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Neighborhood Drug Markets: A risk environment for bacterial sexually transmitted infections among urban youth

Jacky M. Jennings, Ph.D., M.P.H.^{(1),(2)}, Ralph B. Taylor, Ph.D.⁽³⁾, Rama A. Salhi, M.H.S., C. Debra M. Furr-Holden, Ph.D.⁽⁴⁾, and Jonathan M. Ellen, M.D.^{(1),(2)}

(1) Department of Pediatrics, Johns Hopkins School of Medicine, Baltimore, MD

(2) Department of Epidemiology, Bloomberg School of Public Health, Baltimore, MD

(3) Department of Criminal Justice, Temple University, Philadelphia, PA

(4) Department of Mental Health, Bloomberg School of Public Health, Baltimore, MD

Abstract

We hypothesized that neighborhoods with drug markets, as compared to those without, have a greater concentration of infected sex partners, i.e. core transmitters, and that in these areas, there is an increased risk environment for STIs. This study determined if neighborhood drug markets were associated with a high-risk sex partnership and, separately, with a current bacterial STI (chlamydia and/or gonorrhea) after controlling for individual demographic and sexual risk factors among a household sample of young people in Baltimore City, MD. Analyses also tested whether links were independent of neighborhood socioeconomic status. Data for this study were collected from a household study, systematic social observations and police arrest, public health STI surveillance and U.S. census data. Nonlinear multilevel models showed that living in neighborhoods with household survey-reported drug markets increased the likelihood of having a high-risk sex partnership after controlling for individual level demographic factors and illicit drug use and neighborhood socioeconomic status. Further, living in neighborhoods with survey-reported drug markets increased the likelihood of having a current bacterial STI after controlling for individual level demographic and sexual risk factors and neighborhood socioeconomic status. The results suggest that local conditions in neighborhoods with drug markets may play an important role in setting-up risk environments for high-risk sex partnerships and bacterial STIs. Patterns observed appeared dependent on the type of drug market indicator used. Future studies should explore how conditions in areas with local drug markets may alter sexual networks structures and whether specific types of drug markets are particularly important in determining STI risk.

Keywords

USA; sexually transmitted infections; drug markets; social epidemiology; medical geography; core transmitters

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Address correspondence to: Jacky M. Jennings, Ph.D., M.P.H. Assistant Professor, Dept of Pediatrics, School of Medicine The Johns Hopkins University Bayview Medical Center 5200 Eastern Avenue, Mason F. Lord Bldg - Center Towers, Ste 4200 Baltimore, MD 21224 T 410-550-4132 F 410-550-4153 jjennin1@jhmi.edu.

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Introduction

Core transmitters are widely accepted as critical actors in generating endemic and epidemic rates of sexually transmitted infections (STIs) including HIV (Brunham 1991; Cooke & Yorke 1973; Ellen, et al. 1997; May & Anderson 1987; Thomas & Tucker 1996). Core transmitters are a small proportion of people who are frequently infected and frequently transmit an STI (Thomas & Tucker 1996). Reducing infection among core transmitters is seen as critical to effectively reducing population levels of STIs (Over & Piot 1996). Core transmitters together with their sexual partners make up core groups. Core groups create highly interconnected subcomponents of sexual networks that are thought to play a key role in maintaining disease transmission by providing multiple pathways to spread infectious organisms (Brunham 1991). Empirical investigations and mathematical models of disease transmission networks have confirmed the importance of interconnected network structures for the maintenance of endemic disease, including gonorrhea and HIV (Chick, et al. 2000; Cunningham, et al. 2004; Garnett & Johnson 1997; Ghani, et al. 1997; Jolly & Wylie 2002; Koumans, et al. 2001; Morris & Kretzschmar 1997; Newman 2002; Potterat, et al. 1985; Potterat, et al. 1999; Watts & May 1992)

Practitioners of STI prevention and control, however, have had difficulty in actually identifying and thus targeting core groups (Centers for Disease Control & Prevention 2009; Doherty, et al. 2005; Olsen 1973; Over & Piot 1996; Rosenthal, et al. 1995; Woodhouse, et al. 1985). This has led some STI epidemiologists to shift their focus to the identification of geographic areas with high STI rates and/or counts with the hypothesis that core transmitters and their partners are most likely to be found in these areas (Centers for Disease Control & Prevention 2009; Friedman, et al. 1998; Jennings, et al. 2005; Over & Piot 1996). In order to justify the refocusing of public health efforts from individuals to geographies, it is necessary to have empirical data linking core geographic areas and core transmitters. In addition a deeper conceptualization and identification of mechanisms is necessary to help explain why some geographic areas have core transmitters while others do not.

There has been some progress in such a direction. Considerable work has shown that STI prevalence varies by census block group or tract within a city and that the rates are associated with demographic factors such as percentage of African Americans (Becker, et al. 1998; Hamers, et al. 1995; Hart 1993; Jennings, et al. 2005; Lacey, et al. 1997; Potterat 1992; Rothenberg & Judson 1983; Zenilman, et al. 1988). In addition, multiple studies have found that geographic variation in STI prevalence is associated with various features of the socioeconomic environment, including income, unemployment, and education (Cohen, et al. 2000; Ellen, et al. 1995; Holtgrave & Crosby 2003; Rice, et al. 1991; Rothenberg & Judson 1983), family structure (Kilmarx, et al. 1997; Thomas & Gaffield 2003), community physical disorder (Cohen, et al. 2000) racial/ethnic composition (Kilmarx, et al. 1997; Rice, et al. 1991; Rothenberg & Judson 1983; Rothenberg, et al. 2007), social capital (Crosby, et al. 2002; Holtgrave & Crosby 2003), racial/ethnic income inequalities (Thomas & Gaffield 2003) and racial/ethnic residential segregation (Thomas & Gaffield 2003). These findings, however, only go so far: the association between demographic and socioeconomic factors and STI rates at the ecologic level provides limited insight into individual level STI risk.

