Journal of Urban Health: Bulletin of the New York Academy of Medicine, Vol. 87, No. 2
doi:10.1007/s11524-009-9425-9

Neighborhood Socioeconomic Environment and Sexual Network Position

Caroline M. Fichtenberg, Jacky M. Jennings, Thomas A. Glass, and Jonathan M. Ellen

ABSTRACT *Rates of sexually transmitted infections (STIs) are strongly associated with neighborhood poverty; however, the mechanisms responsible for this association remain unclear. Using a population-based study of sexual networks among urban African American adolescents, we tested the hypothesis that poverty, unemployment, and the sex ratio drive STI rates by affecting sexual network structure. Participants were categorized as being in one of three network positions that had previously been found to be strongly linked to infection with chlamydia and gonorrhea: being in a confirmed dyad (i.e., a monogamous pair), being connected to a larger network through one partner, and being in the center of a larger network. We found that only poverty was statistically significantly associated with sexual network position. Residing in the poorest third of neighborhoods was associated with 85% decreased odds of being in confirmed dyads. There was no association of sexual network position with neighborhood employment. Living in a neighborhood with an unequal number of young men and women appeared to be associated with a higher likelihood of being in a confirmed dyad; however, the differences were not statistically significant. These results suggest that poverty may impact STI rates by shaping sexual network structure, but we did not find any evidence that this association operates through unemployment or the sex ratio.*

KEYWORDS *Sexually transmitted infections, Sexual networks, African American, Socioeconomic status*

INTRODUCTION

Rates of sexually transmitted infections differ markedly between different neighborhoods and communities. This variation has been found to be strongly associated with various features of the socioeconomic environment, including income, unemployment, and education,[1–5] family structure,[6,7] community physical disorder,[1] racial/ethnic composition,[3,4,7] social capital,[5,8] racial/ethnic income inequalities,[6] and racial/ethnic residential segregation.[6] In particular, poor neighborhoods with high proportions of African American residents suffer from disproportionately high sexually transmitted infection (STI) rates.[3,4,7] While these associations are strong and consistent, the mechanisms through which these associations occur remain unclear.

Fichtenberg, Jennings, Glass, and Ellen are with the Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA; Jennings and Ellen are with the Department of Pediatrics, Johns Hopkins School of Medicine, Baltimore, MD, USA.

Correspondence: Caroline M. Fichtenberg, Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA. (E-mail: cfichten@jhsph.edu)

One possible mechanism is through sexual networks. Sexual networks, or the networks formed by the sexual partnerships in a population, necessarily shape the spread of STIs since they constitute the pathways through which STIs move from person to person. Furthermore, there is evidence that neighborhood socioeconomic environment could affect sexual networks. Social scientists such as William Julius Wilson and Douglas Massey have described the ways in which the combination of high poverty, chronic unemployment, and social isolation found in some poor urban African American neighborhoods may affect norms about sexuality in ways that favor concurrency and multiple partners.[9–13] More recently, Adimora and colleagues have argued that higher rates of poverty among African Americans may lead to higher incarceration and premature mortality rates among African American males that would in turn lead to unbalanced sex ratios that promote concurrency.[14,15] They also argue that long-term monogamy is further undermined in African American communities by the lack of employed and marriageable African American men resulting from the lack of opportunities in poor African American communities. Taken together, these research findings suggest multiple pathways linking high poverty and joblessness to sexual networks that facilitate STI spread, as summarized in the conceptual model presented in Figure 1. However, these links have yet to be tested empirically owing to the challenges of collecting sexual network data.

Using data from a study of sexual networks in one of San Francisco's historically African American neighborhoods, we test part of this conceptual model, namely, the hypothesis that concentrated poverty and unemployment affect sexual network structure, and that part of this relationship is mediated by the sex ratio.

