to sell alcohol for off-premise consumption per square mile) was created by geocoding 2014 address data obtained from state licensing agencies. Addresses were geocoded to tracts; addresses within a 100-foot buffer of the tract boundary were included in the tract's calculation.

Place-based measures (e.g., voting records) used in past research exploring relationships between social capital, sexual risk, and HIV/STIs were not readily available at the census tract-level.[8,31,32] For this study, tract-level social capital was measured as the prevalence of non-profit institutions providing community services in a census tract (e.g., religious institutions, health and human services). We selected this measure because tax records were publicly available for non-profit institutions and because the prevalence of non-profits has been included in past indices measuring state-level social capital.[31] This measure was created using the Internal Revenue Service (IRS) Business Master File (BMF), obtained from the National Center for Charitable Statistics (NCCS).[40] The IRS BMF contained 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; addresses within a 100-foot buffer of the tract boundary were included in the tract's calculation, and were used to create the prevalence 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.

A number of these tract-level measures were correlated (Pearson's $r \geq 0.6$). In order to capture underlying constructs and to avoid multicollinearity in multivariable models, we used principal components analysis (PCA) with orthogonal rotation (varimax) to condense tract-level variables into components (Table 2.2). The PCA produced two components with eigenvalues >1.0: 1) "social disorder" (i.e., vacant housing units, violent crime rate, STI prevalence, poverty, unemployment) and 2) "social disadvantage" (i.e., renter-occupied housing units, alcohol outlet density). Continuous standardized principal component scores were used as predictors in models. For each component, higher scores are indicative of greater social disorder/social disadvantage, as compared to sample averages.

Tract-level social capital was not correlated with other neighborhood measures and was not included in the PCA so that we could explore relationships of neighborhood social capital independently.

Participant-Level Predictors

Perceived neighborhood cohesion was measured using a four item scale created by Sampson and colleagues[30] 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, ranging from 1 to 5. Higher scores were indicative of more cohesive neighborhoods.

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

We also included WIHS screening data on participant-level characteristics that might confound or modify relationships between tract-level characteristics and sex partner risk by including variables classically included in analyses exploring associations of participant-level characteristics and sexual network characteristics.[e.g.,38,41,42] 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, 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 Test),[43] and social support (4-item scale assessing whether participants had people with whom they could share social events, get advice, be themselves when upset, or feel loved).[44] We averaged responses across social support items, creating a mean score ranging from 1 to 5, with higher scores indicative of greater social support.

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), assuming an ordinal distribution for main partner risk and a binomial distribution for main 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.[45]

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

In Phase 3, we modeled multivariable associations between tract-level characteristics (i.e., social disorder, social disadvantage, and social capital), perceived neighborhood cohesion, and perceived partner risk characteristics, controlling for potential participant-level covariates. A primary aim of our analyses was to test whether relationships between tract-level characteristics and partner risk characteristics were dependent on a participant'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*social disorder), retaining interaction terms with $p<0.05$ in the multivariable model (Final 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) using 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.[46-48] We entered cross-level interaction terms for HIV status and tract-level variables (e.g., HIV status*social disorder) stepwise, interaction terms with $p<0.05$ were considered statistically significant on the additive scale.

Participant-level covariates traditionally included in models evaluating partner risk (e.g., problem drinking) and measures of social capital may lie in the causal pathway between tract characteristics and our outcomes.[30,32,38,41,42,49,50] In Phase 4 (Reduced Model), we excluded variables that might lie on the causal pathway between neighborhood characteristics and sex partner risk characteristics in two separate Reduced Models: 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 characteristics and outcomes if they did indeed lie on the causal pathway, we compared odds ratio estimates for all tract-level variables and perceived neighborhood cohesion in the Final vs. Reduced Model. Differences in magnitude of the odds ratio ±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. Tract characteristics 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, Georgia, North Carolina, and Mississippi; 841 women completed the behavioral screening questionnaire. Of these, 734 (87.3%) women consented to the geocoding protocol and provided geocodable address information (Table 2.3). Sixty four women (7.6%) did not consent to participate in the geocoding protocol; 7 (0.8%) provided address information that could not be matched to census boundaries; and 22 (2.6%) women lived on the street or in a residential treatment facility. A greater proportion of participants who were excluded from these analyses because they did not have geocoded address data reported annual incomes of ≤$18,000, as compared to participants with geocoded address information (86.9% vs. 75.0%, p=0.01). Participants with and without geocoded address data were comparable for all other variables included in these analyses, including the outcomes (i.e., p value >0.05 in chi-square and t-test comparisons).

In the analytic sample (N=734), participants were on average 43 years old (SD=9.3), most identified as non-Hispanic African American (82.8%), and 71.5% of participants were HIV-infected (Table 2.4). The average main partner risk score was 1.7 (SD=1.2) and was comparable across HIV status. Thirty two percent of participants reported that their main sexual partner was “definitely” not monogamous. A greater proportion of HIV-uninfected participants reported having a non-monogamous main partner (39.7% vs. 29.4%).

The WIHS participants lived in 491 distinct census tracts, with cluster sizes ranging from 1 to 7 participants. The majority of tracts (n=347, 70.5%) included one participant. Seventeen percent (n=84) of tracts included two participants, 12.4% (n=61) included three or more participants. In the analytic sample participants on average lived in census tracts with 29.1% (SD=13.6) of residents living in poverty, with 19.1 newly reported STI cases (SD=13.2) per 1,000 residents annually and 13.7 (SD= 13.4) violent crimes per 1,000 residents annually, and with 51.8% (SD=21.7) of housing units renter-occupied (Table 2.4). The mean perceived neighborhood cohesion score was 3.1 (SD=0.8).

Relationships between census tract characteristics, perceived social cohesion, and main sex partner risk by HIV status

The unconditional model intraclass correlation was 9.4% (random intercept variance component=0.34, p=0.10). In bivariate analyses (Table 2.5), tract-level social disorder (OR=1.28, 95% CI=1.09-1.50) was associated with greater percieved main sex partner risk. Tract-level social disadvantage (OR=0.91, 95% CI=0.78-1.05) and tract-level social capital (OR=1.02, 95% CI: 0.99, 1.05) were not associated with main sex partner risk. Being HIV-infected (OR=0.53, 95% CI= 0.39, 0.72) and perceived neighborhood cohesion (OR=0.81, 95% CI=0.68, 0.97) were associated with lower sex partner risk.

In multivariable models, the direction of relationships between social disorder and perceived sex partner risk varied for HIV-infected and HIV-unifected women (Table 2.5, Final Model). For HIV-infected women, one SD higher social disorder was associated with 41% greater perceived sex partner risk (OR=1.41, 95% CI=1.16, 1.72). In contrast, for HIV-uninfected women, tract-level social disorder (OR=0.91, 95% CI=0.73, 1.41) was not associated with perceived partner risk. This relationship persisted in models assessing additive effects on relationships between social disorder and perceived partner risk by HIV status. For each one unit increase in the social disorder component, the absolute perceived partner risk was 4% greater for HIV-infected women (p=0.003), but was not associated with partner risk for HIV-uninfected women (p=0.42).

Tract-level social disadvantage (OR=0.84, 95% CI=0.72-0.97) was associated with lower perceived main sex partner risk among the sample and this relationship did not vary by HIV status. One SD higher social disadvantage was associated with 16% lower perceived partner risk. There were no significant interactions between social disadvantage and perceived partner risk by HIV status on the additive scale (p=0.30).

Tract-level social capital (OR=1.02, 95% CI: 0.99, 1.04) was not associated with perceived partner risk. There were no statistically significant interactions between tract social capital and perceived partner risk by HIV status on the additive scale (p=0.78).

Perceived neighborhood cohesion was borderline statistically significantly associated with lower perceived partner risk (OR=0.84, 95% CI: 0.70, 1.02; p=0.09).

As a final step, we compared odds ratio estimates for all tract-level variables and perceived neighborhood cohesion in the Final 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 interval for perceived neighborhood cohesion narrowed (OR=0.82, 95% CI=0.73, 0.98; p=0.04) in the Reduced Model, rendering its association with perceived partner risk statistically significant, though its relationship to this outcome was borderline statistically significant in the corresponding Full Model (p=0.08). Odds ratio estimates for all tract-level variables in the Final 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 risk.

Relationships between census tract characteristics, perceived social cohesion, and main sex partner non-monogamy by HIV status

The unconditional model intraclass correlation was 3.74% (random intercept variance component=0.13, p=0.31). In bivariate analyses (Table 2.6), tract-level social disadvantage (OR=0.79, 95% CI=0.66-0.94) was associated with a lower odds of reporting a non-monogamous main sex partner. Tract-level social disorder (OR=1.02, 95% CI=0.86-1.21) and tract-level social capital (OR=1.00, 95% CI: 0.97, 1.03) were not associated with reporting a non-monogamous main sex partner. Being HIV-infected was associated with a lower odds of reporting a non-monogamous main sex partner (OR=0.62, 95% CI= 0.43, 0.88). Perceived neighborhood cohesion was not associated with reporting a non-monogamous main sex partner (OR=1.04, 95% CI=0.85, 1.28).

In multivariable models, the direction of relationships between social disorder and reporting a non-monogamous main sex partner varied for HIV-infected and HIV-uninfected women (Table 2.6). For HIV-infected women, tract-level social disorder was borderline statistically significantly associated with greater odds of reporting a non-monogamous main sex partner (OR=1.20, 95% CI=0.96, 1.50; p=0.11). In contrast, for HIV-uninfected women, tract-level social disorder (OR=0.72, 95% CI=0.54, 0.96) was associated with a lower odds of reporting a non-monogamous main sex partner. Specifically, one SD higher social disorder was associated with a 28% *lower* odds of reporting a non-monogomous main sex partner among HIV-uninfected women and a 20% *higher* odds of reporting a non-monogomous main sex partner among HIV-infected women. This relationship persisted in models assessing additive effects on relationships between social disorder and having a non-monogamous main sex partner by HIV status. For each one unit increase in the social disorder component, the absolute risk of having a non-monogamous main partner was 1% greater for HIV-infected women (p=0.01) but 7% lower (p=0.02) for HIV-uninfected women.

Tract-level social disadvantage (OR=0.73, 95% CI=0.60-0.89) was associated with lower odds of reporting a non-monogamous main sex partner (Table 2.6) among the sample and this relationship did not vary by HIV status. Notably, one SD higher social disadvantage was associated with 27% lower odds of reporting a non-monogamous main sex partner. There were no significant interactions between social disadvantage and having a non-monogomous main partner by HIV status on the additive scale (p=0.63).

Tract-level social capital (OR=1.00, 95% CI: 0.97, 1.03) was not associated with having a non-monogamous main partner. There were no significant interactions between tract social capital and having a non-monogomous main partner by HIV status on the additive scale (p=0.44). Perceived neighborhood cohesion was not associated with having a non-monogamous main partner (OR=1.02, 95% CI: 0.81, 1.28).

As a final step, we compared odds ratio estimates for all tract-level variables and perceived neighborhood cohesion in the Final 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 Final 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 reveal that neighborhood characteristics are associated with sex partner risk characteristics among women living in the South, and that these relationships vary by HIV status. Specifically, greater social disadvantage (i.e., more alcohol outlets and renter-occupied housing) was associated with lower odds of partner non-monogamy and lower perceived partner risk in the sample, regardless of HIV status. Neighborhood social disorder (i.e., more vacant housing, violent crime, STIs, poverty, and unemployment) was associated with *less* sex partner non-monogamy among *HIV-uninfected* women and with *greater* non-monogamy and *greater* sex partner risk among *HIV-infected* women. In addition, perceived neighborhood cohesion was borderline statistically significantly associated with *lower* perceived partner risk, regardless of HIV status.

In our sample, greater social disadvantage was associated with lower odds of having a non-mongamous sex partner and lower sex partner risk, regardless of HIV status. Alcohol outlet density, a component in our social disadvantage measure, is associated with sexual network turnover;[51,52] it is possible that women living in areas with greater social disadvantage in our sample did not know their sexual partners well, and as a result were less knowledgeable about their sexual partner's current or past behaviors.[53,54]

The directionality of relationships between social disorder and partner non-monogamy varied by HIV status. In contrast to past research detecting positive associations between social disorder and partner non-monogamy in HIV-uninfected populations,[15,25] and our own finding that greater social disorder is associated with more partner non-monogamy in HIV-infected women, we found that greater social disorder was associated with *less* partner non-monogamy among *HIV-uninfected* women in our sample. The mechanisms supporting this finding are unclear and warrant further exploration. HIV-uninfected women living in more socially disordered 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.[25] However, neighborhood social disorder may promote norms encouraging multiple sexual partnerships[22,23] and sex partner assessments captured risk characteristics of *main* sex partners only. HIV-uninfected women are more likely to have multiple sexual partners than HIV-infected women.[55] If HIV-uninfected women had multiple sex partners, it is possible that they did not identify sex partners with other sexual partners as the “most significant sexual partner”.[56]

In our sample, greater social disorder was associated with *greater* sex partner risk among *HIV-infected* women. HIV-infected women are more likely to have HIV-infected sexual partners,[55] and the partner sexual risk measure, which included partner’s *lifetime* histories of injection drug use, incarceration, and STIs, may be serving as a proxy for being HIV-infected. Past studies have found that individuals living with and at increased risk of HIV tend to select sexual partners in closer proximity than lower risk populations.[57,58] Neighborhoods with greater social disorder tend to have higher prevalences of HIV.[59,60] It is possible that HIV-infected women living in more socially-disordered areas seeking seroconcordant sexual partners have greater access to HIV-infected partners[55] or may sustain relationships with the partner from whom they acquired HIV.

