Health & Place 23 (2013) 128–137

Contents lists available at SciVerse ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

The spatial and temporal association of neighborhood drug markets and rates of sexually transmitted infections in an urban setting

Jacky M. Jennings [a,b,*], Stacy E. Woods [c], Frank C. Curriero [c,d]

[a] *Center for Child and Community Health Research (CCHR), Department of Pediatrics, Johns Hopkins School of Medicine, Baltimore, MD, USA*
[b] *Department of Epidemiology, John Hopkins Bloomberg School of Public Health, Baltimore, MD, USA*
[c] *Department of Environmental Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA*
[d] *Department of Biostatistics, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA*

ARTICLE INFO

Article history:
Received 13 September 2012
Received in revised form
27 May 2013
Accepted 1 June 2013
Available online 27 June 2013

Keywords:
Sexually transmitted infections
Drug markets
Social epidemiology
Ecologic analyses
Spatial analyses

ABSTRACT

This study examined temporal and spatial relationships between neighborhood drug markets and gonorrhea among census block groups from 2002 to 2005. This was a spatial, longitudinal ecologic study. Poisson regression was used with adjustment in final models for socioeconomic status, residential stability and vacant housing. Increased drug market arrests were significantly associated with a 11% increase gonorrhea (adjusted relative risk (ARR) 1.11; 95% CI 1.05, 1.16). Increased drug market arrests in adjacent neighborhoods were significantly associated with a 27% increase in gonorrhea (ARR 1.27; 95% CI 1.16, 1.36), independent of focal neighborhood drug markets. Increased drug market arrests in the previous year in focal neighborhoods were not associated with gonorrhea (ARR 1.04; 95% CI 0.98, 1.10), adjusting for focal and adjacent drug markets. While the temporal was not supported, our findings support an associative link between drug markets and gonorrhea. The findings suggest that drug markets and their associated sexual networks may extend beyond local neighborhood boundaries indicating the importance of including spatial lags in regression models investigating these associations.

1. Introduction

Investigations into the dynamics of STI transmission over the past 30 years have demonstrated that a small group of individuals, called core transmitters, tend to drive STI rates in a population (Yorke et al., 1978; Thomas and Tucker, 1996; Brunham, 1991). Core transmitters maintain and fuel disease rates in the population by repeatedly acquiring and transmitting disease (Ellen et al., 1997). Early definitions of core groups relied largely on information about numbers of sex partners; however, more recent theory and evidence supports defining core groups using information about the sexual network connections among core group members (Potterat et al., 1985; Brunham, 1991; Watts and May, 1992; Kretzschmar and Morris, 1996; Ghani et al., 1997; Morris and Kretzschmar, 1997; Potterat et al., 1999; Koumans et al., 2001; Newman, 2002; Jolly and Wylie, 2002; Cunningham et al., 2004). Empirical investigations of disease transmission networks, along with mathematical models, have confirmed the importance of interconnected network structures for the maintenance of endemic disease, including gonorrhea and HIV (Brunham, 1991). Highly interconnected sexual networks, however, may be necessary but not sufficient to explain core group transmission. Studies have found variability in disease transmission networks within similarly characterized networks (Wylie et al., 2010).

Variability in disease transmission networks may in part be due to place differences. That is, network structures bounded in specific geographic locations may be critical for active and ongoing transmission (Weir et al., 2003; Jennings et al., 2005; Diez Roux, 2007; Wylie et al., 2010; Fichtenberg et al., 2010). The importance of network structures in place is supported by extensive evidence that rates and counts of STIs are heterogenous across city or county geographies (Rothenberg, 1983; Lacey et al., 1997; Jennings et al., 2005; Monteiro et al., 2005; Risley et al., 2007; Schleihauf et al., 2009). Additional studies have shown that important transmission behaviors such as sexual concurrency (overlapping sexual partnerships in time) or high numbers of sex partners do not predict STIs alone; rather the relationship of these behaviors to STI transmission is affected by the prevalence of STIs in the local area (Serwadda et al., 1992; Jennings et al., 2004).

A conceptual framework is presented in Fig. 1. It sets the dynamics investigated here within a broader outline of how neighborhood drug markets may link to other neighborhood factors setting up the likelihood for the transmission and persistence of STIs. Our hypotheses are based on the central idea that

* Corresponding author at: Department of Pediatrics, Johns Hopkins School of Medicine, The Johns Hopkins University, Bayview Medical Center, 5200 Eastern Avenue, Mason F. Lord Bldg – Center Towers, Suite 4200, Baltimore, MD 21224, USA. Tel.: +1 410 550 4132; fax: +1 410 550 4153.
E-mail address: jjennin1@jhmi.edu (J.M. Jennings).

1353-8292/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.healthplace.2013.06.002

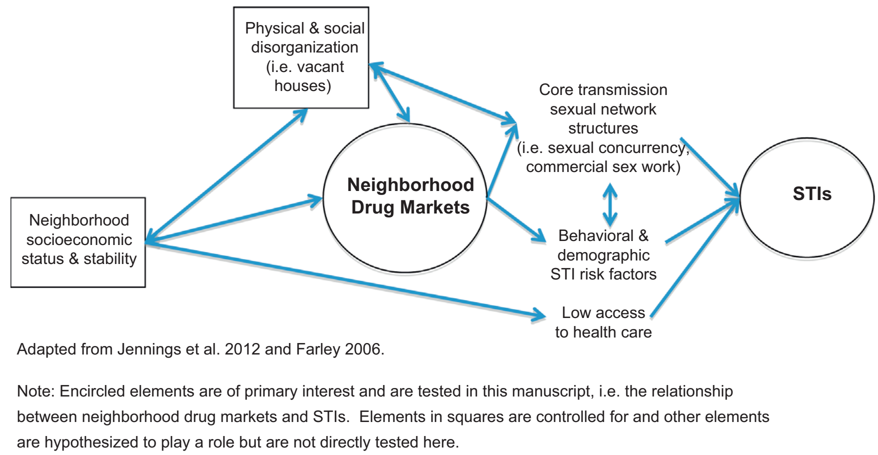

Fig. 1. Orienting framework showing the hypothesized relationship between neighborhood drug markets and sexually transmitted infections (STIs) along with other variables of interest.
Note: Encircled elements are of primary interest and are tested in this manuscript, i.e. the relationship between neighborhood drug markets and STIs. Elements in squares are controlled for and other elements are hypothesized to play a role but are not directly tested here.
Source: Adapted from Jennings et al. (2012) and Farley (2006).

within and around drug markets, multiple complex social phenomena are occurring which result in increased STI transmission. Within drug market social networks, individuals may meet sexual partners and may have overlapping sexual partnerships in time (sexual concurrency) (Ellen et al., 1997). Commercial sex work and the exchange of sex for drugs or money may create networks where a few individuals have large numbers of sexual partners. Commercial sex work and sexual concurrency have been associated with risk for both heterosexual and homosexual transmission of HIV (Flom et al., 2001; Adimora et al., 2007; Gyarmathy and Neaigus 2009; Fast et al., 2010). Sexual activity may not occur physically at the geographical location of the drug market, but sexual networks may occur as a result of connections formed within the drug market social network. There is considerable evidence that individuals engaged in drug dealing or use have high rates of HIV and other STIs including gonorrhea (Friedman et al., 2005; Centers for Disease Control and Prevention, 2009).