METHODS

Study Design

This study used baseline data from the Bayview Networks Study (BNS), a population-based longitudinal study of STI risk factors among African American adolescents that took place in the Bayview and Hunter's Point neighborhoods of San

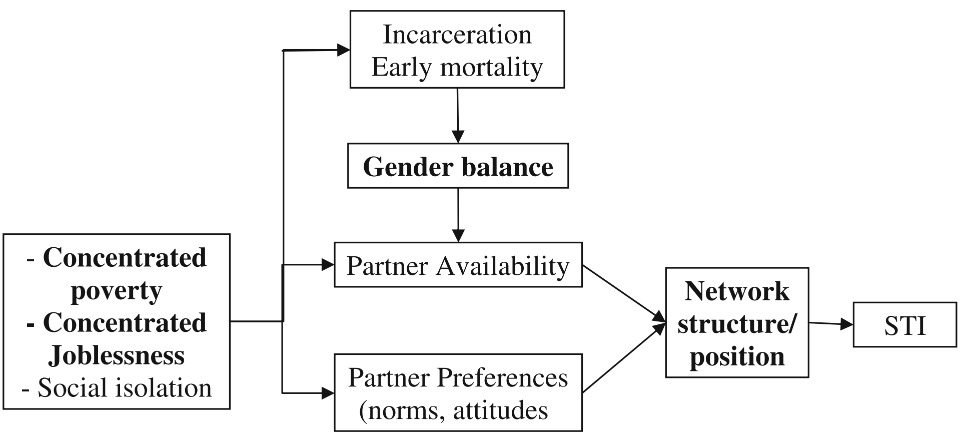


FIGURE 1. Conceptual model with items in *bold* indicating focus for this analysis.

Francisco, CA from 2000 to 2002. Bayview Hunter's Point (BVHP) is a historically black neighborhood that developed after World War II around the local shipyard. While the neighborhood has suffered from the closing of the shipyard in 1974, and now has some of the city's worst rates of STIs, violence, cancer, and diabetes, it contains a range of socioeconomic environments, with a mixture of public housing developments and stable, low-density neighborhoods of long-time homeowners, providing an ideal site for an investigation of the association between neighborhood socioeconomic environment and sexual networks.

The BNS combined population-based and snowball sampling to collect population representative sexual network data. In 2000, a population-based sample of 14–19-year-old African American adolescents living in the Bayview and Hunter's Point neighborhoods (zip code 94124) was recruited using random digit dialing (index participants). Computer-assisted telephone interviews and computer-assisted participant interviews were used to collect demographic and behavioral information. If participants reported sexual activity within the 3 months prior to the interview, they were asked to name up to six individuals with whom they had had sexual contact in the past 3 months for recruitment into the study. Two waves of snowball recruitment were then used to interview these partners and the partners' partners. At each wave of the snowball recruitment, all named partners were pursued for enrollment. All partners were administered the same instrument as the index participants.

All participants had to be at least 14 years old. Informed consent was obtained directly for those 18 and older, while guardian consent with participant assent was obtained for those younger than 18. Participants were asked for permission to contact the sex partners they named. Partners who were contacted were not told that they had been named by someone. Participants were reimbursed $25 for completing the interview. All study procedures received human subjects' ethics approval from the University of California, San Francisco and the Johns Hopkins Medical Institutions.

Analytic Sample

All index participants who reported being sexually active within the 3 months prior to the interview and who were successfully geocoded to census block groups (CBGs) of residence were included in the analysis. Of the 580 eligible teens who were part of the random digit dialing sample, 348 were consented and enrolled (60%). Of these, 168 (48%) were sexually active within the 3 months preceding the interview, and of those, 166 (99%) were successfully geocoded.

Network Position

Participants' sexual networks were based on the partnerships reported by the index participants as well as the interviewed partners and partners of partners. Two assumptions were made in this process. First, a partnership was considered to exist between two individuals as long as one partner reported it, even if the other partner was interviewed and did not report it, based on the assumption that participants were more likely to omit relationships than to invent them. Second, exact relationship timing was not taken into account, based on evidence that short-term cumulative network measures are more relevant for disease transmission than instantaneous measures.[16]

We used a sexual network position categorization that we have validated as a marker of STI infection with chlamydia and gonorrhea in a previous analysis of the

Bayview network data.[17] Based on those results, participants were divided into three groups of increasing STI risk. The first group consisted of individuals in confirmed dyads, in other words, individuals with one partner who was interviewed and reported no other partners. These individuals had previously been found to be least likely of being infected with chlamydia or gonorrhea and are therefore considered to be the low STI risk group. The second group consisted of individuals on the periphery of network components involving more than two people, i.e., individuals with only one partner but whose partner had other partners, or individuals with only one partner who was never interviewed and might therefore have other partners. In our previous analysis, this group was found to be three to five times more likely to be infected than the low-risk group. The third group consisted of individuals in the center of components involving more than two people, i.e., individuals with multiple partners. This group was previously found to be six to seven times more likely to be infected than the low-risk group. In the multivariable regression analyses, we combined the latter two positions because of the small sample size.

