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Exploring the Social Determinants of Sexually Transmitted Disease and High-Risk Sexual Behaviors

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

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Preface

This doctoral thesis includes three studies, presented in Chapters 1-3, that have been prepared as manuscripts for specific journals.

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Abstract 1: A multi-level assessment of disproportionate population sex ratios and high-risk sexual behaviors among STD clinic patients

Low male-to-female sex ratios in a population may influence high-risk sexual behaviors, such as multiple sex partners and inconsistent condom use, which facilitate the transmission of STDs. This study used multi-level modeling to assess whether population sex ratios were associated with these two individual-level behaviors. All analyses were stratified by gender. Interview data were collected from patients (N = 9,203, 48% male) attending participating STD clinics. Interviews included information on socio-demographics and sexual behavior, including number of sex partners in the previous 3 months and condom use at last sex. The sex ratio per census tract was obtained from the U.S. Census Bureau. There was no association between sex ratio and multiple sex partners or condom use for either men or women. That is, we found no evidence that a shortage of men in census tracts was associated with increased engagement in high-risk sexual behavior.

Abstract 2: A multi-level assessment of neighborhood vacancy rates and high-risk sexual behaviors among STD clinic patients

The “broken windows” theory posits that physical neighborhood deterioration, and its association with reduced social cohesion, can lead to changes in individual behaviors. Thus individuals living in neighborhoods with high levels of deterioration may be more likely to engage in high-risk sexual behaviors. This study used multi-level modeling to evaluate the extent to which high residential vacancy rates increased the likelihood of individuals having multiple sex partners. Interview data, including data on patient demographics and sexual behaviors, were collected from patients (N = 6,347, 52% male) attending participating STD clinics in the Richmond, Virginia area from 2008-2010. Neighborhood vacancy rates were obtained from the U.S. Census Bureau. Fifty-one percent of men and 36% of women reported having 2 or more sex partners in the previous 3 months. Men who lived in census tracts with high vacancy rates were slightly more likely to report multiple sex partners (53.9%) compared to men who lived in low vacancy tracts (49.7%). In multi-level models, there was no association between high vacancy rates and having multiple sex partners among either women (OR = 0.98; 95% CI: 0.79, 1.20) or men (1.18; 95% CI: 0.99, 1.42). That is, we found no evidence that increased neighborhood deterioration, as measured by high residential vacancy rates, was associated with increased risk of having multiple sex partners among STD clinic patients.

Abstract 3: Residential segregation and gonorrhea rates in U.S. metropolitan statistical areas

The residential segregation of black populations, often in areas of high economic disadvantage and low social status, may play a crucial role in the observed racial inequities in STD rates. An ecological analysis of 2005-2009 average gonorrhea rates was performed across 277 U.S. metropolitan statistical areas (MSAs). The black isolation index and Gini index of income inequality were used as proxy measures for racial and economic residential segregation respectively, derived from 2005-2009 U.S. Census estimates. We used logistic regression modeling to produce estimates of odds ratios (OR) and 95% confidence intervals (CI) for the association between a high black isolation index and Gini index, both independently and in combination, on gonorrhea rates in MSAs. Effect measure modification was assessed by calculating the relative excess risk due to interaction (RERI) between the two indices. Compared to MSAs with low levels of racial segregation, MSAs with high levels of racial segregation had increased odds of high gonorrhea rates (adjusted OR 5.54; 95% CI: 2.29-13.44). Adjustment for potential confounders did not noticeably impact the relationship between the Gini index and gonorrhea, with higher levels of income inequality predicting higher gonorrhea rates (adjusted OR = 2.47; 95% CI: 1.21-5.03). In combined models, the influence of racial residential segregation on gonorrhea rates was stronger than that of income inequality-based segregation; there was no evidence of additivity or a multiplicative interaction. Residential segregation by race or income equality may be a key component in the perpetuation of high rates of gonorrhea and other STDs among black populations in the U.S.

Chapter 1: A multi-level assessment of disproportionate population sex ratios and high-risk sexual behaviors among STD clinic patients

INTRODUCTION

The epidemiology of sexually transmitted diseases (STDs) in the United States is characterized by immense racial and social inequity in the burden of disease (1-3). For example, in 2009 national rates of gonorrhea were approximately 20 times higher among blacks than whites (4), while the estimated rate of new HIV infections was more than 15 times higher for black women than for white women (5). Contextual factors may contribute to the persistence of pronounced racial inequity in STD rates by influencing sexual behaviors and sexual networks both directly and indirectly (6-8).

One of the contextual factors potentially pertinent to STD transmission is population sex ratios. Low male-to-female sex ratios, in which there is a relative shortage of men in the population, have been associated with elevated STD incidence at the population level, as well as increased engagement in risky sexual behaviors at the individual level (8-11). Sex ratios tend to be lower among black populations, particularly those living in disadvantaged neighborhoods (12). This is likely the result of a combination of several social and economic forces. Premature death rates among black males tend to be significantly higher than among whites males (13-14) and this excess mortality among black males may be influenced by high rates of violent crime. In addition, incarceration rates are disproportionately high among black men, resulting in a type of non-voluntary migration out of communities (15-17).

Low sex ratios in the reproductive age range can have serious implications. At the population level, low male-to-female sex ratios have been linked to familial instability, higher

rates of teenage pregnancy, and increased incidence of STDs (18-20). These associations may result from differences in social norms and behaviors, tied to the balance of power in opposite-sex relations, which is affected by the disproportionate distribution of men and women.

Qualitative studies examining the impact of low sex ratios on sexual behaviors have indicated that gender imbalance is a key determinant of the pattern of sexual interactions between men and women (21-23). In communities where males are in short supply, men may be more likely to have multiple sexual partners, while women may be less likely to insist on condom use and more likely to tolerate male infidelity in primary partnerships (24, 25).

The population or ecological level finding that low male-to-female sex ratios, or high male incarceration rates, are associated with high STD rates has not always persisted when controlled for variables such as poverty and marriage rates, and the association has varied across different diseases (9, 10, 26). Relatively few quantitative studies have incorporated both population-level and individual-level data in the examination of sex ratios on sexual behaviors; these multi-level studies have also yielded mixed results. Smith and Subramanian (27) found that sex ratios were associated with the number of recent sexual partners based on population-level survey data from Australia, but they did not assess for differential effects by gender. Pouget *et al*. (28), using data from the National Health and Nutrition Examination Survey, found that non-Hispanic black men living in counties with low sex ratios and high male incarceration rates were more likely to report multiple opposite sex partners in the past year.
In contrast, Senn *et al*. (29) conducted a study among black patients attending an STD clinic in upstate New York. For men, low sex ratios at the census tract level were not associated with having more sex partners, a finding which may have been influenced by the limited population and low sex ratios in nearly all census tracts included in the study.

This study investigated the association between low male-to-female sex ratios at the population level and individual high-risk sexual behaviors among a large sample of STD clinic patients drawn from a diverse metropolitan area. We also had detailed geographic information on each patient, allowing us to examine sex ratios at the census tract level. Using multi-level modeling, we analyzed two self-reported sexual behaviors: number of sexual partners in the last three months, and condom use at last sexual encounter. We hypothesized a differential effect of sex ratio by gender, such that lower male-to-female ratios are associated with a greater number of sexual partners among men and reduced condom use among women.

METHODS

Data Sources

Two data sources were used for this cross-sectional study. Individual-level interview data were obtained from the STD Surveillance Network (SSuN). Area-based data were pulled from the U.S. Census Bureau.

SSuN is a Centers for Disease Control and Prevention (CDC) sponsored enhanced surveillance initiative comprised of a network of STD clinics and health departments across the United States. The SSuN platform and utility has been described previously (30). In Virginia, the health departments in the localities of Richmond City, Henrico County, and Chesterfield County participate in SSuN. All individuals presenting to public STD clinics located within these localities are asked to complete a self-administered interview form upon registration. Interview data for this study were collected continuously from January 1, 2008 through December 31, 2010, and captured information on basic patient demographics, socio-economic characteristics, and various high-risk behaviors. SSuN activities have been determined to be a

non-research surveillance activity by the CDC National Center for HIV, Viral Hepatitis, STD and Tuberculosis Prevention.

Geographic information, in the form of patient residential addresses, was also captured on the interview forms, and these data were geocoded to obtain census tract assignments by the Virginia Department of Health (VDH) using Centrus software (Pitney Bowes Business Insight). Patients residing outside of the state of Virginia, and those lacking valid address information, were excluded from this analysis. Geocoded patient addresses were linked to area-based demographic and socio-economic measures calculated using data extracted from the U.S. Census Bureau's American Community Survey (ACS) 2005-2009 5-year estimates for the census tracts located in Virginia (12, 31). Only patients residing in tracts with at least 10 other patients were included in the analyses.

Exclusion Criteria

All patients with completed interview forms were initially considered eligible for this study. Exclusion criteria were then applied to limit the study population to patients 15-49 years of age, in order to concentrate on the population of reproductive age and maintain consistency with previous studies. In addition, the study population was limited to exclude patients indicating they were transgender, or of homosexual or bi-sexual orientation, as the focus of the current study is the influence of sex ratios on the male-female sexual dynamic, and risk behaviors specifically associated with heterosexual partnering. Finally, due to the small number of individuals reporting races other than white and black or Hispanic ethnicity in the STD clinic population, this study was limited to those individuals reporting non-Hispanic (NH) white, NH black, or Hispanic race/ethnicity.

Study Measures

There were two outcomes of interest in this study related to high-risk sexual behaviors, operationally defined as not using a condom at last intercourse and having multiple sex partners in the last three months. Separate analyses were performed focusing on each of these measures. Both measures were treated as dichotomous variables, with use of condom at last intercourse coded as yes/no, and multiple sex partners categorized as having had zero to one or more than one sexual partner.

The main determinant in this study was the population-level measure of male-to-female sex ratio by census tract. This measure was defined as the ratio of males to females between the ages of 15 and 49 residing in each interviewee's census tract of residence. The population residing in institutional settings (including correctional facility populations) was excluded from this calculation. The univariate distribution of sex ratios within this range was used to determine the categorical cut points for subsequent analyses based on practical and conceptually meaningful boundaries. Categorizing sex ratios allowed for the examination of nonlinearity of effects while conserving statistical power, and is comparable to the analytic strategy used in previous studies of sex ratios and multiple sex partners (28, 29). This categorization of exposure was made without regard to the two behavioral outcome measures under study to avoid biasing the resulting estimates (32). Therefore, any misclassification introduced by the categorization of sex ratios should be non-differential with respect to the outcomes of interest, and any resulting bias should dilute the estimates of effect toward the null.

Sex ratios were categorized into three categories for analysis, with cut points based on the first and third interquartile range, theoretically allowing a comparison of tracts with "normal"

compared to low or high sex ratios. Conceptually, it is hypothesized that low male-to-female sex ratios in an individual's community contribute to increased engagement in high-risk sexual behaviors. Therefore, the rate of high-risk behaviors would be expected to be higher in areas with lower sex ratios (i.e. ratios much lower than 1), indicating fewer men relative to women in the population. Conversely, in areas with sex ratios close to 1, this dynamic would be expected to change, with a lower rate of engagement in high-risk sexual behaviors. In areas with sex ratios greater than 1, where there are more men relative to women in the population, the impact on sexual partnering and risk behavior dynamic is less well studied.

