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Changes in Exposure to Neighborhood Characteristics Are Associated with Sexual Network Characteristics in a Cohort of Adults Relocating from Public Housing

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Abstract

Ecologic and cross-sectional multilevel analyses suggest that characteristics of the places where people live influence their vulnerability to HIV and other sexually-transmitted infections (STIs). Using data from a predominately substance-misusing cohort of African-American adults relocating from US public housing complexes, this multilevel longitudinal study tested the hypothesis that participants who experienced greater post-relocation improvements in economic disadvantage, violent crime, and male:female sex ratios would experience greater reductions in perceived partner risk and in the odds of having a partner who had another partner (i.e., indirect concurrency). Baseline data were collected from 172 public housing residents before relocations occurred; three waves of post-relocation data were collected every nine months. Participants who experienced greater improvements in community violence and in economic conditions experienced greater reductions in partner risk. Reduced community violence was associated with reduced indirect concurrency. Structural interventions that decrease exposure to violence and economic disadvantage may reduce vulnerability to HIV/STIs.

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Keywords

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Introduction

Racial/ethnic disparities in HIV prevalence in the United States (U.S.) have been documented since the 1970s and persist through the present day (1–4). A growing body of theoretical and empirical work suggests that racial/ethnic differences in characteristics of the places where members of different racial/ethnic groups live may help create and maintain these disparities (5–11). This paper explores whether changing exposure to several neighborhood conditions are related to perceived partner risk and indirect concurrency, defined as having a sexual partner who has another partner (12, 13), in a predominately substance-misusing cohort of African-American adults who were relocated from public housing complexes in Atlanta, Georgia.

Sexual Networks and Disparities in HIV

Racial/ethnic disparities in HIV are not produced by racial/ethnic differences in risk behavior: studies have consistently found either no racial/ethnic differences in risk behaviors (e.g., condom use) or that White study participants are *more* likely to engage in risk behaviors (14–18). Studies have, however, identified stark African-American/White differences in the composition and structure of sexual networks which may help explain persistent disparities in HIV (7, 8, 19–21). This research suggests that African-American adults and adolescents are more likely than Whites to have “risky” sexual partners (19–21). In an analysis of data from the National Health and Social Life Survey, for example, Laumann and Youm found that African-American adults who reported just one partner in the past year were five times more likely than their White counterparts to have had sex with a partner who had ≥4 partners in the past year (20).

Rates of concurrency, defined as the overlap of sexual partners in time, are also higher among African-American adults than they are among White adults (7, 8). Concurrency is a potentially important determinant of HIV transmission in populations because it links dyads to larger sexual networks; these linkages allow HIV to spread through the population more rapidly than is possible in a population that has a similar rate of sexual partnership formation but more serial monogamy in a given time period (22). Having a partner who has other partners (i.e., indirect concurrency) amplifies vulnerability to infection for an HIV-negative index by creating the possibility that he or she will have sex with a recently-infected partner. Individuals are more likely to transmit HIV shortly after they acquire infection because of the high viral load during primary infection and also because their infection is unlikely to have been diagnosed and treated (23–26).

Place Characteristics, Sexual Networks, and Disparities in HIV/STIs

While the creation and sustenance of sexual and romantic partnerships may be experienced as deeply personal and intimate processes, they are also socially-structured ones. Several studies have found that area-level social disorder, economic conditions, and male:female sex

ratios are potential determinants of the prevalence and odds of HIV and other sexually transmitted infections (STIs) (27–41). An emerging line of evidence from recent research also suggests that the relationships between these place characteristics and HIV/STIs may be mediated by network characteristics, including concurrency and partner risk (32, 42–47). Residents of more socially-disordered areas are more likely to report concurrency (47) and to have had high risk partners (32, 43); residents of economically distressed areas also appear to have higher rates of concurrency (45, 47). Likewise, adults living in communities with low sex ratios appear to be more likely to report concurrent partnerships (46–48).

These relationships between place characteristics and sexual networks are salient to understanding racial/ethnic disparities in HIV. Because of historical and present-day *de facto* and *de jure* segregation, African-American and White households tend to be located in neighborhoods that are not only separate but also unequal (49). Because of ongoing structural discrimination (49), predominately African-American neighborhoods have higher rates of social disorder, are more economically distressed, and have lower sex ratios than predominately White neighborhoods (50–52). These place-based characteristics may thus explain a substantial portion of population-level disparities in HIV and other STIs.

A contribution of the present study is its application of a longitudinal multilevel design to study relationships of place characteristics to sexual networks among African-American adults. The majority of prior studies of place characteristics, STIs/HIV, and sexual networks and behaviors has used ecologic designs or cross-sectional multilevel designs (e.g.,32, 33, 36, 47), designs that can hinder causal inference. The few studies that have used multilevel longitudinal designs have focused on adolescent or young adult samples (53–55), and their findings may not be generalizable to adults.