Neighborhood Characteristics

Neighborhoods were operationalized as CBG of residence. CBGs, containing on average 1,000 persons, are the smallest geographical census unit for which socioeconomic data are readily available.[18] The CBG was chosen as the level of aggregation in order to maximize the homogeneity of the neighborhood measures, and because the block group and the larger aggregate census area measure, the census tract, performed equally well in a recent analysis of suitability of various levels of geography for monitoring socioeconomic inequalities in sexually transmitted diseases.[19] All participant addresses were attributed geographic coordinates using MapMarker v8.0 software and MapMarker's CA basemap (MapInfo, Des Plaines, IL, USA). Geolocated addresses were matched to CBGs using ArcView v9 and ArcView's boundary file for CA (ESRI, Redlands, CA, USA). Geocoding rates among index participants were 99%.

The 2000 US Census was the data source for the neighborhood socioeconomic variables. We used percent of individuals below the federal poverty line ("poverty") as our measure of concentrated poverty. The measure of unemployment recorded in the census is known to be a poor indicator of chronic joblessness since it only includes individuals actively seeking work.[20] Therefore, instead of unemployment, we used a measure of employment, the percentage of individuals aged 16 and older who reported being employed, as recommended by Wilson.[11] While this includes individuals who are retired, it is preferable to the census' unemployment measure because it excludes individuals who have given up on seeking legal employment. To measure the sex ratio, we divided the number of men aged 20–24 by the number of women aged 15–19. We used unevenly matched age groups because young women tend to date men who are several years older.[21] Census variables for the year 2000 were obtained through the use of the Geolytics software package (Geolytics, East Brunswick, NJ, USA).

CBG socioeconomic variables were divided into tertiles based on their distribution among the index participants at baseline. Tertiles were used as they are the smallest number of categories that still allow evaluation of dose-response trends. Table 1 presents the tertile boundaries and the number of participants and CBGs in each tertile.

TABLE 1 Distribution of participants/CBG and boundaries of tertiles of CBG socioeconomic variables

		CBG poverty		
Variable	*N* individuals	CBG mean (SD)	CBG median	CBG Min–Max
Poverty (%)				
Tertile 1	60	12.1 (4.7)	13.0	1.6–17.1
Tertile 2	48	20.9 (1.6)	20.9	17.4–22.77
Tertile 3	58	41.8 (11.2)	40.5	22.89–51.9
Employment (%)				
Tertile 1	54	36.7 (2.7)	34.7	31.9–45.7
Tertile 2	61	48.9 (0.9)	49.0	46.0–49.8
Tertile 3	51	57.3 (6.8)	54.1	50.8–73.2
Sex ratio				
Tertile 1	60	0.69 (0.08)	0.71	0.35–0.76
Tertile 2	53	0.97 (0.08)	0.96	0.83–1.13
Tertile 3	53	1.84 (0.99)	1.41	1.18–6.26

Statistical Methods

We first characterized the bivariate relationships between all three CBG variables and network position. Relationships were represented graphically by plotting the relative frequency of the three network positions in each CBG tertile. Chi-squared tests were used to identify unadjusted associations between tertiles and network position. Cross-tabulations and chi-squared tests were conducted using SAS v.9.1 (SAS, Cary, NC, USA).

Multivariable logistic regression models were fit to determine how much of the association between neighborhood socioeconomic environment and network position was due to individual-level demographic characteristics (composition) and to adjust for correlated outcomes within CBGs. We used the dichotomized network position as the outcome, age, and sex as individual-level predictors and tertiles of CBG socioeconomic environment as CBG-level predictors. We used standard logistic regression models due to our small sample size rather than random effects models or generalized estimating equations. Cluster-based robust standard errors[22,23] were used to estimate standard errors that accounted for the potential correlation in network position between individuals in the same CBG. Models were fit using Stata/SE v. 9.1 (Stata, College Station, TX, USA).