Our recent work suggests that specific places are associated with risks for STIs independent of individual STI risk factors. In a multilevel, cross-sectional household study among youth in an urban setting, we demonstrated that places with neighborhood drug markets were associated with an increased likelihood of selecting a high-risk sexual partner and, separately, of current infection with a bacterial STI *at the individual level* (Jennings et al., 2012). Neighborhood drug markets are defined as specific geographic areas where illicit drug dealing (e.g., heroin, cocaine including crack-cocaine, and/or marijuana) occurs (Reuter and MacCoun, 1992). Our findings supported our hypothesis that neighborhood drug markets have the necessary and sufficient factors to maintain disease transmission, namely disease prevalence and highly interconnected network structures. This premise is further supported by other work that has found drug dealers and users have high STI prevalence (Thomas and Tucker, 1996). The strengths of our study were that it extended previous ecologic analyses and used multilevel (neighborhood and individual level) information to deduce the independent effect of place. The study, however, was cross-sectional in design and, thus, we could not conclude a causal effect between neighborhood drug markets and risk for an STI. Furthermore, the study treated neighborhoods as independent units of analyses, which belies the spatial nature of networks and specifically the likely fluidity of networks between adjacent neighborhoods.

In the current study, we built on our previous work and addressed the limitations of causality and spatial effects using spatial and longitudinal ecologic analyses. The objectives of the current study were to (1) investigate whether increased neighborhood drug market activity was associated with increased gonorrhea occurrence in the same neighborhood using ecologic analyses, (2) investigate whether increased neighborhood drug market activity in surrounding or adjacent neighborhoods was associated with increased gonorrhea occurrence in the focal neighborhood using spatial ecologic analyses, and (3) determine whether the presence of drug markets in the previous year is predictive of gonorrhea occurrence in the subsequent year.

2. Methods

2.1. Setting

The study was conducted in Baltimore City, Maryland, a city with a long history of syndemic illicit drug activity and STI infection. Baltimore is located in the Mid-Atlantic United States (U.S.) and had a 2010 population of 620,961 (US Census Bureau, 2011). Baltimore has endemic rates of injection drug-use (IDU) and non-IDU (Gleghorn et al., 1995; Simon and Burns, 1997; Agar and Reisinger, 1999; Nandi et al., 2010; Mehta et al., 2006). The actual numbers of illicit drug users are difficult to calculate, but estimates suggest that in 2002 Baltimore City had 20,120 IDUs, with heroin featuring prominently (United States National Drug Intelligence Center, 2003). Police suggest that illicit drugs are a factor in eight of every ten homicides in the city (Craig, 2000). Baltimore also has endemic rates of STIs, and is a city with severe racial/ethnic disparities in STIs (Centers for Disease Control and Prevention, 2011). In 2010, Baltimore had the second highest gonorrhea rate per 100,000 population among U.S. counties (Centers for Disease Control and Prevention, 2011).

2.2. Data collection

This was a spatial, longitudinal ecologic study. Data on outcomes, exposures, demographics, and socioeconomic indicators were collected for the 710 census block groups (CBGs) in Baltimore City annually from 2002 to 2005 from multiple sources including the Baltimore City Health Department, Baltimore City Police

Department, Baltimore City Planning Department, and U.S. Census. In our study, neighborhoods were defined by CBG boundaries. CBGs excluded from the study population included CBGs with a lack of data on population size ($n=3$) and CBGs where 50% or more of the population resided in group quarters (i.e. the Maryland Penitentiary) ($n=1$). The final study sample size of CBGs was 706.

2.3. Measures

The outcome of interest, STI rates, was evaluated by considering gonorrhea cases. Gonorrhea prevalence was selected as the indicator of STI prevalence because of the standard reporting procedures for gonorrhea and the relatively large number of cases reported in any one year, thus providing stable estimates of disease prevalence. We obtained all reported gonorrhea cases diagnosed in Baltimore City from 2002 to 2005 from the Baltimore City Health Department ($n=15{,}572$). Gonorrhea case addresses were geocoded to a street location using ArcGIS v9.3 (ESRI, Redlands, CA) and Baltimore City Department of Planning basemaps. Records with diagnosis dates prior to January 1, 2002, were removed from the dataset ($n=87$). Of the remaining 15,485 gonorrhea cases, 92.3% (14,298 cases) were successfully geocoded and aggregated to their associated CBG. Cases that did not geocode were missing street address information ($n=807$) or contained an address located outside of the Baltimore City limits ($n=380$). Duplicated geocoded records, defined as records with the same patient ID and diagnosis date, were removed ($n=1775$). Records for patients aged less than 15 years or greater than 49 years, or records with no age or date of birth included, were also removed from the dataset ($n=640$). The final data included 11,966 gonorrhea cases.

The primary exposure of interest was drug market activity by neighborhood. Drug markets are illicit drug dealing (e.g., heroin, cocaine including crack-cocaine, and/or marijuana) within a specific geographic area (Reuter and MacCoun, 1992). In order to evaluate neighborhood drug market activity, we obtained publicly available address level arrest data ($n=30{,}185$) from 2002 through 2005 from the Baltimore City Police Department. Drug market arrest data was defined as any arrest for drug manufacturing, trafficking, importing, and distribution/intent to distribute. We made no distinction between arrests for types or classes of narcotics. Duplicate arrest records, defined as records with the same arrest date, offender's date of birth, offender's home address, and arrest location, were excluded ($n=10$). The remaining drug market arrests ($n=30{,}175$) were geocoded to a street location; 94.4% ($n=28{,}486$) were successfully geocoded and aggregated to their associated CBG. Drug market arrests that did not geocode due to lacking street address data or having an address beyond the boundaries of Baltimore City were excluded ($n=1689$). Arrest records were also excluded from the analysis if they occurred on highways I-95, I-83, or I-895 ($n=44$). The latter exclusion was conducted because the central hypothesis of our study concerns the link between neighborhood drug markets and gonorrhea transmission; this link is unlikely to pertain to drug market arrests made on highways which do not have a relevant neighborhood. We included 28,439 drug market arrests in our final analysis.

While we considered drug market arrests as our primary exposure of interest, we considered drug use arrests as a potential confounder (i.e. in Fig. 1 operationalized as a behavioral risk factor) in final regression models to determine the spatial and longitudinal relationship between drug markets and gonorrhea incidence independent of illicit drug use. This was based on evidence suggesting that drug market and drug use activities may not occur within the same neighborhood (Weisburd and Green, 1994; Saxe et al., 2001). We defined drug use arrests as any arrest for drug possession and obtained the records of these arrests from the Baltimore City Police Department for the years 2002 through 2005 ($n=73{,}542$). Duplicate drug use arrest records were defined and excluded in the same manner as drug market arrests ($n=21$). Non-duplicate drug use arrest data were geocoded and aggregated to a CBG; 93.1% ($n=68{,}412$) were successfully geocoded. Drug use arrests that occurred on highways ($n=172$) were excluded ($n=10$). We considered 68,230 drug use arrests in our final analysis.

Regression analysis controlled for neighborhood compositional factors of socioeconomic status and residential stability. Based on social normative theories and theories of social disorganization as well as empiric evidence, current theories hold that neighborhood drug markets may be more likely to occur and are more visible in low socioeconomic status neighborhoods (Sampson and Lauritsen, 1994). Crum et al. (1996) found that residing in highly disadvantaged neighborhoods increased youth's risk for exposure to cocaine among elementary students in an urban area. Saxe et al. (2001) found in a national telephone survey among 16–44 year olds across 41 communities that the most disadvantaged neighborhoods had the most visible drug problems (Saxe et al., 2001). As shown in our framework (Fig. 1), low socioeconomic status areas may also have individuals who are more likely to practice high-risk sex behaviors resulting in greater risk for STIs. In our study, we treated neighborhood socioeconomic status and residential stability as potential confounders because we were interested in determining whether neighborhood drug markets were associated with increased gonorrhea rates independent of these factors. Using data from the U.S. Census 2000, we measured neighborhood socioeconomic status by constructing an index of four measures: 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 poverty line (United States Census Bureau, 2003). The status index had acceptable reliability (Cronbach's $\alpha=0.78$). We measured residential stability by using the average of two percentages: the percent of owner occupied households, and the percent of households that had been at the same address five years previously. Internal consistency was sufficient for this index, given that it contained only two items (Cronbach's $\alpha=0.72$).

