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Violent crime and preterm birth: which places matter?

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Epidemiology

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2015

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Abstract

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Background: Preterm birth, delivery at less than 37 weeks' gestation, and early term birth, delivery between 37- and 38-weeks' gestation, are major causes of morbidity and mortality in newborns. The risk of preterm or early term birth is not fully explained by individual maternal risk factors. Some evidence suggests living in a high crime neighborhood is a source of psychosocial stress, which may increase the risk of preterm birth. How neighborhood is measured, however, may yield different results.

Methods: A subset of African American women from the Microbiome and Preterm Birth Cohort Study (n = 485) were enrolled in the Spatial Exposure and Microbiome Study (n = 113). Information on maternal demographics, birth outcome, and places they frequent was provided through a questionnaire. Crime data was used from various police reports in Atlanta, GA from 2013. Logistic regression was used to investigate the association between violent crime rates measured at either the census block group or routine activity space on the probability of preterm or early term birth, controlling for potential confounders.

Results: In this Atlanta-based study, 39.8% of participant women deliver preterm or early term. Controlling for age, education, and number of previous births, the odds of preterm or early term birth increased 1.09 (95% CI: 0.74, 1.62) for every one standard deviation change in residential crime, compared to those who had a term birth. Controlling for the same confounders, a one standard deviation change in activity space crime increased preterm or early term birth 12% (OR: 1.12, 95% CI: 0.72, 1.69). Controlling for all confounders, the odds of preterm or early term birth increased 27% (OR: 1.27, 85% CI: 0.85, 1.88) for every one standard deviation change in activity space crime adjusted for time spent in each location, compared to those who had a term birth.

Discussion: There is evidence of an association between area based violent crime and risk of preterm or early term birth, when considering violent crime rate at either the residential or activity space level. Crime measured in activity spaces has a modestly stronger association with preterm or early term birth than crime measured using residential neighborhoods.

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Background/Literature Review

Significance of preterm birth

Preterm birth (PTB), delivery at less than 37 completed weeks of gestation, is the leading cause of perinatal mortality in the United States (U.S.) (1). Rates in the U.S. decreased from 2007 to 2014 due, in part, to declining rates of birth to teens and young mothers and due to a decline in nonmedically indicated or elective deliveries before 39 weeks in the U.S. (2-4). In 2016, however, PTB rates for the country increased for the second year in a row with about 1 of every 10 infants born preterm (5).

Even early term birth (ETB), delivery at 37 to 38 weeks of gestation, infants suffer considerable morbidity and mortality during infancy and childhood because they are born before they are fully developed. In the first month of life, prematurity is the most important cause of death, and is a factor in over 75% of pediatric deaths in the neonatal period (6). For children under the age five, PTB is the second leading cause of death (7). It is estimated that 17% of infant deaths in the U.S. in 2015 were attributed to PTB and low birth weight (5). The risk of death decreases and the probability of a neonate surviving increases with each additional week of gestation.

Long-term health and developmental risk are increased among near-term infants born between 32 and 36 weeks, compared to those born later in pregnancy (8-10). Rates of breathing problems, feeding difficulties, cerebral palsy, developmental delay, vision problems, and hearing problems are all higher among preterm neonates (5). Many of these health complications are accompanied with long hospital stays. For infants born at <28 and at 28 to 31 gestational weeks, the total duration of hospital admissions is 85 and 16 times that for term infants respectively, after adjusting for duration of life (11).

Several factors consistently are associated with an increased risk of PTB, including history of prior preterm birth, advanced maternal age, low BMI, late or no prenatal care, alcohol consumption, smoking, and stress (1, 7, 12). There is a disparity in PTB by race that has long been of concern (1). African American women experience a higher level of preterm singleton births compared to White women (13). For the year 2016 alone, the rate of PTB among African American women was almost double that of the rate among white women (14% vs. 9%) (5). This disparity of PTB between races cannot fully be explained by controlling for demographic confounders alone.

Stress and PTB

These disparities exist and persist in part due to stress (14, 15). Though there is not a universally accepted definition of psychosocial stress, it is clear that it is not a one-dimensional construct but rather an interaction between the individual and the environment. The effect of stress on PTB relies on the links between psychosocial stressors, psychologic stress response, and the cascade of events that occur in the mother, uterus, placenta and fetus before birth (16). These links may be explained and mediated by biological or behavioral mechanisms (17, 18).

Specifically, there are two major physiologic pathways in which stress may affect PTB. The first is direct neuroendocrine pathways. Stress hormones, such as corticotrophin-releasing hormone (CRH), have been shown to be mediators of the stress-preterm relationship (19). Rises in CRH contribute to higher levels of psychological stress and appear to be a precursor of early labor (20). The second potential mechanism is an immune/inflammatory pathway. Maternal stress may model characteristics of systemic and local immunity, increasing susceptibility to infection or the proinflammatory response to an existing infection (18, 21, 22).