One of the challenges of ecologic analyses is as follows. Without indicators for individual level behaviors geography may be just a proxy for individual compositional characteristics of residents rather than an independent risk factor. Just a few studies of this type of health risk have combined ecologic and individual data in the same model. One multilevel study of arrested young people in Florida found, after adjusting for individual-level gender, age, race/ethnicity, and criminal history, that concentrated disadvantage measured at the neighborhood-level was significantly and positively associated with a bacterial STI

(chlamydia and/or gonorrhea) (Dembo, et al. 2009). A multilevel urban household study found that after adjusting for individual-level demographic and behavioral risk factors, young people living in high versus low prevalence STI areas were almost five times (95% confidence interval (CI): 3.65–6.15) more likely to have a current bacterial STI (Jennings, et al. 2010). Such results demonstrate that after controlling for compositional demographic and risk factor variation, ecologic aspects of the environment, concentrated disadvantage and STI prevalence, i.e. pools of infected sex partners, remained as potentially important determinants of STIs.

Despite these findings, a key question remains: how does geography, or more specifically ecologic or structural features associated with geography such as concentrated disadvantage and/or pools of infected sex partners, create individual level risk for STIs? This paper suggests that neighborhood drug markets are one such potential pathway. If so, such markets may increase the local prevalence of core transmitters and change local sexual networks, thereby increasing STI transmission.

Drug market venues are inner-city geographic areas with intensive illicit drug dealing and potentially drug use (e.g., heroin, crack-cocaine, and/or marijuana). Evidence suggests that drug markets tend to be spatially concentrated and do not tend to change significantly from year to year (Weisburd & Green 1994). The research has also shown that drug markets tend to proliferate in areas characterized by lower informal, resident-based or lower formal authority-based control (Eck 1995; Reuter & MacCoun 1992) and specific land uses such as major thoroughfares (Rengert, et al. 2000; Rengert 1996). Areas with drug markets are also often characterized by higher volumes of foot traffic and higher ratios of unknown outsiders to known insiders (Eck 1995). In part this is because drug market areas are likely to attract and be infiltrated by drug users from outside neighborhoods (Eck 1995).

One challenge in investigating neighborhood drug markets is measurement. Although some studies have found drug arrest data to be a good indicator of drug markets (Warner & Coomer 2003), biases have been noted. Some have argued, for example, that variability in drug arrest rates across neighborhoods may be due to variability in police behavior and tactics versus actual differences in drug activity (Blumstein 1995; Tonry 1995). A second challenge is figuring out whether illicit drug using and illicit drug dealing co-occur in a drug market. Both activities may not occur within the same drug markets or within the same neighborhood (Saxe, et al. 2001; Weisburd & Green 1994). A third challenge in this line of research is learning whether drug markets are associated with STIs independently of poverty or whether drug markets mediate poverty impacts. These challenges are addressed in the current work.

Three different data sources – a household study, systematic social observations and drug arrest data – provide potential indicators of neighborhood drug markets. The measurement of drug markets in the household study and drug arrest data were restricted to items which specifically addressed or found evidence of drug dealing versus drug using. In addition, multilevel data allowed for the adjustment of demographic and behavioral STI risk factors at the individual level as well as socio-economic status at the neighborhood level.

The specific study objectives were as follows. First, we investigated if neighborhood drug markets were associated with a high-risk sex partnership and separately, with a current bacterial STI (chlamydia and/or gonorrhea) among a household sample of young people in Baltimore City, MD, where both of these associations are independent of individual risk factors. Second, we then determined whether the above findings were independent of neighborhood socioeconomic status.

In the current work, high-risk sex partnerships were defined as self-report of at least three sex partners in the past 90 days, having had a sex partner who practiced sexual concurrency (i.e., overlapping sexual partnerships in time), ever having an HIV+ and/or injection drug user (IDU) sex partner, or given or received commercial sex work.

Given the extant literature, the transmission of STIs in neighborhoods with drug markets (as compared to neighborhoods without drug markets) may occur in a number of different ways, as shown in our orienting framework (Figure 1). First, transmission may occur at a high rate between core group members in part because core transmitters are more likely to practice sexual concurrency and thus have core transmission sexual network structures. Supporting evidence from multiple studies shows that drug users and individuals involved with the trade of sex for drugs and/or money have high rates of sexual concurrency (Adimora, et al. 2007; Flom, et al. 2001; Gyarmathy & Neaigus 2009; Manhart, et al. 2003). In part the sexual concurrency may occur because of behavior related to drug sales and use. For example, when known drug users have funds and are heading to get drugs, addicted acquaintances will travel to the known nearby markets seeking the initial user, hoping to share in the drugs (Simon & Burns 1997). The drug consumption and perhaps drug sharing, in nearby abandoned houses (Simon & Burns 1997; Spelman 1993) may be accompanied by sex between the first and second user, or between the first user and other potential partners at the site of drug use (Friedman, et al. 1998). Additionally, in close proximity to drug markets, those on foot are more likely to encounter addicted women, willing to exchange sex for drugs and/or money (Friedman, et al. 1998; Ratner 1993).

The transmission of STIs also may occur between core transmitters and lower risk sex partners. We hypothesize that neighborhood drug markets may persistently increase the availability of individuals involved in drug markets, thereby increasing the likelihood local residents will select a sex partner who is engaged in drug market activities. This hypothesis rests on the fact that sex partnerships are often formed in tightly confined social settings with spatial and cultural boundaries (Ellingson, et al. 2004; J. J. Potterat, et al. 1985). These settings become, in a sense, sex marketplaces as they provide the types of individuals and opportunities available for partnering as well as the social rules that guide the selection of sex partners (Ellingson, et al. 2004). Similarly the presence of neighborhood drug markets may alter neighborhood sexual norms surrounding the selection of high-risk sex partners (Friedman, et al. 2003). The altered norms, for example, may increase the acceptability or lessen the inhibition of selecting a sex partner who is involved in drug dealing or using. There is considerable evidence that individuals engaged in drug dealing or use have high rates of STIs and HIV as compared to other groups (Centers for Disease Control & Prevention 2009; Friedman, et al. 2005).