Perceived neighborhood cohesion was associated with lower partner risk, regardless of HIV status. Members of more socially cohesive neighborhoods may be engaged in social networks with more prosocial norms discouraging behaviors captured in the partner risk index (e.g., substance use, criminal activity) and encouraging risk reduction (e.g., condom use).[30,61-64] These women may consequently select sex partners from these cohesive networks or perceive that their main sex partner is less likely to engage in high risk behaviors.[30,61-64] Tract-level prevalence of non-profit organizations was not associated with partner non-monogamy nor partner risk. In ad hoc analyses, we explored alternative operationalizations of the tract-level social capital 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.[65,66] These measures were not associated with our outcomes (results available upon request). Due to the nature of the dataset, we were unable to quantify the breadth and reach of services provided by each institution included in the tract-level social capital measure, including whether these institutions provided services locally.

Past multilevel studies have detected relationships between shortages of men and greater partner risk.[15,22,23] However, 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 to women to test relationships between sex ratios and partner risk in this sample.[56,67] 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) which contribute to a shortage of male partners.[15,23]

These findings are subject to limitations. Although the WIHS study provides a high quality sample of women who are living with and at increased risk of HIV infection in the Southern US, study participants agree to long-term follow-up and may not be representative of the general population of HIV-infected or high risk HIV-uninfected women. The majority of HIV-infected participants were recruited from clinic-based populations and as a result, findings may not extend to HIV-infected women 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. Roughly 32% participants at the Florida study site were excluded from these analyses because they did not provide consent for the geocoding protocol. However, a comparison of participant-level variables included in these analyses, including the outcomes, for participants at the Florida site with and without geocoded address data found no statistically significant differences. Due to the cross-sectional nature of our study, we are unable to draw conclusions regarding the causality of relationships between tract characteristics and sexual partner characteristics. Our analyses utilized census tract-level measures to capture neighborhood characteristics. Residential census tracts may fail to capture the activity spaces in which women engage and access social services or select sex partners. However, past studies have found that individuals living with and at increased risk of HIV tend to select sexual partners in closer proximity than lower risk populations.[57,58]

This multilevel study is among the first to test relationships between neighborhoods and sex partner risk 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 and highlight that these relationships may vary by HIV status. 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, and inform the development of future multilevel interventions designed to improve women's sexual health and reduce HIV/STI transmission.

Table 2.1. Census tract measures, definition, data source, and year

Measure	Definition	Data Source	Year
Social disorder component			
Percent vacant housing units	Percent 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.[1]	Law Enforcement Agencies (i.e., police department, Sheriff's Office)	2013
STI prevalence	Prevalence of newly reported STIs (i.e., CT, NG, and primary and secondary syphilis) per 1,000 tract residents aged 15-64[2]	State Department of Health	2013
Percent poverty	Percent residents with annual income below poverty level	American Community Survey (ACS)	2008-2013
Percent unemployment	Percent unemployed residents ≥ 16 years old	ACS	2008-2013
Social disadvantage component			
Percent renter-occupied housing units	Percent renter occupied housing units	ACS	2008-2013
Alcohol outlet density	The number of businesses with a license to sell beverages containing alcohol (e.g., liquor, beer, wine) for off-premise consumption per tract square mile[1,4]	State Licensing Agencies (e.g., Department of Revenue, Alcoholic Beverage Control Commission)	2014
Social capital			
Non-profit institution prevalence	The prevalence of tax-exempt institutions per 1,000 tract residents	National Center for Charitable Statistics Internal Revenue Service Business Master File	2013

[1]Addresses were obtained from state agencies and geocoded to tracts; addresses within a 100-foot buffer of the tract boundary were included in the tract's calculation.
[2]In Alabama, the number of newly identified STIs were available by ZIP code, but not census tract. ZIP-level STI counts were allocated to tracts based on the proportion of residential population using the 2015 boundaries USPS-HUD ZIP to tract crosswalk file. Twelve ZIP code-census tract combinations were not included in the crosswalk file. For these 15 participants (17% of participants with available census tract data at site), ZIP code STI prevalence was assigned to the participant census tract. We conducted sensitivity analyses, removing these participants from the analytic data set, to explore potential bias introduced by this substitution. The rounded odds ratio estimates for the final models with and without these 15 participants were the same.
[3]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 2.2. Principal components analysis of census tract characteristics, rotated factor pattern (varimax) for the Women's Interagency HIV Study participants enrolled at the southern sites (n=737)[1]

	Factor Patterns and Loading Values[2]		
	Communality Estimates[3]	**Social Disorder Component**	**Social Disadvantage Component**
Variance explained by component	--	3.17	1.69
Census tract characteristic			
Vacant housing	0.67	**82**	1
Violent crime rate	0.70	**80**	25
STI prevalence	0.74	**86**	2
Poverty	0.73	**72**	46
Unemployment	0.61	**68**	39
Renter occupied housing	0.63	37	**70**
Alcohol outlet density	0.77	-4	**88**

[1]Scores were standardized and components were extracted for modeling, 45 observations were omitted due to missing census tract variables.
[2]Factor loadings were multiplied by 100 and rounded to the nearest integer. Factor loadings ≥35 were considered "significant" loadings.
[3]Final Communality Estimate=5.86

Table 2.3. Women's Interagency HIV Study Southern Sites enrollment and availability of geocoded address data, overall and by site (n=841)[1]

Site	Alabama	Florida	Georgia	Mississippi	North Carolina	Total
Enrolled	112	145	272	114	198	**841**
Geocoded address data available	100 (89.29)	90 (62.07)[2]	243 (89.34)	112 (98.25)	189 (95.45)	**734 (87.28)**
Reasons for missing census tract identifier						
No consent	0 (0)	47 (32.41)	17 (6.25)	0 (0)	0 (0)	**64 (7.61)**
Living on street or in a residential treatment facility[2]	10 (8.93)	7 (4.83)	0 (0)	0 (0)	5 (2.53)	**22 (2.62)**
Address could not be geocoded to census tract boundary	1 (0.89)	0 (0)	5 (1.84)	1 (0.88)	0 (0)	**7 (0.83)**
Unknown	1 (0.89)	1 (0.69)	7 (2.57)	1 (0.88)	4 (2.02)	**14 (1.66)**

[1]Four participants (1 in Florida, 3 in Georgia) did not complete the behavioral questionnaire at screening.
[2]Participants with and without geocoded address information at the Florida WIHS study site were comparable for all other variables included in these analyses, including the outcomes (i.e., p value >0.05 in chi-square and t-test comparisons).
[3]The Women's Interagency HIV Study sites, with the exception of Georgia, did not geocode address data for participants living on the street or in a residential treatment facility.

Table 2.4. Distributions of individual and census tract characteristics among 734 women enrolled in the Women's Interagency HIV Study Southern Sites

Characteristics of participants and census tracts	n (%) or Mean (SD)
Outcomes	
Non-monogamous main sex partner	
Overall	236 (32.1)
HIV-infected	153 (29.1)
HIV-uninfected	83 (39.7)
Missing	1 (0.1)
Partner risk score	
Overall	1.76 (1.2)
HIV-infected	1.65 (1.3)
HIV-uninfected	2.05 (1.1)
Missing	1 (0.1)
Partner risk ordinal score (Overall)	
0	132 (18.0)
1	193 (26.3)
2	200 (27.2)
≥3	208 (28.3)
Missing	1 (0.1)
Census tract-level characteristics	
Social disorder component	
Percent vacant housing units	7.8 (6.3)
Violent crime rate per 1,000 residents	13.7 (13.4)
Missing	44 (6.0)
STI prevalence per 1,000 residents	19.1 (13.2)
Missing	1 (0.1)
Percent poverty	29.1 (13.6)
Percent unemployed	16.1 (7.9)
Social disadvantage component	
Percent renter-occupied housing units	51.8 (21.7)
Alcohol outlet density	4.7 (7.6)
Social capital	
Non-profit prevalence per 1000 residents	3.2 (5.7)
Missing	1 (0.1)
Participant-level characteristics	
Perceived neighborhood cohesion	3.1 (0.8)
HIV-infected	525 (71.5)
Age in years	43.2 (9.3)
Married or living as married	203 (27.7)
Missing	1 (0.1)
Non-Hispanic African American	608 (82.8)
Annual household income of $18,000 or less	549 (74.8)
Missing	2 (0.3)
Intimate partner violence	163 (22.2)
Missing	3 (0.4)
Problem drinking	95 (12.9)
Missing	3 (0.4)
Social support	4.1 (0.7)

Table 2.5. Bivariate and multivariable relationships of census tract characteristics to main sex partner risk at screening among women enrolled in the Women's Interagency HIV Study's Southern Sites (n=733)[1]

Characteristics of participants and census tracts	Bivariate OR (95% CI)	Final Model aOR (95% CI)[2]	Reduced Model aOR (95% CI)[3]
Census tract-level characteristics			
Social disorder component	**1.28 (1.09, 1.50)**	0.91 (0.73, 1.14)	0.96 (0.76, 1.20)
HIV-infected*greater social disorder (ref: HIV-infected participants living in tracts with average social disorder)	--	**1.41 (1.16, 1.72)**	**1.45 (1.19, 1.76)**
Social disadvantage component	0.91 (0.78, 1.05)	**0.84 (0.72, 0.97)**	**0.85 (0.73, 0.98**)
Prevalence of non-profit organizations	1.02 (0.99, 1.05)	1.02 (0.99, 1.04)	1.02 (0.99, 1.05)
Participant-level characteristics			
Perceived neighborhood cohesion	**0.81 (0.68, 0.97)**	**0.84 (0.70, 1.02)**	**0.82 (0.69, 0.99)**
HIV-infected	**0.53 (0.39, 0.72)**	**0.61 (0.44, 0.84)**	**0.53 (0.39, 0.74)**
Age in years	1.00 (0.99, 1.02)	1.01 (0.99, 1.02)	1.01 (0.99, 1.02)
Married or cohabitating	0.84 (0.61, 1.14)	0.88 (0.65, 1.21)	0.87 (0.63, 1.19)
Non-Hispanic African American	0.77 (0.53, 1.11)	**0.65 (0.44, 0.95)**	**0.63 (0.42, 0.92)**
Annual household income of $18,000 or less	1.19 (0.86, 1.64)	1.10 (0.79, 1.52)	--
Intimate partner violence	**2.35 (1.67, 3.31)**	**2.04 (1.42, 2.92)**	--
Problem drinking	**1.62 (1.05, 2.50)**	1.21 (0.78, 1.89)	--
Social support	0.91 (0.75, 1.10)	1.09 (0.89, 1.33)	--
Model fit			
Random intercept variance (p-value)	--	0.04 (0.43)	0.08 (0.37)
-2LL	--	1813.23	1831.58
AIC	--	1847.23	1857.58
BIC	--	1916.97	1910.91

[1]1 participant missing outcome
[2]Multivariable analyses restricted to participants with no missing predictors (n=687)

Table 2.6. Bivariate and multivariable relationships of census tract characteristics to the odds of having a non-monogamous main sex partner at screening among women enrolled in the Women's Interagency HIV Study's Southern Sites (n=733)[1]

Characteristics of participants and census tracts	Bivariate OR (95% CI)	Final Model aOR (95% CI)[2]	Reduced Model aOR (95% CI)[3]
Census tract-level characteristics			
Social disorder component	1.02 (0.86, 1.21)	**0.72 (0.54, 0.96)**	**0.75 (0.57, 0.99)**
HIV-infected*greater social disorder (ref: HIV-infected participants living in tracts with average social disorder)	--	**1.20 (0.96, 1.50)**	**1.20 (0.96, 1.50)**
Social disadvantage component	**0.79 (0.66, 0.94)**	**0.73 (0.60, 0.89)**	**0.74 (0.61, 0.90)**
Prevalence of non-profit organizations	1.00 (0.97, 1.03)	1.00 (0.97, 1.03)	1.00 (0.97, 1.03)
Participant-level characteristics			
Perceived neighborhood cohesion	1.04 (0.85, 1.28)	1.02 (0.81, 1.28)	0.97 (0.78, 1.20)
HIV-infected	**0.62 (0.43, 0.88)**	**0.62 (0.42, 0.91)**	**0.57 (0.40, 0.83)**
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)**	**0.38 (0.25, 0.58)**	**0.37 (0.24, 0.57)**
Non-Hispanic African American	0.89 (0.58, 1.35)	0.73 (0.46, 1.15)	0.71 (0.45, 1.12)
Annual household income of $18,000 or less	1.14 (0.78, 1.65)	1.07 (0.71, 1.61)	--
Intimate partner violence	**1.72 (1.16, 2.54)**	**1.60 (1.05, 2.44)**	--
Problem drinking	1.35 (0.85, 2.15)	1.04 (0.62, 1.74)	--
Social support	0.87 (0.70, 1.08)	0.94 (0.74, 1.20)	--
Model fit			
Random intercept variance (p-value)	--	0	0
-2LL	--	806.64	812.77
AIC	--	834.64	832.77
BIC	--	892.07	873.80

[1]1 participant missing outcome

[2]Multivariable analyses restricted to participants with no missing predictors (n=687)

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Chapter 3:

Associations between Neighborhood Characteristics and Sexual Risk Behaviors among HIV-infected and HIV-uninfected Women in the Southern United States

ABSTRACT

Introduction. Research suggests that neighborhood characteristics shape sexual risk in HIV-uninfected adults in the United States (US). This multilevel analysis tests relationships between census tract characteristics and sexual risk behaviors in a predominantly HIV-infected cohort of women living in the Southern US.

