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

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Abstract

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Introduction—Neighborhood characteristics shape sexual risk in HIV-uninfected adults in the United States (US). We assess 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 737 HIV-infected and HIV-uninfected women enrolled in the Women's Interagency HIV Study. Administrative data captured characteristics of census tracts where women lived; participant-level data were gathered via survey. We used principal components analysis to condense tract-level variables into components: 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-level characteristics and condomless vaginal intercourse (CVI), anal intercourse (AI), and condomless anal intercourse (CAI).

Results—Greater social disorder was associated with less AI (OR=0.63, 95% CI=0.43, 0.94) and CAI (OR=0.49, 95% CI=0.30, 0.80), regardless of HIV status. There were no statistically significant additive or multiplicative interactions between tract characteristics and HIV status.

Conclusion—Neighborhood characteristics are associated with sexual risk behaviors among women living in the Southern US, these relationships do not vary by HIV status. Future studies should establish temporality and explore the causal pathways through which neighborhoods influence sexual risk.

Keywords

HIV; Women; Residence Characteristics; Multilevel Analysis; Sexual Behavior

Introduction

The burden of HIV/AIDS in women in the United States (US) has grown substantially over time: 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 Southern US now represents a significant proportion of the HIV/AIDS epidemic. 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 sexually transmitted infections (STIs) in *HIV-uninfected populations,* and in the Southern US 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 [6–10]. Multilevel studies extending this line of research to associations between neighborhood characteristics and sexual risk in individuals 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, condomless sexual intercourse, and risk discordant partnerships [11–18]. Conceptualizing neighborhoods as opportunity structures, residents of neighborhoods with comparatively greater economic disadvantage (e.g., high poverty rates) or social disorder (e.g., more violent crime) may have less access to social and physical resources (e.g., employment) needed to engage in healthful behaviors, and greater exposure to hazards associated with negative health outcomes [19, 20]. For example, a high density of liquor stores in a neighborhood may contribute to greater community-level alcohol consumption, more sexual risk behavior, and connect women to risky sexual networks [6, 19, 20].

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 condomless sexual intercourse among a predominantly male clinic-based population in the Midwestern US [21]. It is possible that the magnitude and direction of relationships between neighborhoods and condom non-use 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 [22]. 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:

1. Characterize relationships between neighborhood characteristics and sexual risk behaviors, and;
2. Test whether the magnitudes and directions of relationships between neighborhood characteristics and sexual risk behaviors vary by HIV status.

Materials and 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 [23–25]. 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. WIHS eligibility criteria included being between 25–60 years old. In addition, 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 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. Methods are described in more detail elsewhere [23–26]. This analysis is restricted to WIHS participants who provided written informed consent to collect and geocode their residential address.

Data Collection and Measures

WIHS collected demographic and behavioral data using interviewer-administered surveys. Participant residential 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).

Primary Outcomes—Outcomes included condomless vaginal intercourse (CVI), anal intercourse (AI), and condomless anal intercourse (CAI) in the past 6 months. CVI 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). CAI was defined as reported inconsistent condom use during anal intercourse (binary, as defined above).

Census Tract-Level Exposures—Measures describing the social and physical environments of the census tracts where participants lived were constructed using existing data sources (e.g., US Census) (Table 1). 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 (Supplemental Digital Content 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 and 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 participants as HIV-infected if they had a reactive serologic enzyme-linked immunosorbent assay test and a confirmed positive western blot or detectable plasma HIV-1 ribonucleic acid.

Covariates included participant-level characteristics that might confound or modify relationships between tract-level characteristics and sexual behaviors. These a priori variables are classically included in analyses exploring associations of participant-level characteristics and sexual risk behaviors [27–29]. Covariates captured demographic characteristics and behaviors in the past 6 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) [30], 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 6 months), 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 by HIV status and 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 [31]. 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 [ICC]).