RESULTS

Participants were on average 17.5 years old at baseline and slightly more likely to be women than men (60% women). By design, all participants were African American. On average, individuals reported 1.6 partners in the last 3 months (SD=1.1), and 69% reported only one recent partner. Based on participant reports as well as reports from interviewed partners and partners' partners, almost half of the study population was in the moderate-risk position, i.e., on the periphery of a larger network component. In comparison, 19% of the sample was in the low-risk position, i.e., linked to an individual who was not linked to other partners, and 31% in the high-risk position, i.e., linked to multiple partners.

Characteristics of the CBGs of residence of the study population at baseline are presented in Table 2, along with characteristics of all CBGs in the city of San Francisco. In comparison to the CBGs in the entire city, the CBGs in which index participants lived were less dense, had a higher proportion Black and Hispanic populations and a lower proportion White and Asian/Pacific Islander, and had a higher proportion below poverty but a higher proportion owner-occupied homes.

In bivariate analyses, only neighborhood poverty was associated with network position ($p=0.004$) (Figure 2). The proportion of participants in the confirmed dyads (low STI risk) decreased in a dose-response fashion from 32% to 7%, and the proportion of participants in the center of network components (high STI risk) increased from 23% to 45%, comparing the lowest to highest poverty tertiles (Figure 2). There were no statistically significant differences in network position by tertiles of employment. For the sex ratio tertiles, the proportion in confirmed dyads was lowest among participants in the middle tertile (CBGs with sex ratios closest to 1) and greatest among participants living in CBGs with more women than men (the low tertile) and in CBGs with more men than women (the high tertile). However, the differences were not statistically significant.

In multivariable models that adjust for age and sex and account for clustering among individuals in the same CBGs, living in the highest poverty tertile was associated with an 85% percent reduction in the odds of being in a confirmed dyad compared to being on the periphery or in the center of larger components (OR 0.15, 95% CI 0.05–0.46) (Table 3). Living in a moderate poverty CBG was associated with a 53% reduction in the odds of being in a confirmed dyad (OR 0.47, 95% CI 0.21–1.07). Neither of the other two variables was statistically significantly associated with network position. As there was no association between the sex ratio and network position, we did not further test the hypothesis that the sex ratio could mediate a relationship between poverty and employment and network position.

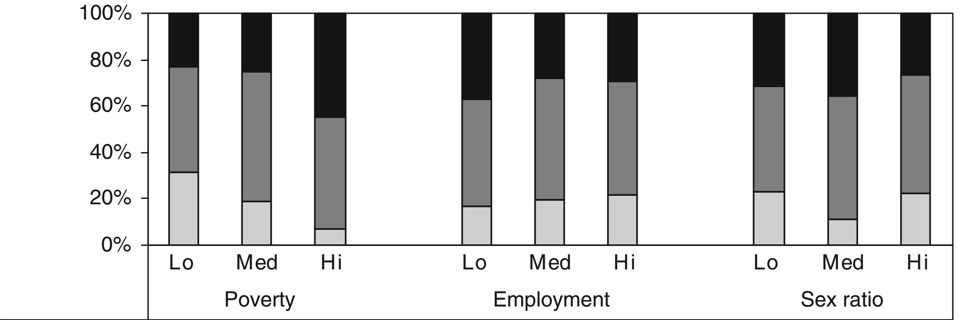
DISCUSSION

We investigated the relationship between neighborhood socioeconomic environment and sexual network position in a population-based sample of urban African American young adults using a network position measure previously shown to be strongly associated with STI infection status. We found that living in a higher poverty CBG was associated with increased likelihood of being in a nondyadic sexual network component, controlling for age and sex. This result provides some of the first quantitative evidence to support the hypothesis that living in an environment characterized by high poverty may affect the structure of sexual networks.