Public Housing Relocations

We apply this longitudinal multilevel design to investigate whether and how changes in exposure to select place characteristics relate to sexual network characteristics in a cohort of African-American adults who were relocated from public housing complexes in Atlanta (Georgia) between 2008–2010. These relocations were part of a major shift in U.S. public housing policy. During the 1950s–1980s, policies sought to concentrate people receiving housing assistance into high-density public housing complexes (56–59). Many of these complexes created concentrated pockets of extreme poverty (49, 59, 60), which were often accompanied by high crime rates (61–64). Massey and others have argued that the construction of these complexes also exacerbated racial/ethnic residential segregation in US cities (49, 65): high-density housing complexes were often built in low opportunity, impoverished predominately African-American neighborhoods in central cities (56, 58, 59, 66), and the vast majority of residents placed in these complexes were African-American, though most people receiving public housing assistance in the US are White (66).

More recent policies have sought to disperse residents of these complexes to voucher-subsidized rental units in the private market (67), which may be scattered across a city and its suburbs (68–71). The 1970s Gautreaux program was the first initiative that sought to accomplish this goal (72), and Gautreaux served as a model for larger housing mobility programs, including “Housing Opportunities for People Everywhere” (HOPE VI) and

Moving to Opportunity (73–75). Studies of HOPE VI relocations suggest that people who relocate to voucher-subsidized rental units tend to remain in predominantly African-American neighborhoods, but move to neighborhoods that are less impoverished and have lower crime rates than the neighborhoods containing their public housing complexes (67). Studies of HOPE VI relocations' effects on social relationships, however, have reached mixed conclusions: some suggest that relocations lead to diminished social capital and increased isolation (63, 76, 77), while others suggest that relocations provide residents with an opportunity to disconnect from negative social networks (78).

Several studies have examined the health implications of public housing relocations. While most have found positive effects (e.g., reduced substance misuse (79) and depression (80, 81)), some have found no effect (e.g., no differences in depression or anxiety between relocators vs. stayers (82, 83)), and a handful have found negative effects (e.g., increased distress and behavioral problems among boys (84)). To our knowledge, however, only one study has explored relocations and sexual behaviors, and this study focused on adolescents, and found no association (74). Expanding the body of research on public housing relocations and health to include sexual behavior among adults is an important next step: reported rates of sexual risk behavior and HIV/STIs are higher among adults in public housing complexes than they are in the general population (85–87). Additionally, relocations appear to alter exposure to local economic and social conditions (63, 79, 80, 88, 89) that have been associated with sexual behaviors and network characteristics (32, 43, 45, 47).

The present study assesses whether post-relocation improvements in local economic and social conditions are associated with reduced perceived partner risk and indirect concurrency in a predominately substance-misusing cohort of African-American adults relocating from public housing complexes in Atlanta. We focus on a predominately substance-misusing sample because of higher rates of substance misuse in the complexes (83, 90, 91), and because of well-established relationships between substance misuse and risky sexual behaviors and networks (32, 92–96). This analysis is guided by the Risk Environment Model, which proposes that vulnerability to HIV and other STIs among substance misusers is generated, in part, by place characteristics and social policies (97).

Methods

Study Sample

Methods for this study have been described elsewhere (79, 80, 98), and are summarized here. Participants were recruited from the seven public housing complexes that were slated for relocation and demolition in Atlanta, GA, in 2008–2010 (99, 100). Complexes housed a total of 2,300 households pre-relocation. Residents moved to voucher-subsidized rental units in the private market; residents could select their new homes, provided that the landlord accepted vouchers and that the new home met specific Atlanta Housing Authority criteria (e.g., no overcrowding).

Eligibility criteria for inclusion in the study included residing in one of the seven complexes targeted for demolition; being ≥18 years old; self-identifying as Non-Hispanic Black/African American; reporting sexual activity in the past year; and not residing with a

previously-enrolled participant. Because a primary objective of the overarching study was to examine trajectories of substance misuse in the cohort, non-probability quota sampling methods were used to establish a sample with diverse histories of substance use at baseline (i.e., 25% were dependent on alcohol or other drugs; 50% were not dependent on alcohol or other drugs but engaged in illicit drug use or binge drinking; 25% had not recently engaged in illicit drug use or binge drinking).

Multiple strategies were used to recruit study participants. Study staff recruited onsite within each housing complex, varying recruitment days and times to reach residents with different activity patterns. We hosted lunches onsite at each complex to allow residents to meet study staff and learn about the study in an informal setting. Additionally, community- and faith-based organizations near the complexes shared information about the study with clients and parishioners. Study participants could also refer interested individuals.

Overview of Data Collection and Measures

Baseline data collection captured the pre-relocation period; participants attended follow-up visits approximately every nine months thereafter. By Wave 2 all participants relocated from their public housing complexes. The present analyses include data from Waves 1–4. During each visit, individual-level information about sexual behavior and networks, substance use, mental and physical health, and perceived neighborhood conditions were captured via a survey administered by trained interviewers. Questions about sexual behaviors and substance use were asked using audio computer-assisted self-interviewing methods to reduce social desirability bias (101–103). At each wave, participants reported their home addresses and these addresses were geocoded to census tracts; 2010 census tract boundaries were used consistently across all waves. Administrative data were analyzed to characterize the tracts where participants lived at each wave.