Study Setting

The setting for the current study presents a unique opportunity to investigate the study objectives. The study was conducted in Baltimore City, Maryland, a city with a long history of syndemics of poverty, illicit drug use (Agar & Reisinger 1999; Gleghorn, et al. 1995; Simon & Burns 1997) and STIs including HIV (Becker, et al. 1998; Jennings, et al. 2005). Baltimore is located in the Mid-Atlantic United States (U.S.) with an estimated 2009 population of 637,418 people (U.S. Census Bureau 2003). About 68% of the city's residents are high school graduates and about 19% have a Bachelor's degree or higher, compared to respective rates of nearly 84% and about 31% in the state (U.S. Census Bureau 2003). Only half of Baltimore residents own their homes, while these numbers are approximately 68% and 66% for the state and nation (U.S. Census Bureau 2003). Baltimore has a 24% poverty rate, nearly double that of the U.S., ranking it as the sixth poorest metropolitan area (U.S. Census Bureau 2003). Thirty-five percent of Baltimore's children live below the poverty line, compared to just 11% statewide and 18% nationally (U.S. Census Bureau 2003).

Baltimore has very high rates of injection drug-use (IDU) and non-IDU (Doherty, et al. 2000; Mehta, et al. 2006; Nandi, et al. 2010; Vlahov, et al. 1991). Baltimore is estimated to have at least 60,000 illicit drug addicts – roughly 10% of the population – and police say drugs are a factor in eight of every ten city homicides (Craig 2000). It is estimated that about 40,000 of the city's estimated 60,000 addicts are IDUs with heroin featuring prominently (Associated Press 1998; United States National Drug Intelligence Center 2003). Baltimore also has endemic rates of STIs and is a city with racial/ethnic disparities in STIs that are four times the national average. In 2007, Baltimore had the 3rd highest chlamydia and 9th highest gonorrhea incidence rate among U.S. cities and in 2009, the 4th highest HIV incidence rate (Centers for Disease Control & Prevention 2009).

Methods

Overview

Data for the current study were collected from a cross-sectional household study. Here we briefly describe the household study design, sampling strategy and study procedures. Details are described in previously published articles (Jennings, et al. 2010). In order to extend the measurement of neighborhood drug markets from that provided by the household survey, we obtained additional information about neighborhood drug markets from systematic social observations and Baltimore City Police arrest data.

Study design, sampling strategy and study population

The Neighborhood Influences on Adolescent and Adult Health (NIAAH) household study was conducted from April 2004 to April 2007. The target population included English-speaking, sexually-active persons between the ages of 15 and 24 years who resided in 486 census block groups (CBGs) which we also refer to as neighborhoods. We estimate that the target population represented comprised of approximately 58,299 persons living in the 486 CBGs in 2005.

The sampling selection for the study was conducted in two stages. In the first stage, among the 710 CBGs in Baltimore City 75% (533/710) CBGs were selected consisting of CBGs with greater than the 25th percentile in gonorrhea prevalence. This subsample was selected to increase the likelihood of identifying infected individuals, and to focus on distinguishing factors associated with a current STI among higher risk areas. Gonorrhea prevalence was generated from public health surveillance data among 15–49 year olds per 100,000 per CBG from 2004–2005. Eligible CBGs were further restricted to CBGs estimated to contain 35 or more households with age-eligible participants (486/533 or 91%) using Census 2000 information (U.S. Census Bureau 2003). A final sample of 65 block groups was selected using a stratified, systematic probability proportional to size sampling strategy.

In the second sampling stage, a total of 27,194 addresses within the 65 selected CBGs were obtained from three different purchasable address lists. These addresses served as the household sampling frame. We then used non-linear optimization to allocate a sample of 13,873 households to the three lists in a way that reduced screening costs while controlling for design effects (Chong & Zak 1996). Our target enrollment for each block group was 10 participants.

Of the 13,873 households in the second stage sampling frame, 99% (13,699) were fielded and of these, 74% (10,173) households were successfully screened. During the screening, two of the 65 CBGs were found to be comprised exclusively of retirement communities and thus were excluded. Among households enumerated, 12% (1,270) had at least one English-speaking person between the ages of 15 and 24. One age-eligible person was randomly selected for screening from each household. Among these households, screenings for sexual

activity were attempted in 77% (981) of the age-eligible households with a completion rate of 70% (682) yielding a response rate to the interview among those selected of 68%. The overall interview response rate was 51% (599) and overall interview with a biologic specimen response rate was 50% (589) (American Association for Public Opinion Research 2006). Of the 589, an additional 2% (14) were excluded from this analysis. Two percent (12) were missing surveys due to technical issues and <1% (2) had missing STI tests yielding 575 participants. The 575 participants lived on 433 unique block units. Of the 433, systematic social observations were able to be successfully conducted on 97% (420) resulting in 99% (568) participants with observations and available for the final study analyses.

Procedures

All sampled households received a lead letter describing the study approximately two weeks before the households were contacted for enumeration. Enumeration, to determine whether the household had at least one age-eligible individual, was conducted by telephone or in-person. Screening was conducted to determine eligibility. In selected households with more than one age-eligible person, one was randomly selected for screening. Eligible, consenting individuals were enrolled and research assistants administered an audio computer-assisted self-interview (audio-CASI) in a private setting.