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 each outcome 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 multivariable model (Final Models). 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 [32, 33]. 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., sex exchange) may lie in the causal pathway between tract characteristics and sexual behaviors. Including these variables in the full model would attenuate relationships between tract characteristics and study 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 2). Eighty seven percent of enrolled women both provided consent to collect and geocode their residential address and provided information that could be geocoded to census boundaries. In the analytic sample (N=737), participants were on average 44 years old (standard deviation [SD]=9.3), 83.3% identified as non-Hispanic African American, 66.8% reported annual household incomes of ≤$18,000, and 71.9% of participants were HIV-infected (Table 3). Forty-two percent of participants reported CVI, 6.8% of participants reported AI, and 4.3% of participants reported CAI in the last 6 months. On average, participants lived in census tracts where 16.1% of residents were unemployed (SD=8.0), 29.1% were living in poverty (SD=13.6), and where roughly half of housing units were renter-occupied (SD=21.7).

A comparison of participant and census tract characteristics by HIV status indicated that HIV-uninfected women reported more CVI (69.6% vs. 31.8%), CAI (7.8% vs. 3.0%), sex exchange (12.6% vs. 3.0%), and homelessness (11.7% vs. 4.4%) than HIV-infected women (p<0.05). HIV-infected women, on average, lived in neighborhood with less violent crime (12.1 vs. 16.9 violent crimes per 1,000 residents) than HIV-uninfected women (p<0.05). All other participant and tract characteristics assessed were comparable by HIV status. Participants missing geocoded address data, as compared to participants with geocoded address data were more likely (p<0.05) to report annual household incomes ≤$18,000 (83.2% vs. 69.0%); alcohol and substance use (48.1% vs. 37.9%); and sex exchange (17.6% vs. 5.7%). We included these variables in the full multivariable models in order to minimize potential confounding [34].

Relationships between census tract characteristics and CVI

The unconditional model ICC was 1.5% (random intercept=0.05, p=0.41). In bivariate analyses (Table 4), tract-level social disorder (OR=1.12, 95% Confidence Interval [CI]=0.96–1.32) and social disadvantage (OR=0.98, 95% CI=0.84–1.15) were not associated with CVI. In the final multivariable model controlling for participant-level characteristics, tract-level social disorder (OR=0.99, 95% CI=0.82–1.20) and social disadvantage (OR=1.00, 95% CI=0.84–1.19) were not associated with CVI. 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% and were not statistically significantly associated with CVI.

Relationships between census tract characteristics and AI

The unconditional model ICC was 7.8% (random intercept=0.28, p=0.37). In bivariate models (Table 5), tract-level social disorder (OR=0.76, 95% CI=0.53–1.09) and social disadvantage (OR= 0.97, 95% CI=0.69–1.38) were not associated with AI. In the final multivariable model controlling for individual characteristics, tract-level social disorder was inversely associated with AI (OR=0.63, 95% CI=0.43–0.94). Notably, a one standard deviation higher social disorder component was associated with a 37% lower odds of AI. Tract social disadvantage (OR= 1.00, 95% CI=0.70–1.42) was not 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 24% higher in the Reduced Model and was no longer statisically significantly associated with AI.

Relationships between census tract characteristics and CAI

Random intercept components in unconditional models for CAI were estimated to be 0. In bivariate analyses (Table 5), tract-level social disorder (OR= 0.58, 95% CI=0.37–0.92) was inversely associated with CAI. Social disadvantage (OR=0.98, 95% CI=0.66–1.45) was not associated with CAI. In the final mutivariable model, social disorder was inversely associated with CAI (OR=0.49, 95% CI=0.30–0.80). Specifically, a one standard deviation higher social disorder component was associated with a 51% lower odds of CAI. Social disadvantage (OR=1.00, 95% CI=0.69–1.47) was not associated with the CAI. 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.

Discussion

Our analyses reveal that neighborhood characteristics are associated with sexual risk behaviors among HIV-infected and high-risk HIV-uninfected women living in the Southern US and that these relationships vary by type of sexual intercourse. Specifically, greater social disorder was associated with less AI and CAI. Neighborhood characteristics were not associated with CVI in our sample.