While we found a strong association between neighborhood poverty and network position, there was no evidence of association between network position and neighborhood employment. This may indicate that employment does not play the crucial role described by Wilson[11] in shaping the behaviors of residents in poor inner-city African American communities. Alternatively, it is possible that the observed lack of association reflects the fact that measures of employment derived from census data are not adequate measures of the kind of chronic joblessness that is hypothesized to be associated with network structure. While the measure that we used, percent employed among those 16 and older, is preferable to using the census' percent unemployed among those looking for work, it may not be a sensitive enough

TABLE 2 Demographic and socioeconomic characteristics of the census block groups (CBGs) of index participants at baseline compared to those of the entire city of San Francisco, CA, based on the 2000 US Census

	Index CBGs				San Francisco			
Variable	*N*	Mean (SD)	Median	Min–Max	*N*	Mean (SD)	Median	Min–Max
Density	33	16,084 (10,733)	13,835	654– 45,020	574	28,894 (22,412)	24,650	43–207,600
Race								
% White	33	17 (19)	8	0–63	574	46 (24)	46	0–100
% Black	33	37 (24)	35	0–74	574	7 (13)	2	0–74
% Hispanic	33	18 (11)	16	5–62	574	13 (15)	8	0–100
% Asian/Pacific Islander	33	23 (17)	18	0–63	574	30 (21)	26	0–100
% Other	33	4 (4)	3	0–16	574	4 (3)	3	0–44
% Female headed households	33	31 (17)	29	0–80	570	19 (12)	17	0–100
Sex ratio	33	1.04 (0.51)	1.00	0.41–2.44	561	2.41 (2.77)	1.73	0.00–40.0
% <High school education	33	29 (12)	30	3–48	574	18 (14)	15	0–78
% Unemployed	33	9 (5)	8	1–22	574	5 (7)	4	0–100
% Below poverty	33	17 (12)	17	2–52	574	11 (9)	8	0–100
% On pub. assist.	33	10 (7)	9	0–23	573	4 (5)	2	0–44
Median income	33	$46,447 ($18,294)	$46,563	$16,809–102,946	574	$62,348 ($25,484)	$60,807	$0–200,001
Median house value	33	$270,458 ($128,805)	$240,100	$97,800– 629,600	574	$485,809 ($227,955)	$448,450	$0–1,000,001
% vacant houses	33	4 (4)	4	0–21	573	4 (4)	4	0–54
% Owner-occupied houses	33	53 (27)	62	5–92	573	42 (27)	38	0–100



	Poverty Lo	Poverty Med	Poverty Hi	Employment Lo	Employment Med	Employment Hi	Sex ratio Lo	Sex ratio Med	Sex ratio Hi
% Center	23.3	25.0	44.8	37.0	27.9	29.4	31.7	35.9	26.4
% Periphery	45.0	56.3	48.3	46.3	52.5	49.0	45.0	52.8	50.9
% Dyad	31.7	18.8	6.9	16.7	19.7	21.6	23.3	11.3	22.6
Chi-squared p-values:	0.004			0.84			0.45		

FIGURE 2. Percentage of participants ($n=166$) in dyads, on the periphery and in the center of sexual network components, according to tertiles of CBG poverty, employment, and young adult sex ratio.

measure of chronic joblessness. Finally, it is also possible that our small sample size reduced our ability to observe statistically significant associations with employment.

Contrary to previous studies,[6,7,13,24] we found no association between the sex ratio and sexual network position. We do not believe this is due to the particular measure we used for the sex ratio (20–24-year-old men/15-19-year-old women), since we observed the same pattern when we used the following alternative age groups: men 19–29 to women 14–24, men to women among 14–29 year olds, and all ages in both groups. Despite these null findings, our small sample size precludes us from conclusively excluding the sex ratio as a possible determinant of sexual network position, especially in light of evidence from other sources linking the two.[14,15]

In addition to low power, one of the major limitations of our analysis is that we were unable to determine how much of the association we observed between neighborhood poverty and sexual network position was due to context as opposed

TABLE 3 Odds of being in a low-risk network position as opposed to a moderate or high-risk position according to CBG poverty

Neighborhood socioeconomic environment	Crude	Adjusted for age and sex
Poverty (ref. = low)		
Med	0.50 (0.21–1.18)	0.47 (0.21–1.07)
High	0.16 (0.05–0.47)	0.15 (0.05–0.46)
Employed (ref. = high)		
Med	0.89 (0.30–2.68)	0.75 (0.14–3.90)
Low	0.73 (0.15–3.60)	0.87 (0.30–2.54)
Sex ratio (ref. = 1)		
<1	2.38 (0.72–7.92)	2.23 (0.65–7.61)
>1	2.29 (0.65–8.04)	2.28 (0.62–8.30)