Several individual-level and contextual factors were considered as potential confounders in the relationship between sex ratios and sexual behaviors. At the individual-level, various socio-demographic factors (age, sex, education, race/ethnicity, employment), sexual history (age of first intercourse, exchanging sex for money or drugs), and history of incarceration are known to be associated with increased likelihood of engaging in high-risk sexual behaviors (33-37). While relatively less is known about the correlates of sex ratios, many of these same factors are likely associated with low sex ratios at the population-level (18, 38, 39). Data pertaining to all the aforementioned individual factors were captured on the SSuN interview forms, and were included in the analysis as potential individual-level confounders.

Area-based measures which were also assessed as potential confounders include: median age, poverty rate (% of population living below poverty level), race (% of population that is black), marital status (% of population over 15 who are currently married), education attainment (% of population over 25 years with HS degree), and unemployment (% civilian labor force 16 years and over currently unemployed). Because of their non-normal distributions, and for

consistency and ease of interpretation, these measures were categorized for analysis based on quartile distributions.

Statistical Analysis

For all statistical analyses, the primary unit of analysis was the individual, but both individual-level and population-based determinants were considered. Low sex ratios were hypothesized to have differential effects on the sexual behaviors of men and women. To capture differences in behavior by sex, all analyses were stratified by gender. Although stratum-specific analyses were performed, the formal evaluation of effect measure modification was beyond the scope of this study.

Preliminary analyses evaluated bivariate associations between all study measures and various covariates and potential confounders. These bivariate comparisons were used to assess the potential for confounding by the individual and area-based measures. An unadjusted logistic regression analysis comparing the two measures of high-risk sexual behavior (multiple sex partners and condom use at last sexual intercourse) by the three sex ratio levels was also performed. The results of these preliminary analyses were used in combination with conceptual considerations to inform the model building process and determine which selection of variables to include in adjusted models.

Associations between sex ratios and the two outcome measures were assessed using separate multi-level logistic regression models, applying a random effects modeling method. A multi-level approach was used because this study examined individuals (patients) grouped within contexts (i.e. census tracts), and thus variability was introduced at both the individual and contextual levels (40-43). Confounding was evaluated by adding covariates to the models in a

stepwise manner and assessing the impact of each covariate on the estimate of effect. Covariates that changed the estimate of effect more than 10 percent were retained in the model. All data analyses were performed with SAS version 9.2, using PROC MIXED for multi-level logistic regression models.

RESULTS

There were a total of 20,029 STD clinic patient interview forms collected between January 1, 2008 and December 31, 2010. These interviews represented 13,714 unique patients. In cases where patients had multiple interviews on file from different visits, one interview was randomly selected for inclusion. After all exclusions, a total of 9,203 patient interviews were available for analysis. Characteristics of the interviewed patients are summarized in Table 1. The proportion of patients reporting multiple sex partners in the past 3 months was higher among men (49.8%) than among women (33.4%), while women were more likely to report condom non-use at last sexual intercourse (69.1%) compared to men (65.1%).

STD clinic patients were residents of 174 census tracts in Virginia. The average sex ratio among the population 15-49 years was 1.01 (StdDev = 0.31; range =0.29-3.15). The sex ratio was less than 1.0 in the majority of the census tracts (n = 101, 58.1%).

Overall, 3,479 of the interviewed patients came from census tracts classified as having low sex ratios, including 39.3% (N = 1,887) of the women and 36.2% (N = 1,592) of the men interviewed. Individual-level characteristics and behaviors stratified by gender and sex ratio are shown in Table I. There were only slight differences in the percentages of either women or men reporting multiple sex partners or condom non-use in tracts with low compared to medium or high sex ratios. For example, 34.2% of women living in tracts with low sex ratios reported

having 2 or more sex partners, while 32.4% of women living in tracts with medium sex ratios reported the same.

Census tract characteristics stratified by sex ratios are shown in Table II. As expected, the median percent black was highest in census tracts with low sex ratios (62.2) compared to medium or high sex ratios (22.4 and 29.0 respectively). Unexpectedly, the median percent married was much higher in the medium sex ratio tracts (52.0), than in either the low (31.1) or high (37.4) sex ratio tracts.

The odds of high-risk behaviors by potential individual- and population-level confounders are presented in Tables III and IV respectively. For both men and women, younger patients were significantly more likely to report multiple sex partners compared to older patients. Conversely, the likelihood of reporting condom non-use was lower among younger ages than among older ages. Black females were significantly less likely than white females to report multiple sex partners (OR = 0.81), and black males were more likely than white males to have multiple sex partners (OR = 1.44). However, no significant differences by race were observed in the likelihood of condom non-use for either men or women.

Multi-level logistic regression modeling results are presented in Table V. For both women and men, the odds of engaging in high risk sex behaviors (either having multiple sex partners or condom non-use) were not significantly different across the three sex ratio categories. For women living in census tracts classified as having low sex ratios, the odds of reporting multiple sex partners were 1.08 times that of women residing in tracts with relatively proportionate sex ratios (95% confidence interval (CI): 0.93-1.25). The odds ratio for having multiple sex partners was 1.10 (95% CI: 0.94-1.29) for women living in low compared to medium sex ratio tracts. The odds of condom non-use were 1.03 (95% CI: 0.88-1.20) for women

and 0.95 (95% CI: 0.81-1.11) for men living in tracts with low compared to medium sex ratios. These estimates did not vary notably when the associations between high-risk behaviors and sex ratios were adjusted for either individual-level or tract-level potential confounders.

DISCUSSION

Logically, a shortage of men among sexually active adult populations should have an impact on both social interactions and STD transmission. The social forces that drive disproportionate sex ratios in communities, combined with the impact of low sex ratios on sexual behaviors, could contribute to the elevated rates of STD transmission and disease burden observed in disadvantaged populations. We hypothesized that a low ratio of men to women in the population would result in greater engagement in high-risk sexual behaviors. Specifically, we expected to find a differential effect of sex ratio by gender, such that lower male-to-female ratios are associated with a greater number of sexual partners among men and reduced condom use among women. Few previous studies have examined this relationship using multi-level modeling and a large sample population drawn from a diverse metropolitan area with historically high rates of STDs.

There was a shortage of men relative to women in 107 (58.1%) of the 174 census tracts studied and, condom use was lower among women than among men. Consistent with previous research, men in general reported greater numbers of sexual partners than did women, with black men reporting the highest frequency of multiple sex partners (44-46). In our analysis of the self-reported behaviors of STD clinic patients, the association between sex ratio and number of sexual partners was in the hypothesized direction. That is, individuals living in areas with low sex ratios were more likely to report having multiple opposite-sex partners and not using a

condom at last sex. However, the associations between high-risk sex behaviors and the sex ratios of the census tracts where patients lived were slight and non-significant.

Two previous multi-level studies, using larger units of analysis and large population-based sample data, have found notable variation in behaviors across sex ratios (27, 28). These studies have indicated that individuals, and men in particular, living in tracts with shortages of men were more likely to have multiple partners. Our findings are more in line with those of Senn et al. (29), whose analysis also focused on patients recruited from a STD clinic setting (29). Among men, Senn et al. also found a slight increase in multiple sex partners as the sex ratio decreased, but this increase was non-significant.

Our failure to find a significant association between population sex ratios and individual behaviors may be related to our study population. By including patients from three separate STD clinics in demographically and economically dissimilar localities, we hoped that the current study would capture a wider range of individual and contextual variation than has been the case for previous STD clinic based research. Nevertheless, the specialized nature of our study population remains an important consideration in the interpretation of this analysis. Prior research has shown that STD clinic attendees differ from the general population in terms of various socio-economic indicators and behaviors, and that the epidemiology of sexual health and STD epidemics may be fundamentally different in these settings (30, 47). The range of both individual behaviors and demographics among STD clinic patients may be more limited than they would be for the general population.

Furthermore, not only are STD clinic patients different in terms of behavior, they also tend to come from specific, often disadvantaged and segregated, census tracts within a broader metropolitan area. The studies that found significant associations between sex ratios and

individual behaviors were based on large population-based national samples (27, 28). These samples may not adequately capture the populations who generally attend STD clinics, as they are often a more transient population. Thus it is possible that variations in both sexual behaviors and the populations sampled has influenced the inconsistent associations observed between behavior and sex ratios in studies based on national population samples compared to those based on STD clinic patient populations.

There are a few limitations worth noting. First, we used census tracts to approximate social and sexual networks. Choices in sexual partnering are influenced by geographic and social proximity, which are generally intertwined (48-50). Census tracts tend to be relatively racially and economically homogenous, but they may not accurately capture true social networks. Secondly, we were missing information on patients' relationship status, which was not collected on the interview forms. As marriage, or engagement in a dedicated primary relationship, is strongly associated with both of the sexual behaviors of interest in this study (46, 51), this omission is a concern, although we attempted to address it by including a population-level measure of marital status in our modeling strategy. We believe it unlikely that this missing data impacted our current findings as a brief review of clinic records indicate that only a small proportion of STD clinic patients are currently married. Nonetheless, recommendations have been made to modify future SSuN data collection activities to capture this important indicator.

Stark racial, economical and social inequities persist in epidemiology of STDs. While further research is needed to determine whether low sex ratios play an important role in the unequal distribution of disease, the present findings suggest that the relationship may not prove to be direct or strong among the populations that attend public STD clinics.

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TABLES

Table 1.1. Patient characteristics and behaviors stratified by gender and sex ratio[a]

	Women			Men		
Patient Characteristics [b]	Low Sex Ratio (N = 1,887)	Med Sex Ratio (N = 2,111)	High Sex Ratio (N = 804)	Low Sex Ratio (N = 1,592)	Med Sex Ratio (N = 1,973)	High Sex Ratio (N = 836)
Age						
<20 years	22.0%	23.4%	22.0%	14.4%	16.0%	13.4%
20-24 years	35.7%	32.2%	34.7%	35.2%	34.8%	33.9%
25-34 years	25.9%	27.5%	27.6%	32.2%	33.4%	34.1%
35-49 years	16.4%	16.9%	15.7%	18.2%	15.9%	18.7%
Race/Ethnicity						
Black (NH)	84.6%	78.8%	73.9%	82.7%	80.2%	71.2%
White (NH)	8.8%	12.8%	14.9%	10.4%	12.6%	18.3%
Hispanic	6.6%	8.4%	11.2%	6.9%	7.2%	10.5%
Education						
< High school	17.7%	15.6%	17.4%	20.4%	18.6%	19.8%
High school / GED	41.5%	36.5%	38.3%	47.6%	45.2%	39.6%
> High school	40.8%	47.9%	44.3%	32.0%	36.2%	40.6%
Employment Status [c]						
Employed	34.9%	35.5%	36.9%	45.9%	46.2%	46.9%
Unemployed	25.0%	23.1%	22.9%	32.0%	28.7%	29.7%
Student (full- or part-time)	32.7%	35.0%	31.8%	18.4%	21.9%	19.7%
Other	7.4%	6.4%	8.3%	3.7%	3.2%	3.6%
History of exchanging sex [d]	0.4%	0.8%	1.1%	1.1%	0.7%	1.3%
History of incarceration [d]	3.3%	3.3%	2.9%	12.3%	9.9%	7.8%
Age of first sexual intercourse						
<14 years	16.6%	16.0%	14.6%	27.5%	25.9%	22.2%
14-15 years	32.6%	32.2%	30.9%	29.7%	30.0%	29.2%
16-17 years	35.1%	34.8%	34.2%	27.3%	28.0%	29.2%
18+ years	15.7%	17.0%	20.3%	15.5%	16.1%	19.4%
Number of sex partners [e]						
0-1 partners	65.8%	67.6%	66.2%	48.9%	50.7%	51.7%
2+ partners	34.2%	32.4%	33.8%	51.1%	49.3%	48.3%
Condom use (last sex)						
Yes	30.4%	30.8%	32.1%	35.2%	34.0%	36.8%
No	69.6%	69.2%	67.9%	64.8%	66.0%	63.2%

[a] Sex ratios are defined as the ratio of men relative to women in the population aged 15-49 years, here categorized as low (<=0.846), medium (0.847-1.107), or high (>1.107). A low sex ratio indicates a shortage of men in the population relative to women.
[b] There were missing data for some demographic and behavioral variables.
[c] Other includes patients who are homemakers, retired, or unable to work.
[d] In the previous 12 months.
[e] Number of sex partners in the previous 3 months.