Outcomes

Perceived Partner Risk: Because a constellation of partner risk characteristics are associated with HIV/STI risk, including substance misuse, incarceration history, and (for men) same-sex sexual contact (43, 96, 104–111), we created an index to measure perceived partner risk. Participants reported the number of partners they had had in the six-month reporting period who they believed had the following characteristics: (a) a history of incarceration; (b) ever injected illicit drugs; (c) currently used marijuana; (d) currently used other illicit drugs (e.g., cocaine); (e) were men who had sex with men; (f) were >5 years older than the participant; (g) currently had HIV/AIDS; or (h) currently had another STI. Responses were summed across items (and partners) to create a continuous partner risk index. Several of these characteristics have been included in other indices capturing partner risk (32, 110, 112, 113).

Perceived Indirect Concurrency: The measure of indirect concurrency was a yes/no question that asked, “During the past 6 months, did you have sex with one person who you thought was involved in a sexual relationship with another person?”

Census-tract level predictors—As described previously (79, 80), tract-level economic disadvantage and social disorder were assessed using indices generated by principal components analysis. The index of economic disadvantage consisted of the following items: median household income, percent poverty, and percent of adults aged >25 whose highest degree was a high-school diploma/GED or less. Baseline data on these items were drawn from Logan's Longitudinal Tract Database (which maps 2000 Decennial Census data to 2010 census tract boundaries) (114); Wave 2–4 data on these items were drawn from the Census Bureau's American Community Survey.

The index of social disorder included annual measures of alcohol outlet density (the number of outlets per square mile) and violent crime rates. Annual data on the locations of businesses licensed to sell alcohol for off-premises consumption were obtained from the Georgia Department of Revenue. Annual data on the locations of violent crimes were obtained from police departments serving the jurisdictions where participants resided at each wave. Data on the locations of off-premises alcohol outlets and of violent crimes were geocoded to tracts for each year of the study period.

Sex ratios were calculated as the ratio of males:females among 18–64 year old African-Americans; men and women living in group quarters (e.g., correctional facilities, residential drug treatment) were excluded from these calculations. The baseline sex ratio variable was created using 2000 Decennial Census data; 2010 Decennial Census data were used to calculate sex ratios for Waves 2–4. We created a three-level ordinal variable for each wave: sex ratios <0.95 were classified as low (i.e., more women than men); ratios of 0.95–1.05 were equitable; and ratios >1.05 were high (i.e., more men than women).

Individual-level predictors—Perceived community violence was measured using a 5-item scale created by Sampson, Raudenbush, and Earls that captured how often participants believed the following events had occurred in their neighborhood in the past six months: fights with weapons; violent arguments among neighbors; gang fights; sexual assault or rape; and robbing or mugging (115). The mean value of responses across the five items was calculated and yielded a scale that ranged from zero (i.e., never observing violence) to eight (i.e., observing violence almost daily) (115). Several additional individual-level covariates were assessed via survey at each wave, including age, gender, marital status, HIV status, educational attainment, and substance misuse.

Analysis—We used descriptive statistics to assess the distributions of individual and census-tract characteristics at each wave and over time. A series of three-level hierarchical generalized linear models, in which time was nested in participants and participants were nested in baseline tracts, was used to model temporal trajectories in perceived partner risk status and in indirect concurrency, and to analyze the relationships of place characteristics to these trajectories (116). First, we evaluated the relationship between time (i.e. number of months since baseline and number of months since relocation) and each outcome. Second, we evaluated the relationship between each census-tract characteristic and each outcome, controlling for time. Third, we evaluated the relationship between each individual-level and census-tract characteristic and each outcome in multivariable analyses that controlled for time and other covariates. Partner risk status was assumed to have a Poisson distribution and

indirect concurrency was assumed to have a Binomial distribution. Continuous census-tract measures (i.e., economic disadvantage and social disorder) were centered at their baseline values, thus creating a baseline variable and a "change since baseline" variable for each continuous tract-level measure (116).

Because our interest was in the possible effects of post-relocation *changes* in place-based characteristics, place characteristics that were operationalized as continuous variables (e.g., social disorder) were included in the final model if a $p<0.20$ was observed for the "change since baseline" variable in bivariate analyses. A $p<0.20$ cutpoint was likewise used to determine whether the ordinal sex ratio variable should be included in multivariable models, and whether to include perceived community violence, a subjectively-evaluated measure of place, in multivariable models. Individual-level predictors with $p<0.05$ in bivariate models were included in the final multivariable models as possible control variables.

We examined whether participant gender might modify relationships between place characteristics and each outcome. Because we posited that substance misuse might lie in the causal pathway between place characteristics and our outcomes, we excluded substance-related variables from our final models. We did, however, explore whether these variables potentially mediated these relationships by comparing parameter estimates when these variables were included and excluded from the multivariable models.

Ethics—Study procedures were approved by Emory University's Institutional Review Board. A Federal Certificate of Confidentiality protected the data.