Other research has studied non-biological mechanisms links between stress and PTB. When stress is prolonged over long periods of time it can turn into chronic stress (23). The stress can be accrued at the individual level or have population aggregate sources. Consequences of chronic stress include increase in risky sexual behavior, decrease utilization of prenatal care for infection detection, and lower treatment compliance, thereby contributing to PTB associated with infection (20). The association between stress and behaviors such as poor eating habits, smoking and substance use which increase intrauterine growth retardation and increases the risk of PTB has also been described (24).

Neighborhood factors, crime, and PTB

Neighborhood disorder, social capital and support, and violent crime may interact to produce an environment that exacerbates stress (25). The link between neighborhood disorder and PTB may be explained by using neighborhood socioeconomic status as a proxy for neighborhood-level maternal resources (26). A case control study was conducted looking at the association between neighborhood socioeconomic context and preterm delivery, independent of maternal socioeconomic status, in African American and White women (26). The results of the study showed that neighborhood socioeconomic contexts were associated with preterm delivery, but not linearly and rather varied with race/ethnicity (26). Among African American women, living in a neighborhood with either high or low median household income was associated with an increased risk of PTB, compared to those of medium household income (26). Among White women, only large positive and negative changes in neighborhood male unemployment were associated with the risk of PTB (26). Other research has shown that adverse neighborhood conditions, including crime, homelessness, and tax delinquency, were associated significantly with risk of urogenital tract infection—a leading cause of PTB (27, 28). In addition, studies have found that women who live in violent crime-ridden neighborhoods are more likely to experience pregnancy complications, even after adjusting for various individual-level sociodemographic factors and health behaviors (23, 29).

The U.S. Department of Justice defines violent crime as murder and nonnegligent manslaughter, rape, robbery, and aggravated assault (30). Exposure to high crime rates are documented in the literature as being related to birth outcomes, asthma and health behaviors, such as physical activity (31). Fear of crime contributes to the underlying mechanisms that explains area differences in health, even after adjusting for health behaviors and socioeconomic factors (32).

Several strong theoretical reasons have been used to describe violent crime as a primary source of stress in urban neighborhoods. First, studying the fear of crime has shown that people tend to perceive crime in geographic terms, making the neighborhood environment a prominent setting for generating fear and, consequently, stress (33). Furthermore, neighborhood crime is not only stressful for people who perceive high personal risks of victimization, but also fear the safety of friends and family, referred to as "altruistic fear" (34). Women also tend to be more fearful of crime than men, largely because they perceive crime in a way that is fundamentally different from males (33). Among women, different crimes are subjectively linked in a way that is not true for other groups. Upon closer examination, a strong correlation was found between certain crimes that can logically occur in a sequence (e.g. robbery and murder, burglary and rape) (33). The strong correlations between fear of these crimes suggested that they were in fact viewed as likely to happen together as part of the same criminal event. Taken together, it would suggest that circumstances or events that appear minor to others can make neighborhood crime and violence particularly important for maternal health (33). Second, research shows that there is an increased risk of mental health problems related to stress among individuals who perceive high crime and disorder in their neighborhoods (35, 36). Neighborhood crime can also lead to social isolation because of a promotion of distrust of others, which has been linked to adverse physical health outcomes (37, 38). Some literature has suggested that living in crime-ridden neighborhoods can perpetuate risky behaviors, including substance use, in part because these individuals perceive themselves to have relatively short life expectancies, leaving them less concerned with how their actions may have long-term health consequences (39, 40).

Defining a neighborhood

Most work to date on neighborhood influences of PTB (or health more generally) uses residential location as the primary spatial anchor, using census tracts to proxy neighborhoods (41-44). Alternatively, census block groups (subunits within census tracts) have been used in some studies (45, 46), or other neighborhood boundaries (29, 47). The decision to use census geography to define neighborhoods is largely driven by convenience and availability of maternal residential addresses on vital records. One major drawback with using residential location as proxied by administrative boundaries as defined by the census, however, is the neighborhood units might only provide a rough measure of neighborhood context and lead to incorrect conclusions about the effects of neighborhood characteristics (43, 48). This is also known as the modifiable area unit problem. Characteristics within each census tract can vary considerably, and individuals who reside in the same tract may have different experiences. The same level of variation may even be true for smaller level of census tract aggregation, block groups, though these areas are more likely to have homogenous characteristics. Two recent studies have attempted to overcome the problems posed by using census geography, using instead boundaries delineated based on homogenous neighborhood clusters and knowledge of traditional Chicago neighborhoods to model neighborhood effects on low birth weight (29, 47). It is surprising that few other studies have looked at how the definition of neighborhood could have an impact on findings of neighborhood effects on health outcomes.