We also controlled for a contextual factor, percent vacant houses (Fig. 1), because social disorganization theory suggests that places with vacant houses may be more likely to lack community structures related to guardianship and social controls and thus are places with a greater likelihood for illegal activity such as drug markets (Sampson and Lauritsen, 1994). Areas with high percentages of vacant houses may be areas with higher rates of unstable sexual partnerships creating core transmission sexual network structures (Farley, 2006). Percent vacant houses was measuring using information from the U.S. Census 2000 on the number of vacant houses over the total number of houses within a census block group.

In sensitivity analyses, we also controlled for another compositional factor, percent African American, because social normative theories and theories of social disorganization suggest that among minority populations, normative constraints against illegal activities such as drug market activity may be difficult to establish and maintain (Shaw and McKay, 1947; Sampson et al., 1997). Percent African America was obtained from the U.S. Census 2000. We have chosen to treat percent minority as a sensitivity analysis rather than a confounder because while African Americans are more likely than other racial/ethnicities in U.S. urban areas to be arrested for drug market activity and to be diagnosed with an STI, race is not a biological determinant of either of these factors but rather a social determinant which is likely highly collinear with the exposure variables included in the conceptual framework.

2.4. Statistical analyses

In ecologic analyses, we analyzed our outcome of interest, CBG gonorrhea count among 15–49 year olds, using spatial and longitudinal models that considered one or more of the following covariates: drug market arrests, drug use arrests, drug market and drug use arrests in neighboring CBGs (the neighbor effect), drug market and drug use arrests in the previous year (temporal effect), socioeconomic status, residential stability and percent vacant houses. In sensitivity analyses, we examined whether the results were robust to additional adjustment for percent African American per CBG.

Given the spatial and longitudinal design for this study, Poisson regression was used to model and link drug market activity to rates of gonorrhea. With Y_{ij} and μ_{ij} denoting the observed and expected gonorrhea counts in CBG i for year j; $i=1,\ldots710$ and $j=2002,\ldots2005$, we modeled $Y_{ij}\sim\text{Pois}(\mu_{ij})$

$$\log(\mu_{ij}) = \log(E_{ij}) + \beta_0 + \beta_1 X_{1ij} + \ldots\beta_p X_{pij} \quad (1)$$

where $X_1,\ldots,X_p$ represents CBG year-specific exposure (drug market) and confounder variables and $\beta_{1,\ldots,}\ \beta_p$ their corresponding regression effects. Since different age and gender groups are associated with different likelihoods of both our outcome of interest (gonorrhea) and our primary exposure of interest (drug market activities) (National Center for Health Statistics, 2010; Lambert et al., 2004; Substance Abuse and Mental Health Services Administration, 2010), CBG gonorrhea counts were first age-gender standardized for each year using indirect standardization (Fisher et al., 1993). Age standardization was completed using the 2000 Census population numbers for residents aged 15–49 years old in each CBG. This age group was selected to reflect the primary age group at risk for gonorrhea infection. These age-gender standardized gonorrhea counts are denoted in Eq. (1) as the Poisson regression offset E_{ij}. Thus, the regression effects $\exp(\beta)$ are interpreted as relative risk after adjusting for differences in age and gender. Age–gender standardized gonorrhea counts are hereafter referred to as gonorrhea counts.

We considered spatial lag versions for the exposure and confounder variables to identify and account for a potential surrounding neighborhood effect. In this study, we defined neighboring CBGs as those that share a boundary with the focal CBG, defining contiguity based on what is known in the literature as the "queen" move in reference to the game of chess (Bivand et al., 2008). A spatial lag variable was defined for each focal CBG as the mean of that variable in the neighboring CBGs. For example, with the drug market variable, we considered the number of drug market arrests per CBG (focal variable) as well as the average number of drug market arrests in the neighboring CBGs (spatial lag variable). Including both focal and spatial lag effects in regression models allowed us to explore interesting synergistic and/or opposing spatial effects.

As stated in the Introduction, the objectives of this study involved determining the effect of drug markets on gonorrhea rates, isolating the contribution of focal and spatially lagged drug markets, and determining whether a temporal lag in drug market activity is predictive of subsequent gonorrhea rates. The Poisson regression formulation in Eq. (1) was used for these objectives, although the data set was limited to years 2003–2005 when assessing the temporal lag effect in drug market activity, with 2002 serving as the baseline year.

Standard regression model building procedures were followed. These included univariate regression models (each covariate in the model by itself) to assess individual variable contributions to gonorrhea counts followed by multivariable regression models (multiple covariates in the model together) based on conceptual relevance and individual level significance of the variables. All included variables were assessed for multicollinearity which can be an issue when using spatially lagged variables. Models were built in a nested fashion with model fit evaluated using variable significance and change in the Poisson regression model deviance. Regression inference was based on a generalized estimating equation approach (GEE) (Liang and Zeger, 1986) to account for the possibility of residual temporal autocorrelation due to the repeated time CBG rates. The issue of possible residual spatial autocorrelation over the CBGs for any given year was explored using Moran's I statistic on the regression residuals (Waller and Gotway, 2004).

All statistical analyses including Poisson regression and descriptive statistics were performed in the R Statistical Computing Environment (R R Development Core Team, 2011) with R contributed packages for GEE-based regression inference and spatial statistical operations, including gee, spdep, and maptools. Data management was shared between R and ArcGIS (ArcGIS v10, Redlands, CA), with all final maps produced in ArcGIS.

3. Results

3.1. Study population

The 706 Baltimore City CBGs included in our analysis encompassed 645,084 residents, of which 330,685 were aged 15–49, our age group of interest. Within the population aged 15–49 years old, 46.7% were males ($n=154{,}481$) and 53.3% were females ($n=176{,}204$).

3.2. Descriptive statistics

Descriptive statistics for the main outcome, main exposure of interest and other measures utilized to adjust regression models are included in Table 1. From 2002 to 2005, there was a 29% decline in the average rate and case counts gonorrhea. Within any given year from 2002 to 2005, the gonorrhea case count and the rate among the population aged 15–49/CBG ranged from 0 to 30 and from 0 to 3250/100,000 (Fig. 2). From 2002 to 2005, there was an 11% increase in the average rate and number of drug market arrests. Within a given year from 2002 to 2005, the drug market arrests ranged from 0 to 234/CBG (Fig. 3).

3.3. Statistical analyses

Poisson modeling results for univariate and multivariable analysis are presented according to each objective. In final models, we controlled for neighborhood compositional factors including drug use arrests, socioeconomic status, residential stability, and vacant housing. In a sensitivity analyses we controlled for percent African American. We interpreted our regression results for drug market and drug use defining a per unit change of 25 arrests. Likewise, percent African American was interpreted per unit change of 10%. Regression results for socioeconomic status and residential stability indices were left in their original units.

Objective 1: The first set of models determined whether increased numbers of neighborhood drug market arrests were associated with increased gonorrhea counts in the same neighborhood using ecologic analyses. In univariate analyses, every unit increase in drug market arrests was significantly associated with a 40% increase in gonorrhea counts in the focal neighborhood (Relative Risk (RR) 1.40, 95% Confidence Interval (CI) 1.26, 1.55) (Table 2). Every unit increase in drug use arrests was significantly associated with a 21% increase in gonorrhea counts (RR 1.21, 95% CI

Table 1
Characteristics of census block groups including gonorrhea counts per 15–49 year olds and drug market arrest data from 2002 through 2005, Baltimore City ($n=706$).