Odds ratios are from logistic regression models with robust standard errors assuming clustering within CBGs but not between (Stata logistic, cluster () option) to composition.[25] Our a priori hypothesis was that while individual-level income may affect network position, it is living in a neighborhood characterized by poverty that is most important, due to contextual pathways through the sex ratio and norms about sexual behaviors. However, distinguishing between these two hypotheses requires individual-level measures of income, which were not available in our dataset. The only related measure was family structure, namely whether individuals lived with both parents. When we included this variable in our multivariable model, the association strengthened slightly ($OR_{mod.\ poverty}=0.43$ (95%CI: 0.19-0.95), $OR_{high\ poverty}=0.13$ (0.04–0.40)). However, given the uncertain relationship between this measure of family structure and income, this is not an ideal way to confirm that our association includes a contextual element. Investigations of this question in datasets that include income measures as well as sexual network data are therefore indicated.

One of the strengths of this study is the use of snowball sampling data to measure sexual network position and the fact that the sexual network position categories were validated against STI risk. There is much evidence documenting the lack of concordance between people's perception of their network position and their actual network position.[26–28] In this study, network position was based on interviews with partners and with partners' partners, thereby reducing the mismeasurement of network position. Furthermore, the network position categories were shown in a previous study to be strongly linked to current infection with chlamydia or gonorrhea, indicating that the association seen here with poverty has direct relevance for STI rates.

There has been much written about how neighborhood socioeconomic environment might impact sexual network structure.[29,30] We believe that this is one of the first studies to document an association between sexual network structure and a feature of neighborhood socioeconomic environment. While we were unable to determine if this association was truly contextual, and we did not find any support for the hypotheses that neighborhood joblessness and the ratio of men to women play important roles in determining sexual network position in this sample, our results suggest that the well-documented association between poverty and STI rates may operate through sexual network structure.[1–6,8] Further study of this possible mechanism should attempt to confirm these results in a larger sample, distinguish between contextual and compositional effects, and further elucidate how neighborhood socioeconomic environment may shape network structure.

CONTRIBUTIONS

C.M. Fichtenberg designed and conducted the analysis and wrote the manuscript; J. M. Jennings and T.A. Glass helped design the analysis and interpret findings; J.M. Ellen conceived and conducted the Bayview Networks Study and helped design the analysis and interpret findings. All co-authors reviewed drafts of the manuscript.

REFERENCES

1. Cohen D, Spear S, Scribner R, Kissinger P, Mason K, Wildgen J. "Broken windows" and the risk of gonorrhea. *Am J Public Health*. 2000; 90(2): 230–236.
2. Ellen JM, Kohn RP, Bolan GA, Shiboski S, Krieger N. Socioeconomic differences in sexually transmitted disease rates among black and white adolescents, San Francisco, 1990 to 1992. *Am J Public Health*. 1995; 85(11): 1546–1548.