Table 1.2. Census tract characteristics stratified by sex ratio[a]

	Low Sex Ratio (N = 43)		Med Sex Ratio (N = 87)		High Sex Ratio (N = 44)	
Tract Characteristics	median	(range)	median	(range)	median	(range)
Median age	31.8	(19.1 – 46.8)	37.0	(21.0 – 67.3)	35.1	(25.1 – 48.7)
Percent black	62.2	(0.0 – 97.6)	22.4	(2.1 – 94.0)	29.0	(6.4 – 98.6)
Percent married	38.1	(3.3 – 69.4)	52.0	(15.3 – 75.2)	37.4	(15.9 – 71.9)
Percent living below poverty level	16.8	(0.6 – 69.0)	7.2	(0.8 – 38.9)	12.0	(1.2 – 60.0)
Percent unemployed	7.9	(0.0 – 39.7)	5.2	(0.6 – 29.0)	6.7	(1.3 – 30.8)
Percent with HS education	81.1	(47.6 – 97.7)	87.7	(54.2 – 100.0)	85.0	(48.6 – 98.2)

[a] Sex ratios are defined as the ratio of men relative to women in the population aged 15-49 years, here categorized as low (<=0.829), medium (0.830-1.107), or high (>1.107). A low sex ratio indicates a shortage of men in the population relative to women.

Table 1.3. Odds of high-risk sexual behaviors by potential individual-level confounders, stratified by gender

	Multiple Sex Partners[a]				**Condom Non-Use**[b]			
	Women		Men		Women		Men	
Potential Confounders	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Age								
<20 years	1.68	(1.37 - 2.07)	1.26	(1.02 - 1.56)	0.62	(0.50 - 0.76)	0.56	(0.44 - 0.70)
20-24 years	1.77	(1.46 - 2.14)	1.20	(1.01 - 1.44)	0.68	(0.55 - 0.82)	0.65	(0.54 - 0.80)
25-34 years	1.48	(1.21 – 1.80)	1.15	(0.96 - 1.37)	0.76	(0.62 - 0.94)	0.71	(0.58 - 0.87)
35-49 years	1.00	--	1.00	--	1.00	--	1.00	--
Race/Ethnicity								
Black (Non-Hispanic)	1.00	--	1.00	--	1.00	--	1.00	--
White (Non-Hispanic)	0.81	(0.67 - 0.97)	1.44	(1.20 - 1.72)	0.83	(0.68 - 1.02)	1.03	(0.85 - 1.24)
Hispanic	0.50	(0.37 - 0.67)	0.66	(0.49 - 0.88)	0.93	(0.69 - 1.25)	0.93	(0.69 - 1.25)
Education								
< High school	1.01	(0.85 - 1.21)	0.89	(0.75 - 1.05)	1.18	(0.97 - 1.44)	1.23	(1.03 - 1.49)
High school / GED	1.00	--	1.00	--	1.00	--	1.00	--
> High school	1.09	(0.95 - 1.25)	1.09	(0.95 - 1.25)	0.81	(0.71 - 0.93)	0.79	(0.69 - 0.91)
Employment Status [c]								
Employed	1.00	--	1.00	--	1.00	--	1.00	--
Unemployed	1.19	(1.01 - 1.39)	1.14	(0.99 - 1.32)	1.18	(0.99 - 1.40)	1.55	(1.32 - 1.82)
Student (full- or part-time)	1.04	(0.89 - 1.20)	1.24	(1.05 - 1.46)	0.79	(0.68 - 0.92)	0.72	(0.72 - 1.01)
Other	0.79	(0.61 - 1.03)	0.82	(0.58 - 1.15)	1.29	(0.97 - 1.71)	1.14	(1.14 - 2.55)
History of exchanging sex [d]	2.44	(1.20 - 4.96)	2.95	(1.43 - 6.06)	1.34	(0.60 - 2.99)	0.74	(0.39 - 1.41)
History of incarceration [d]	1.47	(1.06 - 2.04)	1.10	(0.90 - 1.34)	1.53	(1.04 - 2.27)	1.53	(1.22 - 1.92)
Age of first sexual intercourse								
<14 years	2.24	(1.80 - 2.80)	1.76	(1.42 - 2.18)	1.41	(1.12 - 1.76)	1.33	(1.06 - 1.66)
14-15 years	1.70	(1.40 - 2.07)	1.53	(1.25 - 1.89)	1.32	(1.09 - 1.60)	1.09	(0.88 - 1.35)
16-17 years	1.26	(1.03 - 1.53)	1.28	(1.04 - 1.58)	1.07	(0.89 - 1.29)	1.12	(0.90 - 1.39)
18+ years	1.00	--	1.00	--	1.00	--	1.00	--

[a] Odds shown are for having 2 or more partners in the previous 3 months compared to have 0-1 partners.
[b] Odds are for not using a condom at last sexual intercourse (i.e. condom non-use) compared to using a condom.
[c] Other includes patients who are homemakers, retired, or unable to work.
[d] In the previous 12 months.

Table 1.4. Odds of high-risk sexual behaviors by potential population-level confounders, stratified by gender

	Multiple Sex Partners[a]				Condom Non-Use[b]			
	Women		Men		Women		Men	
Potential Confounders	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Median age								
< 32.6 years	0.96	(0.78, 1.18)	0.81	(0.67, 0.97)	0.87	(0.70, 1.09)	1.10	(0.89, 1.35)
32.6 – 37.5 years	0.95	(0.76, 1.20)	0.75	(0.60, 0.92)	1.05	(0.82, 1.34)	1.01	(0.81, 1.26)
37.6– 42.1 years	1.05	(0.83, 1.33)	0.79	(0.63, 0.98)	0.92	(0.72, 1.18)	1.12	(0.89, 1.42)
> 42.1 years	1.00	--	1.00	--	1.00	--	1.00	--
Percent black								
< 12.6%	1.00	--	1.00	--	1.00	--	1.00	--
12.6 – 25.8%	0.91	(0.65, 1.27)	0.97	(0.70, 1.34)	1.22	(0.87, 1.72)	1.51	(1.09, 2.11)
25.9 – 50.6%	0.73	(0.54, 1.00)	1.11	(0.81, 1.51)	1.34	(0.97, 1.85)	1.56	(1.14, 2.13)
> 50.6%	0.83	(0.62, 1.12)	1.44	(1.08, 1.93)	1.33	(0.99, 1.81)	1.61	(1.20, 2.16)
Percent married								
< 37.6%	0.76	(0.59, 0.97)	1.51	(0.17, 1.94)	1.09	(0.83, 1.42)	1.34	(1.04, 1.73)
37.6 – 50.5%	0.63	(0.48, 0.82)	1.29	(0.99, 1.68)	1.04	(0.79, 1.37)	1.35	(1.03, 1.77)
50.6 – 60.7%	0.71	(0.54, 0.93)	1.18	(0.88, 1.57)	1.05	(0.78, 1.41)	1.21	(0.90, 1.62)
> 60.7%	1.00	--	1.00	--	1.00	--	1.00	--
Percent living below poverty level								
< 4.9%	1.00	--	1.00	--	1.00	--	1.00	--
4.9 – 9.4%	0.91	(0.69, 1.19)	1.09	(0.83, 1.43)	1.03	(0.77, 1.37)	0.97	(0.73, 1.29)
9.5 – 17.6%	0.85	(0.67, 1.09)	1.22	(0.96, 1.56)	1.03	(0.79, 1.33)	0.98	(0.76, 1.27)
> 17.6%	0.93	(0.74, 1.18)	1.27	(1.00 – 1.61)	1.04	(0.81, 1.34)	1.14	(0.89, 1.47)
Percent unemployed								
< 3.5%	1.00	--	1.00	--	1.00	--	1.00	--
3.5 – 5.8%	1.02	(0.81, 1.29)	1.02	(0.80, 1.29)	0.99	(0.78, 1.25)	0.92	(0.71, 1.19)
5.9 – 9.3%	1.14	(0.91, 1.43)	1.25	(0.99, 1.58)	0.89	(0.70, 1.12)	0.83	(0.64, 1.06)
> 9.3%	1.06	(0.86, 1.31)	1.37	(1.10, 1.71)	1.17	(0.94, 1.45)	1.08	(0.86, 1.37)
Percent with HS education								
< 78.0%	0.83	(0.64, 1.08)	1.46	(1.13, 1.89)	1.47	(1.13, 1.92)	1.37	(1.05, 1.78)
78.0 – 86.0%	0.85	(0.66, 1.11)	1.29	(1.00, 1.67)	1.24	(0.95, 1.62)	1.14	(0.87, 1.48)
86.1 – 92.5%	0.77	(0.58, 1.02)	1.18	(0.90, 1.55)	1.33	(1.00, 1.76)	1.06	(0.79, 1.39)
> 92.5%	1.00	--	1.00	--	1.00	--	1.00	--

[a] Odds shown are for having 2 or more partners in the previous 3 months compared to have 0-1 partners.
[b] Odds are for not using a condom at last sexual intercourse (i.e. condom non-use) compared to using a condom.