An additional challenge in examining the effect of the neighborhood on health outcomes is choosing the anchor space for the exposure of interest (49). Using a fixed spatial residential location (e.g. census block group or tract) may not be appropriate for all neighborhood exposures. Evidence suggests that in fact few people are exposed solely to their residential environment, and the degree of non-residential exposure might vary by important factors like age, socioeconomic status, and family burden. In fact, neglecting to take into account non-residential exposures may bias the neighborhood-outcome associations and overestimate the effect that residential interventions would have on the health of residents (50). This bias is often referred to as the “residential” effect fallacy, resulting from a dependency between causally important “nonresidential” factors and the residentially defined exposure of interest (51). For many exposures, residential characteristics may be correlated with those of multiple contexts during daily activities because of a common causal antecedent. As a consequence, the associations between residential neighborhood and health outcomes as classically estimated may capture some of the effect that nonresidential environments visited may have on behaviors and health (50). For violent crime specifically, it is likely that the “residential” effect fallacy is an issue of concept and appropriate boundaries will vary. Thus, careful thought must be given to the spatial boundary used.

Special note should also be taken to spatial autocorrelation, an analytic issue which is neglected in most of the literature on neighborhood effects on birth outcomes with the exception of Morenoff's study of birth weight in Chicago (29). Spatial autocorrelation occurs when adjacent neighborhoods have similar outcomes, that are not accounted for after adjustment for neighborhood characteristics such as high crime rates (49). Adjusting for neighborhood characteristics reduces the impact of spatial autocorrelation by capturing some of the spatial dependence, however, unobserved spatial dependencies can remain and generate correlations among the outcome variable. Morenoff's third research question specifically looks to see if there is evidence that birth weight is related to the wider spatial context within which neighborhoods are imbedded (29). In order to answer this question, he uses multilevel spatial models of birth weight. Neighborhood in this study is defined using the sampling units from the 1995 Project on Human Development in Chicago Neighborhoods Community Survey, which refers to neighborhood as "neighborhood clusters" consisting of one or more geographically contiguous census tract. Violent crime rates, calculated from 1995 Chicago police statistics, are used as an indicator of social environmental stress. Individual-level controls are classified into four groups (maternal race, ethnicity, and nativity; sociodemographics; maternal health behavior; and biomedical measures) and adjusted for in analysis. The "spatial lag" model is used to estimate the spatial effect on birth weight. Morenoff concludes that adjacent neighborhoods exerted an influence on birth weight, suggesting interdependence should be considered in analyses of neighborhood effects, at least in urban contexts (29). Perhaps, however, the results from Morenoff's study reflect individual mobility. The reason crime in the neighboring tracts affect a given woman's outcomes may be a result of being exposed to that place either because the original neighborhood definition was too small or she goes there, and not a result of a spillover effect.

In an attempt to address many of the issues around defining a neighborhood, new theorizing and approaches have been developed to measure experienced environment, sometimes termed "activity spaces". The concept of activity spaces is built on the fact that most individuals are highly mobile (52). The activity space is the set of spatial locations visited by an individual over a given period, corresponding to his/her exhaustive spatial footprint (53). In other words, the social environment and context in which individual live their lives comprises their immediate neighborhood, as well as surrounding neighborhoods in which he/she works, shops, attends school, visits with friends, travels, and so on in the course of their daily lives (29). This new way of thinking about place guides our thinking about how environmental effects may act beyond the residential neighborhood. Furthermore, the way an individual experiences his/her neighborhood may be influenced by the wider context of the surrounding neighborhoods. Take for example, a neighborhood that has low crime rate, but the surrounding areas all have high crime rates. The crime in the surrounding areas could still be an important source of stress for people living in the low-crime neighborhood. This idea is known as a spillover effect, in which the crime in the surrounding neighborhoods produce a negative "spatial externality" for the low-crime neighborhood (29).

Taking an individual's residential environment and neglecting to take into account his/her non-residential activity places has resulted in a mischaracterization of environmental exposures (54). Looking at cardiometabolic research for an example, a review of 131 studies indicated that as much as 90% account only for the residential environment; 6% only took into account nonresidential exposures (e.g. workplace or school); and only 4% accounted for both residence and another anchor point (53). The failure to account for an individual's mobility and connection with multiple geographic places, spatial polygamy, is one of the main limitations of neighborhood and health studies (55). Taking into account daily mobility patterns and activity spaces is important for health promotion, as it helps identify low-mobility populations with access to only low-resources/high-exposure residential environments and mobile populations traveling across exclusively low-resource environments; accurate assessment of environmental exposures; and determination of appropriate activity places (e.g. resident or workplace) for targeting specific interventions (53).

The possibility of violent crime rates explaining spatial patterns in general health outcomes has been explored (32, 56, 57), though there is little evidence to support this hypothesis. The scientific literature reports mixed results in the association between violent crime and PTB. Previous studies have found that pregnancy complications and adverse birth outcomes are increased among women who live in violent, crime-ridden, and physically decayed neighborhoods, after adjusting for a range of individual-level sociodemographic attributes and health behaviors (23, 29). In this analysis, we aim to assess the association between violent crime and PTB/ETB among African American women in the City of Atlanta and see if the association differs when using different definitions for neighborhood. Using disease mapping techniques and logistic regression, we estimate the association between violent crime rates at the aggregated activity space with the probability of PTB/ETB and see if those rates differ from violent crime rates at the census block group level.