Methods. This cross-sectional multilevel analysis included data from 530 HIV-infected and 207 HIV-uninfected women enrolled in the Women's Interagency HIV Study's southern sites (N=737). Administrative data captured characteristics of the census tracts where women lived (e.g., percent residents living in poverty); participant-level data were gathered via survey. We used principal components analysis to condense tract-level variables into components capturing underlying constructs: social disorder (e.g., violent crime rate) and social disadvantage (e.g., alcohol outlet density). We used hierarchical generalized linear models to assess relationships between tract characteristics and unprotected vaginal intercourse (UVI), anal intercourse (AI), and unprotected anal intercourse (UAI), and to test whether these relationships varied by HIV status.

Results. Greater social disorder was associated with a lower odds of AI (OR=0.65, 95% CI=0.43, 0.96) and UAI (OR=0.50, 95% CI=0.31, 0.82), regardless of HIV status. Tract-level social disadvantage was not associated with sexual risk behaviors. There were no

statistically significant additive or mulitplicative interactions between tract characteristics and HIV status.

Conclusion. Study findings reveal that neighborhood characteristics are associated with sexual risk behaviors among women living in the South, and that these relationships do not vary by HIV status. Future studies should establish the temporality of these relationships and explore causal pathways through which neighborhoods influence sexual risk.

Introduction

The burden of HIV/AIDS in women in the United States (US) has grown substantially since the beginning of the epidemic: rising from 8% of all newly diagnosed AIDS cases in 1983 to more than 19% of all new diagnosed HIV infections in 2014.[1,2] The South now represents a significant proportion of the HIV/AIDS epidemic in the US. In 2011, a group of nine states (Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Texas) reported higher HIV diagnosis rates than the US overall (24.5/100,000 vs. 18.0/100,000).[3] Moreover, HIV-infected individuals living in this region experience the highest rates of morbidity and mortality in the US.[3-5]

An emerging line of evidence indicates that several features of the social and built environment influence sexual risk and the transmission of HIV and other STIs in *HIV-uninfected populations*, and in the South in particular.[3-5] Ecologic studies have found that geographic areas with high levels of poverty, social disorder (e.g., violent crime), incarceration, or racial/ethnic residential segregation frequently have higher prevalences of HIV/AIDS and other STIs.[6-16] Multilevel studies extending this line of research to associations between neighborhood characteristics and sexual risk in individuals have found that living in neighborhoods with low male:female sex ratios (i.e., fewer men than women), high incarceration rates, and high poverty rates is associated with non-monogamy, multiple sexual partners, unprotected sexual intercourse, and risk discordant partnerships.[17-28] Conceptualizing neighborhoods as opportunity structures, residents of neighborhoods with comparatively greater economic disadvantage (e.g., high poverty rates) or social disorder (e.g., more vacant houses, violent crime) may have less access to social and structural resources needed to engage in healthful behaviors (e.g., employment opportunities), and greater exposure to hazards associated with negative health outcomes.[29,30] For example, a high density of liquor stores in a neighborhood may contribute to greater community-level alcohol consumption and sexual risk behaviors.[29,30] Similarly, neighborhood attributes may shape sexual partner availability and sexual network characteristics. For instance, low male to female sex ratios may increase the dyadic power of men and ultimately reduce women's ability to negotiate lower risk sexual behaviors, such as monogamy and condom use.[17,24-26,31,32]

However, little is known about whether or how neighborhood characteristics shape sexual risk for women living with HIV infection. To our knowledge, only one multilevel study has explored relationships between neighborhoods and sexual behaviors in *HIV-infected adults*. This study found no association between neighborhood poverty rates, racial/ethnic composition, unemployment rates, and unprotected sexual intercourse among a predominantly male clinic-based population in the Midwestern US.[33] It is possible that the magnitude and direction of relationships between neighborhoods and sexual behaviors vary by women's HIV status, in part because HIV-infected women may be more motivated to protect their own health or that of their sexual partners.[34] An understanding of whether or how neighborhood characteristics and HIV status shape sexual risk behaviors among women can inform the design of interventions to improve women's sexual health and to reduce the transmission of HIV and other STIs.

The present analysis addresses this critical research gap by exploring relationships between neighborhood characteristics and sexual risk behaviors among a predominantly HIV-infected cohort of women living in the Southern US. We seek to:

3) Characterize relationships between neighborhood characteristics and sexual risk behaviors.
4) Test whether the magnitude and direction of relationships between neighborhood characteristics and sexual risk behaviors vary by HIV status.

This analysis is informed by the Socioecologic Framework (SEF), which acknowledges that health behaviors are influenced by multidimensional facets of the social and built environment.[35]

Methods

Participants

The Women's Interagency HIV Study (WIHS) is a multisite, prospective study designed to investigate the progression of HIV among HIV-infected women and the incidence of HIV among women who are at high risk of HIV infection in the US. This cross-sectional analysis utilizes baseline data from women who were newly enrolled at WIHS clinical research sites in Alabama, Georgia, Mississippi, Florida, and North Carolina between October 2013 and September 2015. Eligible women were between 25-60 years old. <u>HIV-infected women</u> 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. <u>HIV-uninfected women</u> reported at least one personal characteristic (e.g., illicit drug use) or male sexual partner characteristic (e.g., injection drug user) associated with increased risk of HIV acquisition within past 5 years. Participants were recruited using a variety of methods, including clinic and community-based organization referrals. 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. Women were compensated for time and travel. Methods are described in more detail elsewhere.[36-39] The analyses described herein are restricted to WIHS participants who provided written informed consent to collect and geocode their home address.

Data Collection and Measures

WIHS collected demographic and behavioral data using interviewer-administered surveys. Participant home addresses were geocoded to 2010 census tract boundaries. We used existing data sources to construct census tract variables that captured neighborhood social and built environments (e.g., US Census).

Primary Outcomes

Outcomes include unprotected vaginal intercourse (UVI), anal intercourse (AI), and unprotected anal intercourse (UAI) in the past 6 months. UVI was defined as reported inconsistent condom use during vaginal intercourse (binary: never or sometimes vs. always). AI was defined as a report of any anal sex (binary: yes/no). UAI was defined as reported inconsistent condom use during anal intercourse (binary: never or sometimes vs. always).

Census Tract-Level Exposures

Census tract measures were constructed as follows:

The 2013 American Community Survey (ACS) 5-year tract estimates were used to determine the percentage of residents living in poverty, percentage of unemployed residents, and percentage renter-occupied housing units.

The percentage of vacant housing units was obtained from the Vacant Address Database, a collaboration by the United States Postal Services and the Office of Housing and Urban Development.[40]

The total number of newly reported cases of primary and secondary syphilis, gonorrhea, chlamydia per census tract in 2013 was obtained from State Health Departments and was used to calculate the STI prevalence per 1,000 residents aged 15-64 for each tract in 2013. In Alabama, the number of newly identified STIs was available by ZIP code, but not census tract. ZIP-level STI counts were allocated to tracts based on the proportion of residential population using the 2015 boundaries USPS-HUD ZIP to tract crosswalk file.[40] Twelve ZIP code-census tract combinations were not included in the crosswalk file. For these 15 participants (17% of participants with addresses geocoded to census tract boundaries), ZIP code STI prevalence was assigned to the participant census tract.

Alcohol outlet density (i.e., the number of businesses with a license to sell alcohol for off-premises per square mile in 2014) was created by geocoding 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. The locations of violent crimes (i.e., murder, non-negligent manslaughter, forcible rape, robbery, and aggravated assault) during 2013 were obtained from law enforcement agencies, geocoded, and used to calculate the violent crime rate per 1000 residents for each tract. For alcohol outlet density and violent crime rate, addresses were geocoded to tracts; outlets/offenses within a 100-foot buffer of the tract boundary were included in the tract's calculation.

In order to capture underlying constructs and to avoid multicollinearity in multivariable models, we used principal components analysis (PCA) with orthogonal rotation (varimax) to condense tract-level variables into components (Table 3.1). The PCA produced two components with eigenvalues >1.0: 1) "social disorder" (i.e., vacant housing units, violent crime rate, STI prevalence, poverty, unemployment) and 2) "social disadvantage" (i.e., renter-occupied housing, alcohol outlet density). Standardized continuous principal component scores were used as predictors in models. For each component, higher scores are indicative of greater than average social disorder/social disadvantage than the sample.

Participant-Level Characteristics

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

Covariates included participant-level characteristics that might confound or modify relationships between tract-level characteristics and sexual risk behaviors. These a priori variables are classically included in analyses exploring associations of participant-level characteristics and sexual risk behaviors.[e.g.,41,42,43] Covariates captured demographic characteristics and behaviors in the past six months and were binary unless otherwise noted: age in years (continuous, mean-centered), married or cohabitating, non-Hispanic African American, annual household income ≤$18,000, self-rated quality of life (QOL) as measured using an abbreviated Medical Outcomes Study Scale (continuous, mean-centered; scores ranged from 0 to 100 with higher scores indicative of better QOL),[44] alcohol or illicit substance use (>7 drinks in the past week, any injection or non-injection use of crack, cocaine, heroin, marijuana, hallucinogens, club drugs, methamphetamines, or recreational prescription drug use in the last six months), sex exchange (exchange of sex for drugs, money or housing), and homeless (currently living in a rooming or halfway house, shelter, welfare hotel, or on the street).

Analysis

We used descriptive statistics to explore distributions of participant and census tract characteristics. We compared characteristics for participants who did and did not provide geocodable address information using t-tests and chi-square tests. All bivariate and multivariable relationships were modeled with hierarchical generalized linear models (HGLMs) using a logit link function with random effects for the intercept, thus allowing for participant-level variation across census tracts.[45] All HGLMs had two levels: participants (Level 1) were nested in census tracts (Level 2). The modeling process had four phases.

In Phase 1, we used an unconditional model to assess the proportion of variance in sexual risk behaviors due to clustering within census tracts (i.e., intra-class correlation).

In Phase 2, we modeled bivariate relationships between each tract- and participant-level characteristic and sexual risk behavior accounting for nestedness.

In Phase 3, we modeled multivariable relationships between tract-level characteristics and sexual risk behaviors, controlling for potential participant-level confounders. In order to determine whether the magnitudes and directions of relationships between tract characteristics and sexual risk behaviors might vary by HIV status, we tested statistically for multiplicative and additive interactions between neighborhood characteristics and study outcomes by HIV status. In Phase 3A, we tested for interaction between tract characteristics and HIV status on the multiplicative scale by entering cross-level interaction terms for HIV status and tract-level variables (e.g., HIV status*social disorder), retaining interaction terms with $p<0.05$ in the final multivariable model. In Phase 3B, we tested for interaction between neighborhood characteristics and HIV status on the additive scale by fitting separate models using a binomial distribution and identity link, controlling for participant-level confounders.[46,47] We entered cross-level interaction terms for HIV status and tract-level variables stepwise. Interaction terms with $p<0.05$ were considered statistically significant on the additive scale.

Participant-level covariates traditionally included in models evaluating sexual risk outcomes (e.g., alcohol and substance use) may lie in the causal pathway between tract characteristics and study outcomes.[48,49] Including these variables in the full model would attenuate relationships between tract characteristics and outcomes if they did indeed lie on the causal pathway. In Phase 4 (Reduced Model), we reran the final multivariable model, excluding variables that might lie on the causal pathway between neighborhood characteristics and sexual risk behaviors (i.e., income, QOL, alcohol and substance use, sex exchange, and homelessness). We compared odds ratio (OR) estimates for all tract-level variables in the Final vs. Reduced Model; >10% differences in magnitude suggested that excluded variables may attenuate relationships between neighborhood characteristics and sexual risk behaviors.

HGLMs were fit using PROC GLIMMIX using Newton Raphson optimization and Gauss-Hermite quadrature approximation in SAS 9.4. Estimates with $p<0.05$ were considered statistically significant.

Results

A total of 845 women were enrolled at WIHS's southern sites (Table 3.2). Eighty seven percent of enrolled women both provided consent to collect and geocode their home address and provided information that could be geocoded to census boundaries. One hundred eight women were excluded from these analyses because they did not have geocoded address information, the majority of these women did not provide consent for geocoding (n=65, 60.2%), lived on the street or in residential treatment facility (n=22, 20.4%), or provided addresses that could not be geocoded to census boundaries (n=7, 6.5%). In the analytic sample (N=737), participants were on average 44 years old (SD=9.3), most identified as non-Hispanic African American (83%), roughly a third were married, 66.8% reported annual household incomes of ≤$18,000, and 71.9% of participants were HIV-infected (Table 3.3). Participants excluded from these analyses because they did not have geocoded address information were more likely to report annual household incomes ≤$18,000 (83.2% vs. 69.0%, p=0.003); alcohol and substance use (48.1% vs. 37.9%, p=0.04); and sex exchange (17.6% vs. 5.7%, p<0.0001). Forty-two percent of participants reported UVI, 6.8% of participants reported AI, and 4.3% of participants reported UAI in the last 6 months. A greater proportion of HIV-uninfected participants reported engaging in UVI (69.6% vs. 31.7%), AI (9.7% vs. 5.7%), and UAI (7.7% vs. 3.0%).