Table 1.5. Logistic regression results for the odds of having multiple sex partners and condom non-use

	Multiple Sex Partners							
	Women				Men			
	Low Sex Ratio[a]		High Sex Ratio[a]		Low Sex Ratio[a]		High Sex Ratio[a]	
Model	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Crude	1.08	(0.93 - 1.25)	1.06	(0.88 - 1.28)	1.10	(0.94 - 1.29)	0.99	(0.82 - 1.19)
Adjusted for individual-level confounders[b]	1.06	(0.91 - 1.24)	1.08	(0.89 - 1.32)	1.08	(0.95 - 1.29)	1.10	(0.87 - 1.28)
Adjusted for CT-level confounders[c]	1.13	(0.97 - 1.32)	1.03	(0.85 - 1.24)	1.04	(0.89 - 1.21)	1.01	(0.84 - 1.22)
Fully adjusted (individual- & CT-level confounders)	1.12	(0.95 - 1.33)	1.03	(0.84 - 1.27)	1.07	(0.90 - 1.28)	1.07	(0.86 - 1.32)
	Condom Non-Use							
	Women				Men			
	Low Sex Ratio[a]		High Sex Ratio[a]		Low Sex Ratio[a]		High Sex Ratio[a]	
Model	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Crude	1.03	(0.88 - 1.20)	0.94	(0.77 - 1.14)	0.95	(0.81 - 1.11)	0.89	(0.74 - 1.08)
Adjusted for individual-level confounders[b]	1.00	(0.86 - 1.17)	0.94	(0.77 - 1.15)	0.90	(0.77 - 1.06)	0.90	(0.74 - 1.10)
Adjusted for CT-level confounders[c]	1.14	(0.97 - 1.34)	0.96	(0.79 - 1.18)	0.91	(0.77 - 1.07)	0.88	(0.73 - 1.07)
Fully adjusted (individual- & CT-level confounders)	1.08	(0.91 - 1.28)	0.97	(0.78 - 1.19)	0.89	(0.74 - 1.08)	0.92	(0.73 - 1.14)

[a] All odds shown are likelihood of behaviors for those living in census tracts with low or high sex ratios compared to medium sex ratios.
[b] Model includes adjustment for the following: age, race/ethnicity, education, employment status, history of exchanging sex, history of incarceration, and age of sexual initiation.
[c] Model includes adjustment for the following: median age, % black, % married, % living under poverty level, % unemployed, and % with less than a high school education.

Chapter 2: A multi-level assessment of neighborhood vacancy rates and high-risk sexual behaviors among STD clinic patients

INTRODUCTION

The epidemiology of sexually transmitted diseases (STDs) in the United States is characterized by immense racial, social, and geographic inequality in the burden of disease (1-5). A study of individual-level risk factors alone is insufficient to fully describe this phenomenon. Understanding the evolution and persistence of these disparities requires consideration of a complex array of factors that characterize the social, cultural, and physical environments in which individuals live (6-8). One of the contextual factors potentially associated with shifts in the social and behavioral characteristics of both individuals and populations is related to neighborhood physical conditions.

The physical environment may provide direct cues that regulate group and individual behavior. That is, physical neighborhood deterioration and its association with reduced social cohesion and the breakdown of informal community controls, may lead to changes in individual behaviors. This “Broken Windows” theory was first proposed by Wilson and Kelling (1982) to explain the relationship between disorder and crime. According to this theory, "if a window in a building is broken *and is left unrepaired*, all the rest of the windows will soon be broken…one unrepaired broken window is a signal that no one cares” (9). The perception of disorder, or lack of informal neighborhood controls, may lead to an increase in socially undesirable behaviors. Signs of inappropriate behavior, such as graffiti or broken windows, have been demonstrated to lead to other inappropriate behaviors, a general deterioration of informal social controls in a community, and the spread of disorder (10-12).

Researchers have attempted to understand the complex interactions between neighborhood conditions and individual behavior in a variety of settings. While much of the original work focused on the association between neighborhood physical conditions and crime (9,13,14), subsequent studies have expanded this scope to include non-criminal behaviors and health outcomes (15,16). This expansion in focus from crime to health is not surprising, as areas with high crime rates also tend to exhibit higher morbidity and mortality rates from all causes, leading to the proposal that "crime and population health share the same social origins" (17). Indeed, factors that undermine the social fabric of a community, such as incarceration and crime, can become manifest in health outcomes such as STDs (18).

There is now a substantial body of evidence indicating that the status of an individual's physical environment plays an important role in influencing both health and health-related behaviors. Visible signs of disorder and deterioration (as evidenced by vacant or blighted lots, graffiti, litter, and so on), along with associated perceptions of neighborhood disorder, may impact overall well-being, mental health, child development, pregnancy, mortality, and myriad other health outcomes (19-22). For example, individuals living in neighborhoods with higher levels of perceived street-level incivilities (e.g., litter, graffiti, crime) are more likely to report frequent feelings of anxiety and depression, as well as overall poorer health (23,24). Furthermore, rates of potentially detrimental health behaviors, such as smoking and illicit drug use, are higher among individuals living in or exposed to areas with higher levels of neighborhood physical disorder and problems (25-27). Directly relevant to STD research, perceived neighborhood cohesion and other contextual factors have been associated with condom use and sexual initiation among adolescents (28,29).

Several ecological epidemiologic studies have linked population STD rates to neighborhood social cohesion and physical conditions. Cohen *et al.* (2000) examined the association between neighborhood conditions and gonorrhea rates using a "broken windows" index which assessed housing quality, abandoned cars, graffiti, trash, and public school deterioration in neighborhoods (30). They found that deteriorated physical conditions were robustly associated with gonorrhea rates, and this association was independent of neighborhood poverty rates. That is, neighborhoods with high levels of poverty and high broken window scores had gonorrhea rates almost twice that of equivalently high-poverty neighborhoods with low broken window indexes. In an expanded ecological study of neighborhood deterioration and health in 107 U.S. cities, Cohen *et al*. (2003) again noted associations between morbidity from sexually transmitted disease, as well as premature mortality from all causes, with neighborhood physical deterioration as measured by the presence of boarded-up vacant housing units (31). These associations remained after controlling for other known socioeconomic correlates of premature mortality and STDs. Finally, Ellen *et al*. (2004) found that perceived social cohesion was significantly lower among young adults residing in census block groups with high gonorrhea rates compared with those residing in block groups with low rates (32).

Overall, the conclusion that can be drawn from these studies is that the physical characteristics of an individual's neighborhood may have an important role in influencing high-risk sexual behaviors. However, the hypothesized association between neighborhood disorder and individual-level sexual behaviors has rarely been examined directly. Most previous studies have been ecological in nature and limited to using STD incident rate data with the census block group or city as the unit of analysis (30,31). These studies have not had access to information on sexual risk behaviors themselves, only on area-level STD rates. While ecological studies are

useful in identifying the determinants of disease prevalence in populations, a more direct examination of the relationship between neighborhood deterioration and individual sexual behaviors is needed to further support the proposed hypothesis, as sexual behaviors may mediate the association between neighborhood deterioration and STD incidence.

This study endeavored to evaluate the association between neighborhood deterioration and high-risk sexual behaviors more directly than has been done previously by assessing variations in self-reported behaviors by neighborhood vacancy rates. In doing so, we hoped to determine whether focus on neighborhood physical conditions might be pertinent in guiding future STD prevention efforts. A multi-level modeling approach was used to account for both individual-level and neighborhood-level effects on the likelihood of having multiple sex partners. We hypothesized that greater neighborhood deterioration is associated with increased likelihood engaging in high-risk sexual behaviors among individuals residing in those neighborhoods, beyond influences attributable to either individual- or area-based factors alone.

METHODS

Data Sources

We used two data sources for this cross-sectional study. Individual-level interview data were obtained from the STD Surveillance Network (SSuN). Area-based data were pulled from the U.S. Census Bureau.

SSuN is a Centers for Disease Control and Prevention (CDC) sponsored enhanced surveillance project comprised of a network of STD clinics and health departments across the United States. The SSuN platform has been described previously (33, 34). In Virginia, the health departments in the localities of Richmond City, Henrico County, and Chesterfield County

participate in SSuN. All individuals presenting to public STD clinics located within these localities are asked to complete a self-administered interview form upon registration. Completion of this interview form is voluntary, but response rates are generally high (i.e. over 74%). Interview data were collected continuously from January 1, 2008 through December 31, 2010, and captured information on basic patient demographics, socioeconomic characteristics, and high-risk behaviors for 13,714 unique patients. When patients had multiple complete interview forms on record from different visits to the STD clinic, only data from one randomly selected visit was included in the analysis.

Geographic information, in the form of patient residential addresses, was also captured on the interview forms. These data were geocoded using Centrus software (Pitney Bowes Business Insight) to obtain census tract assignments. Patients lacking valid address information (N = 270, 2%) were excluded from this analysis. No differences were noted between patients with valid and invalid addresses with regard to primary study measures. Analyses were limited to patients residing in Richmond City (N = 6,391).

Area-based demographic and socioeconomic measures were derived from the U.S. Census Bureau's 2005-2009 American Community Survey 5-year estimates for the census tracts located within Richmond City (35).

Study Measures

The general outcome of interest in this study was individual sexual risk behavior, which was operationally defined as the self-reported number of sexual partners in the last three months. This measure was dichotomized, such that patients were categorized as having had zero to one or more than one sexual partner (hereafter referred to as multiple sex partners).

The conceptual determinant of interest in this study was neighborhood physical condition; or more specifically, visible signs of neighborhood disorder. Neighborhood deterioration by census tract was approximated using the number of vacant housing units per 1,000 residential units (excluding vacation properties). We dichotomized our exposure measure to allow us to examine the odds of multiple sex partners among individuals living areas with high vs. low levels of neighborhood deterioration. The univariate distribution of vacant residential units was used to determine the categorical cut-points for analysis using the 3rd interquartile range (cut-point at 19.92 vacant units per 1,000). This categorization was made without regard to the outcome measure to avoid biasing the resulting estimates (36).

A combination of individual-level and area-level factors were examined as potential confounders in the relationship between neighborhood deterioration and multiple sex partners. At the individual-level, this included self-reported interview data on various socio-demographic characteristics (age, sex, sexual orientation, race/ethnicity, education, and employment status), sexual history (age of first intercourse, exchanging sex), and history of incarceration. These factors are known to be associated with increased likelihood of engaging in high-risk sexual behaviors (37-41).

The relationship between area-based measures and sexual behavior has not been well defined in the literature. However, conceptually, we anticipate that similar socio-economic factors operate to influence individual behaviors at both the individual- and area-levels. Therefore, several measures calculated at the census tract level were assessed as potential confounders, including: median age, poverty rate (% of the population living below the federal poverty level), race (% black), marital status (% over 15 years currently married), educational attainment (% over 25 years with a high school degree), and unemployment (% civilian labor

force over 15 years currently unemployed). For consistency and ease of interpretation, these measures were treated as categorical variables in the analysis based on their quartile distributions.

Statistical Analysis

For all analyses, the primary unit of analysis was the individual, but both individual-level and area-based determinants were considered. We hypothesized effect modification by gender, as the frequency of multiple sex partners varies significantly between men and women and is driven by different social influences. Therefore all analyses were stratified by gender, although the formal evaluation of effect measure modification was beyond the scope of this study.

During preliminary analyses we evaluated bivariate associations between all study measures and various potential confounders. These bivariate comparisons were used to assess the potential for confounding by the individual and area-based measures. We then performed unadjusted logistic regression analyses to compare the odds of multiple sex partners by high compared to low vacancy areas, as well as by the other individual- and area-based measures. We used the results of these preliminary analyses in combination with conceptual considerations to inform the model building process and determine which selection of variables to include in adjusted models.