Results

Of the 194 individuals who screened eligible, 172 (89%) enrolled in the study. Retention rates were high: 95% (n=163) of the baseline sample took part in Wave 2, and 91% (n=156) of the baseline sample took part in Wave 4 (Table I). At baseline more than half of the participants were women, and the mean age of the sample was 43 (SD=14.0). Participants were deeply impoverished: the mean annual household income was $9,849.40 (SD= $8,732.99) at baseline, and participants' economic status did not improve much over time. By design, at baseline 21% met screening criteria for alcohol or other drug dependence and 30% used illegal drugs frequently (weekly or more). As reported elsewhere (79), substance misuse declined in the sample over time. The 22 individuals who were eligible to participate in the study but chose not to enroll were quite similar to study participants (data not shown). The mean ages of the two groups were similar (38 years for non-participants vs. 43 years for participants) and similar percentages of both groups met criteria for drug/alcohol dependence (18% for non-participants vs. 21% for participants), though a higher percentage of non-participants were women (68% vs. 53%).

Relocations took these participants from the seven tracts that contained the public housing complexes at baseline to 77 tracts at Wave 2; some participants moved again between Waves 2–4, and thus participants lived in 83 tracts at Wave 4. The median distance that participants moved between Waves 1 and 2 was 5.17 miles (25^{th} percentile: 2.77; 75^{th} percentile=7.97) as measured along the local street network.

These relocations moved participants to new census tracts that were qualitatively different from the tracts where they lived at baseline. At baseline, the mean poverty rate in the seven tracts where the public housing complexes were located was 46.1% (SD=9.6). At Wave 2 the mean poverty rate was 30.2% (SD=11.8), still elevated but 16 percentage points lower than that of their tracts at baseline. Tract-level poverty rates remained approximately stable across subsequent waves. Changes in measures of other tract-level economic conditions, and of social disorder, followed a similar pattern, with high economic disadvantage and social disorder observed at baseline, followed by substantial improvements between baseline and Wave 2 that were sustained across time.

No participants lived in census tracts with equitable sex ratios at baseline (at baseline, all tracts had far fewer men than women). At Waves 2–4, 15%–23% of the sample lived in tracts with equitable ratios.

Post-relocation changes in census tract conditions and perceived partner risk

Descriptive statistics indicate that perceived partner risk declined for both women and men between Waves 1 and 2 (Table I). The mean perceived partner risk score at baseline was 1.99 (SD=1.65); this mean score dropped by 24% between Waves 1 and 2 (from 1.99 to 1.51) and remained stable thereafter.

Bivariate analysis evaluating the association between time and perceived partner risk (Table II, Model A) demonstrated that the number of months since baseline and the number of months since relocation were significantly associated with partner risk. Together, these covariates indicate that perceived partner risk declined between Waves 1 and 2 (the coefficient for the relationship between the number of months since baseline and perceived partner risk was −0.03 [p=0.002]), and then stabilized thereafter (the coefficient for the relationship between the number of months since relocation and perceived partner risk was 0.03 [p=0.03]). There were no gender differences in these trajectories. Accordingly, these two temporal variables were included in subsequent models evaluating relationships between individual and place characteristics and perceived partner risk.

Bivariate analyses found trends indicating that reductions in the violent crime rate and in perceived community violence were associated with reductions in perceived partner risk (β=0.004, p=0.13 and β=0.04, p=0.13, respectively), though changes in the social disorder component were unrelated to this outcome (Table III, Model A). Bivariate analyses also found a trend such that individuals who experienced greater improvements in economic conditions had lower perceived partner risk scores (β=0.11; p=0.06). Notably, bivariate models suggest that residents of tracts with more women than men, or with more men than women, had lower partner risk scores than residents of tracts with more equitable sex ratios (β=−0.34, p=0.01; and β=−0.50, p=0.03, respectively). In bivariate models, all relationships between individual-level exposures and perceived partner risk were in the expected direction (e.g., drug-dependent participants had higher partner risk scores). Relationships between place characteristics and perceived partner risk did not vary by participant gender.

Because tract-level violent crime rates and tract-level economic conditions were correlated with one another, we ran two separate multivariable models for each of these predictors (i.e.,

Models B and C in Table III, respectively). The relationship between violent crime rates and perceived partner risk persisted in the multivariable model that controlled for possible confounders (Table III, Model B). Specifically, participants who experienced greater declines in violent crime rates had lower scores on the perceived partner risk index (β =0.006; p=0.03). Analyses of the raw data indicate that a decrease in the local violent crime rate of 25% was associated with a decline in the partner risk score of 0.4 (1.6 vs 1.2).

The borderline-statistically significant relationship between economic disadvantage and perceived partner risk also persisted in multivariable models (Table III; Model C). Specifically, there was a trend suggesting that people who experienced greater improvements in tract-level economic conditions reported lower scores on the perceived partner risk index (β=0.10; p=0.09). Analysis of the raw data indicates that participants with a one standard deviation improvement in economic conditions had an average risk score of 1.35 compared to a score of 1.62 for those who did not experience this magnitude of improvement.

As in bivariate analyses, multivariable models suggest that residents of tracts that were home to more women than men, or to more men than women, had lower scores on the perceived partner risk index than did residents of tracts with equitable sex ratios (Model B: β=−0.30, p=0.02, and β=−0.47, p=0.03, respectively). The relationship between high sex ratios (i.e., more men than women) and this outcome was slightly attenuated in the model that included economic conditions (i.e., Model C).