CBG characteristics	2002		2003		2004		2005		All Years	
Focal CBG	Count	Mean (SD)	Count	Mean (SD)	Count	Mean (SD)	Count	Mean (SD)	Count	Mean (SD)
2000 Population aged 15–49 years	NA	NA	NA	NA	NA	NA	NA	NA	330,685	468 (273)
Gonorrhea	3541	5 (4)	3008	4 (4)	2910	4 (4)	2537	4 (3)	11,996	17 (14)
		Median (range)		Median (range)		Median (range)		Median (range)		Median (range)
Drug market arrests [a]	6767	2 (0.234)	7570	3 (0.186)	6605	3 (0.129)	7497	4 (0.95)	28439	12 (0–644)
Drug use arrests [b]	18,341	8 (0.358)	16,052	9 (0.237)	15,839	9 (0.219)	17,998	12 (0.307)	68,230	40 (0–935)
Neighboring CBGs (spatial lag)	Count	Median (range)	Count	Median (range)	Count	Median (range)	Count	Median (range)	Count	Median (range)
Drug market arrests, neighbors [a]	6993	5 (0.62)	7830	6 (0.67)	6806	5 (0.47)	7738	6 (0.51)	29,367	23 (0–211)
Drug use arrests, neighbors [b]	19,291	15 (0.157)	16,805	17 (0.128)	16,643	17 (0.115)	18,767	20 (0.130)	71,506	69 (1–476)
Prior year (temporal lag)	Count	Mean	Count	Mean	Count	Mean	Count	Mean	Count	Mean
Absolute change (Y2–Y1) in drug market arrests per CBG [a]	NA	NA	803	1.14	−965	−1.37	892	1.26	NA	NA
Control variables	Count	Mean (SD)	Count	Mean (SD)	Count	Mean (SD)	Count	Mean (SD)	Count	Mean (SD)
Socioeconomic status [c]	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.01 (0.82)
Residential stability [d]	NA	NA	NA	NA	NA	NA	NA	NA	NA	54.03 (18.72)
		Mean % (range)		Mean % (range)		Mean % (range)		Mean % (range)		Mean % (range)
Vacant houses [e]	NA	NA	NA	NA	NA	NA	NA	NA	NA	14.69 (0–100)
Percent African American [f]	NA	NA	NA	NA	NA	NA	NA	NA	NA	65.56 (0–100)

[a] Drug market arrest data was defined as any arrest for drug manufacturing, trafficking, and distribution/intent to distribute and was obtained for 2002 through 2005 from the Baltimore City Police Department.
[b] Drug use arrest data was defined as any arrest for possession and was obtained for 2002 through 2005 from the Baltimore City Police Department.
[c] Neighborhood socioeconomic status was defined as an average of individual z-scores from Census 2000 measures including 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 poverty line (Cronbach's $\alpha=0.78$).
[d] Residential stability was defined as the average of two percentages from Census 2000 measures including percent of owner occupied households and percent of households that had been at the same address five years previously (Cronbach's $\alpha=0.72$).
[e] Percent vacant houses was defined as the percent of all dwellings that were uninhabited per Census 2000.
[f] Percent African American was defined as the percent of the total population that self-identified as Black or African–American.

1.17, 1.24). Every unit increase in socioeconomic status was significantly associated with a 44% decline in gonorrhea counts (RR 0.44, 95% CI 0.41, 0.47). Every unit increase in residential stability was not significantly associated with gonorrhea counts (RR 1.00, 95% CI 1.00, 1.00). Every unit increase in percent vacant houses was significantly associated with gonorrhea counts (RR 1.25, 95% CI 1.08, 1.32). Every unit increase in percent African American was significantly associated with gonorrhea counts (RR 1.21, 95% CI 1.20, 1.23).

Prior to building the multivariable models, we ran a multicollinearity check for all covariates. The drug market and drug use arrest variables were highly correlated with correlation coefficients ranging from 0.76 to 0.86 for years 2002 to 2005. Since arrests due to drug market activity was our primary exposure variable and showed stronger associations to gonorrhea count than drug use arrests in univariate models, the drug market arrest variable was retained while the drug use arrest variable was removed from multivariable modeling. No other correlations among focal effects were of notable strength to cause issues with modeling.

In multivariable regression models after controlling for socioeconomic status, residential stability and percent vacant houses, every unit increase in drug market arrests was associated with a 11% increase in gonorrhea counts (RR 1.11, 95% CI: 1.05, 1.16) (Table 2, Objective 1, Model 1). Socioeconomic status, residential stability and percent vacant houses in this model also remained significantly associated with gonorrhea counts (RR 0.43, 95% CI: 0.40, 0.46; RR 1.01, 95% CI: 1.01, 1.01; RR 1.09, 95% CI: 1.06, 1.12). In sensitivity analyses controlling for percent African American in addition to the other control variables, every unit increase in drug market arrests was associated with an 15% increase in gonorrhea counts (RR 1.15, 95% CI: 1.09, 1.20) (Table 2, Objective 1, Model 2).

Objective 2: The second set of models determined whether increased numbers of drug market arrests in surrounding neighborhoods were associated with increased gonorrhea in the focal neighborhood (i.e. spatial lag model to investigate the neighbor effect). In univariate analysis, every unit increase in the average of drug market arrests in adjacent neighborhoods was associated with a 128% increase in gonorrhea counts in the focal neighborhood (RR 2.28, 95% CI: 2.12, 2.45) (Table 2, unadjusted RR). Univariate analysis showed that every unit increase in the average of drug use arrests in adjacent neighborhoods was associated with a 44% increase in gonorrhea counts in the focal neighborhood
(RR 1.44, 95% CI: 1.40, 1.49). These spatial lag effects (the drug market and drug use arrests for adjacent neighborhoods) were more strongly associated with gonorrhea counts in univariate models than their respective focal effects (the drug market and drug use arrests for focal neighborhoods). The spatial lag variables for drug market and drug use arrests were highly correlated, with a correlation coefficient of no lower than 0.82 for any year, mirroring the correlation between focal drug market and drug use arrest variables described above. Since drug market arrests in adjacent neighborhoods were more strongly associated with gonorrhea counts in focal neighborhoods than were drug use arrests in adjacent neighborhoods, the spatial lag version of drug market arrests but not of drug use arrests was retained in further modeling. Correlations between the focal and spatial lag drug market arrests were no larger than 0.62 for any year causing no issues when both were in the model together.

In multivariable regression models, every unit increase in drug market arrests in adjacent neighborhoods was significantly associated with a 27% increase in gonorrhea counts in the focal neighborhood (RR 1.27, 95% CI 1.16, 1.36) (Table 2, Objective 2, Model 1). Focal drug market arrests remained significantly associated with increased gonorrhea counts (RR 1.06, 95% CI 1.01, 1.12). Socioeconomic status, residential stability and percent vacant houses also remained significantly associated with gonorrhea