We assessed association between vacancy rates and multiple sex partners using separate multi-level logistic regression models for men and women, applying a random effects modeling method to simultaneously examine the effects of both individual-level and neighborhood-level factors on sexual risk behavior. A multi-level approach was used since we examined individuals (i.e. patients) grouped within contexts (i.e. census tracts), and thus variability was introduced at

both the individual and contextual levels (42-45). We evaluated confounding by adding covariates to the models in a stepwise manner and assessing the impact of each covariate on the estimate of effect. Covariates that changed the estimate of effect more than 10 percent were retained in the final model. All analyses were performed with SAS version 9.3, using PROC MIXED for multi-level regression modeling.

Sensitivity Analysis

Several sensitivity analyses were performed to validate our main multi-level logistic regression analysis test the robustness of these findings. Alternative forms of exposure to our main determinant (vacancy rates) were created to assess the impact our choice of arbitrary categorization might have had on the relationship under study. These alternative forms included a priori categorization at 2 and 3 levels (using different cut-points based on univariate distribution of the data), as well as treating vacancy rates as a continuous variable. Additionally, the number of sex partners was assessed as a continuous variable using Poisson regression modeling, also performed across different forms of the exposure.

RESULTS

There were a total of 6,347 patient interviews available for analysis (excludes 12 transgender patients and 32 patients with missing gender). Patients were fairly evenly distributed between men (N = 3,273) and women (N = 3,074). The majority were black (84.0%), heterosexual (89.9%), and between 20 and 34 years of age (60.0%). The proportion of patients reporting multiple sex partners in the previous 3 months was higher among men (50.9%) than among women (35.6%). Characteristics of the interviewed patients by dichotomized vacancy

rates are summarized in Table 1. Overall, 785 (25.5%) of the women and 957 (29.2%) of the men resided in census tracts classified as having high vacancy rates. While there was no notable difference in reporting multiple sex partners (i.e. 2 or more sex partners) among women living in census tracts with low compared to high vacancy rates, men living in high vacancy tracts were slightly more likely to report having multiple sex partners (53.9% compared to 49.7%). Most of this difference was driven by men who reported 3-4 sex partners (18.7% among high vacancy tracts compared to 14.3% among low vacancy tracts). There was no difference in the median number of sex partners across high and low vacancy tracts for either men (median = 2; interquartile range (IQR): 1, 2) or women (median = 1; IQR: 1, 2).

STD clinic patients were residents of 63 census tracts in Richmond City, Virginia. The average vacancy rate among these tracts was 14.6 per 100 residential units (range: 0.0, 40.3). Census tract characteristics stratified by sex ratios are summarized in Table 2. Not surprisingly, the median percent of the population that was unemployed was highest in tracts with high vacancy rates (median = 15.8; IQR: 7.6, 21.5) compared to low vacancy rates (median = 7.6; IQR: 4.8, 11.8). The median percent living below the poverty level and percent black were also higher among high vacancy tracts. There was an average of 101 patients per tract (range: 4, 323).

The odds of reporting multiple sex partners by potential individual- and population-level confounders are presented in Tables 3 and 4 respectively. For both men and women, younger patients were significantly more likely to report multiple sex partners compared to older patients. There was little difference between heterosexual and homosexual individuals, but patients reporting bisexual orientation were more likely to report multiple sex partners (odds ratio (OR) = 3.8; 95% confidence interval (CI): 2.8, 5.3). Early age of first sexual intercourse was also

strongly associated with increased risk of reporting multiple sex partners, with the odds 2.6 (95% CI: 2.0, 3.4) times greater among the very early initiations (< 14 years) compared to the late initiators (18+ years). Only slight differences in behavior were noted by race/ethnicity, education, or employment status. At the population-level, only measures of percent unemployment for women and percent married or with less than high school education for men were associated with multiple sex partners.

Multi-level logistic regression modeling results are presented in Table 5. Among women, the odds of having multiple sex partners did not vary by whether they lived in tracts with high or low vacancy rates, regardless of adjustment for either individual-level or tract-level confounders (crude OR = 0.98; 95% CI: 0.79, 1.20). We observed a slight difference in behavior among men, such that men residing in high vacancy tracts had marginally greater odds of reporting multiple sex partners (crude OR = 1.18; 95% CI: 0.99, 1.42). This estimate did not vary notably when the association between multiple sex partners and vacancy rates was adjusted for individual-level or tract-level potential confounders, although the association lost strict statistical significance in the fully adjusted model. Age of first sex and percent unemployment were the strongest confounders of this relationship, but neither impacted the estimate of effect by more than 10%.

Results of sensitivity analyses supported these findings. Alternative parameterizations of vacancy rates did not yield different estimates of effect; the relationship between vacancy rates and number of sex partners remained non-significant. We also re-ran all multi-level logistic regression models while limiting the study population to patients who lived in census tracts with a minimum of 10 patients to ensure an adequate number of patients per tract for analysis of patient differences both within and between tracts. Only 25 women and 34 men (or 5 and 4

census tracts respectively) were excluded based on these criteria, and their exclusion did not alter any of our findings.

DISCUSSION

The broken windows theory posits that visual cues related to deterioration of the physical environment are associated with reduced social cohesion, the breakdown of informal community controls, and ultimately changes in individual behaviors (9,15,16). With regard to STDs, physical neighborhood deterioration may influence individual engagement in high-risk sexual behaviors and subsequently population STD rates. Our study improves upon previous research in the field of STDs and broken windows as we were able to incorporate information on self-reported sexual risk behaviors and individual characteristics as well as neighborhood-level contextual factors. Previous ecological studies (30,31) have not directly assessed individual behaviors.

Here we evaluated the association between high neighborhood vacancy rates and the likelihood of having multiple sex partners among a population of STD clinic patients. We found no association between high vacancy rates and greater likelihood of having multiple sex partners among women (OR = 0.98; 95% CI: 0.79, 1.20), and only a marginally increased odds among men (1.18; 95% CI: 0.99, 1.42). This small increase is unlikely to be practically significant. These estimates remained essentially unchanged after accounting for the influence of either individual-level or neighborhood-level potential confounders. These findings were robust across various sensitivity analyses utilizing different parameterizations of primary variables and alternative regression models. Our findings indicate that vacancy rates are likely not a strong predictor of individual behaviors among STD clinic patients.

Consistent with previous research, we found that men in general reported greater numbers of sexual partners than did women (46,47). Also consistent with the literature, having greater numbers of sex partners was associated with younger current age (47), and age of sexual initiation (48,49). Unlike previous research, we did not find that blacks reported greater numbers of sex partners than whites; in contrast, white patients were slightly more likely to report having multiple sex partners (48% among whites vs. 43% among blacks), although this association was only significant among women. Few previous studies have assessed associations between area-based measures and number of sex partners, but STD rates are associated with several area-based measures, such as neighborhood deterioration (30,31), crime rates and social disorder (18,32), poverty and racial/ethnic composition (6,50,51). Sexual initiation is also related to several dimensions of neighborhood context, including socioeconomic characteristics and racial/ethnic composition (29,52).

Previous work has indicated that concentrated poverty, income inequality, and racial/ethnic composition are all associated with decreased community social cohesion and both subjective (perceived) and objective disorder (53-55). Theoretically these factors should also be associated with variations in individual behaviors, as has been indicated by studies of sexual initiation and condom use (28,29). We therefore assessed these contextual factors as potential confounders in the relationship between vacancy rates and multiple sex partners. However, while racial composition (% black) and marriage rates were independently associated with increased risk of multiple sex partners, other population-level factors were not, and we did not note any significant modification in the relationship between vacancy rates and multiple sex partners due to inclusion of these factors in our multi-level models.

There are some important considerations to note in the interpretation of this analysis. Our study population was limited to patients attending public STD clinics. Previous research has indicated that STD clinic attendees differ from the general population in terms of various socio-economic indicators and behaviors, and that the epidemiology of STD epidemics are fundamentally different in these settings (56). For example, the frequency of multiple sex partners and concurrency is often significantly higher in the STD clinic population than in the general population. For example, among our study population, 51% of men and 36% of women reported having two or more sex partners in the previous 3 months (22% and 11% reported 3 or more). Previous national studies have indicated that these proportions in the general population are between 17-18% and 10-14% over the past year for men and women respectively (46,47), although frequencies are higher among blacks, non-married individuals, and younger age groups which comprise the largest proportion of patients visiting Richmond area STD clinics. Such variation in sexual behaviors between populations could significantly impact the association between behavior and neighborhood characteristics. While we believe that studying characteristics of the specialized and often disadvantaged populations that visit STD clinics is a valid and important endeavor, our findings may be of limited generalizability.

We chose to assess the association between neighborhood vacancy rates and one specific high-risk behavior; having multiple sexual partners. This outcome measure was chosen because of its strong associations with both individual risk of acquiring an STD and enhanced spread of STDs through populations (57-59). However, we were missing data on patient marital status, as this information was not captured on the SSuN interview forms. Marital status is strongly associated with having multiple partners (47,60). We believe it unlikely that this missing data impacted our current findings as a brief review of clinic records indicate that only a small

proportion of STD clinic patients are currently married. Nonetheless, recommendations have been made to modify future SSuN data collection activities to capture this important indicator.

We used data from the 2005-2009 ACS 5-year estimates to calculate our main determinant measure using residential vacancy rates at the census tract level as a proxy for neighborhood deterioration. Some argue that measures derived from direct observation of neighborhood physical conditions may be better suited than theoretically related measures obtained from administrative data sources (16,61,62). For example, census-based data generally fail to capture key physical properties of neighborhoods such as graffiti, abandoned cars, litter, and so on, which are concrete physical signs of neighborhood disorder and possible manifestations of deteriorating social cohesion. However, the costs of such direct observations are generally considerable (15), and may not yield substantial analytical benefits when assessing physical neighborhood deterioration. After a series of studies conducted in New Orleans, Cohen *et al*. (2003) concluded that the Census-derived measure of vacant boarded-up houses was a relatively good proxy for neighborhood deterioration based on direct observation methods (30,31,63). While this exact measure is not available for post-1990 Census data, the rate of vacant residential units used for this study is a close surrogate. Additionally, direct observation measures may exhibit shortcomings when applied to diverse neighborhoods (62), and observational methodologies are not standardized making comparisons across studies difficult (64,65).

In contrast, while physical markers are often used as objective measures of disorder, it is possible that the individual perception of disorder rather than actual measurable indicators of such may have more influence on behavior (28,29,66,67). For example, Perkins & Taylor (1996) found that cues in the social and physical environment generate a fear of crime in

residents that is distinct from crime itself (68). Nonetheless, using tangible physical signs of disorder to approximate perceived disorder is not totally unwarranted, especially in lieu of readily available data on community resident perceptions.

Our choice of the census tract as our area-based unit of analysis, to serve as a proxy for an individual's neighborhood environment, is supported by the literature (69). However, census-based measures may be of limited utility in measuring socially-based phenomena (15,70). The relation between disorder and health behaviors may be more adequately explained by social rather than physical characteristics of the environment, often conceptualized as neighborhood social cohesion, social capital, or collective efficacy (18,71-73). However, the concept of social cohesion has been variously defined (74,75), effects may vary by context and population subgroup (76,77), and capturing it is difficult and relies on subjective perceptions of social networks, organizations and structures. Furthermore, it is not unreasonable to assume that physical neighborhood deterioration is in fact associated with the more nebulous phenomena of social cohesion and disorder, and that the two are generally highly interrelated.

