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Male Incarceration Rates and Rates of Sexually Transmitted Infections: Results from a Longitudinal Analysis in a South-Eastern US City

Emily F. Dauria, Ph.D.¹, Kirk Elifson, Ph.D.², Kimberly Jacob Arriola, Ph.D.², Gina Wingood, Sc.D.², and Hannah L.F. Cooper, Sc.D.²

¹Department of Psychiatry and Human Behavior, Alpert Medical School, Brown University, Providence, RI, USA

²Department of Behavioral Sciences and Health Education, Rollins School of Public Health, Atlanta, GA, USA

Abstract

Background—In the United States (US), rates of certain sexually transmitted infections (STIs) are increasing. Contextual factors appear to play an important role in shaping STI transmission dynamics. This longitudinal study explores the relationship between one contextual determinant of health (the male incarceration rate) and rates of newly-diagnosed STIs in census tracts in Atlanta, GA.

Methods—The sample consisted of all census tracts in Atlanta (N=946). Annual data on STI diagnoses were drawn from the Georgia surveillance system for 2005–2010; annual male incarceration data were drawn from the Georgia Department of Corrections. for 2005–2010; data on potential confounders were drawn from the US Census. Multivariable growth models were used to examine the association between the male incarceration rate and rates of newly-diagnosed STIs, controlling for covariates.

Results—Census tracts with higher baseline male incarceration rates had a higher baseline rate of newly-diagnosed STIs. Census tracts with increasing male incarceration rates experienced a more rapid increase in their rate of newly-diagnosed STIs. Census tracts with medium and high baseline male incarceration rates experienced a *decrease* in their rate of newly-diagnosed STIs over time.

Conclusions—The present study strengthens the evidence that male incarceration rates have negative consequences on sexual health outcomes, though the relationship may be more nuanced than originally thought. Future multilevel research should explore individual sexual risk behaviors and networks in the context of high male incarceration rates to better understand how male incarceration shapes rates of STIs.

Contact Information for Corresponding Author: Emily F. Dauria, PhD, MPH, Department of Psychiatry and Health Behavior, Alpert Medical School at Brown University, Bradley Hasboro Children's Research Center, 1 Hoppin Street, Coro West, Suite 204, Providence, RI 02903, Phone: (401) 444-8945, Fax: (401) 444-8742, emily_dauria@brown.edu.

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Keywords

Public health; longitudinal analyses; neighborhood/place; sexually transmitted infections; social epidemiology

INTRODUCTION

In the United States (US), rates of certain sexually transmitted infections (STIs) are increasing.[1] From 1992 to 2012, the reporting of Chlamydia increased from 182.3 to 456.7 cases per 100,000 population.[1] From 2009 to 2012, after a period when rates of gonorrhea were the lowest in recorded history, rates gradually increased from 98.1 to 107.5 cases per 100,000 population.[1] A similar trend was evident for syphilis.[1] The southern region of the US consistently has the highest burden of STIs. In the state of Georgia, rates of Chlamydia, gonorrhea, and syphilis varied throughout the early 2000s through 2012, however, for each year during that time Georgia's STI rates were higher than those reported nationally. [1 2] From 2005 to 2012, rate trajectories in Georgia were not linear but increased over time: rates of Chlamydia increased from 380.1 to 534.0 cases per 100,000 and rates of syphilis increased from 21.8 to 24.8 per 100,000. Gonorrhea rates decreased slightly, from 179.6 cases to 156.1 cases per 100,000. [1 2] While individual sexual behaviors (e.g. number of partners) [3] may explain some of this variation, contextual factors (e.g. economic oppression) have received significant attention for their contribution to explaining changes in sexual health outcomes.[4 5]

It has been hypothesized that the relationship between incarceration rates and rates of STIs is important[6 7] and emerging evidence supports this hypothesis.[8–10] High incarceration rates can have devastating consequences for sexual networks [11 12] by altering their size and composition in ways that accelerate the spread of STIs. By removing a large number of men from a neighborhood, high incarceration rates can disrupt existing sexual partnerships. [10 13 14] Partners left behind may engage in high-risk sexual relationships to fulfill financial, emotional, or sexual needs.[10 13–15] Additionally, during periods of incarceration men may engage in same-sex sexual behavior; increasing their risk of STI transmission.[10 12] Finally, recently-released men may resume old sexual partnerships while also forming new ones.[10 15] Collectively, these factors may help explain mechanisms through which high male incarceration rates contribute to national rates of STIs.