Receptive CAI confers high risk STIs, including HIV [28, 35]. Studies exploring individual-level predictors of CAI among women suggest that CAI may be influenced by complex social and economic factors, yet no multilevel studies have explored relationships of neighborhoods characteristics to CAI specifically [28, 29, 36]. In this analysis, social disorder was *inversely* associated with CAI. The direction of this relationship was unexpected. Elements of our neighborhood disorder component, including STI prevalence and violent crime, are associated with partner concurrency, STI acquisition, and greater perceived sexual partner risk [16, 37, 38]. 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 [39–41]. The reduced models which tested associations between tract-level social disorder, AI, and CAI, 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*. Individual perceptions of neighborhood social disorder are influenced by individual- and network-level characteristics and relationships of social disorder to sexual risk are complex [42, 43]. 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 [43]. Additional research is needed to explore the direct and indirect pathways through which neighborhood social disorder influences sexual risk.

To our knowledge, only three multilevel studies have explored relationships of neighborhood characteristics to condomless sex in heterosexual adults; none of these studies distinguish between types of sexual intercourse (e.g., CVI vs. CAI) [14, 18, 21]. Our finding that the relationship between neighborhood characteristics and sexual risk behaviors varies by type of intercourse 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 condomless sexual intercourse [18, 21]. This is consistent with our own finding that the social disorder component, which included measures of tract-level poverty and unemployment, was not associated with CVI. A third study found that sex ratios were associated with condomless sexual intercourse among women [14]. 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 were unable to test relationships between sex ratios and sexual behaviors. Past research has cited the challenges of exploring these relationships in predominantly African American populations in light of persistent social inequities (e.g., incarceration) which contribute to a shortage of male partners [11, 44].

These findings should be interpreted in light of the study's limitations. Although WIHS provides a large, high-quality sample of women living with and at increased of HIV infection in the Southern US, study participants agree to indefinite, long-term study follow-up and may not be representative of the broader population. 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 [24, 45]. Participant-level data were collected using interviewer-administered surveys, which may be subject to social desirability bias [46]. Alternative forms of data collection (e.g., computer-assisted) would be preferable for future research. Participants who were excluded from the analysis reported individual characteristics associated with increased sexual risk (e.g., sex exchange) and may have lived in qualitatively different neighborhoods. However, participants with and without address data were not statistically different with respect to study outcomes and we included these variables in the full multivariable models in order to minimize potential confounding [34]. Residential census tracts may fail to capture the activity spaces in which sexual risk behaviors most frequently occur. However, 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 [47, 48]. WIHS did not capture data on the length of stay in the baseline census tract. 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 behaviors.

Conclusion

This is the first multilevel study to test relationships between neighborhood characteristics and AI and CAI and the first to explore relationships between neighborhoods and sexual risk behaviors by women's HIV status. Collectively, these findings support past research on the importance of neighborhood environments in shaping sexual risk among women living in the US. 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.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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List of Abbreviations

AI	Anal intercourse

AIDS	Acquired immune deficiency syndrome
ART	Antiretroviral therapy
CAI	Condomless anal intercourse
CI	Confidence interval
CVI	Condomless vaginal intercourse
HAART	Highly active antiretroviral therapy
HGLM	Hierarchical generalized linear model
HIV	Human immunodeficiency virus
ICC	Intraclass correlation
OR	Odds ratio
PCA	Principal components analysis
QOL	Quality of Life
SD	Standard deviation
STI	Sexually transmitted infection
US	United States
WIHS	Women's Interagency HIV Study

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Table 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	US Department of 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	Number of newly reported STIs (i.e., Chlamydia, gonorrhea, 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)	2009–2013
Percent unemployment	Percent unemployed residents ≥ 16 years old	ACS	2009–2013
Social disadvantage component			
Percent renter-occupied housing units	Percent renter occupied housing units	ACS	2009–2013
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 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. 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 2

Women's Interagency HIV Study enrollment and availability of participant census tract identifier, overall and by site

Site	Alabama	Florida	Georgia	Mississippi	North Carolina	Total
Enrolled	112	146	275	114	198	**845**
Census tract identifier available	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 for geocoding	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.