Finally, we need to acknowledge that the potential role of neighborhood temporal dynamics on behaviors might be of interest in itself (15). The majority of studies examining neighborhood effects and social processes which impact health are cross-sectional in design, including the current study. Future research may want to focus on associations between variations in behaviors as neighborhoods change over time. Additionally, not all vacancies have the same meaning, and neighborhood age or socio-economic status may be moderating factors. The housing market collapse of 2008 occurred during this study period, likely resulting in dramatic changes in residential vacancies that were not tied to actual neighborhood deterioration. For example, it is likely that there were high vacancy rates in newly developed neighborhoods as

many units sat empty awaiting economic rebound. At the same time, there were likely decreases in vacancies in neighborhoods comprised predominantly of rental properties, where there might be more crowding and risk behavior. A closer look at the impact of major housing market changes is warranted in future work.

There are intriguing practical applications associated with the study of broken windows and health, in that broken windows can potentially be fixed. Unlike many other potential social determinants of health and sexually transmitted disease, such as poverty and race/ethnicity, where the implications for prevention are vague, broken windows are a programmatically addressable factor. Graffiti can be removed, boarded-up houses can be renovated, and community gardens or parks can be added. While it has never been conclusively proven (11,78), the possibility that reducing signs of physical disorder in a community might have a corresponding impact on reducing social disorder lends itself to intriguing prevention opportunities. However, we found no evidence that neighborhood vacancy rates influence individual risky sexual behaviors among STD clinic patients. Future research is still needed to determine whether measures of broken windows might be a useful consideration in prevention programs for the general population.

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TABLES

Table 2.1. Potential individual-level confounders stratified by gender and vacancy rate[a]

	Women				Men			
	Low Vacancy (N = 2,289)		High Vacancy (N = 785)		Low Vacancy (N = 2,316)		High Vacancy (N = 957)	
Patient Characteristics[b]	N	%	N	%	N	%	N	%
Age								
<20 years	469	20.5%	188	23.9%	282	12.2%	133	13.9%
20-24 years	820	35.9%	227	28.9%	663	28.7%	279	29.2%
24-34 years	600	26.2%	171	21.8%	771	33.3%	274	28.7%
35+ years	398	17.4%	199	25.4%	598	25.8%	269	28.2%
Race/Ethnicity								
Black (Non-Hispanic)	1,898	83.4%	708	90.7%	1,842	79.9%	846	89.4%
White (Non-Hispanic)	195	8.6%	45	5.8%	305	13.2%	67	7.1%
Hispanic	138	6.1%	17	2.2%	133	5.8%	25	2.6%
Other (Non-Hispanic)	44	1.9%	11	1.4%	24	1.0%	8	0.8%
Sexual Orientation								
Heterosexual	1,665	90.5%	545	88.0%	1,617	89.6%	650	90.9%
Homosexual	49	2.7%	19	3.1%	133	7.4%	47	6.6%
Bisexual	126	6.8%	55	8.9%	54	3.0%	18	2.5%
Education								
< High school	395	18.1%	169	22.7%	470	21.2%	215	24.3%
High school graduate/GED	867	39.7%	316	42.4%	908	40.9%	413	46.6%
> High school	924	42.3%	261	35.0%	844	38.0%	258	29.1%
Employment Status[c]								
Employed	776	35.8%	207	27.5%	999	45.2%	370	41.2%
Unemployed	549	25.3%	243	32.3%	656	29.7%	322	35.9%
Student (full- or part- time)	662	30.5%	235	31.3%	424	19.2%	155	17.3%
Other	182	8.4%	67	8.9%	132	6.0%	51	5.7%
History of exchanging sex[d]	17	0.7%	16	2.0%	26	1.1%	8	0.8%
History of incarceration [d]	87	3.8%	38	4.8%	191	8.2%	101	10.6%
Age of first sexual intercourse								
<14 years	383	18.9%	137	20.0%	387	23.9%	188	30.3%
14-15 years	631	31.2%	228	33.3%	478	29.6%	158	25.4%
16-17 years	654	32.3%	219	32.0%	397	24.6%	162	26.1%
18+ years	354	17.5%	101	14.7%	354	21.9%	113	18.2%
Number of sex partners[e]								
0 partners	101	4.7%	33	4.5%	118	6.0%	54	6.9%
1 partner	1,280	59.5%	446	60.5%	873	44.3%	308	39.2%
2 partners	538	25.0%	183	24.8%	573	29.1%	227	28.9%
3 partners	134	6.2%	48	6.5%	191	9.7%	95	12.1%
4 partners	44	2.0%	14	1.9%	91	4.6%	52	6.6%
5+ partners	54	2.5%	13	1.8%	124	6.3%	49	6.2%

a Rate of vacant residental housing units, dichotomized based on 3rd interquartile range (cutpoint at 19.92%)

b There are missing data for some demographic and behavioral variables.

c Employed includes employed and self-employed; Other includes homemaker, retired, and unable to w ork

d In previous 12 months

e Number of sex partners in the previous 3 months

Table 2.2. Census tract characteristics stratified by vacancy rate

Census Tract Characteristic	Low Vacancy Rate[a] median	(IQR)	High Vacancy Rate[a] median	(IQR)
Median age	32.65	(29.3 - 39.9)	37.60	(31.0 - 44.3)
Percent black	53.94	(15.7 - 82.1)	86.26	(44.6 - 91.1)
Percent married	31.19	(22.4 - 38.2)	25.44	(23.2 - 31.2)
Percent living below poverty level	16.76	(11.1 - 29.9)	20.16	(17.3 - 32.4)
Percent unemployed	7.61	(4.8 - 11.8)	15.78	(7.6 - 21.5)
Percent with HS education	83.55	(74.0 - 93.3)	73.83	(69.4 - 83.5)

[a] Rate of vacant residental housing units, dichotomized based on 3rd interquartile range (IQR): low vacancy < 19.92%; high vacany >= 19.2%.

Table 2.3. Odds of multiple sex partners by potential individual-level confounders

	Women		Men	
Potential Confounders	OR[a]	(95% CI)	OR[a]	(95% CI)
Age				
<20 years	1.84	(1.43 - 2.37)	1.36	(1.05 - 1.76)
20-24 years	1.77	(1.41 - 2.24)	1.31	(1.07 - 1.60)
24-34 years	1.69	(1.32 - 2.16)	1.22	(1.00 - 1.48)
35+ years	1.00	--	1.00	--
Race/Ethnicity				
White (NH)	1.00	--	1.00	--
Black (NH)	0.71	(0.54 - 0.94)	0.97	(0.78 - 1.22)
Hispanic	0.50	(0.32 - 0.79)	0.74	(0.49 - 1.11)
Other (NH)	0.71	(0.38 - 1.31)	0.62	(0.27 - 1.41)
Sexual Orientation				
Heterosexual	1.00	--	1.00	--
Homosexual	1.09	(0.66 - 1.81)	1.33	(0.97 - 1.82)
Bisexual	3.81	(2.76 - 5.27)	1.31	(0.81 - 2.12)
Education				
< High school	1.11	(0.89 - 1.38)	0.99	(0.81 - 1.22)
High school graduate/GED	1.00	--	1.00	--
> High school	1.09	(0.91 - 1.29)	1.15	(0.97 - 1.37)
Employment Status[b]				
Employed	1.00	--	1.00	--
Unemployed	1.16	(0.95 - 1.41)	1.02	(0.85 - 1.22)
Student (full- or part- time)	1.07	(0.88 - 1.30)	1.14	(0.93 - 1.41)
Other	0.96	(0.71 - 1.31)	0.78	(0.55 - 1.09)
History of exchanging sex[c]	2.25	(1.08 - 4.69)	5.29	(2.03 - 13.78)
History of incarceration[c]	1.65	(1.14 - 2.37)	0.85	(0.66 - 1.09)
Age of first sexual intercourse				
<14 years	2.61	(1.99 - 3.43)	1.33	(1.04 - 1.70)
14-15 years	1.79	(1.39 - 2.30)	1.29	(1.01 - 1.65)
16-17 years	1.27	(0.98 - 1.64)	1.32	(1.03 - 1.69)
18+ years	1.00	--	1.00	--

[a] Odds ratios are for having 2 or more partners in the previous 3 months compared to having 0-1 partners

[b] Employed includes employed and self-employed; Other includes homemaker, retired, and unable to work

[c] In previous 12 months

Table 2.4. Odds of multiple sex partners by potential population-level confounders

	Women		Men	
Potential Confounders	OR[a]	(95% CI)	OR[a]	(95% CI)
Median Age				
< 30 years	1.14	(0.93 - 1.39)	1.06	(0.87 - 1.28)
30-34 years	0.89	(0.69 - 1.15)	0.82	(0.66 - 1.03)
35-40 years	1.27	(0.99 - 1.64)	0.96	(0.76 - 1.22)
40+ years	1.00	--	1.00	--
Percent black				
< 20%	1.00	--	1.00	--
20-59%	0.91	(0.63 - 1.31)	1.31	(0.98 - 1.77)
60-79%	1.29	(0.88 - 1.87)	1.39	(1.00 - 1.93)
80%+	0.99	(0.70 - 1.40)	1.38	(1.04 - 1.83)
Percent married				
< 20%	1.28	(0.89 - 1.86)	1.43	(1.01 - 2.03)
20-29%	1.21	(0.86 - 1.72)	1.27	(0.92 - 1.75)
30-39%	1.31	(0.92 - 1.86)	1.19	(0.86 - 1.64)
40%+	1.00	--	1.00	--
Percent living below poverty level				
<10%	1.00	--	1.00	--
10-19%	0.75	(0.53 - 1.06)	0.99	(0.72 - 1.38)
20-29%	0.92	(0.65 - 1.29)	1.00	(0.72 - 1.40)
30%+	0.83	(0.59 - 1.16)	1.01	(0.73 - 1.40)
Percent unemployed				
<5%	1.00	--	1.00	--
5-8%	1.38	(1.02 - 1.85)	1.08	(0.84 - 1.41)
9-13%	1.22	(0.91 - 1.64)	1.09	(0.84 - 1.41)
14%+	1.22	(0.92 - 1.63)	1.27	(0.98 - 1.64)
Percent with HS education				
<70%	0.87	(0.62 - 1.21)	1.33	(1.00 - 1.76)
70-79%	0.88	(0.63 - 1.23)	1.53	(1.16 - 2.03)
80-89%	0.92	(0.65 - 1.31)	1.33	(0.99 - 1.79)
90% +	1.00	--	1.00	--

[a] Odds ratios are for having 2 or more partners in the previous 3 months compared to having 0-1 partners

Table 2.5. Multi-level logistic regression results for the odds of having multiple sex partners

	Women		Men	
	High vs Low Vacancy		High vs Low Vacancy	
Model	OR[a]	(95% CI)	OR[a]	(95% CI)
Crude	0.98	(0.79 - 1.20)	1.18	(0.99 - 1.42)
Adjusted for individual-level confounders[b]	0.96	(0.74 - 1.24)	1.16	(0.92 - 1.45)
Adjusted for CT-level confounders[c]	0.95	(0.72 - 1.24)	1.15	(0.89 - 1.48)
Fully adjusted (individual-& CT-level confounders)	1.00	(0.73 - 1.39)	1.17	(0.85 - 1.61)

[a] Odds of multiple sex partners among individuals living in census tracts with high compared to low vacancy rates.