Research examining the relationship between incarceration rates and STI rates and incidence remains a relatively new area of inquiry.[8–10] Initial studies found a positive correlation between incarceration rates and STI rates in the general population.[8–10] Most of the studies on incarceration rates and STIs, however, have been cross-sectional [8 9] and are unable to establish a causal relationship. Associations have been identified at the county-level, where male incarceration rates and the rate of newly-diagnosed STIs may vary too much to document the nature of their association.[16] Individuals tend to select sexual partners from the neighborhoods in which they live,[17] therefore a smaller geographic unit (e.g. census tracts) may be better suited to examine this relationship over time.[18] Lastly,

because these studies examined incarceration among men and women combined, [8–10] they are unable to determine the true relationship between male incarceration rates and sexual health outcomes.

This longitudinal study aims to examine the relationship between male incarceration rate and the rate of newly-diagnosed STIs in census tracts in Atlanta, Georgia, over time. We hypothesize that 1) at baseline, census tracts with higher male incarceration rates will have a higher rate of newly-diagnosed STIs, 2) the rate of newly-diagnosed STIs will increase at a faster rate over time in census tracts with higher baseline male incarceration rates than census tracts with lower baseline male incarceration rates, and 3) census tracts where male incarceration rates are increasing at a faster rate will experience a more rapid increase in the rate of newly-diagnosed STIs.

MATERIALS AND METHODS

The sample consists of all census tracts in the 28-county Atlanta Metropolitan Statistical Area (MSA) (n=946). Data were analyzed for the years 2005 through 2010.

Measures

Our primary dependent variable was the annual rate of newly-diagnosed cases of Chlamydia, gonorrhea, and primary stage syphilis in each census tract in the Atlanta MSA (2005–2010). Georgia's Department of Community Health (GA DCH) provided annual STI surveillance data. Case counts of newly-diagnosed STIs were suppressed for census tracts with less than five cases. To reduce the number of tracts with suppressed data, tract-level counts of the three STIs of interest were aggregated to create a single measure. For 2005 to 2010 there were 161, 120, 126, 134, 129, and 99 census tracts with suppressed STI data, respectively. To calculate an annual rate of newly-diagnosed cases of STIs, we divided the aggregate number of STI cases reported in each census tract by the adult population (aged 18–59) of the census tract, and multiplied by 1,000.[10] Annual rates were calculated from 2005 through 2010.

Our independent variable was tract-level male incarceration rate. Georgia's Department of Corrections (GA DOC) provided records for each male entering prison in the Atlanta MSA (2005–2010, n=167,605). Information included "last known address" (inmate self report upon admission) and date of incarceration and release. Each address was geocoded to a corresponding census tract in ArcGIS.[19] Unmatched addresses were geocoded a second time using Google Earth Pro.[20] Using ArcGIS and Google Earth Pro, 82.60% (n=138,443) of the addresses were matched with 70–100% accuracy; 17.40% (n=29,162) remained unmatched. Once assigned to a census tract, male incarceration rates for each year and tract were calculated by dividing the mean number of incarcerated men by the tract's adult male (aged 18–64) population, multiplied by 1,000.[10] Annual rates were calculated for the number of men who are incarcerated in a given year, from each census tract, from 2005 through 2010.

We considered the following for inclusion in adjusted models as possible confounders: tract-level percent who identified as non-Hispanic Black/ African American, percent unemployed,

percent living in poverty, percent married, and the percent aged 26 or older who had a high school diploma as their highest educational attainment. Due to the changes in tract-level boundaries from 2000 to 2010 we used the Longitudinal Tract Data Base (LTDB),[21] which provides a public-use database that creates estimates from 2010 tract-boundaries for tract-level data for 2000. From this database we used 2000 and 2010 decennial data and interpolated values for 2005 through 2009 assuming linear change over time.

Analysis

Univariate analyses were used to summarize characteristics of the tracts. Hierarchical linear modeling was used to test our hypothesis that male incarceration rates were positively related to the rate of newly-diagnosed STIs over time. First we fit an unconditional growth model (allowing for heteroscedastic error variances) to determine whether the rate of newly-diagnosed STIs changed systematically over time. We then added male incarceration rate, a time varying predictor, and interaction terms between time and change in male incarceration rate into the model. Bivariate analyses were used to determine associations between covariates and the rate of newly-diagnosed STIs. Male incarceration rate (and all other continuous predictor variables) was centered at its baseline value. Lastly, we built and tested a multivariable model to examine the hypothesis that census tracts with a higher male incarceration rate and a large increase from their baseline incarceration rate have higher and increasing rate of newly-diagnosed STIs, controlling for covariates identified as significant ($p < 0.05$) in bivariate analyses.