3. Rice RJ, Roberts PL, Handsfield HH, Holmes KK. Sociodemographic distribution of gonorrhea incidence: implications for prevention and behavioral research. *Am J Public Health*. 1991; 81(10): 1252–1258.
4. Rothenberg RB. The geography of gonorrhea. Empirical demonstration of core group transmission. *Am J Epidemiol*. 1983; 117(6): 688–694.
5. Holtgrave DR, Crosby RA. Social capital, poverty, and income inequality as predictors of gonorrhoea, syphilis, chlamydia and AIDS case rates in the United States. *Sex Transm Infect*. 2003; 79(1): 62–64.
6. Thomas JC, Gaffield ME. Social structure, race, and gonorrhea rates in the southeastern United States. *Ethn Dis*. 2003; 13(3): 362–368.
7. Kilmarx PH, Zaidi AA, Thomas JC, et al. Sociodemographic factors and the variation in syphilis rates among US counties, 1984 through 1993: an ecological analysis. *Am J Public Health*. 1997; 87(12): 1937–1943.
8. Crosby RA, Holtgrave DR, DiClemente RJ, Wingood GM, Gayle JA. Social capital as a predictor of adolescents' sexual risk behavior: a state-level exploratory study. *AIDS Behav*. 2003; 7(3): 245–252.
9. Massey DS, Denton NA. *American Apartheid: Segregation and the making of the underclass*. Cambridge: Harvard University Press; 1993.
10. Wilson W. *The truly disadvantaged: The inner city, the underclass, and public policy*. Chicago: University of Chicago Press; 1987.
11. Wilson W. *When work disappears: The world of the new urban poor*. New York: Knopf; 1996.
12. Andrinopoulos K, Kerrigan D, Ellen JM. Psycho-social factors that influence sex partner selection among urban male and female African-American adolescents. *J Adolesc Health*. 2004; 34(2): 125.
13. Brewster KL. Neighborhood context and the transition to sexual activity among young black women. *Demography*. 1994; 31(4): 603–614.
14. Adimora AA, Schoenbach VJ, Bonas DM, Martinson FE, Donaldson KH, Stancil TR. Concurrent sexual partnerships among women in the United States. *Epidemiology*. 2002; 13(3): 320–327.
15. Adimora A, Schoenbach V. Contextual factors and the Black-White disparity in Heterosexual HIV transmission. *Epidemiology*. 2002; 13(6): 707–712.
16. Ghani AC, Swinton J, Garnett GP. The role of sexual partnership networks in the epidemiology of gonorrhea. *Sex Transm Dis*. 1997; 24(1): 45–56.
17. Fichtenberg CM, Muth SQ, Brown B, Padian NS, Glass TA, Ellen JM. Sexual network position and risk of sexually transmitted infections. *Sex Transm Infect*. 2009; 85(7): 493–498.
18. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: a comparison of area-based socioeconomic measures–the public health disparities geocoding project. *Am J Public Health*. 2003; 93(10): 1655–1671.
19. Krieger N, Waterman PD, Chen JT, Soobader MJ, Subramanian SV. Monitoring socioeconomic inequalities in sexually transmitted infections, tuberculosis, and violence: geocoding and choice of area-based socioeconomic measures—the public health disparities geocoding project (US). *Public Health Rep*. 2003; 118(3): 240–260.
20. Chamlin M, Cochran J. Unemployment, economic theory, and property crime: a note on measurement. *J Quant Criminol*. 2000; 16(4): 443–455.
21. Laumann EO, Gagnon JH, Michael RT, Michaud JM. *The social organization of sexuality: Sexual practices in the United States*. Chicago: The University of Chicago Press; 1994.
22. White H. Maximum-likelihood estimation of mis-specified models. *Econometrica*. 1982; 50: 1–25.
23. Royall R. Model robust confidence-intervals using maximum-likelihood estimators. *Int Stat Rev*. 1986; 54: 221–226.

24. Cubbin C, Santelli J, Brindis CD, Braveman P. Neighborhood context and sexual behaviors among adolescents: findings from the national longitudinal study of adolescent health. *Perspect Sex Reprod Health*. 2005; 37(3): 125–134.
25. Oakes JM. The (mis)estimation of neighborhood effects: causal inference for a practicable social epidemiology. *Soc Sci Med*. 2004; 58(10): 1929–1952.
26. Drumright LN, Gorbach PM, Holmes KK. Do people really know their sex partners? Concurrency, knowledge of partner behavior, and sexually transmitted infections within partnerships. *Sex Transm Dis*. 2004; 31(7): 437–442.
27. Lenoir CD, Adler NE, Borzekowski DL, Tschann JM, Ellen JM. What you don't know can hurt you: perceptions of sex-partner concurrency and partner-reported behavior. *J Adolesc Health*. 2006; 38(3): 179–185.
28. Stoner BP, Whittington WL, Aral SO, Hughes JP, Handsfield HH, Holmes KK. Avoiding risky sex partners: perception of partners' risks v partners' self reported risks. *Sex Transm Infect*. 2003; 79(3): 197–201.
29. Adimora AA, Schoenbach VJ. Social context, sexual networks, and racial disparities in rates of sexually transmitted infections. *J Infect Dis*. 2005; 191(Suppl 1): S115–S122.
30. Thomas JC, Clark M, Robinson J, Monnett M, Kilmarx PH, Peterman TA. The social ecology of syphilis. *Soc Sci Med*. 1999; 48(8): 1081–1094.