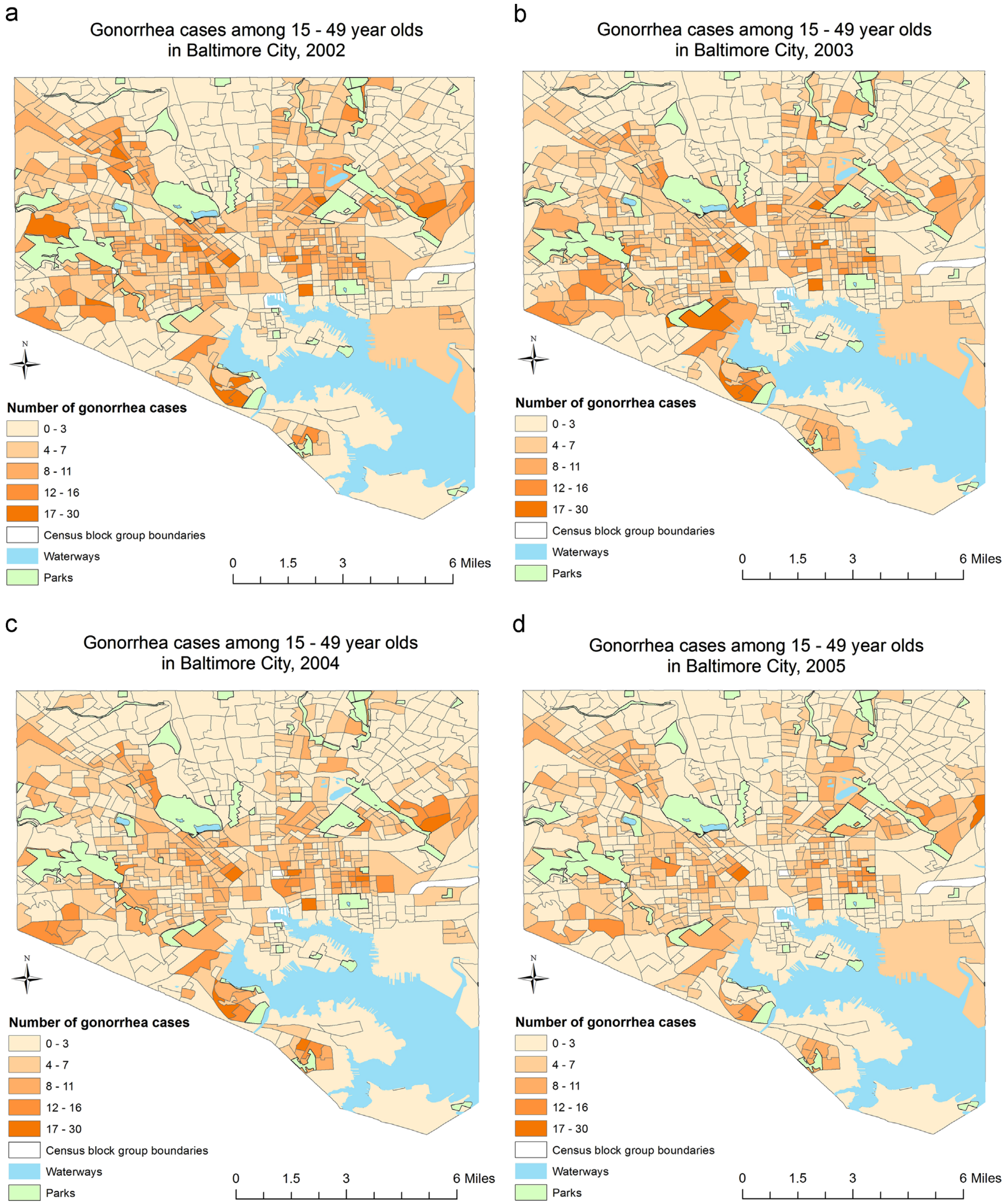

Fig. 2. Gonorrhea case counts among 15–49 year olds by year per census block group, Baltimore City, 2002–2005.

counts (RR 0.46, 95% CI: 0.43, 0.49; RR 1.01, 95% CI: 1.01, 1.01; RR 1.06, 95% CI: 1.03, 1.10). In sensitivity analyses controlling for percent African American, every unit increase in drug market arrests in adjacent neighborhoods was significantly associated with a 21% increase in gonorrhea counts in the focal neighborhood (RR 1.21, 95% CI 1.12, 1.31) (Table 2, Objective 2, Model 2). By including African American in the model, however, focal drug market arrests were no longer significantly associated with increased gonorrhea counts (RR 1.05, 95% CI 1.00, 1.10).

Objective 3: The third set of models determined whether the presence of drug markets in the previous year in a focal neighborhood predicted gonorrhea occurrence in the same neighborhood in the subsequent year. In univariate analyses, every unit change in drug market arrests in the previous year (temporal lag) predicted a

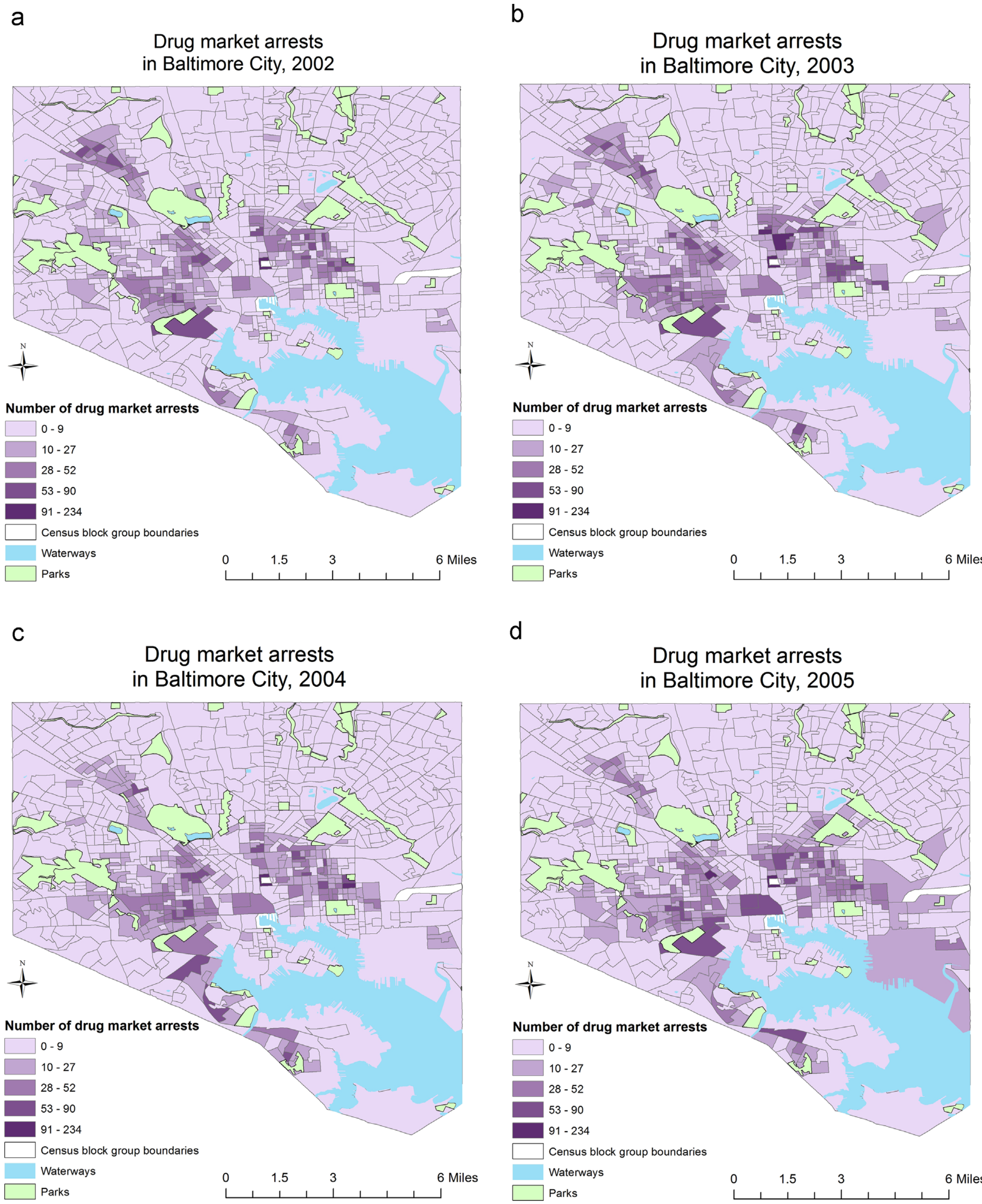

Fig. 3. Drug market arrest counts by year per census block group, Baltimore City, 2002–2005.