There was no relationship between changes in perceived community violence and perceived partner risk in the multivariable models (Table III; Models B and C in). Because perceived community violence might mediate the relationship between violent crime rates and perceived partner risk, we re-ran the model without perceived community violence (data not shown). Neither the magnitude nor the statistical significance of the relationship between violent crime rates and the outcome changed when perceived community violence was dropped from the multivariable model. Similarly, when we dropped this variable from the model assessing the association between economic disadvantage and partner risk, the magnitude of the relationship remained the same (β=0.10 vs. β=0.11) though the p-value declined (from p=0.09 to p=0.06).

Post-relocation changes in census tract conditions and partner concurrency

Descriptive statistics indicate that indirect concurrency was high at baseline and declined post-relocation for women and men (Table I). At baseline, over one third of the sample (37.5%) reported indirect concurrency; this figure declined to 28.7% at Wave 2, and to roughly 21% at Waves 3 and 4.

Bivariate analysis evaluating the association between time and indirect concurrency demonstrated that the number of months since baseline was significantly associated with indirect concurrency (Table II; Model B). With each passing month since baseline, the odds of indirect concurrency declined by 3% (OR=0.97; p=0.001). There were no gender differences in rates of change over time in concurrency. Accordingly, all subsequent models

evaluating the relationships between individual and place characteristics and indirect concurrency included the number of months since baseline (Table IV; Model A).

Perceived community violence was associated with the odds of reporting indirect concurrency (Table IV; Model A). Specifically, lower perceived community violence at baseline, and declines in perceived community violence over time, were associated with reduced odds of indirect concurrency (OR=1.23; p=0.02; and OR=1.24; p=0.01, respectively). No tract-level measures were associated with indirect concurrency. Effect modification by gender for each possible relationship between place characteristics and concurrency was assessed, and no modification was found.

The relationships between perceived community violence (assessed at baseline and as change over time) and indirect concurrency persisted in multivariable models that controlled for possible individual-level confounders (Table IV; Model B; AOR=1.22; p=0.02; and AOR=1.24; p=0.01, respectively). Analyses of the raw data indicate that participants who experienced declines in community violence (as opposed to no change or worsening community violence on an ordinal scale) had a reduction in indirect concurrency of 14 percentage points (36% vs. 22%).

Including drug-related variables (i.e., drug dependence and the frequency of illegal drug use) did not substantially alter the magnitudes of any of the relationships between changes in place-based exposures and either perceived partner risk or concurrency, suggesting that substance misuse does not mediate these relationships (data not shown).

Discussion

In this predominately substance-misusing cohort of adults relocating from public housing complexes, participants experienced significant post-relocation improvements in local conditions and declines in network-level HIV/STI risk. Similar to other public housing relocations (61, 64, 68), participants relocated to census tracts that were less poor (though still impoverished) and less violent. In addition, participants relocated to census tracts that had less spatial access to off-premises alcohol outlets and slightly more equitable male-to-female sex ratios. Simultaneous with these changes in local conditions, the mean score on the perceived partner risk index declined by 24% between Waves 1 and 2; this reduction persisted across Waves 3 and 4. The rate of indirect concurrency declined linearly over time.

The primary objective of this analysis was to determine whether changes in place-based characteristics were associated with these changes in perceived partner risk and concurrency. We note that many of the following interpretations of our findings assume that participants selected partners from their census tract or from a tract that was very similar to their own. Supporting this assumption is a prior study of high-risk heterosexuals, which found that participants tend to select partners from either their own census tract or from an adjacent tract (117).

In this cohort, post-relocation declines in violent crime rates were associated with lower perceived partner risk, and reductions in economic disadvantage also appeared to be associated with this outcome. These findings are consistent with several ecologic studies of

social disorder, economic conditions, and HIV/STI prevalence (27, 28, 38, 118–120), and with an emerging line of multilevel research on adolescents and young adults (32, 39, 40, 45, 54, 55, 121). Several processes may explain these associations. First, if lower levels of social disorder and economic disadvantage do indeed predict less risk behavior – perhaps in part by creating conditions that allow social capital to flourish (122, 123) – then study participants who moved to less violent or economically-distressed census tracts may have had a less risky pool of adults from which to select new partners. Second, and consonant with findings generated by Latkin et al (43) and Curley (78), members of our cohort who moved to less violent or economically-distressed census tracts might have severed ties with existing risky partners or might have actively sought out less risky partners. Our past analyses of data from this cohort indicate that relocaters who experienced greater reductions in local social disorder or economic disadvantage were less likely to misuse substances and had fewer depressive symptoms (79, 80). These changes may in turn have led participants to seek out partners who did not misuse substances themselves, or who were otherwise viewed as more "prosocial." These two possibilities are not mutually exclusive; both may be at play here.

As noted, the higher prevalence of risk-discordant partnerships among African-American adults may help explain racial/ethnic disparities in HIV in the US. Given that our sample was high risk at baseline (i.e., had a high prevalence of substance misuse) and that participants reported reductions in perceived partner risk over time, one could interpret our findings as suggesting that relocations *increased* risk discordance in Atlanta by exposing lower-risk Atlantans to higher-risk former public housing residents. Our past research, however, does not support this interpretation: we observed post-relocation declines in substance misuse (79) and in the odds of testing positive for an STI in the cohort (124).