Atlanta crime rates

The national rates for violent crime have increased from 373.7 per 100,000 in 2015 to 386.3 per 100,000 in 2016 (58). In Atlanta, the rates for violent crime are higher than the national average, though the rates have decreased from 2015 to 2016 (1,119.6 per 100,000 vs. 1,083.6 per 100,000 respectively) (58).

As of 2017, 32.2% of Georgia's, and 52.4% of Atlanta's, population identifies as Black or African American (59). The rate of PTB in the state was 10.8% for 2015, compared to 10.4% for the city of Atlanta (7). Both of these rates are higher than the national rate of PTB (9.6%) (60). In Atlanta, 13.9% of PTB were for African Americans women (60).

Methods

Data

Birth data was extracted from the Microbiome and Preterm Birth Cohort Study at Emory University (2014 – current). This study is attempting to understand how biobehavioral determinants influence the microbiome of African American women during pregnancy and whether the disruption of the microbiome may cause PTB. Women are enrolled early in pregnancy at one of two Atlanta hospitals, Grady and Emory Midtown. The two hospitals represent a safety net public hospital, and a primarily private-practice hospital respectively. This enrollment strategy is aimed to produce a socioeconomically diverse cohort of pregnant African American women. The analysis was limited to live, singleton births born to mothers residing within metro Atlanta, Georgia at the time of birth. Infants with a birth weight below 500g or born before 20 weeks' gestation were excluded from analysis.

Mothers' activity space data was extracted from the Spatial Exposome and Microbiome Study (SESAME Street), a sub-study of the Microbiome and Preterm Birth Cohort Study, also conducted at Emory University (2016 – current). Women in the SESAME Street Study filled out a questionnaire, answering questions about some of the places they typically go, such as where they work or buy groceries. To help answer the questions, participants used a Google map to drop a pin for each location (home, grocery store, restaurant). Once the location was identified, a few simple questions were asked about the place such as how often this location was visited. This information was used to define a woman's activity space.

For this analysis, infants born between 2016 – 2018 were included. They were considered preterm if they were born before the 37th week of gestation, early term if they were born between 37 and 38 weeks of gestation, and full term if they were born in or after the 39^{th} week. Gestational age was estimated from the mother's last menstrual period and confirmed via ultrasound.

Violent crime is defined as any instance of homicide, rape, assault, or robbery reported within the nine counties of metro Atlanta, Georgia in 2013 (DeKalb, Gwinnett, Cobb, Clayton, Coweta, Douglas, Fayette, and Henry). Various police agencies in the Atlanta metro area provided the crime data as a count of events occurring within each block group in 2013. The crime rate for each block group was calculated by dividing the total number of crimes in a block group by the population of that block group as determined from the 2017 5 year-American Community Survey conducted by the U.S. Census Bureau. Crime numerators and denominators were at the block group scale, and these values were converted to points at the centroids. The local varying spatial-intensity of violent crime in metro Atlanta was estimated using kernel density estimation. In order to perform KDE estimation, the analyst must specify a kernel bandwidth. This denotes the width of the kernel function, and as a result, dictates how smooth the resulting intensity surface will be. In this study we used an adaptive bandwidth. This approach changes the kernel radius (bandwidth) across the map in response to the relative density of points, with relatively more smoothing (larger bandwidth) in areas with sparse point data, and relatively less smoothing (smaller bandwidth) in areas with more point density.

We measured violent crime at two spatial scales to conduct different, yet similar, analyses. The primary objective was to compare the difference in the relationship between the exposure of violent crime and the outcome of PTB/ETB when the crime is measured as residential crime (using census geography) and when it is measured as activity space crime. A secondary objective, however, is how to appropriately define crime at the activity space level. Time spent at or frequency of visits to a location outside of one's residential location could affect the relationship between crime and birth before 39 weeks' gestation. Furthermore, the two additional spatial scales created included an exposure variable that adjusted for time spent in each location outside of one's home (calculated as minutes per day) and an exposure variable adjusted for frequency of visits to each location outside of one's home (calculated as number of visits per week). Scatterplots were made to measure the correlation between residential crime and activity space crime measured three different ways.

Individual-level covariates that were considered included age (in 5 categories: ≤ 19, 20-24, 25-29, 30-34, and 35+), education (less than high school education, high school graduate/GED, and more than high school education), and marital status (married or unmarried). Additionally, several maternal health-related covariates were considered: chronic or pregnancy-associated hypertension, gestational diabetes, the number of previous births (0, 1, 2, or greater), and number of previous preterm births (0, 1, or 2). Finally, we considered alcohol and tobacco use during pregnancy. All individual-level maternal covariates were determined from survey data.

Modeling

We used logistic regression to estimate the association between violent crime and odds of PTB/ETB within each residential area or activity space and controlled for potential confounders. The exposure of interest in the model was the violent crime rate at the neighborhood level defined (residential or activity space). The exposure was considered as a continuous variable and as a categorical variable. When considered a continuous variable, a one unit change in crime reflected a change in one standard deviation (SD) for each respective measure of crime. To be considered a categorical variable, crime rates were divided into quartiles of the distribution of exposed women.