38% increase in gonorrhea in the current year in the focal neighborhood (RR 1.38, 95% CI: 1.25, 1.53) (Table 2, Unadjusted RR). Drug use arrests in the previous year predicted a 21% increase in gonorrhea in the current year in the focal neighborhood (RR 1.21, 95% CI: 1.17, 1.25). As in our previous models, because of a high correlation between drug market and use arrests, we included only the temporally lagged drug market arrest variable in further modeling.

In multivariable regression models that included the temporally lagged drug market arrest variable and controlled for drug market arrests in adjacent neighborhoods (the spatially lagged drug arrest variable) and drug market arrests in the focal neighborhood as well as focal socioeconomic status, residential stability and percent vacant houses, every unit change in drug market arrests in the previous year was not predictive of increased gonorrhea in the current year (RR 1.04, 95% CI: 0.98, 1.10)

Table 2
Unadjusted (RR) and adjusted relative risks (ARR) for age-adjusted and sex-adjusted gonorrhea counts per 15–49 year olds per Census Block Group from 2002 through 2005, Baltimore City ($n=706$).

Characteristic	Unadjusted		Objective 1				Objective 2				Objective 3	
			Model 1		Model 2		Model 1		Model 2		Model 1	
Focal neighborhood	RR	95% CI	ARR	95% CI	ARR	95% CI	ARR	95% CI	ARR	95% CI	ARR	95% CI
Drug market arrest counts [a]	1.40	(1.26, 1.55)	1.11	(1.05, 1.16)	1.15	(1.09, 1.20)	1.06	(1.01, 1.12)	1.05*	(1.00, 1.10)	1.07	(1.00, 1.14)
Drug use arrest counts** [b]	1.21	(1.17, 1.24)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Adjacent neighborhood (spatial lag)												
Drug market arrest count, neighbors 1	2.28	(2.12, 2.45)	NA	NA	NA	NA	1.27	(1.16, 1.36)	1.21	(1.12, 1.31)	1.28	(1.17, 1.40)
Drug use arrest count, neighbors [b]	1.44	(1.40, 1.49)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Prior year (temporal lag)												
Drug market arrest counts in the previous year [a]	1.38	(1.25, 1.53)	NA	NA	NA	NA	NA	NA	NA	NA	1.04*	(0.98, 1.10)
Drug use arrest counts in the previous year [b]	1.21	(1.17, 1.25)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Neighborhood control variables												
Socioeconomic status [c]	0.44	(0.41, 0.47)	0.43	(0.40, 0.46)	0.58	(0.54, 0.63)	0.46	(0.43, 0.49)	0.61	(0.57, 0.66)	0.46	(0.42, 0.50)
Residential stability [d]	1.00*	(1.00, 1.00)	1.01	(1.01, 1.01)	1.01	(1.01, 1.01)	1.01	(1.01, 1.01)	1.01	(1.01,1.01)	1.01	(1.01, 1.01)
Percent vacant houses [e]	1.25	(1.88, 1.32)	1.09	(1.06, 1.12)	1.09	(1.06, 1.12)	1.06	(1.03, 1.10)	1.07	(1.04, 1.10)	1.05	(1.02, 1.09)
Percent African American[f]	1.21	(1.20, 1.23)	NA	NA	1.32	(1.12, 1.15)	NA	NA	1.13	(1.12, 1.14)	NA	NA

* Not significant.
** Drug use arrests not utilized in multivariable models due to high correlation with drug market arrests.
[a] Drug market arrest data was defined as any arrest for drug manufacturing, trafficking, and distribution/intent to distribute address and was obtained for 2002 through 2005 from the Baltimore City Police Department.
[b] Drug use arrest data was defined as any arrest for possession and obtained for 2002 through 2005 from the Baltimore City Police Department.
[c] Neighborhood socioeconomic status was defined as an average of individual z-scores from Census 2000 measures including 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 poverty line (Cronbach's $\alpha=0.78$).
[d] Stability was defined as the average of two percentages from Census 2000 measures including percent of owner occupied households, and percent of households that had been at the same address five years previously (Cronbach's $\alpha=0.72$).
[e] Percent vacant houses was defined as the percent of houses defined as vacant of all houses.
[f] Percent African American was defined as the percent of the total population that self-identified as Black or African–American.

(Table 2, Objective 3). Drug market arrests in the adjacent neighborhoods (spatial lag) remained significantly associated with gonorrhea (RR 1.28, 95% CI: 1.18, 1.40). Sensitivity analyses were not conducted due to the lack of association of the main variable of interest.

As a descriptive tool and modeling aid we also estimated Moran's I statistic to assess the degree of spatial similarity among CBG gonorrhea rates and final regression model residuals, the later to check the assumption of independence. Moran's I for the CBG gonorrhea rates was significantly positive for each year indicating strong spatial similarity, adjacent CBGs have similar gonorrhea rates than non-adjacent CBGs as expected. Moran's I decreased substantially when calculated on the final regression model residuals from Objective 1 and further decreased when estimated on the regression residuals from Objective 2 with the inclusion of the spatial lag drug market effect. Moran's I remained statistically significant though at the 0.05 level when based on these regression residuals, however, inference for the Poisson regression was based on a quasi – Poisson approach accounting for over dispersion.

4. Discussion

The overall goals of this paper were to extend previous research, to investigate the current temporal association, the spatial nature and the one year prior temporal association between neighborhood drug markets and STIs and using spatial and longitudinal ecologic analyses. Our results support our hypotheses for objectives one and two and do not support our hypothesis for objective three. We found that increases in drug market arrests in a focal neighborhood were significantly associated with a 15% increase in age and sex standardized gonorrhea counts, independent of neighborhood socioeconomic status and residential stability in the focal neighborhood (objective one). We also found that increases in drug market arrests in adjacent neighborhoods were significantly associated with a 32% increase in age and sex standardized gonorrhea counts, independent of neighborhood drug markets, socioeconomic status and residential stability in the focal neighborhood (objective two). Increases in drug market arrests in the previous year in the focal neighborhood did not predict increases in age and sex standardized gonorrhea counts, adjusting for drug markets in the focal neighborhood and adjacent neighborhoods, socioeconomic status and residential stability (objective three).

The findings suggest that drug markets and their associated sexual networks extend beyond local neighborhood boundaries. Specifically, the results suggest that within a single year, the gonorrhea rates of a particular neighborhood (CBG) are associated with the drug market activity in neighboring CBGs. This indicates the importance of including spatial lag effects in regression models investigating these associations. The importance of spatial lags in regression models is also supported by Freisthler et al. (2005) in a study examining the spatial relationship between drug availability and rates of drug use in neighborhoods (defined as zipcodes). The study found that among youth, 12 to 18 years of age, drug sales in areas adjacent to the youth's primary residence were positively associated with self-reported drug use (Freisthler et al., 2005). The study also found that among adults, drug sales within a neighborhood were negatively associated with drug use, while drug sales in adjacent neighborhoods were positively related to drug use (Freisthler et al., 2005). Our findings supporting previous research have important implications to our understanding of neighborhood STI profiles as well as to intervention strategies.

While our results suggest that drug market arrests is more highly associated with gonorrhea rates than drug use arrests, we also found that drug market and drug use arrests have a high degree of overlap in their respective contributions to gonorrhea rates. Teasing out the independent effects of drug markets versus drug use may be difficult, but it may also be important as it relates to specifying intervention opportunities.