Declines in perceived community violence over time were associated with reductions in indirect partner concurrency, perhaps for the reasons discussed above. In contrast to the perceived partner risk findings, however, reductions in our *objective* measure of community violence (i.e., violent crime rates) were not associated with reduced concurrency. Jennings et al have discussed the reasons why findings might differ across objective and subjective measures of social disorder, and have proposed that discrepancies may partly be explained by differences in the time periods referenced by measures (32). Here, our objective measure of violent crime rates captured the calendar year, while the subjective measure captured the past six months; possibly, more recent experiences of community violence are more potent predictors of indirect concurrency, while longer-term exposure to violence is a more potent predictor of perceived partner risk. It is also possible that census tracts are not the optimal geographic scale at which to operationalize exposure to violence when indirect concurrency is the outcome; the measure of "perceived violence" allowed participants to use their own subjective definition of their neighborhood.

In contrast to past research, sex ratios were not associated with indirect concurrency and imbalanced sex ratios actually appeared to *protect* against perceived partner risk. Measures of community sex ratios are evolving, and there is uncertainty about what populations should be included and excluded from them (e.g., should these measures exclude all residents of group quarters or just individuals who are incarcerated?) and about whether they

should be operationalized as continuous or categorical variables. Additionally, our measure of indirect concurrency did not capture how *certain* participants were that their partner had another partner. Misclassification of the outcome may thus have obscured a true association between sex ratios and indirect concurrency. We are unsure why imbalanced sex ratios were protective against perceived partner risk in this sample. Future analyses with this cohort will explore possible mediators of this relationship, including changes in network norms and other network characteristics.

Limitations and Strengths

Several limitations should be considered when interpreting this study's results. The study cohort is not a random sample of residents from public housing complexes because no sampling frame of residents existed that was stratified by substance misuse status. It was not possible to use targeted sampling or respondent-driven sampling methods to create the sample because both methods require intact networks, and the relocations (which were underway when recruitment began) potentially disrupted residents' networks. As discussed elsewhere (79), however, our sample's sociodemographic characteristics (e.g., median income, household size, marital status) are similar to those of the underlying population of residents in each of these seven complexes (as reported by the Department of Housing and Urban Development) and to HOPE VI relocaters in five cities (as reported by the Urban Institute).

We could not create a comparison group of non-relocaters for this study because no severely distressed/obsolete complexes remain in Atlanta. It is possible that the reductions in partner risk and concurrency observed in this study may have been driven by participant aging or historical changes in the city. Given that these outcomes were associated with changes in community violence and economic disadvantage in ways that are consistent with past literature (32, 43, 45, 47), however, this alternative interpretation seems unlikely.

An ongoing debate in public housing policy is whether distressed public housing complexes should be demolished or revitalized. This analysis cannot directly contribute to this debate because we have no comparison group of individuals who were allowed to remain in their public housing complexes while these complexes, and the surrounding neighborhoods, were being revitalized.

Self-reported information about characteristics of sexual partners may be limited by participants' lack of knowledge about their partners' risk status and concurrent sexual partners. Past research has demonstrated that an individual's ability to accurately report on the sexual behaviors of their partners varies by behavior (125). Participant perceptions of partner risk and indirect concurrency are commonly used in the field (19, 32, 44, 93, 94, 126), and in the case of this cohort are substantiated by biomarkers: we used PCR methods to test participant urine at each wave for one of three STIs (i.e., Chlamydia, trichomonas vaginalis, and gonorrhea) and found substantial declines in these STIs post-relocation (124).

Because of the way we measured the outcomes, declines in perceived partner risk or in indirect concurrency could have been a function of post-relocation reductions in the *total number* of partners, and not of the risk status of the partners participants chose; tract-level

predictors could thus have merely been predicting changes in partner number, and not changes in partner risk or concurrency. Post-hoc analyses, however, support the idea that participants did indeed have had lower risk partners post-relocation: adding a covariate that captured the number of recent partners to the multivariate models did not diminish the magnitudes of the relationships between changes in place-based phenomena and either outcome. Additionally, another post-hoc analysis suggests that reporting a new partner since the last interview does not mediate the relationship between changes in place-based exposures and either outcome. Future analyses with data from this cohort will assess the role of turnover in sexual networks in this cohort in more detail.

Despite these limitations, the high retention rate supports the internal validity of our findings, and the multilevel longitudinal design of this study enabled assessment of the temporal association between place characteristics and sexual partnerships while controlling for individual-level confounders.

Conclusions

In this predominately-substance misusing cohort of African-American adults relocating from public housing complexes, reduced exposure to community violence was associated with lower perceived partner risk and odds of indirect concurrency, and improved economic conditions were associated with reductions in perceived partner risk. These findings lend further support to the hypothesis that place characteristics influence sexual networks. They also testify to the possibility that racial/ethnic differences in the quality of the places where people live – differences that these relocations appear to have slightly diminished – may drive disparities in HIV and other STIs, and that efforts to further diminish these place-based inequalities may help eliminate these disparities.