To examine whether census tracts with a high baseline male incarceration rate and census tracts with a larger change from their baseline male incarceration rate have a higher and faster increase in their rate of newly-diagnosed STIs than census tracts with a lower baseline male incarceration rate and a smaller change from their baseline male incarceration rate, we tested the regression of the rate of newly-diagnosed STIs on time at low, medium, and high values of baseline male incarceration rate and change in the male incarceration rate from baseline. We defined high/large, medium, and small/low as one standard deviation above the mean, at the mean and one standard deviation below the mean of the baseline male incarceration rate and change in male incarceration rate from baseline, respectively.

We conducted a sensitivity analysis to determine whether our results were robust across models where values for tract-level suppressed STI case counts were set to missing, and the minimum and maximum possible values (0 and 4 respectively).[22] To address issues of multicollinearity we ran the model with and without variance inflation factors >4 to ensure that the strength and direction of the main effects of male incarceration rates and the rate of newly-diagnosed STIs did not change. Finally, we conducted regression diagnostics to identify possible influential outliers. Models were run with and without outliers to ensure that associations identified in the full model remained. Estimation was done using maximum likelihood. Analyses were conducted in SAS version 9.3 (Cary, N.C.).

Ethics

Emory University's Institutional Review Board approved all study protocols and the GA DCH approved the use of STI data.

RESULTS

Table 1 shows the sociodemographic characteristics of all census tracts in the Atlanta MSA (n=946). The covariates varied at baseline, though there was little change over time. At baseline, the average tract-level male incarceration rate was 2.77 per 1,000 adult men. Male incarceration rates varied throughout the study period, with the largest increase occurring between the years 2009 and 2010 (from 2.69 to 4.38/1,000 adult men). The mean rate of newly-diagnosed STIs at baseline was 10.74; a rate that varied widely across census tracts (SD=11.36). Rates of newly-diagnosed STIs increased from their lowest point in 2005 (10.74 per 1,000 adults) until 2007 when they decreased (from 13.28 to 12.14 per 1,000 adults) until 2009 when they increased again slightly to 12.18 (per 1,000 adults).

We fit three multilevel models (*Models A–C*) (Table 2). An unconditional growth model examined whether the rate of newly-diagnosed STIs changed systematically over time (*Model A*). On average, 13.31 adults per 1000 were newly diagnosed with an STI in 2005; this mean was significantly different from 0 indicating a systematic change in the rate of newly-diagnosed STIs over time. *Model B* explores the unadjusted relationship of male incarceration rate and the rate of newly-diagnosed STIs over time. This model contained baseline rate of male incarceration, change since baseline in rate of male incarceration, log(time), and interaction terms for log(time) and baseline rate of male incarceration and log(time) and the change since baseline rate of male incarceration. Examining the main effects and interaction term for baseline male incarceration rate suggested that at baseline, census tracts with higher male incarceration rates had a higher rate of newly-diagnosed STIs ($p<0.001$). The magnitude of the relationship between baseline rate of male incarceration and the rate of newly diagnosed STIs decreased approximately 0.09 each year ($P = 0.04$). The main effects and interaction term for change from baseline rate of male incarceration revealed that census tracts with increasing rates of incarceration have a lower rate of newly-diagnosed STIs at baseline ($p=0.03$).

Bivariate associations between covariates and the rate of newly-diagnosed STIs were explored and all covariates had a statistically significant association with rate of newly-diagnosed STIs ($p<0.01$) for each year of the study period (data not shown). Covariates were tested individually in *Model B* (data not shown); each potential confounder was statistically significant and included in the final model (*Model C*).

Census tracts that had increasing rates of incarceration had a lower rate of newly-diagnosed STIs at baseline ($p<0.0001$) (*Model C*). Unlike the unadjusted model (*Model B*), there was no significant association identified between the interaction of baseline rate of male incarceration and log(time) ($p= 0.17$). In order to examine whether census tracts with low, medium, or high baseline rates of male incarceration had different trajectories of STIs over time, we tested the regression of the rate of newly-diagnosed STIs on time at different values of baseline rate of male incarceration (Figure 1A). The intercepts and slopes for low baseline rate of male incarceration are not statistically significant ($p=0.47$) (data not shown). For medium baseline rates of male incarceration, the rate of newly-diagnosed STIs significantly decreased by 0.79 (per 1,000 adults) each year from 2005 to 2010 ($p=0.0019$).