Participants lived in 492 distinct census tracts, 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, 70.5%); two for 16.9% (n=83) of tracts, and three or more for 12.6% (n=62) of tracts. On average, participants lived in census tracts with 16.1% of residents unemployed (SD=8.0) and 29.1% living in poverty (SD=13.6). Participants lived in tracts with on average five alcohol outlets per square mile (SD=7.6) and where roughly half of housing units were renter-occupied (SD=21.7).

Relationships between census tract characteristics and UVI

The unconditional model intraclass correlation was 1.5% (unconditional model random intercept=0.05, p=0.41). In bivariate analyses (Table 3.4), tract-level social disorder (OR=1.11, 95% CI=0.94-1.31) and social disadvantage (OR=0.98, 95% CI=0.84, 1.15) were not associated with UVI. In the final multivariable model controlling for participant-level characteristics, tract-level social disorder (OR=0.96, 95% CI=0.79-1.17) and social disadvantage (OR=1.00, 95% CI=0.84-1.19) were not associated with UVI.

There were no statistically significant interactions between census tract characteristics and HIV status on the multiplicative or additive scale (p>0.05). Odds ratios for tract-level characteristics in the final model, as compared to the reduced model were within 10% for both social disorder and social disadvantage and were not statistically significantly associated with UVI.

Relationships between census tract characteristics and AI

The unconditional model intraclass correlation was 7.8% (unconditional model random intercept=0.28, p=0.37). In bivariate models (Table 3.5), tract-level social disorder (OR=0.77, 95% CI=0.53-1.11) and social disadvantage (OR= 0.97, 95% CI=0.69-1.38) were not significantly associated with AI. In the final multivariable model controlling for participant-level characteristics, tract-level social disorder was significantly associated with the odds of AI (OR=0.65, 95% CI=0.43, 0.99). Notably, a one standard deviation higher social disorder component was associated with a 35% lower odds of AI. Tract social disadvantage (OR= 1.00, 95% CI=0.70, 1.43) was not significantly associated with AI.

There were no statistically significant interactions between census tract characteristics and HIV status on the multiplicative or additive scale (p>0.05). Odds ratios for tract-level characteristics in the final model, as compared to the reduced model were within 5% for the social disadvantage component. The estimate for the social disorder component was 23% higher in the Reduced Model and was no longer statisically significantly associated with AI.

Relationships between census tract characteristics and UAI

Random intercept components in unconditional models for UAI were estimated to be zero. In bivariate analyses (Table 3.6), tract-level social disorder (OR= 0.59, 95% CI=0.37-0.93) was statistically significantly associated with a lower odds of UAI. Social disadvantage (OR= 0.98, 95% CI=0.66-1.44) was not associated with UAI. In the final mutivariable model, social disorder was statistically significantly associated with a lower odds of UAI (OR=0.50, 95% CI=0.31, 0.82). Specifically, a one standard deviation higher social disorder component was associated with a 50% lower odds of UAI. Social disadvantage (OR= 1.01, 95% CI=0.69-1.48) was not signifcantly associated with the UAI.

There were no statistically significant interactions between census tract characteristics and HIV status on the multiplicative or additive scale ($p>0.05$). The estimate for the social disorder component was 20% higher in the Reduced Model. Odds ratios for tract-level characteristics in the final model, as compared to the reduced model were within 10% for the social disadvantage component.

Sensitivity Analyses

We conducted sensitivity analyses, removing the 15 participants from Alabama with ZIP code STI prevalence assigned to the participant census tract from the analytic data set, to explore potential bias introduced by this substitution. The rounded odds ratio estimates for Final Model with and without these 15 participants were the same for all outcomes.

Discussion

Our analyses reveal that neighborhood characteristics are associated with sexual risk behaviors among women HIV-infected and HIV-uninfected women living in the South and that these relationships vary by type of sexual intercourse. Specifically, greater social disorder was associated with a lower odds of AI and UAI. Neighborhood characteristics were not associated with UVI in our sample.

Unprotected receptive anal intercourse confers high risk of transmission of STIs, including HIV.[42,50] Studies exploring individual-level predictors of UAI among women suggest that UAI may be influenced by complex social and economic factors, yet no multilevel studies in which individuals are nested in neighborhoods have explored relationships of neighborhoods characteristics to UAI specifically.[42,43,51] In this analysis, *greater* social disorder was associated with a *lower* odds of UAI. The direction of this relationship was unexpected. Elements of the neighborhood disorder component, including STI prevalence and violent crime, are associated with partner concurrency, STI acquisition, and greater perceived sexual partner risk.[21,22,27] It is possible that women living in neighborhoods with greater social disorder perceived their partners to be riskier, and that these perceptions discouraged engaging in AI or promoted condom use during AI.[52-54] Notably, the reduced models which tested associations between tract-level social disorder, AI, and UAI, excluding participant-level characteristics that may lie on the causal pathway (i.e., income, QOL, alcohol and illicit substance use, sex exchange, and homelessness), found that excluding these participant-level characteristics attenuated relationships towards the *null*. Latkin and colleagues found that individual perceptions of neighborhood social disorder are influenced by individual- and network-level characteristics and that relationships of social disorder to sexual risk are complex.[49,55] It is possible that women who are homeless or engaged in high risk activities (e.g., sex exchange) may be more acutely aware of their neighborhood environments and consequently may perceive their neighborhoods to be *more* socially-disordered.[55] Additional research is needed to explore the direct and indirect pathways through which neighborhood social disorder influences sexual risk.[56]

To our knowledge, only three multilevel studies in which individuals are nested in neighborhoods have explored relationships of neighborhood characteristics to unprotected sex in heterosexual adults; none of these studies distinguish between types of sexual intercourse (e.g., UVI vs. UAI).[18,24,33] Our finding that the relationships between neighborhood characteristics and sexual risk behaviors vary by the type of sex underscores the importance of evaluating these outcomes independently. Two of these three studies found no relationship between neighborhood economic characteristics (e.g., median income, unemployment) and unprotected sexual intercourse.[18,33] This is consistent with our own finding that the social disorder component, which includes measures of tract-level poverty and unemployment, was not associated with UVI. A third study, by Green and colleagues, found that lower sex ratios were associated with unprotected sexual intercourse among women.[24] In our predominantly African American sample, the vast majority of women lived in tracts with ratios of men to women well below equity and as a result, we did not have sufficient numbers of participants living in tracts with equitable or excess ratios of men to women to test relationships between sex ratios and sexual risk. Past research has cited the challenges of exploring relationships between sex ratios and sexual risk in predominantly African American populations in light of persistent social inequities (e.g., incarceration) which contribute to a shortage of male partners.[17,26]

These findings should be interpreted in light of the study's limitations. Although the WIHS is a high quality, large sample of women living with and at increased of HIV infection in the Southern US, WIHS study participants agree to indefinite, long-term study follow-up and may not be representative of the broader US population. Notably, the majority of HIV-infected participants were recruited from clinic-based populations and may not be representative of HIV-infected women who are not connected to HIV care. Participant-level data were collected using interviewer-administered surveys, which may be subject to social desirability bias.[57] Alternative forms of data collection (e.g., computer-assisted) would be preferable for future research in this area. Participants who were not included in the analysis reported individual characteristics associated with increased sexual risk (i.e., lower income, alcohol and substance use, sex exchange) and may have lived in qualitatively different neighborhoods. Notably, participants with and without geocoded address information were not statistically different with respect to UVI, AI, or UAI. Residential census tracts may fail to capture the activity spaces in which sexual risk behaviors most frequently occur. However, past studies have found that individuals living with and at increased risk of HIV tend to select sexual partners in closer proximity than lower risk populations.[58,59]

Despite these limitations, this is the first multilevel study to test relationships between neighborhood characteristics and AI and UAI and the first to explore relationships between neighborhoods and sexual risk behaviors 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. Additional longitudinal and qualitative studies are needed to establish the causality of these relationships and to better understand the pathways through which neighborhood characteristics shape sexual risk, and inform the development of future multilevel interventions designed to improve women's sexual health and reduce HIV/STI transmission.

Table 3.1. Principal components analysis of census tract characteristics, rotated factor pattern (varimax) for the Women's Interagency HIV Study participants enrolled at the southern sites (n=737)[1]

	Factor Patterns and Loading Values[2]		
	Communality Estimates[3]	**Social Disorder Component**	**Social Disadvantage Component**
Variance explained by component	--	3.17	1.69
Census tract characteristic			
Vacant housing	0.67	**82**	1
Violent crime rate	0.70	**80**	25
STI prevalence	0.74	**86**	2
Poverty	0.73	**72**	46
Unemployment	0.61	**68**	39
Renter occupied housing	0.63	37	**70**
Alcohol outlet density	0.77	-4	**88**

[1]Scores were standardized and components were extracted for modeling, 45 observations were omitted due to missing census tract variables.
[2]Factor loadings were multiplied by 100 and rounded to the nearest integer. Factor loadings ≥35 were considered "significant" loadings.
[3]Final Communality Estimate=5.86

Table 3.2. Women's Interagency HIV Study enrollment and availability of geocoded address data, overall and by site

Site	Alabama	Florida	Georgia	Mississippi	North Carolina	Total
Enrolled	112	146	275	114	198	**845**
Home address geocoded to census tract boundary	100 (89.29)	90 (61.64)	246 (89.45)	112 (98.25)	189 (95.45)	**737 (87.22)**
Reasons for missing census tract identifier						
No consent	0 (0)	48 (32.88)	17 (6.18)	0 (0)	0 (0)	**65 (7.69)**
Living on street or in a residential treatment facility[1]	10 (8.93)	7 (4.79)	0 (0)	0 (0)	5 (2.53)	**22 (2.60)**
Address could not be geocoded to census tract boundary	1 (0.89)	0 (0)	5 (1.82)	1 (0.88)	0 (0)	**7 (0.83)**
Unknown	1 (0.89)	1 (0.68)	7 (2.55)	1 (0.88)	4 (2.02)	**14 (1.66)**

[1]The Women's Interagency HIV Study, with the exception of the site in Georgia, did not geocode address data for participants living on the street or in a residential treatment facility.

[2]Participants enrolled at the Florida site who did not have a home address geocoded to a census tract boundary were more likely to report sex exchange than Florida participants with census tract identifiers (2.2% vs. 19.6%, p<0.001).

Table 3.3. Distributions of participant and census tract characteristics among 737 women enrolled in the Women's Interagency HIV Study Southern Sites

Characteristics of participants and census tracts	n (%) or Mean (SD)
Outcomes	
Unprotected vaginal intercourse	
Overall	312 (42.3)
HIV-infected	168 (31.7)
HIV-uninfected	144 (69.6)
Missing	1 (0.1)
Anal intercourse	
Overall	50 (6.8)
HIV-infected	30 (5.7)
HIV-uninfected	20 (9.7)
Missing	1 (0.1)
Unprotected anal intercourse	
Overall	32 (4.3)
HIV-infected	16 (3.0)
HIV-uninfected	16 (7.7)
Missing	4 (0.5)
Census tract-level characteristics	
Social disorder component	
Percent vacant housing units	7.81 (6.3)
Violent crime rate per 1,000 residents	13.75 (13.4)
Missing	44 (6.0)
Percent poverty	29.06 (13.6)
Percent unemployed	16.06 (8.0)
STI prevalence per 1,000 residents	19.10 (13.3)
Missing	1 (0.1)
Social disadvantage component	
Percent renter-occupied housing units	51.86 (21.7)
Alcohol outlet density	4.76 (7.6)
Missing	1 (0.1)
Participant-level characteristics	
HIV-infected	530 (71.9)
Age in years	43.71 (9.3)
Married or living as married	244 (33.1)
Missing	3 (0.4)
Non-Hispanic African American	614 (83.3)
Missing	11 (1.5)
Annual household income of $18,000 or less	492 (66.8)
Missing	24 (3.3)
Quality of life index	67.11 (20.5)
Missing	3 (0.4)
Alcohol or illicit substance use	279 (37.9)
Missing	1 (0.2)
Sex exchange	42 (5.7)
Missing	1 (0.1)
Homeless	47 (6.4)
Missing	12 (1.6)

Table 3.4. Bivariate and multivariable relationships of census tract characteristics to the odds of unprotected vaginal intercourse among women enrolled in the Women's Interagency HIV Study's Southern Sites (n=736)[1]

Characteristics of participants and census tracts	Bivariate OR (95% CI)	Final Model aOR (95% CI)[2]	Reduced Model aOR (95% CI)
Census tract-level characteristics			
Social disorder component	1.11 (0.94, 1.31)	0.96 (0.79, 1.17)	1.05 (0.87, 1.27)
Social disadvantage component	0.98 (0.84, 1.15)	1.00 (0.84, 1.19)	0.98 (0.82, 1.16)
Participant-level characteristics			
HIV-infected	**0.20 (0.14, 0.29)**	**0.20 (0.14, 0.30)**	**0.18 (0.11, 0.28)**
Age in years	**0.96 (0.95, 0.98)**	**0.96 (0.94, 0.98)**	**0.96 (0.95, 0.98)**
Married or living as married	**2.26 (1.65, 3.09)**	**2.36 (1.62, 3.44)**	**2.36 (1.62, 3.43)**
Non-Hispanic African American	1.15 (0.76, 1.76)	1.03 (0.61, 1.72)	0.95 (0.58, 1.57)
Annual household income of $18,000 or less	0.78 (0.56, 1.09)	0.82 (0.55, 1.22)	--
Quality of life index	0.99 (0.99, 1.00)	0.99 (0.99, 1.00)	--
Alcohol and illicit substance use	**2.17 (1.60, 2.94)**	**1.70 (1.16, 2.49)**	--
Sex exchange	**4.14 (2.04, 8.41)**	1.85 (0.81, 4.19)	--
Homeless	**2.28 (1.22, 4.25)**	2.05 (0.98, 4.32)	--
Model fit			
Random intercept variance (p-value)	--	0	0.0006 (0.50)
-2LL	--	733.83	753.37
AIC	--	757.83	769.37
BIC	--	811.48	801.94

[1]One participant missing outcome.
[2]Multivariable models restricted to participants with no missing predictors (n=646).