Biologic samples including urine samples for males and self-administered vaginal swabs for females were collected for polymerase chain reaction amplification testing (Amplicor® CT/NG Test, Roche) for gonorrhea and chlamydia. Self-administered vaginal swabs for females and urine samples for males have been shown in previous research to be feasible and acceptable methods for collecting biologic samples for STI testing and to have high sensitivity and specificity with NAAT (Gaydos & Rompalo 2002; Marrazzo, et al. 2007; Masek, et al. 2009; Rompalo, et al. 2001). Participants received \$25 to \$45 remuneration for participation in the study dependent on their year of entry. The study protocol was approved by the Johns Hopkins University Institutional Review Board.

Measures including Outcomes, Main Exposure variables and Potential Confounders
Outcomes: There were two main outcomes of interest at the individual level. The first was self-report of a high-risk sex partnership defined as index report of in the past 90 days of three or more sex partners, having had a sex partner who practiced concurrency, ever having an HIV+ and/or IDU sex partner, or given or received commercial sex work. The second outcome was current infection with a bacterial STI defined as gonorrhea and/or chlamydia.
Main Exposure Variables: The main exposure variable of interest was residence in an area with a neighborhood drug market. Participants were provided with a hard-copy map of their census block group and asked to think about this area when asked questions regarding “their neighborhood.” Participants were then asked via ACASI “In your neighborhood, are there any places like a street corner, block, house, club, bar, or other place where drug activity, like people selling or buying drugs, happens?” (yes/no). Individual responses within each neighborhood were aggregated to the proportion reporting yes within a neighborhood and then coded to greater than 50% of residents reporting yes (1) vs. less than or equal to 50% reporting yes (0). At the CBG level, within-neighborhood respondent agreement on neighborhood drug market presence had a reliability of 0.50 and a statistically significant intra class correlation of 0.10 ($P<0.001$). In ecologic analyses at the CBG level, report of neighborhood drug markets was significantly associated with increased gonorrhea counts (Incidence Rate Ratios (IRR) 3.05, 95 CI% 2.07, 4.51, $P<0.001$) using Poisson regression and a total population offset and separately with decreased socioeconomic status (β -1.74, 95 CI% -2.54, -0.93, $P<0.001$) using linear regression.

To supplement the measurement of neighborhood drug markets, additional information was obtained from systematic social observations. The methods of the systematic social

observations conducted as a part of Neighborhood Inventory for Environmental Typology (NifETy) Study have been previously described (Furr-Holden, et al. 2008; Furr-Holden, et al. 2010;). Briefly, investigators of the household study provided to the NifETy Study Principal Investigator the unit block information for the addresses of the study participants but not the actual addresses. The NifETy rating team was then sent to assess the unit block, or face-block, of each household study participant. Assessments were conducted from July 2009 to August 2009.

The rating team used a multi-item assessment tool to conduct systematic social observations. Trained raters (a total of 12) entered their observations on Palm OS Zire 31 Personal Digital Assistant (PDA) devices programmed with Pendragon Forms 5.0 software to include skip patterns and branch trees for related items, to reject illogical entries, and to require each field be complete before advancing to the next item. Raters travelled in pairs from 11 a.m. to dusk to conduct ratings. A standard procedure was established to ensure consistency across raters and independent assessments. Without discussing their observations, raters traveled opposite sides of the street within visible range of one another and traversed the block face a minimum of three times at a modest walking pace. With each pass raters walked up one side of the street and down the other side. They were instructed to look down alleys, in gutters, and in yards visible from the street but not to walk down alleys or on private property and not to touch or move anything. The goal was to capture the experience of the neighborhood from the perspective of a keenly observant pedestrian.

Raters summarized the drug activity of each block unit based specific drug activity indicators such as the number of drug vials, baggies and obvious signs of drug selling. Ratings were captured in the following response categories - none (0), low (1), medium (2) and high (3). Because we were interested in capturing any drug market activity, multiple rater information on a block unit was aggregated to the greater value to generate one value for a block unit. Ratings for multiple block units within a neighborhood were summed to create one continuous measure at the neighborhood level. The inter rater reliability was statistically significant and moderate at the block unit level at 0.57 ($P<0.05$). At the CBG level, the reliability of this measure was 0.88. In ecologic analyses at the CBG level, the average report of neighborhood drug markets was not significantly associated with increased gonorrhea counts (IRR 1.18, 95 CI% 0.94, 1.49, $P=0.15$) using Poisson regression with a population offset and was significantly associated with decreased socioeconomic status ($\beta -0.65$, 95 CI% -0.99 , -0.31 , $P<0.000$) using linear regression.

Alternatively, to supplement the measurement of neighborhood drug markets, we used publicly available drug arrest data from 2004 through 2007 (the years of the household survey) from the Baltimore City Police Department. Drug arrests specifically for drug manufacturing, distribution, or intent to distribute were geocoded to a street location using ArcGIS v9.3 and Baltimore City Department of Planning basemaps (ESRI, Redlands, CA). 92% of the drug arrests were able to be geocoded. Geolocated addresses were matched to census block groups using ArcView v9 and ArcView's boundary file for MD and summed across the years. In ecologic analyses at the CBG level, drug arrest counts were significantly associated with increased gonorrhea counts (IRR 1.01, 95 CI% 1.00, 1.01, $P=0.002$) using Poisson regression with a population offset and were significantly associated with decreased socioeconomic status ($\beta -0.01$, 95 CI% -0.02 , -0.01 , $P<0.001$) using linear regression.

Potential Confounders: For the analysis of neighborhood drug markets and high-risk sex partnership we controlled for demographic factors identified in the literature as being associated with increased risks for risky sexual partnerships and increased likelihood of engagement in drug market activities including age (continuous) and gender (Lambert, et al. 2004; National Center for Health Statistics 2010; Substance Abuse and Mental Health

Services Administration 2010). We also controlled for individual level report of illicit drug use because individual level drug use may act as a confounder between reports of neighborhood level drug markets and selection of a high-risk sex partner (see Figure 1. Orienting Framework). A drug user may be more likely to have knowledge of a neighborhood drug market and thus report a drug market. A drug user may also be more likely to select a high-risk sex partner, particularly given that the definition of a high-risk sex partner includes selection of an IDU as a sex partner.