Table 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	Overall n (%) or Mean (SD)	HIV-infected n (%) or Mean (SD)	HIV-uninfected n (%) or Mean (SD)
Outcomes			
Condomless vaginal intercourse[1]	312 (42.3)	168 (31.8)	144 (69.6)
Anal intercourse	50 (6.8)	30 (5.7)	20 (9.7)
Condomless anal intercourse[1]	32 (4.3)	16 (3.0)	16 (7.8)
Census tract-level characteristics			
Social disorder component			
Percent vacant housing units	7.8 (6.3)	7.6 (6.3)	8.3 (6.3)
Violent crimes per 1,000 residents[1]	13.7 (13.4)	12.8 (12.1)	16.0 (16.0)
Percent poverty	29.1 (13.6)	28.6 (13.3)	30.3 (14.5)
Percent unemployed	16.1 (8.0)	15.7 (7.7)	16.9 (8.5)
Sexually transmitted infections per 1,000 residents[2]	19.1 (13.3)	18.1 (12.5)	21.7 (14.8)
Social disadvantage component			
Percent renter-occupied housing units	51.9 (21.7)	50.7 (21.6)	54.9 (21.7)
Alcohol outlet density[3]	4.8 (7.6)	4.7 (7.4)	5.0 (8.1)
Participant-level characteristics			
HIV-infected	530 (71.9)	--	--
Age in years	43.7 (9.3)	44.3 (9.1)	42.7 (9.7)
Married or living as married	244 (33.1)	176 (33.3)	68 (33.0)
Non-Hispanic African American	614 (83.3)	438 (82.6)	176 (85.0)
Annual household income of $18,000 or less	492 (66.8)	365 (70.8)	127 (64.1)
Quality of life index	67.1 (20.5)	67.6 (20.6)	65.8 (20.2)
Alcohol or illicit substance use	279 (37.9)	182 (34.4)	97 (46.9)
Sex exchange[1]	42 (5.7)	16 (3.0)	26 (12.6)
Homeless[1]	47 (6.4)	23 (4.4)	24 (11.7)

[1] Comparison by HIV staus $p<0.05$.

[2] 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. 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 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

Bivariate and multivariable relationships of census tract characteristics to the odds of condomless 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%)	Final Model aOR (95%)[2]	Reduced Model aOR (95%)[2]
Census tract-level characteristics			
Social disorder component[3]	1.12 (0.96–1.32)	0.99 (0.82–1.20)	1.08 (0.90–1.29)
Social disadvantage component[4]	0.98 (0.84–1.15)	1.00 (0.84–1.19)	0.98 (0.82–1.16)
Participant-level characteristics			
HIV-infected	0.18 (0.12–0.26)	0.20 (0.14–0.29)	0.12 (0.11–0.26)
Age in years	0.96 (0.94–0.98)	0.96 (0.94–0.98)	0.96 (0.95–0.98)
Married or living as married	2.13 (1.52–2.98)	2.32 (1.59–3.38)	2.32 (1.61–3.35)
Non-Hispanic African American	0.91 (0.59–1.41)	0.96 (0.58–1.56)	0.88 (0.55–1.42)
Annual household income of $18,000 or less	0.75 (0.54–1.06)	0.80 (0.54–1.18)	--
Quality of life index	0.99 (0.99–1.00)	0.99 (0.99–1.00)	--
Alcohol and illicit substance use	2.07 (1.50–2.86)	1.78 (1.22–2.59)	--
Sex exchange	3.92 (1.91–8.02)	1.81 (0.80–4.09)	--
Homeless	2.37 (1.22–4.59)	2.02 (0.96–4.25)	--
Model fit			
Random intercept variance (p- value)	--	0	0
-2LL	--	741.10	761.75
AIC	--	765.10	775.75
BIC	--	818.90	804.28

[1]One participant missing outcome.