Table 3.5. Bivariate and multivariable relationships of census tract characteristics to the odds of anal intercourse among women enrolled in the Women's Interagency HIV Study's Southern Sites (n=736)[1]

Characteristics of participants and census tracts	Bivariate OR (95% CI)	Final Model aOR (95% CI)[2]	Reduced Model aOR (95% CI)
Census tract-level characteristics			
Social disorder component	0.77 (0.53, 1.11)	**0.65 (0.43, 0.96)**	0.80 (0.57, 1.13)*
Social disadvantage component	0.97 (0.69, 1.38)	1.00 (0.70, 1.43)	0.95 (0.68, 1.33)
Participant-level characteristics			
HIV-infected	0.55 (0.29, 1.04)	0.70 (0.33, 1.49)	0.54 (0.27, 1.06)
Age in years	**0.95 (0.91, 0.98)**	**0.95 (0.91, 0.99)**	**0.96 (0.92, 0.99)**
Married or living as married	1.23 (0.66, 2.32)	0.85 (0.39, 1.82)	0.88 (0.43, 1.77)
Non-Hispanic African American	**0.41 (0.19, 0.85)**	0.44 (0.18, 1.08)	**0.40 (0.18, 0.88)**
Annual household income of $18,000 or less	0.89 (0.46, 1.72)	0.77 (0.35, 1.70)	--
Quality of life index	0.99 (0.98, 1.01)	0.99 (0.97, 1.01)	--
Alcohol and illicit substance use	**4.34 (2.09, 9.03)**	**3.35 (1.49, 7.55)**	--
Sex exchange	**3.99 (1.52, 10.47)**	2.81 (0.89, 8.88)	--
Homeless	2.52 (0.82, 7.79)	1.98 (0.57, 6.90)	--
Model fit			
Random intercept variance (p-value)	--	0.88 (0.24)	0.48 (0.31)
-2LL	--	276.89	298.70
BIC	--	302.89	314.70
AIC	--	355.81	347.27

[1]One participant missing outcome.
[2]Multivariable models restricted to participants with no missing predictors (n=646).
[*]>10% difference between Full and Reduced Model.

Table 3.6. Bivariate and multivariable relationships of census tract characteristics to the odds of unprotected anal intercourse among women enrolled in the Women's Interagency HIV Study's Southern Sites (n=733)[1]

Characteristics of participants and census tracts	Bivariate OR (95% CI)	Final Model aOR (95% CI)[2]	Reduced Model aOR (95% CI)
Census tract-level characteristics			
Social disorder component	**0.59 (0.37, 0.93)**	**0.50 (0.31, 0.82)**	**0.59 (0.37, 0.94)****
Social disadvantage component	0.98 (0.66, 1.44)	1.01 (0.69, 1.48)	0.95 (0.66, 1.36)
Participant-level characteristics			
HIV-infected	**0.37 (0.18, 0.76)**	**0.40 (0.17, 0.94)**	0.32 (0.15, 0.72)
Age in years	0.97 (0.93, 1.01)	0.96 (0.92, 1.01)	0.98 (0.94, 1.02)
Married or living as married	1.21 (0.58, 2.53)	0.83 (0.34, 2.01)	0.98 (0.42, 2.25)
Non-Hispanic African American	0.63 (0.27, 1.51)	0.68 (0.24, 1.92)	0.65 (0.24, 1.73)
Annual household income of $18,000 or less	0.77 (0.36, 1.65)	0.51 (0.20, 1.29)	--
Quality of life index	**0.98 (0.96, 0.99)**	**0.97 (0.95, 0.99)**	--
Alcohol and illicit substance use	**4.50 (2.04, 9.91)**	**4.04 (1.63, 10.01)**	--
Sex exchange	2.64 (0.87, 7.97)	1.64 (0.44, 6.05)	--
Homeless	2.93 (1.07, 8.04)	2.53 (0.71, 9.02)	--
Model fit			
Random intercept variance (p-value)	--	0	0
-2LL	--	184.93	208.86
AIC	--	208.93	222.86
BIC	--	257.75	251.34

[1]Four participants missing outcome.
[2]Multivariable models restricted to participants with no missing predictors (n=643).
[*]>10% difference between Full and Reduced Model.

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Chapter 4:

Do Relationships between Neighborhood Characteristics and STI Status among Women Vary by HIV status?

ABSTRACT

Introduction. High rates of neighborhood poverty are associated with sexually transmitted infections (STIs) among HIV-negative women. This multilevel analysis tests relationships between census tract characteristics and current STI status in a predominantly HIV-infected cohort of women living in the southern United States (US).

Methods. This cross-sectional multilevel analysis included data from 530 HIV-infected and 207 HIV-uninfected women enrolled at the Women's Interagency HIV Study's southern sites (N=737). Administrative data (e.g., US Census) described the census tract-level social disorder (e.g., violent crime rate, vacant housing) and social disadvantage (i.e., alcohol outlet density, renter-occupied housing) where women lived. Participant-level data were gathered via survey. Testing positive for a current STI was defined as a laboratory-confirmed diagnosis of Chlamydia trachomatis, Neisseria gonorrhoeae, Trichomonas vaginalis, or treponema pallidum. We used hierarchical generalized linear models to determine relationships between tract characteristics and current STI status, and to test whether these relationships varied by HIV status.

Results. Eleven percent of participants tested positive for at least one current STI. Greater tract-level social disorder (OR=1.34, 95% CI=0.99, 1.87) and social disadvantage (OR=1.34, 95% CI=0.96, 1.86) were borderline statistically significantly associated with

having a current STI. There was no evidence of additive or mulitplicative interaction between tract characteristics and HIV status.

Conclusion. Findings suggest that neighborhood characteristics may be associated with current STIs among women living in the South, and that relationships do not vary by HIV status. Future research should establish the temporality of these relationships and explore pathways through which neighborhoods create vulnerability to STIs.

Introduction

Although the HIV epidemic was initially concentrated in the northeastern and western regions of the United States (US), the South now bears a significant burden of the epidemic.[1-3] Roughly half of individuals living with HIV in 2010 were diagnosed in the South, though just 37% of the US population lives in this region.[2] The South also experiences persistently high prevalences of other sexually transmitted infections (STIs).[1] Co-infection with STIs is common in people living with HIV.[4,5] STIs contribute to comorbidities (e.g., infertility, pelvic inflammatory disease) and may facilitate the transmission of HIV and other STIs to sexual partners.[4,5]

Features of the social and built environment may shape women's vulnerability to STIs. Geographic areas with high levels of poverty and social disorder tend to have high prevalences of STIs, including HIV.[6-19] Multilevel studies exploring associations between neighborhood characteristics and STI infection in individuals have confirmed associations found in ecologic studies, and have expanded neighborhood-based predictors to include neighborhood STI prevalence and sex ratios.[20-36] An understanding of whether neighborhood factors influence current STI status could inform prevention and treatment efforts. However, the vast majority of multilevel research exploring relationships between neighborhoods and STI aquistion study these relationships in youth or young adults;[27-30,32-36] these findings may not extend to adults. In addition, to our knowledge, no multilevel studies investigating the associations between neighborhood exposures and STIs have explored these relationships in a predominantly *HIV-infected* cohort. It is unclear how neighborhood characteristics create vulnerability to STI acquistion for people living with HIV. It is possible that the magnitude or direction of relationships between neighborhood characteristics and STIs are different for HIV-infected versus HIV-uninfected women. For example, neighborhood characteristics may be less influential for HIV-infected women because they have stronger incentives to protect their health or that of their partner.[37]

This multilevel cross-sectional study describes associations between neighborhood characteristics and current STI status among a predominantly HIV-infected cohort of women living in the South, and tests whether the associations between neighborhood characteristics and having an STI vary by women's HIV status. This analysis is guided by the Socioecological Framework (SEF), which acknowledges that health outcomes are shaped by physical and social environments in which behaviors occur.[38]

Methods

Sample and Recruitment

The Women's Interagency HIV Study (WIHS) is a multisite, prospective study designed to characterize the impact and progression of HIV among US women.[39,40] In 2013, WIHS expanded to clinical research sites in the southern US (i.e., Alabama, Florida, Georgia, Mississippi, and North Carolina). These sites enrolled HIV-infected women and HIV-uninfected women who were at high risk of HIV acquisition between October 2013 and September 2015. WIHS eligibility criteria included being a women between 25-60 years old. HIV-infected 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. HIV-uninfected women reported *either she or her sexual partner* met at least one of the following criteria in the last five years: clinical STI diagnosis; using injection drugs, crack, cocaine, heroin, or methamphetamine; sex for drugs, money, or shelter; unprotected sex with three or more partners; sex with six or more partners; or sex with a known HIV-positive partner.

Participants were recruited using several strategies, including clinic and community-based organization referrals. Institutional Review Board Approval was obtained at each of the collaborating institutions and written informed consent was obtained prior to initiation of study procedures. Women were compensated for time and travel. Methods are described in detail elsewhere.[39,40] This analysis is restricted to participants who provided written informed consent to collect and geocode their home address.

Data Collection and Measures

Outcome: Current Sexually Transmitted Infection

The outcome, testing positive for a current STI (binary), was defined as a laboratory-confirmed diagnosis for at least one of the following at baseline: Chlamydia trachomatis (CT), Neisseria gonorrhoeae (GC), Trichomonas vaginalis (TV), or treponema pallidum (syphilis). Assessment for each STI was conducted according to WIHS protocol-requirements (Table 4.1). Participants who tested positive for an STI were referred to medical providers for treatment.

Because WIHS protocol specified collection of cervical swabs for CT and NG testing, women were not tested for these pathogens if they had undergone a hysterectomy; we classified these test results as missing. The Alabama site, however, used urine nucleic acid amplification testing (NAAT) for CT and NG detection. Participants who did not have laboratory test results for all four of the STIs available and did not have at least one positive test among available results were excluded from the analyses (n=63, 8.55%). Study sites other than Georgia had higher rates of missing STI data as did HIV-infected participants ($p<0.05$). We used maximum likelihood estimation and included covariates associated with missing outcome data in all multivariable models, thus controlling for potential bias introduced.[41]

Census Tract-Level Characteristics

Baseline participant home addresses were geocoded to census tracts. Measures describing the social and built environments of the census tracts where women lived were constructed using existing data sources (e.g., US Census) (Table 4.2). Several tract-level predictors were correlated. We used principal components analysis (PCA) with orthogonal rotation (varimax) to condense tract-level variables into components in order to capture underlying constructs and avoid multicollinearity in multivariable models (Table 4.3). We extracted two continuous standardized principal component scores for factors with eigenvalues >1.0: (1) “social disorder” (i.e., percent vacant housing units, violent crime rate, STI prevalence, percent poverty, percent unemployed); and (2) “social disadvantage” (i.e., percent renter-occupied housing units, alcohol outlet density). For each factor, a one standard deviation increase indicates greater than average social disorder or social disadvantage for the sample.

Participant-Level Characteristics

WIHS collected all demographic and behavioral data using interview-administered questionnaires. Participant-level characteristics that might confound or modify relationships between tract-level characteristics and testing positive for an STI were determined a priori via a literature review.[4,5,22,42,43]

The effect modifier of interest was being HIV-infected, defined by WIHS as a reactive serologic enzyme-linked immunosorbent assay test and a confirmed positive western blot or detectable plasma HIV-1 ribonucleic acid.

Control variables captured demographic characteristics and behaviors in the past six months and were binary unless otherwise noted: age in years (continuous mean-centered); married or cohabitating; non-Hispanic African-American; less than high school education; annual income ≤$18,000; self-rated quality of life (QOL) (continuous mean-centered, measured using an abbreviated Medical Outcomes Study Scale ranging from 0-100, with higher scores indicative of greater QOL[44]); alcohol and illicit substance use (>7 drinks in the past week or any injection or non-injection use of crack, cocaine, heroin, marijuana, hallucinogens, club drugs, methamphetamines, or recreational prescription drug use in the last 6 months); exchange of sex for drugs, money or housing; homeless (currently living in a rooming or halfway house, shelter, welfare hotel, or on the street); lifetime history of CT, GC, TV, or syphilis; unprotected sex (vaginal or anal); and study site (5-level categorical).