For high baseline rates of male incarceration, the rate of newly-diagnosed STIs significantly decreased by 0.94 (per 1,000 adults) each year from 2005 to 2010 ($p=0.0005$).

In *Model C*, the significant interaction between change from baseline rate of male incarceration and log(time) suggested that over time, for every one-unit increase in change from baseline rate of male incarceration, the rate of newly-diagnosed STIs increased approximately 0.53, when adjusting for covariates ($p < 0.0001$). The parameter estimate for the main effect of baseline rate of male incarceration decreased compared to the bivariate model but remained significant ($p<0.001$). Figure 1b explored the nature of the interaction between change from baseline rate of male incarceration and the rate of newly-diagnosed STIs. The slope of the trajectory of census-tracts with a slight change from baseline rate was significant ($p=0.0002$)(data not shown). The slope of the trajectory in census-tracts with a medium change from baseline in rate of male incarceration was significant ($p=0.05$), however, the slope of the trajectory was not significantly different in tracts that experience a large change in rate of male incarceration from baseline ($p=0.54$).

DISCUSSION

This study explored the longitudinal relationship between male incarceration rate and the rate of newly-diagnosed STIs at the census tract level in the Atlanta MSA. Findings from the adjusted model support our hypotheses that census tracts with higher baseline rates of male incarceration will have a higher mean rate of newly-diagnosed STIs and that census tracts with increasing male incarceration rates will experience a more rapid increase in the rate of newly-diagnosed STIs. Census tracts with a less rapid change from their baseline rate of male incarceration have a rate of newly-diagnosed STIs that decreased over time. Finally, our analyses do not support our hypothesis that census tracts with a higher baseline rate of incarceration will experience a faster increase in the rate of newly-diagnosed STIs than census tracts with lower baseline male incarceration rates. In fact, our findings suggest that census tracts with medium and high baseline male incarceration rates experience a *decrease* in their rate of newly-diagnosed STIs over time.

Our findings support and extend previous research on incarceration rates and STIs.[9 10] To our knowledge, only one previous study has examined the longitudinal relationship of incarceration rates with STIs. Thomas et al.[8] calculated the correlation between county-level incarceration rates in a given-year and STIs one and two years later. Rates of Chlamydia and gonorrhea consistently increased with increasing incarceration rates. We established a longitudinal relationship between tract-level male incarceration rates and the rate of newly-diagnosed STIs. Recent studies have illuminated possible mechanisms through which male incarceration rates influence rates of STIs[10 14 23] suggesting that high incarceration rates and the resulting shortage of males are associated with having a larger number of sexual partners, [23 24] overlapping partnerships, [10 25] engaging in transactional sex[14] and a greater risk of having unprotected sex with a risky partner.[24 25]

In this study, census tracts with medium and high baseline male incarceration rates experienced a decrease in their rate of newly-diagnosed STIs over time. While we cannot

explain what mechanism (or mechanisms) contribute to this finding, we note that, in these tracts, the criminal justice system removed large numbers of high-risk men from the community. Compared to individuals who have not been incarcerated, incarcerated individuals have more risk factors associated with acquiring and transmitting STIs (e.g. injection drug use).[25] Further, rates of STIs are much more prevalent among correctional inmates than in the total US population.[26] Thus the removal of high-risk or infectious men from a neighborhood might lessen transmission in that census tract. Alternatively, this finding may reflect a ‘ceiling effect’; rates of newly-diagnosed STIs are unlikely to increase in areas with already high rates of newly-diagnosed STIs (note census tracts with high male incarceration rates). Further research examining factors that may influence STI transmission dynamics (e.g. local STI-prevention efforts, healthcare access) is needed in census tracts with high male incarceration rates.

Due to the amount of suppressed STI data, we were unable to examine racial/ethnic differences in the association between male incarceration rates and the rate of newly-diagnosed STIs. Given that Black adults are imprisoned at a higher rate than other racial/ethnic groups, male incarceration may help explain national racial/ethnic disparities in STIs. [27] In 2011, Black adults represented roughly 13% of the national population,[28] however, they accounted for approximately 38% of prisoners under state and federal jurisdiction.[27] Black adults have the highest rates of STIs of all racial/ethnic groups in the US. In 2012, the rate of gonorrhea among Black adults was 14.9 times that of White adults, the rate of Chlamydia was 6.8 times that of White adults, and the rate of primary and secondary syphilis was 6.1 times that of White adults.[29] Future research should longitudinally examine the relationship between male incarceration rates on the rate of newly-diagnosed STIs among Black adults.