There are a number of limitations to these analyses. This was an ecologic study, which utilized observational data. Based on a counter-factual causal framework, the usefulness of observational data for investigating the effect of neighborhood is controversial (Oakes, 2004). More specifically, since we cannot rule out that the association between neighborhood drug markets and gonorrhea rates is confounded by some unmeasured neighborhood factor, we must proceed with caution regarding causal pathways and inference. In addition, this was an ecologic study and we cannot make inferences to the individual level, although we highlight our previous multilevel findings suggesting an individual level association (Jennings et al., 2012). We excluded highway drug markets because we assumed that they would not have any relationship to neighborhoods close by. This assumption may be false and may have inadvertently decreased the drug market counts in specific areas. In these analyses, we chose CBGs as the smallest geographic area for which census data is publically available and based on prior evidence that CBGs are a relevant geographic area for infectious diseases (Krieger et al., 2003). CBGs, however, are administrative boundaries and thus, may not represent the true organic nature of neighborhoods and more importantly, the geographic area which is mostly likely to capture the spatial nature of the transmission dynamics between the processes under study. Data on drug arrests and gonorrhea are based on the efforts of the police and the public health department, respectively. The efforts of each of these agencies are likely to result in incomplete data and thus, these reports may not align with actual drug markets or disease occurrence. These biases may serve to misclassify neighborhoods. The extent and effect of the missingness and whether it would alter the associations identified is unknowable. Another limitation is that it is possible that drug markets and gonorrhea are linked in other ways than those hypothesized and supported in this paper. It is possible, for example that those who use/sell drugs may be more familiar with clinical settings due to health problems or even needle acquisition, and their exposure to these settings may increase their likelihood of getting tested for (and diagnosed with) gonorrhea. Additionally, the presence of drug market activities may elevate levels of stress or despair among the general population, producing more risky sexual behavior and therefore gonorrhea counts.

In summary, while the temporal link was not supported, our findings suggest that there is an associative link between drug markets and STIs and that the spatial nature of this association extends beyond the focal neighborhood. Future studies should extend these analyses to determine in multilevel longitudinal analyses whether focal and adjacent neighborhood drug markets impact individual level risk for an STI. In addition, future studies should examine more closely whether specific types of drug markets, for example those that crack and heroin markets versus marijuana markets, and the geography of drug markets for example small versus large drug markets play different roles in the transmission of STIs.

Acknowledgment

This work was supported by the National Institute of Drug Abuse (Grant no. K01 DA022298-01A1).

References

Adimora, A.A., Schoenbach, V.J., Doherty, I.A., 2007. Concurrent sexual partnerships among men in the United States. American Journal of Public Health 97, 2230–2237.
Agar, M., Reisinger, H., 1999. Numbers and trends: heroin indicators and what they represent. Human Organization 58, 365–374.
Bivand, R.S., Pebesma, E.J., Gomes-Rubio, V., 2008. Applied Spatial Data Analysis. Springer, New York.
Brunham, R.C., 1991. The concept of core and its relevance to the epidemiology and control of sexually transmitted diseases. Sexually Transmitted Diseases 18, 67–68.
Centers for Disease Control and Prevention, 2011. Sexually Transmitted Disease Surveillance, 2010. Centers for Disease Control and Prevention: Division of STD/HIV Prevention, Atlanta, GA.
Centers for Disease Control and Prevention, 2009. Sexually Transmitted Disease Surveillance, 2008. Centers for Disease Control and Prevention: Division of STD/HIV Prevention, Atlanta, GA.
Craig, T., 2000. Drugs Worsen in City, U.S. Says: Traffic in Cocaine, Heroin, Ecstasy Assessed by DEA. Baltimore Sun.
Crum, R.M., Lillie-Blanton, M., Anthony, J.C., 1996. Neighborhood environment and opportunity to use cocaine and other drugs in late childhood and early adolescence. Drug and Alcohol Dependence 43, 155–161.
Cunningham, S.D., Michaud, J.M., Johnson, S.M., Rompalo, A., Ellen, J.M., 2004. Phase-specific network differences associated with the syphilis epidemic in Baltimore city, 1996–2000. Sexually Transmitted Diseases 31, 611–615.
Diez Roux, A.V., 2007. Integrating social and biologic factors in health research: a systems view. Annals of Epidemiology 17, 569–574.
Ellen, J.M., Hessol, N.A., Kohn, R.P., Bolan, G.A., 1997. An investigation of geographic clustering of repeat cases of gonorrhea and chlamydial infection in San Francisco, 1989–1993: evidence for core groups. The Journal of Infectious Diseases 175, 1519–1522.
Farley, T., 2006. Sexually transmitted diseases in the Southeastern United States: location, race, and social context. Sexually Transmitted Diseases 33 (7), S58–-S64, Supplement:.
Fast, D., Shoveller, J., Shannon, K., Kerr, T., 2010. Safety and danger in downtown Vancouver: understandings of place among young people entrenched in an urban drug scene. Health and Place 16, 51–60.
Fisher, L.D., Van Belle, G., Heagerty, P., Lumley, T., 1993. Biostatistics. Wiley, New York.
Fichtenberg, C.M., Jennings, J.M., Glass, T.A., Ellen, J.M., 2010. Neighborhood socio-economic environment and sexual network position. Journal of Urban Health 87, 225–235.
Flom, P.L., Friedman, S.R., Kottiri, B.J., Neaigus, A., Curtis, R., Des Jarlais, D.C., Sandoval, M., Zenilman, J.M., 2001. Stigmatized drug use, sexual partner concurrency, and other sex risk network and behavior characteristics of 18- to 24-year-old youth in a high-risk neighborhood. Sexually Transmitted Diseases 28, 598–607.
Freisthler, B., Gruenewald, P.J., Johnson, F.W., Treno, A.J., Lascala, E.A., 2005. An exploratory study examining the spatial dynamics of illicit drug availability and rates of drug use. Journal of Drug Education 35, 15–27.
Friedman, S.R., Lieb, S., Tempalski, B., Cooper, H., Keem, M., Friedman, R., Flom, P.L., 2005. HIV among injection drug users in large US metropolitan areas, 1998. Journal of Urban Health: Bulletin of the New York Academy of Medicine 82, 434–445.
Ghani, A.C., Swinton, J., Garnett, G.P., 1997. The role of sexual partnership networks in the epidemiology of gonorrhea. Sexually Transmitted Diseases 24, 45–56.
Gleghorn, A.A., Jones, T.S., Doherty, M.C., Celentano, D.D., Vlahov, D., 1995. Acquisition and use of needles and syringes by injecting drug users in Baltimore, Maryland. Journal of Acquired Immune Deficiency Syndromes and Human Retrovirology: Official Publication of the International Retrovirology Association 10, 97–103.
Gyarmathy, V.A., Neaigus, A., 2009. The relationship of sexual dyad and personal network characteristics and individual attributes to unprotected sex among young injecting drug users. AIDS and Behavior 13, 196–206.
Jennings, J., Glass, B., Parham, P., Adler, N., Ellen, J.M., 2004. Sex partner concurrency, geographic context, and adolescent sexually transmitted infections. Sexually Transmitted Diseases 31, 734–739.
Jennings, J.M., Curriero, F.C., Celentano, D., Ellen, J.M., 2005. Geographic identification of high gonorrhea transmission areas in Baltimore, Maryland. American Journal of Epidemiology 161, 73–80.
Jennings, J.M., Taylor, R.B., Salhi, R.A., Furr-Holden, C.D.M., Ellen, J.M., 2012. Neighborhood drug markets: a risk environment for bacterial sexually transmitted infections among urban youth. Social Science and Medicine 74, 1240–1250.
Jolly, A.M., Wylie, J.L., 2002. Gonorrhoea and chlamydia core groups and sexual networks in Manitoba. Sexually Transmitted Infections 78, i145–i151.
Koumans, E.H., Farley, T.A., Gibson, J.J., Langley, C., Ross, M.W., McFarlane, M., Braxton, J., St Louis, M.E., 2001. Characteristics of persons with syphilis in areas of persisting syphilis in the United States: sustained transmission associated with concurrent partnerships. Sexually Transmitted Diseases 28, 497–503.
Kretzschmar, M., Morris, M., 1996. Measures of concurrency in networks and the spread of infectious disease. Mathematical Biosciences 133, 165–195.
Krieger, N., Waterman, P.D., Chen, J.T., Soobader, M., Subramanian, S.V., 2003. 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 Reports 118, 240–260.
Lacey, C.J.N., Merrick, D.W., Bensley, D.C., Fairley, I., 1997. Analysis of the socio-demography of gonorrhoea in Leeds, 1989–93. British Medical Journal 314, 1715.
Lambert, S.F., Brown, T.L., Phillips, C.M., Ialongo, N.S., 2004. The relationship between perceptions of neighborhood characteristics and substance use among