Analysis

We used descriptive statistics to describe distributions of participant- and census tract-level variables at baseline. We modeled bivariate and multivariable relationships with hierarchical generalized linear models (HGLMs) using a logit link with random effects for the intercept in order to model participant-level clustering within census tracts.[45] All HGLMs had two levels: participants (Level 1) were nested in census tracts (Level 2). Modeling was conducted in four stages.

In Stage 1, we used an unconditional model to assess the proportion of variance in the odds of testing positive for an STI attributable to clustering within census tracts.[46]

In Stage 2, we modeled bivariate relationships between each tract- and participant-level characteristic and testing positive for an STI.

In Stage 3, we modeled multivariable relationships between tract-level characteristics and STIs, controlling for potential participant-level confounders. Because an aim of this study was to determine whether the magnitudes and directions of relationships between tract characteristics and having a current STI might vary by HIV status, we tested statistically for multiplicative and additive interactions between neighborhood characteristics and testing positive for an STI by HIV status. In Stage 3A, we tested for interaction between tract characteristics and HIV status on the multiplicative scale by entering cross-level interaction terms for HIV status and tract-level variables (e.g., HIV status*social disorder), retaining interaction terms with $p<0.05$ in the multivariable model. In Stage 3B, we tested for interaction between neighborhood characteristics and HIV status on the additive scale by fitting separate models using a binomial distribution and identity link, controlling for participant-level confounders.[47,48] We entered cross-level interaction terms for HIV status and tract-level variables (e.g., HIV status*social disorder) stepwise, interaction terms with $p<0.05$ were considered statistically significant on the additive scale.

Participant-level covariates traditionally included in models evaluating STI outcomes (e.g., alcohol and substance use) may lie in the causal pathways between tract characteristics and current STI status.[4,5,22,42,43,49,50] Including these variables in the full model would attenuate relationships between tract characteristics and outcomes if they did indeed lie on the causal pathway. In Stage 4 (Reduced Model), we therefore re-ran the final multivariable model excluding variables that might lie on the causal pathway between neighborhood characteristics and STIs (i.e., income, QOL, alcohol and substance use, homelessness, STI history, unprotected sex). We compared odds ratio (OR) estimates for all tract-level variables in the Final vs. Reduced Models; differences in magnitude >10% suggested that excluded variables may attenuate relationships between neighborhood characteristics and STIs.

HGLMs were fit using PROC GLIMMIX using Newton Raphson optimization and Gauss-Hermite quadrature approximation in SAS 9.4. Estimates with $p<0.05$ were considered statistically significant.

Results

Characteristics of census tracts and participants

A total of 845 women were enrolled at WIHS's southern sites (Table 4.4). Eighty seven percent of enrolled women both consented to collecting and geocoding their home address and provided information that could be geocoded to census boundaries. One hundred eight women were excluded from these analyses, the majority of these women did not provide consent for geocoding (n=65, 60.2%), lived on the street or in residential treatment facility (n=22, 20.4%), or provided addresses that could not be geocoded to census boundaries (n=7, 6.5%). In the final analytic sample (n=737), participants on average lived in census tracts with 29.1% of residents living in poverty (SD=13.6) and with 19.1 newly reported STI cases per 1,000 residents (SD=13.3) and 13.7 violent crimes per 1,000 residents annually (SD= 13.4) (Table 4.5). On average, tracts contained roughly five alcohol outlets per square mile (SD=7.8).

Participants were on average 44 years old (SD=9.3), 83.3% identified as non-Hispanic African American, and 64.0% reported a previous lifetime STI diagnosis. Seventy two percent of participants were HIV-infected. Eleven percent of participants tested positive for at least one STI at baseline: 1.2% tested positive for CT, 0.8% tested positive for GC, 6.2% tested positive for TV, and 2.8% tested positive for syphilis. The proportion testing positive for any STI was comparable by HIV status. Participants excluded from these analyses because they did not have geocoded address information were more likely to report annual household incomes ≤$18,000 (83.2% vs. 69.0%, p=0.003); alcohol and substance use (48.1% vs. 37.9%, p=0.04); and sex exchange (17.6% vs. 5.7%, p<0.0001).

Proportion of variance in the odds of testing positive for an STI attributable to census tracts

Participants lived in 492 distinct census tracts, with the number of participants per tract (cluster sizes) ranging from 1 to 8 participants. The cluster size was one for majority of tracts (n=347, 70.5%); two for 16.9% (n=83) of tracts, and three or more for 12.6% (n=62) of tracts. Clustering by census tracts accounted for 24.0% of the variance in the odds of testing positive for an STI (unconditional model random intercept variance=1.04, p=0.08).

Associations between tract-level social disorder, social disadvantage and current STI status

In bivariate analyses (Table 4.6), neither tract-level social disorder (OR=1.18, 95% CI=0.91-1.52) nor social disadvantage (OR=1.21, 95% CI=0.94-1.54) were associated with current STI status.

In the final multivariable model controlling for participant-level characteristics (Table 4.6), tract-level social disorder (OR=1.30, 95% CI=0.99-1.72, p=0.06) was borderline statistically significantly associated with having a current STI when excluding participant-level covariates that may lie on the causal pathway (Reduced Model A). Tract-level social disadvantage (OR=1.34, 95% CI=0.96-1.86, p=0.08) was borderline statistically significantly associated with having a current STI (Final Model A). Specifically, a one standard deviation higher social disorder component was associated with a 30% greater odds of having a current STI and a one standard deviation higher social disadvantage component was associated with a 34% greater odds of having a current STI.

There was no evidence of effect modification of the relationships between social disorder, social disadvantage, and having a current STI by HIV status on the multiplicative or additive scale ($p>0.05$). Odds ratios for tract-level characteristics in the final model (Final Model A), as compared to the reduced model excluding participant-level variables that might lie on the causal pathway (Reduced Model A) were within 4% for all comparisons, suggesting that excluded variables did not lie on the causal pathway. However, the confidence interval narrowed for the social disorder component in the Reduced Model, rendering this relationship borderline statistically significant (Reduced

Model: OR=1.30, 95% CI=0.99, 1.72; p=0.06 vs. Full Model: OR=1.25, 95% CI=0.94, 1.66; p=0.13).

Discussion

In this multilevel analysis controlling for participant-level characteristics, we found that greater tract-level neighborhood social disorder (i.e., greater violent crime, vacant housing, STI prevalence, poverty, unemployment) and social disadvantage (i.e., more alcohol outlets, renter-occupied housing) were borderline statistically significantly associated with having a current STI among women living in the South and that these relationships did not vary by HIV status. To our knowledge, this study is among the first to test relationships between neighborhood characteristics and STIs in adult women[23,27,28] and the first to analyze whether these relationships varied by HIV status.

Our findings are consistent with past studies exploring relationships between neighborhood conditions and STIs in young adults. These studies have found that neighborhood poverty and neighborhood STI prevalence (elements of the social disorder component) are associated with testing positive for a current STI.[27-29,51] Similarly, *changes* in neighborhood social disorder and social disadvantage are associated with *changes* in network characteristics and STIs: reductions in neighborhood poverty, violence (elements of the social disorder component), and alcohol outlets (an element of the social disadvantage component) are associated with less sexual partner risk, fewer sexual partners in close proximity (i.e., spatially assortive partnerships), fewer partners entering sexual networks, and with lower neighborhood STI prevalence over time.[6,9,20,21,23] Neighborhood social disorder and social disadvantage may create vulnerability to STIs by promoting norms supporting higher risk sexual behaviors and substance use, connecting women to higher risk sexual networks, and ultimately increasing the probability of having a sexual partner with an STI.[27,28,42,51]

Interestingly, in this predominantly HIV-infected cohort, none of the participant-level characteristics included in our bivariate or multivariable models were associated with current STI status. Similarly, the effect estimates for social disorder and social disadvantage in the full multivariable model versus the reduced model found that all estimates were well within the a priori 10% threshold, further supporting that these participant-level factors (i.e., annual income, QOL, alcohol and illicit substance use, sex exchange, homelessness, STI history, unprotected sex) did not lie on the causal pathway connecting neighborhood characteristics and STIs. It is likely that sexual network characteristics, and not individual attributes, are key mediators of the relationships between neighborhood characteristics and current STI status.[6,9,20-24] However, it is possible that additional mechanisms, which merit further exploration, create vulnerability to STI infection among HIV-infected women. For example, being on ART has been linked to decreased STI risk among HIV-infected women,[4] and an emerging line of research suggests that neighborhood factors shape HIV care and treatment among HIV-infected populations.[52-56]

The one study exploring relationships between neighborhood sex ratios and STIs among heterosexual adults found a relationship between more equitable sex ratios and a lower odds of testing positive for an STI.[22] We were unable to include sex ratios as a neighborhood-level exposure because, in our predominantly African American sample, the vast majority of women lived in tracts with ratios of men to women well below equity. Past research has cited the challenges of exploring relationships between sex ratios and sexual risk in predominantly African American populations in light of persistent social inequities (e.g., incarceration) which contribute to a shortage of male partners.[24,31]

Findings are subject to limitations. Although the WIHS study provides a high quality sample of women who are living with and at increased risk of HIV infection in the Southern US, study participants agree to long-term follow-up and may not be representative of the general population. The majority of HIV-infected participants were recruited from clinic-based populations and consequently, results may not extend to HIV-infected women who are not connected to HIV care and treatment. Participants excluded from these analysis due to a lack of geocoded address data reported individual characteristics associated with increased sexual risk (e.g., alcohol and substance use) and may have lived in qualitatively different neighborhoods. However, participants with and without geocoded address information were not statistically different with respect to current STI status. Due to the cross-sectional nature of our study, we are unable to draw conclusions regarding the causality of relationships between tract characteristics and STIs. Furthermore, residential census tracts may fail to capture the activity spaces in which sexual risk behaviors most frequently occur. However, past studies have found that individuals living with and at increased risk of HIV tend to select sexual partners in closer proximity than lower risk populations.[23,57]

Collectively, our findings underscore the importance of neighborhood characteristics in shaping women’s risk for STIs and suggest that relationships between neighborhood characteristics and testing positive for an STI do not vary by HIV status. Additional research is needed to establish the causal direction of these relationships and to elucidate the pathways through which neighborhood conditions create vulnerability to STIs among HIV-infected and high risk HIV-uninfected women living in the Southern US. If future research supports our findings, interventions designed to reduce women's STI risk should seek to improve neighborhood conditions or mediators of relationships between neighborhoods and STIs.

Table 4.1. Specimen type, test, and sensitivity and specificity for sexually transmitted infection (STI) evaluation Women's Interagency HIV Study Southern Sites

STI	**Specimen Type**	**Site**				
		Alabama	**Florida**	**Georgia**	**North Carolina**	**Mississippi**
		Test (Sensitivity, Specificity)				
Chlamydia	Cervical swab[1]	APTIMA Nucleic Acid Amplification Test (NAAT) (94.30, 98.00)	Becton Dickinson (BD) Probetec ET System (93.80, 99.80)	Aptima Combo 2 for CT/NG (96.60, 98.50)	Gen Probe Aptima (98.30, 96.10)	ROCHE Cobas polymerase chain reaction (PCR) (94.90, 99.40)
Gonorrhea	Cervical swab	APTIMA NAAT (92.00, 99.80)	BD Probetec ET System (88.00, 99.80)	Aptima Combo 2 for CT/NG (96.60, 98.50)	Gen Probe Aptima (97.30, 99.00)	ROCHE Cobas PCR (96.60, 99.90
Trichomoniasis	Vaginal swab	APTIMA NAAT (100.00, 98.10)	Wet mount (N/A)	Wet mount (N/A)	Wet mount (N/A)	Wet mount (N/A)
Syphilis	Serum	BD Screening rapid plasma regain (RPR) with confirmatory Treponema pallidum haemagglutination assay or Treponema pallidum particle agglutination assay (Screening: 3.00-100.00, 98.00, Confirmatory: 99.40, 100.00)	Arlington Scientific RPR Card (95.00, 98.00)	BD RPR titer, with confirmatory IgG enzyme immunoassay if reactive (N/A)	Labcorp Screening RPR with Confirmatory Quantitative RPR (Screening: 99.00, 98.40; Confirmatory: 100.00, 99.80)	BD RPR (86.00, N/A)

Table 4.2. Census tract measures, definition, data source, and year

Measure	Definition	Data Source	Year
Social disorder component			
Percent vacant housing units	Percent 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[1]	Law Enforcement Agencies (i.e., police department, Sheriff's Office)	2013
Sexually transmitted infection (STI) prevalence	Prevalence of newly reported STIs (i.e., CT, NG, and primary and secondary syphilis) per 1,000 tract residents aged 15-64[2]	State Department of Health	2013
Percent poverty	Percent residents with annual income below poverty level	American Community Survey (ACS)	2008-2013
Percent unemployment	Percent unemployed residents ≥ 16 years old	ACS	2008-2013
Social disadvantage component			
Percent renter-occupied housing units	Percent renter occupied housing units	ACS	2008-2013
Alcohol outlet density	The number of businesses with a license to sell beverages containing alcohol (e.g., liquor, beer, wine) for off-premise consumption per tract square mile[1,3]	State Licensing Agencies (e.g., Department of Revenue, Alcoholic Beverage Control Commission)	2014