The lowest quartile (Q1), representing the lowest level of crime was used as the referent group. All covariates that were significantly associated with both PTB/ETB and violent crime rate in descriptive analyses were included in the model. After review of scientific literature and consideration of sample size limitations, interaction was not included in the model.

A directed acyclic graph (DAG) orientated approach was used for model selection. Based on theoretical relationships, an argument can be made that tobacco and alcohol consumption, prior PTB, chronic or pregnancy-associated hypertension, and gestational diabetes are mediators on the path from exposure to violent crime and an outcome of PTB/ETB. In this scenario, we argue that the mediators are a result of the stress induced by exposure to violent crime and should therefore not be adjusted for in the model. This was represented in Model 1. Alternatively, these variables may also be confounders. We can argue that people who consume tobacco and alcohol, have had a previous PTB, and have chronic or pregnancy-associated hypertension, and gestational diabetes are more likely to inhabit high crime areas and more likely to have a PTB/ETB. These variables should therefore be adjusted for in the model. This was represented in Model 2.

Spatial analyses were done using R. All statistical analyses were done using SAS 9.4, and logistic regression was done using PROC GENMOD in SAS.

Results

By September 1, 2018, a total of 505 African American women were enrolled to the Microbiome and Preterm Birth Cohort Study. Of these, 485 women had a pregnancy or birth outcome recorded and were included in the study. Sixteen women electively withdrew from the study or were ineligible due to inaccurate gestational age at intake visit, being found to have twins, or some other disqualifying condition such as severe anomalies. The remaining four were lost to follow-up.

From the sample of 485 women, data was gathered on 116 women for the SESAME Street Study. Three of the women were excluded because their residential location was not contained in one of the nine counties of metro Atlanta used for the crime scale. The remaining 113 births were used in analysis.

Figure 1 depicts the kernel density smoothed quartiles of violent crime rates derived from events and population aggregated to block groups in metro Atlanta. Q1 represents the lowest quartile of crime and Q4 represents the highest quartile. The majority of the high crime is in DeKalb and Fulton counties, with some spillover into Cobb and Gwinnett. There is a small hot spot of high crime in Henry County and a larger hotspot in Coweta County.

Figures 2 depicts the correlation between residential crime and activity space crime measured in three different ways. There is not a strong one-to-one relation between residential crime and activity space crime measured in any of the three ways, though there appears to be a much stronger relationship between activity space crime un-adjusted and residential crime compared to the other two measures of activity space crime adjusting for time and frequency of visits. This would suggest that women go to places that are different from where they live.

Descriptive statistics

For all births, gestational age at birth ranged from 29 to 41 weeks with a median of 39 weeks (IQR: 38-40 weeks). Overall, 39.8% of infants (n = 45) were born preterm or early term. Of the births born before 39 weeks, 15.6% were preterm (n = 7; 6.2% of all births).

The number of births that were preterm or early term in a given residential crime quartile ranged from 8 to 14 (Table 1). Women living in a high-crime neighborhood (the 4th, or highest, crime quartile) were more likely to give birth to a preterm or early term infant and more likely to be unmarried. In regard to education, women with more than a high school degree were equally likely to live in the lowest crime quartile as they were to live in the highest crime quartile. Women having less than a high school degree were least likely to live in the highest crime neighborhood.

Preterm or early term birth was most common among women 25 – 29 years of age (48.3% of births in this age group), followed by women less than 20 years old (42.9% of women in this age group) (Table 2). Women over the age of 35 were least likely to have a preterm or early term birth (28.6% of births in this age group). Overall, few mothers reported alcohol use during pregnancy (n = 4). Of those, one resulted in a preterm birth. Mothers of preterm or early term infants were more likely to report tobacco use during pregnancy, as well as more likely to be afflicted with gestational diabetes and chronic hypertension compared to mothers of term infants. Mother's with 2 or more previous births or 2 or more previous preterm births were also more likely to given birth to a preterm or early term infant.

Modeling

The results from three logistic models relating different definitions of spatial exposure to violent crime with the odds of PTB/ETB are shown in Table 3. No model showed statistically significant results. The results from modeling crime quartiles did not suggest any improvement in fit compared to modeling crime as a continuous variable.

Model 0 is the empty model, considering the exposure of interest alone. Not controlling for any confounders, a 1-SD unit change in residential crime is associated with a 1.18 (95% CI: 0.81, 1.71) increase in the odds of PTB/ETB when compared to women who had a term birth. Alternatively, when looking at activity space crime alone, a one unit change in SD of activity space crime is associated with a 21% (OR: 1.21, 95% CI: 0.24, 1.78) increase in PTB/ETB when compared to women who had a term birth.