This study has limitations. First, there has been some debate about the use of census tracts to estimate the scale and boundaries of neighborhoods,[16] however, census tracts are used frequently in studies examining various health outcomes at the neighborhood level.[30 31] Second, our findings are based on addresses provided by inmates and may not accurately represent where an offender lived at the time of his incarceration. Third, due to the amount of suppressed data we were unable to explore the longitudinal relationship between male incarceration rate and each STI independently at the tract-level. It is likely, however, that Chlamydia may have driven our results given the relative burden of these three STIs in the Atlanta MSA during the study period. Finally, given that the present study has an ecologic design, we were unable to explore how individual- and network-level factors influence our study outcomes.

Despite these limitations, this study strengthens the evidence that male incarceration rates have negative consequences on sexual health outcomes, though the relationship may be more nuanced than originally thought. Future multilevel research should explore individual sexual risk behaviors and networks in the context of high male incarceration rates to better understand how male incarceration shapes rates of STIs. Findings from these studies could be used to help identify geographic areas where prevention programs and interventions may be most needed.

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Figure 1.

Line graphs examining the interaction between baseline rate of male incarceration and log(time) on the rate of newly-diagnosed STIs (Figure 1A) and the interaction between change in baseline rate of male incarceration and log (time) on rate of newly-diagnosed STIs in the Atlanta MSA, 2005–2010 (Figure 1B).

Table 1

Distributions of census tract level characteristics in the Atlanta Metropolitan Statistical Area (MSA), 2005–2010 (N=946).

	2005	2006	2007	2008	2009	2010
Characteristics of census tracts	Mean (SD)					
% residents who are non-Hispanic Black/African American	32.26 (30.48)	32.73 (30.43)	33.17 (30.42)	33.59 (30.43)	33.98 (30.46)	34.23 (30.45)
% living in poverty	12.35 (10.63)	12.73 (10.86)	13.12 (11.13)	13.51 (11.45)	13.90 (11.81)	14.29 (12.21)
% unemployed	7.69 (5.38)	8.07 (5.22)	8.44 (5.12)	8.79 (5.12)	9.12 (5.24)	9.45 (5.52)
% of adults (25 years) whose highest degree is a high school diploma or less	40.88 (18.57)	40.62 (18.50)	40.38 (18.47)	40.15 (18.48)	39.92 (18.54)	39.70 (18.66)
% Married	50.91 (15.68)	50.43 (15.75)	49.95 (15.86)	49.47 (16.01)	49.00 (16.20)	48.52 (16.43)
Rate of Male Incarceration (per 1,000 men 18 to 64 years old)	2.77 (5.11)	2.69 (5.07)	2.78 (5.02)	2.41 (4.64)	2.69 (4.99)	4.38 (5.22)
Rate of newly-diagnosed STIs* (per 1,000 adults 18 to 64 years old)	10.74 (11.36)	13.21 (17.84)	13.28 (14.84)	12.38 (14.39)	12.14 (13.80)	12.18 (12.97)

* Note: Suppressed data were set to missing.

Hierarchical linear models examining the unadjusted and adjusted association between tract-level rate of male incarceration and the tract-level rate of newly-diagnosed STIs, Atlanta MSA, 2005–2010.

Table 2

	Model A		Model B		Model C	
	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	13.31	1.02***	8.15	1.10***	-1.31	1.62
Main effects						
Log (Time)	-0.63	0.23**	-0.39	0.29	-0.18	0.35
BL rate of male incarceration	---	---	1.83	0.19***	0.60	0.07***
Rate of male incarceration CS	---	---	-0.44	0.20*	-0.74	0.18***
BL % living in poverty	---	---	---	---	0.52	0.04***
% living in poverty CS	---	---	---	---	-0.52	0.09***
BL % NH-Black	---	---	---	---	0.21	0.01***
% NH-Black CS	---	---	---	---	0.19	0.07**
BL % Married	---	---	---	---	0.001	0.03
% Married CS	---	---	---	---	-0.01	0.09
BL % of adults (>25 years) whose highest level of educational attainment is high school	---	---	---	---	-0.05	0.02**
% of adults (>25 years) whose highest level of educational attainment is high school CS	---	---	---	---	0.13	0.07
BL % unemployed	---	---	---	---	0.03	0.06
% Unemployed CS	---	---	---	---	0.13	0.08
Interactions						
Log(Time) × BL rate of male incarceration	---	---	-0.09	0.04*	-0.07	0.05
Log(Time) × Rate of male incarceration CS	---	---	0.30	0.14*	0.53	0.13***

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$.

Note: BL= Baseline and CS= Change score from baseline