For the analyses of the association between neighborhood drug markets and current bacterial STI, individual level demographic and behavioral sexual risk factors were used to adjust the regression models for the most proximal individual level factors associated with a current STI to determine the independent association of neighborhood drug markets. We chose our individual level factors based on STI transmission and acquisition models including demographic factors associated with efficiency of transmission, i.e. age, gender and sexual risk behaviors (condom use last sex [yes, no] and number of sex partners in the past 90 days [0–1, 2]). For these analyses, we did not control for individual level illicit drug use for two reasons. Individual level drug use in of itself is not a risk factor for a current bacterial STI (see Figure 1. Orienting Framework). An STI is transmitted through sexual contact and requires an act of unprotected sexual intercourse between an infected individual and an uninfected individual. Individual drug use including alcohol use among young people may interfere with judgment and decision-making, whereby increasing risky sexual behaviors. The risky sexual behaviors may include decreased condom use (Bachanas, et al. 2002; Feigelman, et al. 1995; Millstein & Moscicki 1995; Shrier, et al. 2001) and/or increased likelihood to engage in commercial sex work, i.e., have high numbers of sex partners (Word & Bowser 1997). Thus, in regression models, we control for risky sexual behaviors but not individual level drug use.

Neighborhood drug markets may be more likely to occur and are more visible in disadvantaged neighborhoods. Crum, et al. (1996) found that among elementary students in one urban area residing in highly disadvantaged neighborhoods increased young people's risk for exposure to cocaine. Saxe, et al. (2001) found in a national telephone survey among 16 to 44 year olds across 41 communities that the most disadvantaged neighborhoods had the most visible drug problems. Because we were interested in determining whether neighborhood drug markets contributed to increased STI risk independent of neighborhood disadvantage, measured as socioeconomic status, we conducted final multivariable regression analyses controlling for neighborhood socioeconomic status. Using data from the U.S. Census 2000, we measured neighborhood socioeconomic status by constructing an index of four measures of socioeconomic status. The index was constructed as an average of individual z-scores for median house value, median household income, percent of the population 25 years of age and older with a greater than or equal to a college education, and percent of households above the U.S. Federal poverty line. The index had acceptable reliability (Cronbach's $\alpha = 0.78$).

We conducted a sensitivity analyses to test whether our significant findings changed after adjusting for individual level socioeconomic status. Individual socioeconomic status was not in our orienting framework because we hypothesized that condom use and number of sex partners would mediate the relationship between individual level socioeconomic status and the outcomes of interest. It could be argued, however, that individual level socioeconomic status may still be playing a confounding role. To address this possibility we conducted a sensitivity analysis. Individual socioeconomic status was measured as the highest school grade completed by their mother or female guardian. Response categories included less than high school, high school or GED, or more than high school. We did not conduct a similar sensitivity analysis adjusting for race/ethnicity at the individual or neighborhood level for

the following reasons. The sample was predominantly African American (88%), socioeconomic status in this city is highly correlated with race/ethnicity at the individual and neighborhood levels and importantly, race is not a biological determinant of STIs but rather a social determinant which is likely highly collinear with the exposure variables included in the orienting framework.

Statistical Analyses

Overview Statistical analyses included the calculation of statistical analysis weights, measurement and exploratory analyses, the calculation of weighted summary statistics and the generation of a series of nonlinear multilevel models. Weights were used to adjust for the complex sampling strategy. All statistical analyses were conducted using STATA (STATA Intercooled, version 10.0; STATA Corp., College Station, TX) and HLM (HLM, version 6.02; Scientific Software International, Inc, Lincolnwood, IL).

Hypothesis Testing Exploratory analyses were conducted and weighted summary statistics were generated including means and standard deviations (SD) for continuous-scaled characteristics and number and frequencies for categorical scaled characteristics. We then conducted a series of weighted nonlinear multilevel models. Separate models tested whether each neighborhood drug market measure was associated with each outcome, high-risk sex partnerships and a current bacterial STI. Neighborhood drug market measures that were significant at $P < 0.10$ were further explored in multivariable models. Next, we used a multivariable model to test the association between the control variables for high-risk sex partnerships (i.e., individual level demographic factors - age, sex, drug use) and control variables for a current bacterial STI (i.e., individual level demographics - age, sex – and sexual risk behaviors - condom use at last sex and number of sex partners in the past 90 days). The control variables were added into the model as a block. The purpose of this analysis was to test directionality of the control variables but not (as in a risk factor approach) to exclude variables based on their association. We then tested whether neighborhood drug markets were associated with high-risk sex partnerships and separately, a current bacterial STI after controlling for the individual level demographic and behavioral risk factors. In final regression models we further controlled for neighborhood socioeconomic status and statistical significance of the drug market variables was determined by a confidence interval that did not include 1.0 and a P value less than 0.05.

We compared model fit using a multi-parameter likelihood-ratio test for the variance-covariance components in HLM (Raudenbush, et al. 2004). The test compares the deviance statistic of a restricted model to an alternative. The test is based on the difference between the deviance statistics of the two models, which has a chi-square distribution with equal degrees of freedom equal to the number of parameters estimated in the models being compared (Raudenbush, et al. 2004). We compared a restricted model with individual confounders only to a model including neighborhood drug markets and then we compared the latter model to a model including neighborhood socioeconomic status. Finally, we also conducted sensitivity analyses entering into the final models individual socioeconomic status to determine whether the relationships identified in the final models persisted.