Model 1 considers tobacco and alcohol consumption, prior PTB, chronic or pregnancy-associated hypertension, and gestational diabetes as mediators. Controlling for age, education, and number of previous births, the odds of PTB/ETB is increased 1.09 (95% CI: 0.74, 1.62) times for every 1-SD unit change in residential crime, compared to those who had a term birth. When controlling for the same confounders and instead looking at 1-SD unit change in activity space crime, the odds of PTB/ETB increased 1.12 (95% CI: 0.72, 1.69) times, compared to those who had a term birth. When adjusting activity space crime for time spent in each location, there is a 24% (OR: 1.24, 95% CI: 0.86, 1.81) increase in preterm or early term birth for every 1-SD unit increase in crime, after controlling for age, education, marital status, and number of previous births.

Model 2 considers tobacco and alcohol consumption, prior PTB, chronic or pregnancy-associated hypertension, and gestational diabetes as confounders. Controlling for all confounders, the odds of PTB/ETB is 1.07 (95% CI: 0.71, 1.62) times higher for every 1-SD unit change in residential crime, compared to those who had a term birth. When using activity space crime as the exposure and controlling for all confounders, there is a 6% (OR: 1.06, 95% CI: 0.68, 1.66) increase in preterm or early term birth for every 1-SD unit change in activity space crime, compared to those who had a term birth. Adjusting activity space crime for frequency of visits to each location, there is a 12% (OR: 0.88, 95% CI: 0.59, 1.29) decrease in preterm or early term birth for every 1-SD unit change in crime, compared to the odds of those who had a term birth.

Discussion

The risk of PTB among African American women in Atlanta, GA is similar to the national average of PTB for African American women; 13.9% of singleton infants were born before the 37^{th} gestational weeks in 2018, compared to 13.4% nationally (7, 60). In this Atlanta-based study, PTB/ETB in African American women was associated with low levels of education and marriage, and high levels of hypertension, tobacco or alcohol consumption, and diabetes. All of these results are consistent with prior findings.

By controlling for individual risk factors in logistic regression, we were able to estimate the association between violent crime and preterm or early term birth. We find modest evidence to support an association between high levels of violent crime in a mother's neighborhood and an increased odds of giving birth to a preterm or early term infant, though the association differs based on the definition of "neighborhood" and whether or not possible risk factors were considered confounders or mediators. When tobacco and alcohol consumption, prior PTB, chronic or pregnancy-associated hypertension, and gestational diabetes were considered as possible intermediaries between crime and birth outcomes (and therefore excluded from models), activity space crime was associated with a higher odds of preterm or early term birth than when considering residential crime as the exposure. After adjusting for time spent in each location, the odds of PTB/ETB increased. When tobacco and alcohol consumption, prior PTB, chronic or pregnancy-associated hypertension, and gestational diabetes were instead considered as confounders, activity space crime was associated with a similar odds of preterm or early term birth compared to when considering residential crime as the exposure. After adjusting for time spent in each location, however, the odds of PTB/ETB was higher than when these variables were excluded from the model.

Strengths and Weaknesses

We considered exposure to violent crime measured as residential crime (using census geography) and when it is measured as activity space crime (measured 3 different ways) to be the exposure of interest. In contrast to prior studies, we were able to calculate odds ratios that evaluated how the definition of a neighborhood can change results. As we saw with the scatterplots comparing residential crime versus activity space crime, women travel to places that are different from where they live.

This study is unique in that crime – which may be risk factor for PTB in the total population – has not been examined as a factor for a within-race study. The difference is that we may be reducing unmeasured confounding related to racial segregation. In other words, in a total population study of crime and PTB, it could be that it is not crime but some other aspect of place that are predictors of racial concentration and crime. However, by using a within-race comparison there could still be economic segregation, but the potential effects of racial stratification are less relevant. This also could explain why our results demonstrate a weaker association compared to others.

Another possible issue with a within-race study is that – because of racial segregation – we have a truncated distribution of crime, and there may be a ceiling effect. In other words, if the effect of crime is from no crime to moderate crime, and African American women in our study only live in moderate and high crime areas, we may not see the full impact, simply because of fundamental spatial selection processes.

Our logistic regression analyses showed an association between high violent crime rates on two distinct scales (residential area and activity space) and an increased odds of PTB/ETB. This study adds to previous evidence that neighborhood characteristics, and violent crime in particular, may be an important contributor to the risk of PTB.

Women in general experience higher risk of PTB/ETB at very young maternal ages and again at older ages. There is evidence, however, to support the theory that women who are chronically exposed to stress, "age" more quickly, thereby increasing their risk for giving birth before term more so than their less-stressed counterparts (61, 62). It is possible that this idea of the "weathering hypothesis" is occurring among women continuously exposed to crime. Older women living in or experiencing high-crime neighborhoods perhaps are exposed to long period of crime, poverty, segregation, and other stressing factors associated with high-crime neighborhoods. Measuring exposure to high levels of crime in the year of pregnancy may, therefore, be a proxy for measuring exposure to high level of environmental stressors over longer periods of time. Though we evaluated the exposure of crime using four different spatial measurements, we did not control for concurrent neighborhood deprivation and segregation or long-term stress in the women giving birth, a limitation of our study.