[1]Addresses were obtained from state agencies and geocoded to tracts; addresses within a 100-foot buffer of the tract boundary were included in the tract's calculation.
[2]In Alabama, the number of newly identified STIs were available by ZIP code, but not census tract. ZIP-level STI counts were allocated to tracts based on the proportion of residential population using the 2015 boundaries USPS-HUD ZIP to tract crosswalk file. Twelve ZIP code-census tract combinations were not included in the crosswalk file. For these 15 participants (17% of participants with available census tract data at site), ZIP code STI prevalence was assigned to the participant census tract. We conducted sensitivity analyses, removing these participants from the analytic data set, to explore potential bias introduced by this substitution. The rounded odds ratio estimates for Final Model A with and without these 15 participants were the same.
[3]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 4.3. Principal components analysis of census tract characteristics, rotated factor pattern (varimax) for the Women's Interagency HIV Study participants enrolled at the southern sites (n=737)[1]

	Factor Patterns and Loading Values[2]		
	Communality Estimates[3]	**Social Disorder Component**	**Social Disadvantage Component**
Variance explained by component	--	3.17	1.69
Census tract characteristic			
Vacant housing	0.67	**82**	1
Violent crime rate	0.70	**80**	25
STI prevalence	0.74	**86**	2
Poverty	0.73	**72**	46
Unemployment	0.61	**68**	39
Renter occupied housing	0.63	37	**70**
Alcohol outlet density	0.77	-4	**88**

[1]Scores were standardized and components were extracted for modeling, 45 observations were omitted due to missing census tract variables.
[2]Factor loadings were multiplied by 100 and rounded to the nearest integer. Factor loadings ≥35 were considered "significant" loadings.
[3]Final Communality Estimate=5.86

Table 4.4. Women's Interagency HIV Study enrollment and availability of geocoded address data, overall and by site

Site	Alabama	Florida	Georgia	Mississippi	North Carolina	Total
Enrolled	112	146	275	114	198	**845**
Home address geocoded to census tract boundary	100 (89.3)	90 (61.6)[2]	246 (89.4)	112 (98.2)	189 (95.4)	**737 (87.2)**
Reasons for missing census tract identifier						
No consent	0 (0)	48 (32.9)	17 (6.2)	0 (0)	0 (0)	**65 (7.7)**
Living on street or in a residential treatment facility[1]	10 (8.9)	7 (4.8)	0 (0)	0 (0)	5 (2.5)	**22 (2.6)**
Address could not be geocoded to census tract boundary	1 (0.9)	0 (0)	5 (1.8)	1 (0.9)	0 (0)	**7 (0.8)**
Unknown	1 (0.9)	1 (0.7)	7 (2.5)	1 (0.9)	4 (2.0)	**14 (1.7)**

[1]The Women's Interagency HIV Study sites, with the exception of Georgia, did not geocode participant address data for participants living on the street or in a residential treatment facility.
[2]Participants enrolled at the Florida site who did not have a home address geocoded to a census tract boundary were more likely to report sex exchange than Florida participants with census tract identifiers (2.2% vs. 19.6%, $p<0.001$).

Table 4.5. Distributions of census tract and participant characteristics among 737 women enrolled in the Women's Interagency HIV Study Southern Sites

Characteristics of participants and census tracts	**n (%) or Mean (SD)**
Outcomes	
Laboratory confirmed STI	
HIV-infected	58 (10.9)
HIV-uninfected	21 (10.1)
Overall	79 (10.7)
Missing	63 (8.5)
Chlamydia	
HIV-infected	5 (0.9)
HIV-uninfected	4 (1.9)
Overall	9 (1.2)
Missing	32 (4.3)
Gonorrhea	
HIV-infected	5 (0.9)
HIV-uninfected	1 (0.5)
Overall	6 (0.8)
Missing	37 (5.0)
Trichomoniasis	
HIV-infected	34 (6.4)
HIV-uninfected	12 (5.8)
Overall	46 (6.2)
Missing	15 (2.0)
Syphilis	
HIV-infected	17 (3.2)
HIV-uninfected	4 (1.9)
Overall	21 (2.8)
Missing	19 (2.6)
Census tract-level characteristics	
Social disorder component	
Percent vacant housing units	7.8 (6.3)
Violent crime rate per 1,000 residents	13.5 (13.4)
Missing	44 (6.0)
Percent poverty	29.1 (13.6)
Percent unemployed	16.1 (8.0)
STI prevalence per 1,000 residents	19.1 (13.3)
Missing	1 (0.1)
Social disadvantage component	
Percent renter-occupied housing units	51.9 (21.7)
Alcohol outlet density	4.8 (7.6)
Missing	1 (0.1)
Participant-level characteristics	
HIV-infected	530 (71.9)
Age in years	43.7 (9.3)
Married or living as married	244 (33.1)
Missing	3 (0.4)
Non-Hispanic African American	614 (83.3)
Missing	11 (1.5)

Annual household income of $18,000 or less Missing	492 (66.8) 24 (3.3)
Quality of life index Missing	67.1 (20.5) 3 (0.4)
Alcohol or illicit substance use Missing	279 (37.9) 1 (0.2)
Sex exchange Missing	42 (5.7) 1 (0.1)
Homeless Missing	47 (6.4) 12 (1.6)
Lifetime STI diagnosis	472 (64.0)
Unprotected vaginal or anal sex Missing	274 (42.3) 4 (0.5)

Table 4.6. Bivariate and multivariable relationships between census tract characteristics and the odds of having a current STI among women enrolled in the Women's Interagency HIV Study Southern Sites (n=737)

Characteristics of census tracts and participants	Bivariate OR (95% CI)	Final Model A[1] aOR (95% CI)	Reduced Model A aOR (95% CI)
Census tract-level characteristics			
Social disorder component	1.18 (0.91, 1.52)	1.25 (0.94, 1.66)	**1.30 (0.99, 1.72)**
Social disadvantage component	1.21 (0.94, 1.54)	**1.34 (0.96, 1.86)**	**1.34 (0.96, 1.87)**
Participant-level characteristics			
HIV-infected	1.22 (0.68, 2.17)	1.51 (0.76, 3.00)	1.34 (0.71, 2.51)
Age in years	1.03 (1.00, 1.06)	1.02 (0.99, 1.05)	1.02 (0.99, 1.05)
Married or living as married	0.76 (0.44, 1.33)	0.95 (0.52, 1.74)	0.99 (0.55, 1.79)
Non-Hispanic African-American	1.51 (0.69, 3.31)	0.87 (0.38, 1.99)	0.88 (0.38, 2.02)
Annual household income of $18,000 or less	1.24 (0.70, 2.19)	0.86 (0.46, 1.58)	--
Quality of Life Index	1.00 (0.99, 1.01)	1.00 (0.99, 1.02)	--
Alcohol or illicit substance use	1.56 (0.93, 2.63)	1.46 (0.82, 2.60)	--
Sex exchange	1.05 (0.36, 3.08)	1.12 (0.33, 3.79)	--
Homeless	1.10 (0.40, 2.94)	1.24 (0.43, 3.46)	--
Lifetime STI diagnosis	1.12 (0.65, 1.92)	1.13 (0.61, 2.10)	--
Unprotected vaginal or anal sex	0.92 (0.54, 1.56)	1.19 (0.65, 2.20)	--
Study site (ref=Georgia)			
Alabama	**0.28 (0.10, 0.77)**	**0.17 (0.05, 0.60)**	**0.17 (0.05, 0.61)**
Florida	0.54 (0.24, 1.21)	**0.32 (0.10, 0.99)**	0.30 (0.10, 0.91)
Mississippi	0.55 (0.27, 1.16)	0.64 (0.29, 1.44)	0.60 (0.27, 1.33)
North Carolina	**0.22 (0.10, 0.50)**	**0.24 (0.10, 0.59)**	**0.24 (0.10, 0.59)**
Model fit			
Random intercept variance (p-value)	--	0.32 (0.29)	0.39 (0.24)
-2LL	--	400.28	403.41
AIC		438.28	427.41
BIC		514.07	475.27

[1]Multivariable modeling was restricted to participants with no missing data for predictor or outcome variables (n=589)

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Chapter 5: Conclusion

Introduction

Although the HIV epidemic was initially concentrated in the northeastern and western regions of the United States (US), the South now bears a significant burden of the epidemic, accounting for 49% of all new HIV infections in 2011.[1,2] Similarly, the burden of HIV/AIDS in women in the US has grown substantially since the beginning of the epidemic: rising from 8% of all newly diagnosed AIDS cases in 1983 to more than 19% of all new diagnosed HIV infections in 2014.[3,4] While studies have found that several features of the social and built environment, such as high levels of poverty, social disorder, and low male:female sex ratios, are associated with HIV and other sexually transmitted infections (STIs) and sexual risk behaviors, including partner non-monogamy and multiple sex partners, among predominantly *HIV-uninfected populations*,[5-29] no multilevel studies (longitudinal or cross-sectional) investigating the associations between neighborhood exposures, HIV/STIs, and sexual risk have explored these relationships in a predominantly *HIV-infected* cohort of *women*. It is unclear how neighborhood characteristics influence sexual risk and create vulnerability to STI acquistion for women living with HIV.

Summary of Key Findings

This dissertation used multilevel approaches to investigate the associations of neighborhood characteristics with sexual risk behaviors, sex partner risk, and STIs in a predominantly HIV-infected cohort of women living in the Southern US.

Our key findings by chapter are as follows:

In **Chapter 2**, we found that greater tract-level social disadvantage (i.e., more alcohol outlets and renter-occupied housing units) was *inversely* associated with sex partner risk and sex partner non-monogamy, regardless of HIV status. Relationships between tract-level social disorder (i.e., more vacant housing, violent crime, STIs, poverty, and unemployment) varied by HIV status. Greater tract-level social disorder was *positively* associated with sex partner risk and sex partner non-monogamy among *HIV-infected* women but was *inversely* associated with sex partner non-monogamy among *HIV-uninfected* women. Greater perceived neighborhood cohesion was *inversely* associated with perceived sex partner risk, regardless of HIV status. Tract-level social capital (i.e., prevalence of non-profit organizations) was not associated with sex partner risk nor sex partner non-monogamy.

In **Chapter 3**, we found that greater tract-level social disorder was *inversely* associated with anal intercourse (AI) and unprotected anal intercourse (UAI), regardless of HIV status.

In **Chapter 4**, we found that greater tract-level social disorder and greater social disadvantage were each *positively* associated with having a current laboratory-confirmed STI, regardless of HIV status.

Measures of partner risk (Chapter 2) were collected at screening and captured *main* sex partner characteristics only, whereas measures of sexual risk behaviors (Chapter 3) were collected at enrollment and reflected sexual behaviors with *any* male sexual partner in the previous six months. Current STI status (Chapter 4) was determined via laboratory assessment at enrollment. The median time between the screening and enrollment visit was 14 days (interquartile range: 14-26 days).

As described in previous chapters and summarized in Figure 5.1, **greater tract-level social disadvantage** was associated with *less partner non-monogamy* (OR=0.73 95% CI=0.60, 0.96) and *lower partner risk* (OR=0.84, 95% CI=0.72, 0.97) but was *positively* associated with *having a current STI* (OR=1.34, 95% CI=0.96, 1.86), regardless of HIV status. **Greater tract-level social disorder** was associated with *less AI* (OR=0.65, 95% CI=0.43, 0.96) and *less UAI* (OR=0.50, 95% CI=0.31, 0.82), regardless of HIV status. Relationships between social disorder and sex partner risk varied by HIV status. **Greater tract-level social disorder** was associated with *greater partner risk* (OR=1.41, 95% CI= 1.16, 1.72) and *greater partner non-monogamy* (OR=1.20, 95% CI=0.96, 1.50) among *HIV-infected women*, but *less partner non-monogamy* (OR=0.72, 95% CI=0.54, 0.96) among *HIV-uninfected women*. **Greater tract-level social disorder** was *positively* associated with *having a current STI* (OR=1.34, 95% CI=0.99, 1.87), regardless of HIV status. **Tract-level social capital** was not associated with *sex partner risk* nor *partner non-monogamy*. **Perceived neighborhood cohesion** was associated with *lower partner risk* (OR=0.84, 95% CI=0.70, 1.02), regardless of HIV status.