Results

Statistical analyses

Weighted summary statistics showed that participants were on average 19 years old, 63% were female, 88% African American, and 20% reported that their mother had less than a high school degree or GED (Table 1). Thirty-nine percent of participants reported no condom use at last sex and 23% reported greater than or equal to two sex partners in the past

90 days. Sixteen percent of participants reported using marijuana weekly or more than weekly, less than 1% reported ever using injection drugs and 10% reported ever using other non-over-the-counter illicit drugs. High-risk sex partnerships were reported by 39% of participants and 7% were currently infected with a bacterial STI including 1% and 6% with a current gonorrhea or chlamydia infection, respectively.

At the neighborhood level, the mean of the median house values was \$60,801 and the median household income was \$21,283 (Table 2). On average, 76% of households were above the U.S. Federal Poverty Line and the median percent of the population 25 years of age and above with equal to or greater than a college education was 8%. Eighty-one percent (51) of neighborhoods had greater than 50% of participants reporting the existence of drug markets. The average report of drug activity from the systematic social observations was 0.80 on a scale from 1 to 4. The median number of drug arrests per neighborhood was 22.

Outcome – High-risk sex partnership: In weighted nonlinear multilevel analyses, survey-reported existence of drug markets was statistically associated ($P<0.10$) with a high-risk sex partnership (OR 1.79, 95% CI 0.91, 3.53, $P=0.089$) (Table 3). In weighted bivariate analyses, the average report of drug activity by systematic social observations was not significantly associated with a high-risk sex partnership (OR 0.83, 95% CI 0.57, 1.10, $P=0.232$) and neighborhood drug arrest counts for drug manufacturing, distribution, or intent to distribute were not significantly associated with a high-risk sex partnership (OR 1.00, 95% CI 0.98, 1.01, $P=0.490$). Thus, the latter two measures were not tested in full models.

In weighted multilevel analyses in a model with individual level demographic factors only, a high-risk sex partnership was significantly associated with age (OR 1.09, 95% CI 1.02, 1.17, $P=0.018$) and being male (OR 2.53, 95% CI 1.77, 3.61, $P<0.000$) and significance was borderline for the association with ever using non-prescription drugs (OR 2.37, 95% CI 0.99, 5.65, $P=0.052$) (results not shown in Table 3). Survey-reported existence of drug markets remained significantly associated with a high-risk sex partnership after adjusting for individual level demographic and drug use factors (OR 2.54, 95% CI 1.21, 5.33, $P=0.015$) and after adjusting for neighborhood socioeconomic status (OR 2.60, 95% CI 1.18, 5.70, $P=0.019$) (Table 3).

The deviance statistic for the model with individual control variables only was 1750.92 with 5 estimated parameters. The deviance statistic for a more general model including survey-reported neighborhood drug markets was 1743.58 with 6 estimated parameters. The chi-square statistic comparing the two models was significant (X^2 7.34, $P=0.007$) suggesting that the model including survey-reported neighborhood drug markets improved the model's explanation of the variation in the outcome, i.e the model fit. The deviance statistic for a model which included survey-reported neighborhood drug markets and neighborhood socioeconomic status was 1743.12 with 7 estimated parameters. The chi-square statistic comparing the latter model to a more restricted model without neighborhood socioeconomic status was not significant (X^2 0.46, $P>0.05$) suggesting that the contribution of neighborhood socioeconomic status to the explanation of the variation in the outcome was negligible.

Sensitivity analyses conducted with the final model after additional adjustment for individual socioeconomic status resulted in similar findings. Survey-reported existence of drug markets remained significantly associated with increased risk for a current bacterial STI after adjustment for individual and neighborhood factors including individual level socioeconomic status (OR 2.28, 95% CI 1.07, 4.85, $P=0.034$). In this model, higher individual level socioeconomic status was significantly associated with decreased risk a high-risk sex partnership (OR 0.87, 95% CI 0.76, 0.99, $P=0.033$).

Outcome – current bacterial STI: In weighted bivariate analyses, survey-reported existence of drug markets was statistically associated with an increased risk for a current bacterial STI (OR 7.38, 95% CI 2.06, 26.41, $P=0.003$) (Table 4). In weighted bivariate analyses, the average report of drug activity by systematic social observations was not significantly associated with a current bacterial STI (OR 0.89, 95% CI 0.56, 1.43, $P=0.629$) and neighborhood drug arrest counts for drug manufacturing, distribution, or intent to distribute were not significantly associated with a current bacterial STI (OR 1.00, 95% CI 0.99, 1.01, $P=0.642$). Thus, the latter two measures were not tested in full models.

In weighted multilevel analyses in a model with individual level demographic and sexual risk behavior factors only, a current bacterial STI was not significantly associated with age (OR 0.91, 95% CI 0.80, 1.02, $P=0.11$), sex (OR 0.86, 95% CI 0.45, 1.65, $P=0.66$), condom use at last sex (OR 1.13, 95% CI 0.57, 2.25, $P=0.72$) and number of sex partners in the past 90 days (OR 1.49, 95% CI 0.75, 2.94, $P=0.26$) (results not shown in Table 4). Survey-reported existence of drug markets remained significantly associated with increased risk for a current bacterial STI after adjusting for individual level demographic and sexual risk behavior factors (OR 6.54, 95% CI 1.85, 23.13, $P=0.005$) and after adjusting for neighborhood socioeconomic status (OR 10.89, 95% CI 1.87, 63.31, $P=0.009$) (Table 4).

The deviance statistic for the model with individual control variables only was 1308.54 with 6 estimated parameters. The deviance statistic for a more general model including survey-reported neighborhood drug markets was 1303.24 with 7 estimated parameters. The chi-square statistic comparing the two models was significant (X^2 5.30, $P=0.020$) suggesting that the model with survey-reported neighborhood drug markets was a better fit. The deviance statistic for a model which included survey-reported neighborhood drug markets and neighborhood socioeconomic status was 1302.74 with 8 estimated parameters. The chi-square statistic comparing the latter model to a more restricted model without neighborhood socioeconomic status had a significant chi-square (X^2 5.50, $P=0.018$) suggesting that the model which also included neighborhood socioeconomic status was a better fit.