In this study, we adjusted for confounders thinking about whether crime causes preterm or early term birth. Though we adjusted for many confounders, we did not account for neighborhood confounders which would have helped explain whether the definition used for neighborhood affects the results. The confounders we did adjust for were limited by the data provided through the surveys. It is possible there was misclassification bias due to women neglecting to be truthful about their response to alcohol or tobacco consumption during pregnancy. Further analyses using a sub-study of women for validation and bias adjustment may find different associations. In addition, our analyses and results were limited by the sample size. Out of 113 births, only 7 were preterm and 38 were early term. The number of PTBs was too small to note any association between exposure to violent crime and having a PTB, which is why we combined the outcome to include a PTB/ETB. Even with the 45 births, however, our sample was too small to find statistical significance.

Moreover, our analysis of violent crime was limited to reported crimes in 2013, and not all violent crimes are reported to the police, so crime rates in some areas may be higher than reported. Reporting rates differ by race, age, and sex of the victim, as well as the type of crime, resulting in potential misclassification bias.

Future Directions

In these analyses, we conducted logistic regression that adjusted for individual level covariates in the model to see whether crime causes PTB/ETB. Our results show the strongest association between crime and PTB/ETB exists when crime is measured at activity spaces and adjusted for time spent in each place. These findings suggest taking into account daily mobility patterns and activity space can help us identify low-mobility women with access to only low-resources and mobile women traveling to exclusively low-resource environments, and how this impacts access to prenatal care during pregnancy. Implications for health interventions include increased social support for women who have increased time in high crime areas.

Future analysis can be conducted to explore how the definition of neighborhood changes the results. Using a multilevel logistic regression, neighborhood level factors and confounders can be accounted for. A random intercept model can be used to represent each neighborhood (residential or activity space). In this way, the model can account for otherwise unobserved variation in preterm or early term birth risk.

Our results, limited by sample size, did not account for interaction. As more woman enroll in the SESAME Street Study, there will be more power to test for interaction on the multiplicative scale.

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Table 1. Distribution of U.S. Singleton Live African American Births[a] in residential violent crime rate quartiles[b] of metro Atlanta, GA

	Total N	**Q1[c] %**	**Q2 %**	**Q3 %**	**Q4 %**
Overall	113	25.7	24.8	23.0	26.6
Outcome					
Preterm Birth (PTB)[d]	7	6.9	0.0	11.5	6.7
Early Term Birth (ETB)[e]	38	20.7	46.4	26.9	40.0
PTB/ETB	45	27.6	46.4	38.5	46.7
Maternal demographics					
Education					
< HS education	20	17.2	21.4	23.1	10.0
High school grad/GED	50	31.0	57.1	50.0	40.0
> HS education	43	51.7	21.4	26.9	50.0
Marital status					
Married	18	27.6	10.7	15.4	10.0
Unmarried	95	72.4	89.3	84.6	90.0
Age Category					
≤19	14	13.8	10.7	15.4	10.0
20-24	43	31.0	53.6	42.3	26.7
25-29	29	20.7	14.3	23.1	43.3
30-34	20	24.1	21.4	7.7	16.7
35+	7	10.3	0.0	11.5	3.3
Maternal health related covariates					
Alcohol use during pregnancy					
Yes	4	3.6	0.0	3.9	6.7
No	107	96.4	100.0	96.2	93.3
Tobacco use during pregnancy					
Yes	14	10.3	14.3	15.4	10.0
No	99	89.7	85.7	84.6	90.0
Gestational diabetes					
Yes	2	3.5	0.0	3.9	0.0
No	111	96.6	100.0	96.2	100.0

Chronic hypertension					
Yes	6	6.9	7.1	3.9	3.3
No	107	93.1	92.9	96.2	96.7
Gestational hypertension					
Yes	24	31.0	10.7	15.4	26.7
No	89	69.0	89.3	84.6	73.3
Parity					
Mother's first birth	1	0.0	0.0	3.9	0.0
1 previous birth event	31	31.0	28.6	15.4	33.3
2 previous birth events	33	37.9	32.1	19.2	26.7
>2 previous birth events	48	31.0	39.3	61.5	40.0
Prior preterm birth					
No previous PTB	101	96.6	96.4	84.6	80.0
1 previous PTB	11	3.5	3.6	11.5	20.0
2 previous PTB	1	0.0	0.0	3.9	0.0

[a] Data was used from the Microbiome and Preterm Birth Cohort Study at Emory University and the sub study Spatial Exposome and Microbiome Study

[b] Violent crime is defined as any instance of homicide, rape, assault, or robbery reported within the nine counties of metro Atlanta, GA in 2013 (DeKalb, Gwinnett, Cobb, Clayton, Coweta, Douglas, Fayette, and Henry). Data was taken from various police agencies in the metro Atlanta area from 2013. Crime rates for each block group were calculated by dividing the total number of crimes in a block group by the population of that block group as determined from the 2017 5 year-American Community Survey conducted by the U.S. Census Bureau.