Associations of tract-level social disadvantage with sex partner risk and STIs

Our finding that tract-level social disadvantage is associated with having a current STI, regardless of HIV status, is consistent with natural experiments which found that reductions in alcohol outlets (an item in the social disadvantage component) were associated with decreased STI prevalence over time.[12,15] Alcohol outlets may increase women's vulnerability to STI acquistion through a number of mechanisms, most notably by connecting women to higher risk sexual networks.[7,24] However, in our sample, greater social disadvantage was associated with less sex partner non-mongamy and less sex partner risk, regardless of HIV status. The social environments promoted by alcohol outlets encourage sexual network turnover;[29,30] it is possible that women living in areas with greater social disadvantage in our sample did not know their sexual partners well, and as a result were less knowledgeable about their sexual partner's current or past behaviors.[31,32]

Associations of tract-level social disorder with sexual behaviors, sex partner risk, and STIs

In our sample, greater social disorder was associated with having a current STI, regardless of HIV status. This finding is consistent with past studies exploring relationships between neighborhood conditions and STIs in young adults, which found that neighborhood poverty (an element of the social disorder component) is associated with testing positive for a current STI.[7,24] Similarly, numerous ecologic studies have found that geographic areas with more poverty, vacant housing, or violent crime (items in the social disorder component) tend to have higher prevalences of STIs.[13,33-37]

For HIV-infected women, greater social disorder was associated with greater partner risk and more partner non-monogamy, which may in part explain relationships between greater social disorder and having a current STI. Sexual network characteristics, including partner non-monogamy, can increase an individual's risk by creating overlapping sexual networks which facilitate the transmission of STIs.[26,38,39] Having a non-monogamous partner has been identified as a risk factor for HIV/STI transmission among women who were otherwise low risk.[38] However, in our sample, greater social disorder was also associated with less AI and UAI, regardless of HIV status. However, in our sample, HIV-infected women living in neighborhoods with greater social disorder perceived their partners to be riskier and non-monogamous; these perceptions may have discouraged women from engaging in AI or promoted condom use during AI.[40-42]

For HIV-uninfected women in our sample, the relationship between greater social disorder and having a current STI is puzzling when also considering the inverse relationships between social disorder and sex partner non-monogamy, AI, and UAI. In contrast to past studies which have found that greater social disorder is positively associated with sex partner non-monogamy in HIV-uninfected populations,[5,26] in our sample, greater social disorder was associated with *less* partner non-monogamy among HIV-uninfected women. The reasons for this finding are unclear. One possible explanation is that HIV-uninfected women living in more socially disordered 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.[26] However, neighborhood social disorder has been associated with having multiple sex partners among *HIV-uninfected* populations[10,23] and sex partner assessments captured risk characteristics of *main* sex partners only. HIV-uninfected women are more likely to have multiple sexual partners than HIV-infected women.[43] If HIV-uninfected women had multiple sex partners, it is possible that they did not identify sex partners with other sexual partners as the "most significant sexual partner."[44] In our sample, greater social disorder was also associated with less AI and UAI, regardless of HIV status. Sexual behavior assessments captured intercourse with *any* sexual partner. If HIV-uninfected women living in more socially disordered neighborhoods did in fact have multiple partners, it is possible that they perceived non-main sex partners to be riskier and altered their sexual behaviors accordingly.[10,23,40-42] Future research exploring the pathways through which neighborhoods influence sexual behaviors and sexual partnerships may help to elucidate these findings.

Associations of Social Organizational Factors and Sex Partner Risk

Perceived neighborhood cohesion was associated with lower partner risk, regardless of HIV status. Members of more socially cohesive neighborhoods may be engaged in social networks with more prosocial norms discouraging behaviors captured in the partner risk index (e.g., substance use, criminal activity) and encouraging risk reduction (e.g., condom use).[45-49] These women may consequently select sex partners from these cohesive networks or perceive that their main sex partner is less likely to engage in high risk behaviors.[45-49] Tract-level prevalence of non-profit organizations was not associated with partner non-monogamy or sexual risk characteristics. Due to the nature of the dataset used to create tract-level social capital measures, we were unable to quantify the level and reach of services provided by non-profit organizations within each tract, including whether these organizations provided services locally. Our exploration of the relationships between social organizational factors and sexual health was limited to the screening visit. As a result, we are unable to make conclusions about the associations between social organizational factors, sexual behaviors, and current STI status in this sample, as these outcomes were evaluated at enrollment.

Strengths and Limitations

Findings should be interpreted within the context of the following strengths and limitations. The Women's Interagency HIV study (WIHS) study provided a high quality sample of women who are living with and at increased risk of HIV infection across several states in the Southern US.[50-52] However, study participants agree to long-term follow-up and may not be representative of the general population of HIV-infected or high risk HIV-uninfected women. The majority of HIV-infected participants were recruited from clinic-based populations and as a result, findings may not extend to HIV-infected women who are not connected to HIV care and treatment.

Although this research provides new insight on relationships between neighborhood characteristics and three aspects of HIV-infected women's sexual health (i.e., sexual behaviors, sex partners, and STI status), the cross-sectional multilevel design does not permit us to draw conclusions regarding the causality of these relationships. We are also not able to attribute sexual behaviors to specific sexual partners, nor are we able to determine the duration of infection or source among women testing positive for a current STI. Furthermore, behavioral assessments at screening utilized Computer-Assisted Personal Interview (CAPI); computer-assisted survey technologies have been shown to reduce reporting bias of sensitive behaviors.[53,54] Behavioral assessments at enrollment were interviewer-adminstered and as a result, the reporting of sexual behaviors (e.g., UAI) may be subject to social desirability bias.[53,54] However, current STI status at enrollment was determined via laboratory assessment and as a result is not subject to reporting biases such as recall or social desirability.[55]

Participants who were not included in the analysis because they did not have geocoded home address data reported individual characteristics associated with increased sexual risk (e.g., lower income, sex exchange) and may have lived in qualitatively different neighborhoods from the participants included in the analyses. However, participants excluded from these analyses because they did not have geocoded address data were not statistically different with respect to sexual behaviors, sex partner characteristics, nor STI status.

Our analyses utilized census tract-level measures to capture neighborhood characteristics. Residential census tracts may fail to capture the activity spaces in which women engage and access social services, select sex partners, or engage in sexual risk behaviors. However, past studies have found that individuals living with and at increased risk of HIV tend to select sexual partners in closer proximity than lower risk populations.[28,56]

Directions for Future Research

This dissertation research is the first to use multilevel models to test relationships between neighborhood characteristics and sexual risk behaviors, sex partner characteristics, and laboratory-confirmed STIs among a predominantly HIV-infected cohort of women. Collectively, these findings suggest that neighborhood characteristics may shape sexual risk behaviors, sex partner characteristics, and current STI status among women living in the South, and that the magnitudes and directions of these relationships vary by neighborhood exposure and HIV status. Future research can advance our understanding of how neighborhood characteristics shape partner selection, sexual behaviors, and vulnerability to STIs in the following ways:

1) Utilize multilevel longitudinal designs.

As noted in Chapter 1, the vast majority of research exploring relationships between neighborhoods and sexual health has utilized ecologic designs,[12-22] which are unable to assess relationships between neighborhood characteristics and individual-level outcomes (e.g., sexual behaviors) and to control for individual-level factors.[57,58] Multilevel studies in which individuals are nested in places have confirmed many of the ecologic findings concerning neighborhood characteristics and STIs/HIV, and have expanded the range of outcomes considered to include sexual behaviors (e.g., multiple partners) and characteristics of sexual partnerships (e.g., partner non-monogamy, risk discordant partnerships).[5,7-11,23-29,59] However, the vast majority of multilevel research on the relationships of neighborhood characteristics to HIV/STIs and related sexual risk behaviors has been (1) cross-sectional, which limits our ability to determine temporality[5-11,59] or (2) has been conducted in youth or young adults,[7-9,24,25,60-64] and thus may produce findings that may not be generalizable to adults.

To our knowledge, only one multilevel study has explored relationships of neighborhoods to sexual behaviors in *HIV-infected adults*.[59] Shacham and colleagues found no association between neighborhood poverty rates, racial/ethnic composition, unemployment rates, and unprotected sexual intercourse among a predominantly male clinic-based population in the Midwestern US.[59] These results are consistent with our own finding that the social disorder component, which included measures of tract-level poverty and unemployment, was not associated with unprotected vaginal intercourse (UVI). However, Shacham and colleagues did not distinguish between types of unprotected sexual intercourse (e.g., UVI versus UAI) and in our sample, greater social disorder was associated with less AI and UAI. Our finding that the relationships between neighborhood characteristics and sexual risk behaviors vary by the type of sexual intercourse underscores the importance of evaluating these outcomes independently.

Multilevel longitudinal study designs would contribute to our understanding of relationships between *changes* in neighborhood conditions, and sexual behaviors, the formation, duration, and stability of sexual partnerships, and STIs by HIV status *over time* and could inform the development of subsequent interventions designed to enhance women's sexual health and to reduce the transmission of HIV and other STIs. To our knowledge, only six papers using multilevel, longitudinal designs have included adults, and none have assessed predominantly HIV-infected cohorts.[23,24,26-29] Of note, four of these papers utilized data from the same predominantly substance-using cohort in Atlanta, Georgia and findings may not extend to the general population nor to other regions of the US.[26-29]

2) Assess biological outcomes.

In our sample, the directions of relationships between neighborhood characteristics and sexual behaviors, sex partner risk, and STIs were not always consistent (e.g., greater social disorder was associated with less AI and UAI, but more STIs), underscoring the need to evaluate both behavioral and biological outcomes in future research. Biological outcomes are not subject to reporting biases which may influence behavioral measures, such as recall and social desirability bias.[55] To our knowledge, only two multilevel, longitudinal studies enrolling adults have used biological outcomes.[24,27] The National Institutes of Health has identified the inclusion of biological outcomes as a priority area for determining future HIV/AIDS research funding.[65]

3) Assess pathways.

The mechanisms through which neighborhood characteristics influence sexual behaviors are complex, but relatively understudied; the vast majority of research exploring the pathways between neighborhood characteristics and sexual risk has focused on substance-using populations.[66-68] Our research suggests that individual-level characteristics (e.g., alcohol and illicit substance use, sex exchange) may lie on the causal pathway between neighborhood social disorder and sexual risk behavior, regardless of HIV status. Conversely, in this predominantly HIV-infected sample, none of the individual-level characteristics (e.g., unprotected vaginal or anal intercourse, homelessness) included in our analyses were associated with current STI status. It is possible that additional mechanisms, which merit further exploration, create vulnerability to STI infection among HIV-infected women. For example, being on antiretroviral therapy (ART) has been linked to decreased STI risk among HIV-infected women,[69] and an emerging line of research suggests that neighborhood factors shape HIV care and treatment among HIV-infected populations.[59,70,71] Additional research is needed to explore the direct and indirect pathways (e.g., structural equation modeling)[72] through which neighborhoods shape sexual health in both HIV-infected and HIV-uninfected women.[73] A greater understanding of these mechanisms could be used to inform the design of subsequent research evaluating these relationships and ultimately inform the development of interventions.

4) Utilize qualitative research designs.

In our sample, the directionality of relationships of neighborhood characteristics and sexual health outcomes was not always consistent with past literature.[5,26] In particular, we were puzzled by our finding that greater social disorder was positively associated with having a current STI, but was also associated with less AI, UAI, and partner non-monogamy among HIV-uninfected women. Qualitative research could provide additional, invaluable insight on the processes through which neighborhood characteristics shape partner selection and related sexual behaviors.[44,46,74]

5) Network research.

The vast majority of research utilizing multilevel designs to explore relationships between neighborhood characteristics and aspects of sexual networks, including this dissertation research, have utilized measures of *perceived* partner risk.[5,23,26,62] However, neighborhood characteristics, such as the density of alcohol outlets or shortages of men relative to women, may create social environments which render women less knowledgeable about their sexual partner(s)' current or past behaviors and may influence the stability and fluidity of sexual partnerships over time.[29,30] Sociometric network studies including all or a portion of individuals belonging to a sexual network could provide a more complete picture of neighborhood influences on sexual network dynamics and HIV/STI risk.[29,31,32]

Conclusion

This dissertation research extends our understanding of the associations between neighborhood characteristics and women's sexual health and fills critical gaps in our understanding of whether and how neighborhood characteristics are associated with the sexual health of women living with HIV. Additional longitudinal, qualitative, and network research with behavioral and biological outcomes is needed to (1) establish the causality of these relationships; (2) better understand the pathways through which neighborhood characteristics shape sexual partnerships, sexual behaviors, and create vulnerability to STIs; and (3) elucidate relationships between neighborhood characteristics and sexual network dynamics. If future research supports our findings, interventions designed to improve women's sexual health and reduce HIV/STI transmission should seek to improve neighborhood conditions or mediators of relationships between neighborhoods and sexual risk behaviors, sex network characteristics, and STIs.

Figure 5.1. Associations between neighborhood characteristics, sexual risk behaviors, sex partner risk, and sexually transmitted infections by HIV status among women enrolled in the Women's Interagency HIV Study Southern Sites

Census tract-level predictors	**Unprotected vaginal sex**		**Anal sex**		**Unprotected anal sex**		**Sex partner risk level**		**Sex partner non-monogamy**		**Sexually transmitted infection**	
	HIV+	**HIV-**	**HIV+**	**HIV-**	**HIV+**	**HIV-**	**HIV+**	**HIV-**	**HIV+**	**HIV-**	**HIV+**	**HIV-**
Social Disorder	n.s.	n.s.	↓	↓	↓	↓	↑	n.s.	↑	↓	↑	↑
Social Disadvantage	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	↓	↓	↓	↓	↑	↑
Social Capital	--	--	--	--	--	--	n.s.	n.s.	n.s.	n.s.	--	--
Perceived Neighborhood Cohesion[1]	--	--	--	--	--	--	↓	↓	n.s.	n.s.	--	--

[1] Perceived neighborhood cohesion was evaluated at screening only.

Key: ↓ =lower

↑ =greater

n.s. =not significant

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