[b] Model includes adjustment for the following: age, race/ethnicity, sexual orientation, education, employment status, history of exchanging sex, incarceration within the past year, and age of first sexual intercourse.

[c] Model includes adjustment for the following: median age, % black, % married, % living under poverty level, % unemployed, and % with less than high school educaiton.

Chapter 3: Residential segregation and gonorrhea rates in U.S. metropolitan statistical areas

INTRODUCTION

The epidemiology of sexually transmitted disease (STD) in the United States is characterized by immense racial, social, economic, and geographic inequality. In the 2009 annual summary of STD surveillance, the Centers for Disease Control and Prevention (CDC) reported that national rates of *Neisseria gonorrhoeae* (NG) infection were approximately 20 times higher in blacks than whites, and Chlamydia rates were more than eight times higher in blacks.[1] The residential segregation of black populations, often in areas of high economic disadvantage and low social status, may play a crucial role in the observed racial inequities in health.[2-3] Despite significant social changes over the last half century, most metropolitan cities in the United States remain extremely segregated along racial and economic lines.[3-5]

Residential segregation, especially on the dimensions of concentration and isolation, is believed to be conducive to the spread of infectious diseases.[6-7] STDs such as gonorrhea are inherently social diseases, surviving and proliferating through continued interactions between individuals in a social group.[8] Residential segregation creates distinct social networks with little crossover among them. While this might inhibit the spread of disease outside of these networks, it may also perpetuate the persistence of endemically high rates within them. Therefore, residential segregation is likely a key component in the endemically high rates of STDs observed among socially disadvantaged black populations.

A few previous ecological studies have indicated that racial segregation is associated with rates of syphilis, gonorrhea, and chlamydia.[9-11] However, there are several limitations to the

existing literature regarding segregation and STDs. Most previous studies have utilized relatively simple measures of residential segregation, such as racial composition.[10-11] Such measures are generally considered a poor proxy for segregation as they fail to fully capture the spatial distribution of racial settlement patterns.[12-13] More sophisticated measures, such as the isolation index, are generally believed to be better at measuring the actual degree of segregation across a defined geographic area.[14] Additionally, many previous studies have assessed segregation measures at the county or city level.[9-10] This may introduce bias and lead to mis-estimation of segregation effects as important trends in segregation may exist only when counties are considered in context. Residential segregation tends to be a metropolitan-area phenomenon, with the largest disparities in income and racial residential patterns observed between central cities and their outlying suburbs.[15-16] For example, in most metropolitan areas, blacks are substantially more likely than whites to reside in the central city than in the surrounding suburban counties. Therefore, the MSA is arguably a better geographic context for the study of segregation effects on health.

Finally, research considering the interaction between economic and racial segregation is still largely lacking, despite evidence that both are important predictors of neighborhood settlement patterns and likely of STD rates.[16-17] The purpose of this study was therefore to address these three issues by performing an ecological analysis to examine the influence of racial and economic residential segregation, both independently and in combination, on gonorrhea rates in U.S. metropolitan areas. Our hypothesis was that higher degrees of residential racial and economic segregation are independently associated with higher gonorrhea rates in metropolitan areas, and that MSAs that are highly segregated across both of these dimensions will experience higher rates of gonorrhea than areas segregated along only one.

METHODS

This was a cross-sectional, ecological study. The study population was comprised of United States metropolitan statistical areas (MSAs) with total populations of 100,000 or more and black populations of at least 5,000. In addition to ensuring sufficient data per unit for analysis, this strategy for selecting MSAs was comparable to that applied by previous studies of black segregation and health.[18-19] MSAs were constructed by the Office of Management and Budget to define counties (i.e. suburbs) clustered around a central city.[20]

Data on annually reported cases and rates of gonorrhea from 2005 to 2009 for MSAs were obtained from the CDC. The CDC receives morbidity data for notifiable infectious diseases through regular reporting from state and local disease surveillance systems.[1]. Measures of residential racial and economic segregation for each MSA were extracted from the U.S. Census Bureau's American Community Survey (ACS) 2005-2009 5-year estimates. These data were based on a sampling of approximately 3 million addresses each year, or nearly 2 million final interviews annually.[21]

The primary outcome measure for study was the 5-year (2005-2009) average gonorrhea incidence rate at the MSA-level per 100,000 person-years. Gonorrhea rates were defined as the total number of gonorrhea cases reported from the counties comprising each MSA during the defined time period (i.e. all cases diagnosed each year), divided by the Census-estimated population of that MSA during the same period. MSAs were classified as having either high or low gonorrhea rates based on whether they fell above or below the average national rate for the 2005-2009 time period (112.4 cases per 100,000 person-years).[1]

Two measures were assessed in this study as potential determinants of STD rates: racial and economic residential segregation. Racial segregation was assessed using the isolation index,

while economic segregation was estimated using the Gini index of household income inequality. The isolation index measures between-group contact, or the extent to which members of a minority population are exposed to other members of the same minority population.[22] Specifically, the degree of black isolation relative to whites was the focus, since black isolation may be better suited to capturing patterns of unhealthy exposures and infectious disease risk than many other measures of distribution.[6,9,13] Operationally, the racial composition of each census tract within its larger MSA region was used to calculate the isolation index, which is computed as the minority-weighted average of the minority proportion in each area.[14, 22] The isolation index ranges from 0 to 1.0, with higher values indicating a greater degree of isolation. The Gini index of household income inequality also ranges from 0.0 to 1.0. Lower values indicate that all households have equal shares of income, whereas higher values approaching 1.0 indicate that the majority of income is consolidated into a few households.[23-24]

Metropolitan areas were classified as either high or low segregation based on the distributional properties of the data combined with conceptual considerations for both measures of segregation. This categorization was made without regard to the outcome measure to avoid biasing the resulting estimates.[25] Dichotomizing our exposure measures allowed us to examine the distribution of gonorrhea rates among areas with high vs. low levels of segregation, and permitted us to maximize the contrast between these two exposure groups while conserving statistical power. Sensitivity analyses were conducted with alternative parameterizations (median split, natural breaks, continuous) for both segregation indices as well as for gonorrhea rates to assess whether our choice of categorization influenced findings.

MSA-level measures that were included in the analysis to control for the potentially confounding effect of context on the relationship between segregation and gonorrhea rates,

included: median age, racial composition (% of the population that is black), education (% of population 25 years and over with less than high school education), population density (population per square kilometer), poverty (% of people living below the poverty level), median annual household income, unemployment (% of civilian labor force 16 years and over currently unemployed), marital status (% of population 15 and over currently married), and the percent of female headed households. All of these contextual factors are associated with both gonorrhea rates and segregation, and similar covariates have been assessed in previous segregation studies. [1,9,11] Continuous variables were dichotomously categorized according to natural breaks in their distribution. Geographic region (northeast, midwest, south and west) was also considered as a potential confounder as high gonorrhea rates tend to be concentrated in the south, and patterns of residential segregation also vary substantially by region.[1,4] In initial analyses we included each of the four regions, but because of the small numbers of MSAs with high gonorrhea rates in some regions, we collapsed geographic regions into two groups (south or midwest; northeast or west) for the assessment of effect modification. Geographic region was treated as a fixed effect in the modeling process.

Statistical Analysis

Preliminary analyses assessed bivariate associations between the two segregation indices of interest (black isolation and Gini), other contextual variables, and gonorrhea rates at the MSA-level. These bivariate comparisons were used to assess the potential for confounding and collinearity. The results of preliminary analyses were used in combination with conceptual considerations to inform the model building process and determine which selection of variables to consider for inclusion in adjusted models.

Logistic regression models were used to assess the relationship between gonorrhea rates at the MSA-level and the two contextual determinants of interest. Initially, separate regression models were run for each determinant to examine whether each was independently associated with gonorrhea rates after adjusting for other MSA-level socioeconomic factors identified as potential confounders. Confounding was evaluated using an iterative process evaluating the impact of covariates on the estimates of effect. Covariates whose addition changed the estimate of effect more than 10 percent were retained in the model.

Effect measure modification was assessed by evaluating departures from additivity and multiplicativity.[25-26] First, we included 3 dummy variables in the model to capture the combined black isolation and Gini indices with low black isolation and low Gini indices as the reference category. From this model, we estimated the relative excess risk due to interaction for the adjusted odds ratio (RERI-OR) and associated likelihood-based 95% confidence intervals.[26] Next we included a product-term for the interaction between the black isolation and Gini indices, and assessed the resulting coefficient to determine departure from a multiplicative model. We hypothesized that the combination of racial and economic segregation would result in a positive departure from additivity and multiplicativity. That is, we expected that income segregation modifies the relationship between racial segregation and STD rates, and vice versa, such that areas that are highly segregated both racially and economically experience significantly higher gonorrhea incidence than do areas that are highly segregated along just one of these dimensions.

RESULTS

A total of 277 metropolitan statistical areas were included in this analysis, 156 of which were categorized as having high gonorrhea rates (above the national average of 112.4 cases per 100,000) for the 2005-2009 time period. Gonorrhea rates in all MSAs ranged from 12.3 to 466.4 cases per 100,000 person-years, with higher rates observed among MSAs in the southern and mid-western regions of the U.S. The average black isolation index across all MSAs was 0.30 (SD = 0.18), while the average Gini index was 0.45 (SD = 0.02).

Among MSAs with high-gonorrhea rates, 68.6% and 61.5% were also categorized as having high black isolation indices and Gini indices respectively. Conversely, among low-gonorrhea rate MSAS, only 17.4% and 35.5% were categorized as having low isolation and Gini indices. The distribution of other MSA characteristics by low and high gonorrhea rates are summarized in Table 1. MSAs with high gonorrhea rates had higher proportions of most indicators of socio-economic disadvantage relative to MSAs with low rates. For example, the proportion of female headed households was 58.3% compared to 13.2% among MSAs with high and low gonorrhea rates respectively.

MSAs with a high black isolation index had an approximately 10-fold increased odds of high gonorrhea rates (crude OR = 10.4, 95% CI: 5.8-18.6). The crude odds of high gonorrhea rate were 2.9 times greater for MSAs with high Gini index compared to those with a low Gini index (95% CI: 1.8-4.8). The crude odds of high gonorrhea rates by other MSA characteristics are summarized in the left column of Table 2. As part of the preliminary analysis, logistic regression models were run separately with black isolation index and Gini index as the primary predictors of high gonorrhea rates, adjusting for several potential confounders (Table 2). After adjustment, the strength of the association between black isolation index and gonorrhea rates was

reduced, dropping from a crude odds ratio of 10.40 to an adjusted odds ratio (AOR) of 5.54 (95% CI: 2.29-13.44). The largest contributors to this dilution of effect were the following three measures: the proportion of the population that was black, the proportion of female headed households, and the proportion living under the federal poverty level. Adjustment for potential confounders did not noticeably impact the relationship between the Gini index and gonorrhea (AOR = 2.47, 95% CI: 1.21-5.03).