[2]Multivariable models restricted to participants with no missing predictors (n=654).

[3]Component generated from principal components analysis (PCA) including tract-level percent vacant housing units, violent crime rate, sexually transmitted infection prevalence, percent poverty, and percent unemployment.

[4]Component generated from PCA including tract-level percent renter-occupied housing and alcohol outlet density

Table 5

Bivariate and multivariable relationships of census tract characteristics to the odds of anal intercourse behaviors among women enrolled in the Women's Interagency HIV Study's Southern Sites

	Anal Intercourse (n=736)[1]			Condomless Anal Intercourse (n=733)[2]		
Characteristics of participants and census tracts	Bivariate OR (95%)	Final Model aOR (95%)[3]	Reduced Model aOR (95%)[3]	Bivariate OR (95%)	Final Model aOR (95%)[4]	Reduced Model aOR (95%)[4]
Census tract-level characteristics						
Social disorder component[5]	0.76 (0.53–1.09)	**0.63 (0.43–0.94)**	0.78 (0.56–1.10) *	**0.58 (0.37–0.92)**	**0.49 (0.30–0.80)**	**0.58 (0.36–0.92)** *
Social disadvantage component[6]	0.97 (0.69–1.38)	1.00 (0.70–1.42)	0.96 (0.68–1.34)	0.98 (0.66–1.45)	1.00 (0.69–1.47)	0.95 (0.66–1.36)
Participant-level characteristics						
HIV-infected	0.52 (0.27–1.02)	0.71 (0.33–1.50)	0.54 (0.27–1.07)	0.35 (0.16–0.76)	0.40 (0.17–0.94)	0.33 (0.15–0.72)
Age in years	0.95 (0.92–0.99)	0.95 (0.91–0.99)	0.96 (0.92–0.99)	0.97 (0.93–1.01)	0.96 (0.92–1.01)	0.98 (0.94–1.02)
Married or living as married	1.33 (0.47–1.92)	0.86 (0.41–1.84)	0.89 (0.44–1.79)	1.33 (0.45–2.31)	0.84 (0.35–2.02)	0.98 (0.43–2.26)
Non-Hispanic African American	0.42 (0.19–0.92)	0.44 (0.18–1.08)	0.43 (0.20–0.94)	0.63 (0.25–1.61)	0.77 (0.28–2.12)	0.69 (0.26–1.83)
Annual household income of $18,000 or less	0.91 (0.45–1.82)	0.80 (0.36–1.74)	--	0.74 (0.33–1.65)	0.53 (0.21–1.35)	--
Quality of life index	0.99 (0.97–1.00)	0.99 (0.97–1.01)	--	0.98 (0.96–0.99)	0.97 (0.95–0.99)	--
Alcohol and illicit substance use	3.60 (1.73–7.47)	3.21 (1.45–7.12)	--	4.15 (1.78–9.67)	3.94 (1.60–9.72)	--
Sex exchange	4.43 (1.71–11.52)	2.81 (0.92–8.58)	--	3.02 (0.98–9.28)	1.69 (0.46–6.18)	--
Homeless	2.31 (0.73–7.29)	2.08 (0.61–7.07)	--	2.76 (0.90–8.45)	2.60 (0.73–9.23)	--
Model fit						
Random intercept variance (p-value)	--	0.75 (0.26)	0.48 (0.31)	--	0	0
-2LL	--	279.01	300.33	--	186.08	209.5
AIC	--	305.01	316.33	--	210.08	223.5
BIC	--	357.99	348.93	--	263.82	254.8

[1] One participant missing outcome.

[2] Four participants missing outcome.

[3] Multivariable models restricted to participants with no missing predictors (n=654).

[4] Multivariable models restricted to participants with no missing predictors (n=651).

[5]Component generated from principal components analysis (PCA) including tract-level percent vacant housing units, violent crime rate, STI prevalence, percent poverty, and percent unemployment.

[6]Component generated from PCA including tract-level percent renter-occupied housing and alcohol outlet density.

* >10% difference between Full and Reduced Model.