urban African American adolescents. American Journal of Community Psychology 34, 205–218.
Liang, K.Y., Zeger, S.L., 1986. Longitudinal data analysis using generalized linear models. Biometrika 73, 13–22.
Oakes, J.M., 2004. The (mis)estimation of neighborhood effects: causal inference for a practicable social epidemiology. Social Science and Medicine 58, 1929–1952.
Mehta, S.H., Galai, N., Astemborski, J., Celentano, D.D., Strathdee, S.A., Vlahov, D., Nelson, K.E., 2006. HIV incidence among injection drug users in Baltimore, Maryland (1988–2004). Journal of Acquired Immune Deficiency Syndromes 43, 368–372.
Monteiro, E.F., Lacey, C.J.N., Merrick, D., 2005. The interrelation of demographic and geospatial risk factors between four common sexually transmitted diseases. Sexually Transmitted Infections 81, 41–46.
Morris, M., Kretzschmar, M., 1997. Concurrent partnerships and the spread of HIV. AIDS 11, 641–648.
Nandi, A., Glass, T.A., Cole, S.R., Chu, H., Galea, S., Celentano, D.D., Kirk, G.D., Vlahov, D., Latimer, W.W., Mehta, S.H., 2010. Neighborhood poverty and injection cessation in a sample of injection drug users. American Journal of Epidemiology 171, 391–398.
National Center for Health Statistics, 2010. Health, United States, 2009: With Special Feature on Medical Technology, Hyattsville, Maryland.
Newman, M.E., 2002. Spread of epidemic disease on networks. Physical Review E: Statistical, Nonlinear, and Soft Matter Physics 66, 016128.
Potterat, J.J., Rothenberg, R.B., Woodhouse, D.E., Muth, J.B., Pratts, C.I., Fogle 2nd, J.S., 1985. Gonorrhea as a social disease. Sexually Transmitted Diseases 12, 25–32.
Potterat, J.J., Zimmerman-Rogers, H., Muth, S.Q., Rothenberg, R.B., Green, D.L., Taylor, J.E., Bonney, M.S., White, H.A., 1999. Chlamydia transmission: concurrency, reproduction number, and the epidemic trajectory. American Journal of Epidemiology 150, 1331–1339.
R R Development Core Team, 2011. 〈http://www.R-project.org〉.
Reuter, P., MacCoun, R.J., 1992. Street drug markets and inner-city neighborhoods: Matching policy to reality. In: Steinberg, J.B., Lyon, D.W., Vaiana, M.E. (Eds.), Urban America: Policy Choices for Los Angeles and the Nation. Rand Corporation, Santa Monica, CA, pp. 227–251.
Risley, C.L., Ward, H., Choudhury, B., Bishop, C.J., Fenton, K.A., Spratt, B.G., Ison, C.A., Ghani, A.C., 2007. Geographical and demographic clustering of gonorrhea in London. Sexually Transmitted Infections 83, 481–487.
Rothenberg, R.B., 1983. Gonorrhea: empirical demonstration of core group transmission. American Journal of Epidemiology 117, 688–694.
Sampson, R.J., Raudenbush, S.W., Earls, F., 1997. Neighborhoods and violent crime: a multilevel study of collective efficacy. Science 277 (5328), 918–924.
Sampson, R.J., Lauritsen, J., 1994. Understanding and Preventing Violence: Social Influences, 3. In: Reiss Jr., A.J., Roth, J. (Eds.), National Academy Press, Washington, DC, pp. 1–114.
Saxe, L., Kadushin, C., Beveridge, A., Livert, D., Tighe, E., Rindskopf, D., Ford, J., Brodsky, A., 2001. The visibility of illicit drugs: implications for community-based drug control strategies. American Journal of Public Health 91, 1987–1994.
Schleihauf, E., Watkins, R.E., Plant, A.J., 2009. Heterogeity in the spatial distribution of bacterial. Sexually Transmitted Infections 85, 45–49.
Serwadda, D., Wawer, M.J., Musgrave, S.D., Sewankambo, N.K., Kaplan, J.E., Gray, R.H., 1992. HIV risk factors in three geographic strata of rural Rakai District, Uganda. AIDS 6, 983–989.
Shaw, C.R., McKay, H.D., 1947. Juvenile Delinquency and Urban Areas. University of Chicago Press, Chicago.
Simon, D., Burns, E., 1997. The corner: a year in the life of an inner-city neighborhood, 1st ed. Broadway Books, New York.
Substance Abuse and Mental Health Services Administration, 2010. Results from the 2009 National Survey on Drug Use and Health: Volume I. Summary of National Findings. Substance Abuse and Mental Health Services Administration, Rockville, MD.
Thomas, J.C., Tucker, M.J., 1996. The development and use of the concept of a sexually transmitted disease core. The Journal of Infectious Diseases 174, S134–S143.
United States Census Bureau, 2003. Census 2000, Summary File 3 (SF 3). Available from: 〈http://www.geolytics.com/Default.asp〉 (accessed 2.12.03.).
United States National Drug Intelligence Center, 2003. Heroin in the Northeast. U.S. Dept. of Justice, National Drug Intelligence Center, Johnstown, Pa.
US Census Bureau, 2011. US Census Bureau Delivers Maryland's 2010 Census Population Totals. 〈http://2010.census.gov/news/releases/operations/cb11-cn20.html〉.
Waller, L.A., Gotway, C.A., 2004. Applied Spatial Statistics for Public Health Data. Wiley, New York.
Watts, C.H., May, R.M., 1992. The influence of concurrent partnerships on the dynamics of HIV/AIDS. Mathematical Biosciences 108, 89–104.
Weir, S.S., Pailman, C., Mahlalela, X., Coetzee, N., Meidany, F., Boerma, J.T., 2003. From people to places: focusing AIDS prevention efforts where it matters most. AIDS 17, 895–903.
Weisburd, D., Green, L., 1994. In: MacKenzie, D., Uchida, C. (Eds.), Defining the Street-Level Drug Market in Drugs and Crime: Evaluating Public Policy Initiatives. Sage, Newbury Park, CA.
Wylie, J.L., Shaw, S., DeRubeis, E., Jolly, A., 2010. A network view of the transmission of sexually transmitted infections in Manitoba, Canada. Sexually Transmitted Infections 86, iii10–iii16.
Yorke, J.A., Hethcote, H.W., Nold, A., 1978. Dynamics and control of the transmission of gonorrhea. Sexually Transmitted Diseases 5, 51–56.