Sensitivity analyses conducted with the final model after additional adjustment for individual socioeconomic status resulted in similar findings. Survey-reported existence of drug markets remained significantly associated with increased risk for a current bacterial STI after adjustment for individual and neighborhood factors including individual level socioeconomic status (OR 9.52, 95% CI 1.30, 69.84, $P=0.027$). In this model, higher individual level socioeconomic status was significantly associated with decreased risk for an individual level STI (OR 0.74, 95% CI 0.62, 0.88, $P=0.001$).

Discussion

The central hypothesis of this study was that neighborhood drug markets increase the local concentration of core transmitters and their sex partners, i.e. core groups, and in doing so, increase the likelihood that local residents will select a high-risk sex partner, and that they will have a current bacterial STI. To measure neighborhood drug markets, we used three measures including survey-reports from participants in a household study, systematic social observations and publicly available drug arrest data. We found that living in a neighborhood with survey-reported drug markets significantly increased, more than doubled, the likelihood of having a high-risk sex partnership and significantly increased, by almost 11 times, the likelihood of having a current bacterial STI after controlling for individual level factors and in final analyses, neighborhood socioeconomic status. These relationships, however, were not significant when measuring drug markets from systematic social observations or from publicly available drug arrest data.

With regard to our central hypothesis, our findings suggest that conditions associated with drug markets may play an important role in creating pools of infected sex partners, i.e. core transmitters, and in creating individual level bacterial STI risk for individual residents. The results of this study support our work and that of others describing the neighborhood nature of bacterial STI transmission (Jennings, et al. 2010; Potterat 1992; Potterat, et al. 1983; Rothenberg & Judson 1983). The results also support previous ethnographic findings and suggest that drug markets in urban areas may represent STI risk environments for local residents.

It is unclear why only one of our neighborhood drug market measures was associated with the likelihood of a high-risk sex partnership and a current bacterial STI. One reason may have been the temporality of the data collection. While some evidence suggests that drug markets do not tend to change significantly from year to year (Aral, et al. 1991), other evidence suggests that drug markets may move because of exogenous forces such as police activity. Thus over time there may have been some changes in the location of neighborhood drug markets and because our drug market measures varied in their temporal assessments, this may have affected associations (or the lack of) found. Although the household survey measure was not explicit about time, study participants likely reported on the current drug market activity in their neighborhood. The outcome measure was also a measure of their current infection status and thus these two measures may have been well-linked in time. The systematic social observations were conducted at a later time period (2007 to 2009) than the outcome data from our household survey (2004 to 2007). In addition the systematic social observations were conducted over three time periods lasting 30 to 40 minutes as compared to the survey-report which was not defined temporally and thus may have resulted in a longer temporal picture. The drug arrest measure included summed data from 2004 through 2007 and thus this measure in may not be temporally well-linked to the outcomes which were assessed at one time point for each individual within this time period. The different associations found between our neighborhood drug market measures and outcomes may have also been due to differences between the drug market measures in sensitivity and specificity to different types of drug markets. Drug markets vary in scale, clientele, type of drugs sold, and geography of the network involved (Aral, et al. 1991; Eck 1994; Forsyth, et al. 1992; Rodriguez, et al. 2005). The household survey (NIAAH) asked about whether or not drugs were bought or sold within the neighborhood. We hypothesized that this measure would be a highly sensitive measure of neighborhood drug markets and thus to increase the specificity to our linkage of interest, i.e., increased availability of core transmitters, we coded neighborhoods as having a drug market if greater than 50% of residents reported these activities. Given the required level of agreement, this measure may have identified a particular type of drug market such as large, open outdoor drug markets or more problematic drug markets. The systematic social observations relied on the rating of observers and included indicators of drug use and sales; thus, this measure may have been less specific to drug markets alone and may have also been sensitive to areas with drug use. The drug arrest measure may be sensitive and specific to the types of drug markets that are most likely to be under surveillance by the police department, those most complained about by local residents or those most representative of the most problematic drug markets. Thus these data may also be picking up a specific type of drug market which is slightly different than the other two drug market measures. Future work should attempt to clearly define and distinguish these variations in drug markets in order to test their impact on sexual networks and STI risk.

This study has a number of limitations. Because the individual-level data collected were egocentric it is likely that an index participant's knowledge about his/her sex partner's high-risk status is limited, thereby resulting in underreporting (Lenoir, et al. 2006). Nonetheless, reporting of high-risk sex partner behaviors through direct questioning has been shown to be a reliable method for use with audio-CASI (Nelson, et al. 2007). Misclassification due to

underreporting would have likely attenuated the associations found. The outcome of self-reported high-risk sex partnership includes measures of current behavior (past 90 days) and “ever” behavior (HIV positive and IDU sex partner). The variability of the time frame of the items may not link well with the time of exposure to neighborhood drug markets. We intend to improve upon this measurement in future work. Finally, because the data used for these analyses was cross-sectional, a causal link between drug markets and sex partner concurrency cannot be inferred.

The results presented in this paper suggest that structural-level factors, specifically neighborhood drug markets, may increase the presence of core transmitters and their sex partners, i.e. core groups, and in doing so create a risk environment for STIs. Future studies should continue to explore how drug markets may alter the structure of sexual networks and whether specific types of drug markets are particularly important. Future work also should seek to determine whether changes in neighborhood drug markets cause changes in sexual networks and ultimately individual level risks for STIs.

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Figure 1. Orienting Framework linking neighborhood drug markets to selection of a high-risk sex partners and ultimately, a current bacterial STI (items in shaded circles are the focus of the current study and solid lines indicate the primary hypotheses).