Table 3 shows our evaluation of the synergistic effects of black isolation and income inequality as measured by the Gini indices. Among MSAs with both high black isolation and high Gini indices, the adjusted odds of high gonorrhea rates were 6.95 (95% CI: 2.34, 20.64) compared to those with low levels of black isolation and low Gini index. The adjusted odds of high gonorrhea rates among MSAs with a high black isolation and low Gini index were 4.84 (95% CI: 1.68, 13.94), while that for MSAs with a low black isolation and high Gini index were 1.31 (95% CI: 0.51, 3.32). The reference category for all comparisons was the combination of low black isolation and low Gini indices. There was little excess risk due to interaction: the adjusted RERI was 1.81 (95% CI: -13.69, 24.00). That is, we did not find evidence of departure from additivity of effects: the joint effect was on the order of the effect of a high Gini index alone (AOR = 1.61). In contrast, the adjusted RERI was smaller than the AOR of 4.96 when looking at black isolation alone.

When we included a product-term in the model representing the interaction between black isolation and Gini indices, the departure from a multiplicative model was not statistically significant (coefficient = 0.06, Wald chi-square = 0.03, p-value 0.86). That is, MSAs with a combination of racially segregated residential patterns and high levels of income inequality had marginally increased likelihoods of also having high gonorrhea rates, but this association was not

significant. The expected AOR for the joint effect of high isolation and high Gini indices, assuming no interaction effect was 6.31, which was not notably different from the observed AOR of 6.95. A high black isolation index remained the strongest predictor of high gonorrhea rates.

DISCUSSION

This study sought to examine the influence of racial and economic residential segregation on gonorrhea rates in U.S. metropolitan areas. We hypothesized that higher degrees of residential racial and economic segregation were associated with higher gonorrhea rates in metropolitan areas, and that these two phenomena may interact such that the combined influence of high levels of segregation across multiple dimensions would be greater than the influence of any one dimension alone. The results of our analysis only partially supported this hypothesis. After adjustment to control for the potentially confounding contribution of various social structures related to race and social class, we found an association between high black isolation and Gini indices with high gonorrhea rates in MSAs when each was considered individually, but we did not find evidence of additive or multiplicative effect due to the combination of these two indices. A high black isolation index was the strongest predictor of high gonorrhea rates.

The proportion of a population that is black is strongly predictive of area gonorrhea rates, primarily since rates of many STDs are so much higher among black populations.[1,27] However, we must still elucidate the factors which contribute to high rates among black populations. Residential segregation is one of the mechanisms which may contribute to creating and sustaining endemically high rates of disease among black populations. Our study supports previous work indicating that segregation is a more important predictor of high rates of disease than the percentage of blacks in a population.[9] That is, it is not necessarily a MSA's racial

composition that leads to higher rates of disease, but rather the degree to which black populations are inequitably distributed within larger urban areas.

Furthermore, we found that racial segregation, as measured by black isolation, was a larger driver of differences in gonorrhea rates than was income inequality. It is possible that a different measure of income segregation, perhaps measuring black-white income inequality rather than overall household inequality across MSAs, would yield different results. Future research is needed in this direction. However, it is also possible that racial segregation is more relevant to perpetuating disparities in STD rates than is income inequality. If such is the case, reform within the health care system may not be adequate to effectively reduce inequities as the driving forces behind different in disease rates may not be related to access to health care, but rather to the social conditions and structures that place some populations at higher risk of infection.

This does not mean that economic conditions are not relevant to STD epidemiology. The proportion of female-headed households and proportion of the population living below the poverty level were notable confounders in the association between racial segregation and gonorrhea rates, and their individual contribution to gonorrhea rates should not be ignored. However, our results support previous work indicating that a broad approach addressing both economic and social determinants is necessary to alleviate disease disparities. Tackling such geographically-based social disparities is not a simple proposition, but it may be necessary to effect significant change.

This study addresses many issues inherent in the previous literature regarding segregation and STDs. We chose to assess the degree of black isolation as our measure of racial residential segregation. Studies suggest that black isolation may better at capturing patterns of unhealthy

exposures and infectious disease risk than other measures of distribution, such as racial composition or the dissimilarity index.[6,9,13] Also, disease transmission dynamics play out within social networks. Because racial isolation determines features of social and sexual networks, and hence may mediate individual exposure to STDs, it seems that the isolation index may be well suited to study sexually transmitted diseases.

The ecological nature of this study is also a strength in the context of the phenomenon under study, as the objective was to examine population-level determinants of disease rates. In general, individual-level analysis may be of limited utility in the study of STD epidemiology, as the risk of infection often depends more the characteristics of populations and the social environment, rather than individual behaviors or characteristics.[28-30]

While our study has several methodological strengths, our findings must be interpreted with several limitations in mind. Our dichotomization of both outcome and determinant measures, while done in such a manner as to avoid bias, may have obscured the true association between these factors. However, the results of several sensitivity analyses indicate that applying alternative parameterizations did not alter our substantive findings. Additionally, the Gini index of income inequality may not be the best measure to capture the impact of income segregation on STD rates. While concentrated economic disadvantage and poverty are known predictors of high STD rates, there is evidence that the degree of black-white income inequality may be pertinent in addition to the distribution of income within a given area.[9] Future studies should assess the utility of such a measure.

Our findings lend further credence to the theory that residential segregation may have an important role in perpetuating racial inequities in gonorrhea rates. However, segregation is inextricably tied to disparities in other social determinants of health, none of which are easily

addressed within the context of normal STD prevention programs. Yet reduction in these social disparities is key to reducing STD disparities.[3] Addressing these issues necessitates collaboration with other health promotion campaigns, including both infectious and chronic diseases. There is substantial evidence that residential segregation impacts not only STDs, but a variety of other indicators of health and well-being as well.[13] Therefore, to a substantial degree, the success of efforts to alleviate the inequitable burden of STDs is likely to depend on the effectiveness of policy-level measures aimed at decreasing segregation.

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TABLES

Table 3.1. Metropolitan statistical area characteristics by high or low rate of gonorrhea, 2005-2009

	Low Gonorrhea Rate* (Total N = 121)		High Gonorrhea Rate† (Total N = 156)	
MSA Characteristic	***N***	***%***	***N***	***%***
Demographic Composition				
Median Age < 36	45	37.2	73	46.8
Black Population > 18%	6	5.0	72	46.2
Married < 52%	41	33.9	72	46.2
Economic Indicators				
Less than HS education > 17%	28	23.1	54	34.6
Female headed households > 26%	16	13.2	91	58.3
Living below federal poverty level > 15%	28	23.1	74	47.4
Unemployment > 8%	21	17.4	55	35.3
Median household income < $51,722	64	52.9	127	81.4
Black-white median income ratio < 0.7	78	64.5	143	91.7
Geographic Characteristics				
Median population density (persons per square kilometer)		85.4		83.6
Region				
Midwest	21	17.4	45	28.9
Northeast	28	23.1	6	3.9
South	34	28.1	100	64.1
West	38	31.4	5	3.2
Primary Determinants				
Isolation index > 0.297	21	17.4	107.0	68.6
Gini index > 0.448	43	35.5	96.0	61.5

* > 112.42 cases per 100,000 person-years

† ≤ 112.42 cases per 100,000 person-years

Table 3.2. Odds of high gonorrhea rates by segregation indices and potential confounders among MSAs, 2005-2009*

	Crude Model	Isolation Index Model	Gini Index Model	Combined Model
	Crude odds ratio (95% confidence interval)	*Adjusted odds ratio† (95% confidence interval)*	*Adjusted odds ratio† (95% confidence interval)*	*Adjusted odds ratio† (95% confidence interval)*
Primary Determinants				
High Isolation index (> 0.297)	10.40 (5.83 - 18.56)	5.54 (2.29 - 13.44)	-- --	4.96 (2.02 - 12.17)
High Gini index (> 0.448)	2.90 (1.77 - 4.75)	-- --	2.47 (1.21 - 5.03)	1.61 (0.74 - 3.51)
Demographic Composition				
Median Age < 36	1.49 (0.92 - 2.41)	1.74 (0.81 - 3.73)	-- --	1.64 (0.76 - 3.53)
Black Population > 18%	15.71 (8.24 - 29.96)	2.91 (0.91 - 9.25)	8.46 (2.92 - 24.47)	3.27 (1.02 - 10.49)
Economic Indicators				
Female headed households > 26%	9.19 (4.97 - 16.98)	3.50 (1.52 - 8.05)	4.25 (1.92 - 9.40)	3.60 (1.57 - 8.26)
Living below federal poverty level > 15%	3.00 (1.77 - 5.08)	1.87 (0.79 - 4.40)	0.86 (0.38 - 1.98)	1.49 (0.58 - 3.79)
Median household income < $51,722	3.90 (2.28 - 6.68)	1.68 (0.65 - 4.33)	1.65 (0.70 - 3.88)	1.76 (0.68 - 4.58)
Geographic Characteristics				
Median population density (persons per square kilometer)	0.94 (0.70 - 1.27)	1.25 (0.73 - 2.13)	-- --	1.18 (0.69 - 2.03)
Census Region				
Midwest	16.29 (5.61 - 47.32)	7.57 (2.34 - 24.53)	12.46 (3.97 - 39.67)	7.91 (2.41 - 25.94)
Northeast	1.63 (0.45 - 5.88)	0.50 (0.10 - 2.65)	0.80 (0.19 - 3.42)	0.49 (0.09 - 2.61)
South	22.35 (3.14 - 61.39)	4.66 (1.43 - 15.13)	5.29 (1.69 - 16.59)	4.17 (1.27 - 13.69)
West	1.00 --	1.00 --	1.00 (referent)	1.00 (referent)

* Odds shown are for the likelihood of having a high gonorrhea rate compared to a low gonorrhea rate

† Only parameters whose inclusion resulted in >10% change in the odds ratio for the association between gonorrhea rates and segregation were included in the adjusted models

Table 3.3. Assessment of effect measure modification between black isolation index and Gini index*

	No. MSAs	*Crude odds ratio (95% confidence interval)*	*Adjusted odds ratio† (95% confidence interval)*
High black isolation, high Gini index	81	18.81 (8.52 - 41.55)	6.95 (2.34 - 20.64)
High black isolation, low Gini index	47	10.94 (4.71 - 25.43)	4.84 (1.68 - 13.94)
Low black isolation, high Gini index	58	2.40 (1.19 - 4.84)	1.31 (0.51 - 3.32)
Low black isolation, low Gini index	91	1.00 (referent)	1.00 (referent)

* All odds ratios shown are for the likelihood of having a high gonorrhea rate (the reference category is having a low gonorrhea rate).

† Model adjusted for potential confounders including: median age, % black, % female headed households, % living in poverty, median income, population density, and census region (south/midwest vs northeast/west).

Vita

River Ann Pugsley was born on September 5, 1980 in Heidelberg, Germany, and is an American citizen. She graduated from Loudoun Valley High School in Purcellville, Virginia in 1999. She received her Bachelor of Science in Biology with a dual degree in History and a minor in Spanish from the University of Virginia, Charlottesville, Virginia in 2003. She received a Master of Public Health from Virginia Commonwealth University in 2005, followed by a graduate certificate in Geographic Information Systems in 2007. She is currently employed as an epidemiologist with the Virginia Department of Health.