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Table I

Distributions of individual- and census-tract level characteristics at baseline and across time among 172 African-American adults relocated from public housing complexes in Atlanta, Georgia between 2008 and 2010.

Characteristic of participants[1] and census tracts	Wave 1 % (N) or Mean (SD) N(171[2])	Wave 2 % (N) or Mean (SD) (N=163)	Wave 3 % (N) or Mean (SD) (N=160)	Wave 4 % (N) or Mean (SD) (N=156)
Participant Characteristics				
Gender				
Woman[3]	53.4% (97)	58.3% (95)	57.5% (92)	57.1% (89)
Man	43.6% (75)	41.7% (68)	42.5% (68)	43.0% (67)
Age (years)	42.9 (14.0)	43.1 (13.9)	43.2 (14.0)	43.5 (13.8)
Married or living as married	9.4% (16)	9.5% (16)	9.4% (15)	9.7% (15)
High-school diploma/GED (baseline)	52.6% (90)	51.9% (84)	52.5% (83)	52.9% (82)
Annual Household Income	$9,849.40 ($8,732.99)	$10,473.86 ($9,655.89)	$11,217.11 ($9,533.78)	$9,966.22 ($9,137.36)
Only reported same-sex behavior in six-month reporting period				
Men	6.8% (5)	7.5% (5)	7.5% (5)	9.1% (6)
Women	5.3% (5)	4.3% (4)	1.1% (1)	3.5% (3)
Self reported HIV positive (at visit)	8.8% (15)	9.9% (16)	8.8% (14)	10.26% (16)
Binge drinking twice or more (past 30 days)	38% (63)	26% (41)	28% (44)	19% (29)
Use of illicit drugs weekly or more	30% (50)	25% (40)	19% (30)	19% (29)
Met screening criteria for dependence on alcohol or other drugs	21% (36)	11% (18)	9% (14)	9% (14)
Moved to a new census tract since the last wave	---	100% (163)	28% (45)	28% (43)
Perceived community violence	2.75 (2.19)	0.62 (1.11)	0.70 (1.22)	0.61 (1.02)
Perceived partner risk	1.99 (1.65)	1.51 (1.41)	1.43 (1.33)	1.46 (1.33)
Indirect concurrency	37.5% (57)	28.7% (37)	21.3% (27)	21.5% (28)
Census tract characteristics				
Median household income	$15,809.9 ($4482.6)	$33,476.0 ($15,788.3)	$33,784.5 ($16,020.0)	$33,804.8 ($16,245.0)
Poverty rate	46.1% (9.6)	30.2% (11.8)	30.1% (12.0)	30.0% (12.6)
Percent of adults (≥25 years) whose highest degree is a high school diploma/GED or less	67.1% (13.4)	49.1% (17.6)	48.8% (17.9)	48.6% (18.1)
Violent crime rate (per 1000)	35.6 (15.8)	20.7 (14.7)	20.7 (14.4)	21.5 (15.7)
Density of alcohol outlets per square mile	9.3 (8.0)	6.4 (5.0)	6.4 (5.1)	6.7 (5.8)
Economic Disadvantage Component	0.82 (0.54)	−0.29 (0.94)	−0.31 (0.96)	−0.32 (0.99)
Social Disorder Component	0.35 (1.32)	−0.16 (0.79)	−0.16 (0.77)	−0.08 (0.88)
Male:female sex ratio[4]				
<0.95 (fewer men than women)	100.0% (172)	67.5% (110)	71.1% (113)	75.0% (117)
0.95–1.05 (roughly equal)	0% (0)	23.3% (38)	20.1% (32)	15.4% (24)

Characteristic of participants[1] and census tracts	Wave 1 % (N) or Mean (SD) N(171[2])	Wave 2 % (N) or Mean (SD) (N=163)	Wave 3 % (N) or Mean (SD) (N=160)	Wave 4 % (N) or Mean (SD) (N=156)
>1.05 (more men than women)	0% (0)	9.2% (15)	8.8% (14)	9.6% (15)

[1] Note: Individual characteristics pertain to the last 6 months unless otherwise stated.

[2] Baseline survey data were lost for one participant, so the baseline N=171, though 172 individuals were in the cohort.

[3] Women included three individuals who were transgendered (male to female).

[4] Sex ratios were calculated for African-American adults (aged 18–64), excluding people living in group quarters (e.g., correctional facilities, shelters).

Table II

Temporal trajectories of perceived partner risk and of indirect concurrency (i.e., having a sex partner who also has other sex partners) in a cohort of 172 Black adults relocated from public housing complexes in Atlanta, Georgia between 2008 and 2010.

Temporal Predictors[5]	Model A Temporal trends in perceived partner risk 3 (p-value)	Model B Temporal trends in indirect concurrency OR (p-value)
Number of months since baseline	−0.03 (0.002)	0.97 (0.001)
Number of months since relocation	0.03 (0.03)	----[6]
Variance components		
Intercept (community)	0.00	0.00
Intercept (individual)	0.63	1.37

[5] Bivariate models tested the relationship between number of months since baseline and the number of months since relocation with each outcome

[6] The variable assessing the number of months since relocation did not predict indirect concurrency, and so was excluded from this model.