TABLE 1

Characteristics of the NIAAH Household Study Sample of 15–24 Year Olds (n=568) From Selected Neighborhoods (n=63), Baltimore, Maryland, 2004–2007.^a

Individual-level characteristics		
Demographics	Mean	SE
Age	19.1	0.2
Gender	N	%
Female	360	63.3
Male	208	36.7
Race/Ethnicity		
Black	501	88.2
White	40	7.1
Other	27	4.7
Maternal education (n=554)		
Less than a high school degree/GED	108	19.5
High school degree/GED	249	45.0
Greater than a high school degree/GED	196	35.4
Sexual behaviors		
Condom use last sex, no (n=567)	221	38.9
Number of sex partners in the past 90 days		
0–1	438	77.1
2	130	22.9
Drug use		
Non-prescription drug use, ever (n=562)	58	10.5
Injection drug use, ever (n=562)	4	0.7
Outcomes of Interest		
High-risk sex partnership (in the past 90 days greater than or equal to three sex partners, having had a sex partner who practiced concurrency, ever having an HIV+ and/or IDU sex partner, or given or received commercial sex work)	220	38.8
Current bacterial STI (chlamydia and/or gonorrhea)	37	6.5

SE, standard error.

^aUnweighted counts and weighted means/percentages presented.

TABLE 2

Characteristics of the NIAAH Neighborhoods including information from NifETy Systematic Social Observations and Drug Arrest Data, Baltimore, Maryland, 2004 – 2007 (n=63).

Neighborhood-level characteristics		
Socioeconomic status	mean	SD
House value ^a	60,801.6	16,452.7
Household income ^a	29,283.4	10,313.8
Percent of households above the Federal Poverty Line ^a	75.7	14.5
	median	SD
Percent of the population 25 years of age and above with equal to or greater than a college education [†]	7.4	11.8
Drug markets	%	n
Survey-reported neighborhood drug markets from a household study (NIAAH)	81.0	51
	mean	SD
Average report of drug activity by systematic social observations (NifETy) (scale 1 to 4)	0.80	0.62
	median	SD
Count of neighborhood drug arrests for drug manufacturing, distribution, or intent to distribute (publicly available drug arrest data)	22.3	42.9

^aThese four individual socioeconomic status measures were z-scored and averaged to create one index of neighborhood socioeconomic status.

TABLE 3

The Odds Ratios of the Association between Neighborhood Drug Markets and a High-risk Sex Partnership among a Household Sample of 15–24 Year Olds (n=568) From Selected Neighborhoods (n=63), Baltimore, Maryland, 2004 – 2007.

Outcome – High-risk sex partnership ^b		Model 1 ^a OR	95% CI	Model 2 ^a AOR	95% CI	Model 3 ^a AOR	95% CI
Survey-reported neighborhood drug markets from a household study (NIAAH)		1.79 [*]	0.91, 3.53	2.54 ^{**}	1.21, 5.34	2.60 ^{**}	1.18, 5.70
Control variables							
Individual-level							
Age				1.09 ^{**}	1.02, 1.17	1.09 ^{**}	1.02, 1.17
Sex	female			Referent		Referent	
	male			2.65 ^{**}	1.84, 3.82	2.65 ^{**}	1.84, 3.82
Non-prescription drug use, ever (n=562)				2.50 ^{**}	1.06, 5.92 [*]	2.49 ^{**}	1.06, 5.88
Neighborhood-level							
Socioeconomic status						1.01	0.80, 1.29

Model 1, Neighborhood level variable of interest and outcome;

Model 2, Neighborhood level variable of interest, individual level control variables, and outcome;

Model 3, Neighborhood level variable of interest, individual and neighborhood level control variables, and outcome;

OR, odds ratio;

AOR, adjusted odds ratio;

CI, confidence interval

^aThe models are nonlinear multilevel models using multilevel sampling weights.

^bHigh-risk sex partnership defined as in the past 90 days greater than or equal to three sex partners, having had a sex partner who practiced concurrency, ever having an HIV+ and/or IDU sex partner, or given or received commercial sex work.

^{**}P < 0.05.

^{*}P < 0.10.

TABLE 4

The Odds Ratios of the Association Between Neighborhood Drug Markets and a Current Bacterial STI among a Household Sample of 15–24 Year Olds (n=568) from Selected Neighborhoods (n=63), Baltimore, Maryland, 2004–2007.

Outcome – Current bacterial STI ^b		Model 1 ^a OR	95% CI	Model 2 ^a AOR	95% CI	Model 3 ^a AOR	95% CI
Survey-reported neighborhood drug markets from a household study (NIAAH)		7.38	2.06, 26.41 ^{**}	6.54 ^{**}	1.85, 23.14	10.89 ^{**}	1.87, 63.31
Control variables							
Individual-level							
Age				0.91	0.81, 1.03	0.91	0.81, 1.03
Sex	female			Referent		Referent	
	male			0.89	0.46, 1.72	0.90	0.46, 1.79
Condom use at last sex	yes			Referent		Referent	
	no			1.13	0.57, 2.23	1.15	0.57, 2.31
No. of sex partners in the past 90 days	0–1			Referent		Referent	
	2			1.42	0.72, 2.81	1.45	0.72, 2.91
Neighborhood-level							
Socioeconomic status						1.41	0.82, 2.43

Model 1, Neighborhood level variable of interest and outcome;

Model 2, Neighborhood level variable of interest, individual level control variables, and outcome;

Model 3, Neighborhood level variable of interest, individual and neighborhood level control variables, and outcome;

OR, odds ratio;

AOR, adjusted odds ratio;

CI, confidence interval

^aThe models are nonlinear multilevel models using multilevel sampling weights.

^bCurrent bacterial STI defined as a current chlamydia and/or gonorrhea infection.

^{**} P < 0.05.

* P < 0.10.