Table III

Bivariate and multivariable multilevel Poisson regressions of perceived partner risk on individual and place characteristics in a cohort of 172 Black adults relocated from public housing complexes in Atlanta, Georgia between 2008 and 2010.[7]

Predictors	Model A[8] Bivariate Model β (p-value)	Model B[9] Multivariable Model β (p-value)	Model C Multivariable Model β (p-value)
Intercept	----	1.30 (<0.0005)	1.36 (<0.0005)
Number of months since baseline	−0.03 (0.002)	−0.03 (0.06)	−0.03 (0.07)
Number of months since relocation	0.03 (0.03)	0.03 (0.11)	0.03 (0.13)
Individual Characteristics			
Gender	−0.30 (0.02)	−0.13 (0.22)	−0.12 (0.26)
Age	−0.02 (< 0.0005)	−0.02 (< 0.0005)	−0.02 (< 0.0005)
Married	−0.46 (0.04)	−0.43 (0.02)	−0.43 (0.02)
High School diploma/GED	−0.07 (0.58)	----	----
Household income	−0.004 (0.86)	----	----
HIV positive	0.78 (<0.0005)	0.87 (< 0.0005)	0.85 (< 0.0005)
Drug dependence	0.27 (0.03)	----	----
Binge drinking 2 or more times/month	0.05 (0.64)	----	----
Illegal drug use >1–3 times/month	0.32 (0.002)	----	----
Place Characteristics			
Economic disadvantage			
- baseline	0.20 (0.07)		0.04 (0.66)
- change since baseline	0.11 (0.06)		0.10 (0.09)
Sex ratio (ref group=equity)			
More women	−0.34 (0.01)	−0.30 (0.02)	−0.33 (0.01)
More men	−0.50 (0.03)	−0.47 (0.03)	−0.39 (0.07)
Social disorder			
- baseline	−0.08 (0.17)		
- change since baseline	0.003 (0.95)		
Alcohol density			
-baseline	−0.02 (0.10)		
-change since baseline	−0.002 (0.78)		
Violent crime rate (per 1000)			
- baseline	−0.006 (0.89)	0.002 (0.58)	
- change since baseline	0.004 (0.13)	0.006 (0.03)	
Perceived community violence			
- baseline	0.09 (0.002)	0.05 (0.06)	0.05 (0.08)
- change since baseline	0.04 (0.13)	0.03 (0.23)	0.03 (0.31)
Variance components			
Intercept (community)	-----	0.00	0.00

Predictors	Model A[8] Bivariate Model β (p-value)	Model B[9] Multivariable Model β (p-value)	Model C Multivariable Model β (p-value)
Intercept (individual)	-----	0.43	0.44

[7] Drug-related covariates were not included in the final models because they might lie in the causal pathway linking place characteristics to perceived partner risk.

[8] Bivariate models tested the relationship between each individual-level and census-tract level predictor and the outcome, controlling for the number of months since baseline and the number of months since relocation.

[9] Because our measures of tract-level economic conditions were associated with our measures of tract-level violent crime rates, we ran two separate multivariable models, one for each of these predictors.

Table IV

Bivariate and multivariable multilevel logistic regressions of indirect concurrency on individual and place characteristics in a cohort of 172 Black adults relocated from public housing complexes in Atlanta, Georgia between 2008 and 2010.

Predictors	**Model A[10] Bivariate Model OR (p-value)**	**Model B[11] Multivariable Model AOR (p-value)**
Intercept	----	0.30 (<0.0005)
Number of months since baseline	0.97 (0.001)	0.98 (0.12)
Individual Characteristics		
Gender	1.49 (0.21)	----
Age	0.99 (0.20)	----
Married	0.24 (0.02)	0.24 (0.02)
High-School Diploma/GED	1.16 (0.64)	----
Household income	1.00 (0.96)	----
HIV status positive	1.16 (0.77)	----
Drug dependence	3.34 (0.001)	----
Binge drinking 2 or more times/month	2.21 (0.01)	----
Illegal drug use >1–3 times/month	1.68 (0.10)	----
Place Characteristics		
Economic disadvantage		
- baseline	1.31 (0.35)	----
- change since baseline	0.95 (0.75)	----
Sex ratio (ref group=equity)		
More females	0.92 (0.82)	----
More males	0.55 (0.39)	----
Social disorder		
- baseline	0.92 (0.53)	----
- change since baseline	0.93 (0.62)	----
Alcohol outlet density		
-baseline	0.99 (0.56)	----
-change since baseline	0.99 (0.68)	----
Violent crime rate (per 1000)		
- baseline	1.00 (0.95)	----
- change since baseline	1.00 (0.68)	----
Perceived community violence		
- baseline	1.23 (0.02)	1.22 (0.02)
- change since baseline	1.24 (0.01)	1.24 (0.01)
Variance components		
Intercept (community)	----	0.00
Intercept (individual)	----	1.31

[10] Bivariate models tested the relationship between each individual-level and census-tract level predictor and the outcome, controlling for the number of months since baseline.

[11] Drug-related covariates were not included in the final models because they might lie in the causal pathway linking place characteristics to indirect concurrency.