[c] Q1 represents the lowest crime quartile

[d] Preterm birth includes live births that occurred at gestational ages 21-36 weeks inclusive

[e] Early term birth includes live births that occurred at gestational ages 37-38 weeks inclusive

Table 2. Demographics and health characteristics of infants and mothers of infants born preterm (PTB)[a] and early term (ETB)[b] in a cohort of U.S. Singleton Live African American Births[c]

	Total	**PTB**		**ETB**		**PTB/ETB**	
	N	**N**	**%**	**N**	**%**	**N**	**%**
Overall	113	7	6.2	38	33.6	45	39.8
Maternal demographics							
Education							
< HS education	20	0	0.0	8	40.0	8	40.0
High school grad/GED	50	4	8.0	17	34.0	21	42.0
> HS education	43	3	7.0	13	30.2	16	37.2
Marital status							
Married	18	1	5.6	6	33.3	7	38.9
Unmarried	95	6	6.3	32	33.7	38	40.0
Age Category							
≤ 19	14	1	7.1	5	35.7	6	42.9
20-24	43	2	4.7	15	34.9	17	39.5
25-29	29	4	13.8	10	34.5	14	48.3
30-34	20	0	0.0	6	30.0	6	30.0
35+	7	0	0.0	2	28.6	2	28.6
Maternal health related covariates							
Alcohol use during pregnancy							
Yes	4	1	25.0	0	0.0	1	25.0
No	107	6	5.6	38	35.5	44	41.1
Tobacco use during pregnancy							
Yes	14	2	14.3	4	28.6	6	42.9
No	99	5	5.1	34	34.3	39	39.4
Gestational diabetes							
Yes	2	0	0.0	1	50.0	1	50.0
No	111	7	6.3	37	33.3	44	39.6
Chronic hypertension							
Yes	6	1	16.7	2	33.3	3	50.0
No	107	6	5.6	36	33.6	42	39.3

Gestational hypertension								
Yes	24		2	8.3	6	25.0	8	33.3
No	89		5	5.6	32	36.0	37	41.6
Parity								
Mother's first birth	1		0	0.0	1	100.0	1	100.0
1 previous birth event	31		0	0.0	7	22.6	7	22.6
2 previous birth events	33		2	6.1	10	30.3	12	36.4
>2 previous birth events	48		5	10.4	20	41.7	25	52.1
Prior preterm birth								
No previous PTB	101		4	4.0	32	31.7	36	35.6
1 previous PTB	11		2	18.2	6	54.5	8	72.7
2 previous PTB	1		1	100.0	0	0.0	1	100.0
Violent Crime[d]	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Residential	11.9	8.1	12.1	8.4	12.8	8.1	12.7	8.1
Activity Space (AS)	12.8	5.2	13.5	5.7	13.3	5.6	13.4	5.5
AS Adjusted for Time	10.7	10.8	4.9	3.7	13.4	13.7	12.1	13.0
AS Adjusted for Frequency	8.5	6	10.8	9.9	8.4	5.6	8.8	6.4

[a] Preterm birth includes live births that occurred at gestational ages 21-36 weeks inclusive

[b] Early term birth includes live births that occurred at gestational ages 37-38 weeks inclusive

[c] Data was used from the Microbiome and Preterm Birth Cohort Study at Emory University and the sub study Spatial Exposome and Microbiome Study

[d] Violent crime is defined as any instance of homicide, rape, assault, or robbery reported within the nine counties of metro Atlanta, GA in 2013 (DeKalb, Gwinnett, Cobb, Clayton, Coweta, Douglas, Fayette, and Henry). Data was taken from various police agencies in the metro Atlanta area from 2013. Crime rates for each block group were calculated by dividing the total number of crimes in a block group by the population of that block group as determined from the 2017 5 year-American Community Survey conducted by the U.S. Census Bureau.

Table 3. Odds of preterm birth[a] or early term birth[b] in a cohort of U.S. Singleton Live African American Births[c] when using different measurements of neighborhood violent crime rates[d] for the exposure

	Model 0	**Model 1**	**Model 2**
Residential Crime[e]	1.18 (0.81, 1.71)	1.09 (0.74, 1.62)	1.07 (0.71, 1.62)
Activity Space Crime[f]	1.21 (0.24, 1.78)	1.12 (0.72, 1.69)	1.06 (0.68, 1.66)
Activity Space Crime Adjusted for Time[g]	1.22 (0.86, 1.73)	1.24 (0.86, 1.81)	1.27 (0.85, 1.88)
Activity Space Crime Adjusted for Frequency[h]	1.07 (0.77, 1.49)	0.93 (0.65, 1.35)	0.88 (0.59, 1.29)

Model 0 is the model with only the exposure term and does not adjust for any confounders
Model 1 is the model the model that adjusts for age, education, and number of previous births
Model 2 is the model that adjusts for all possible confounders

[a] Preterm birth includes live births that occurred at gestational ages 21-36 weeks inclusive

[b] Early term birth includes live births that occurred at gestational ages 37-38 weeks inclusive

[c] Data was used from the Microbiome and Preterm Birth Cohort Study at Emory University and the sub study Spatial Exposome and Microbiome Study

[d] Violent crime is defined as any instance of homicide, rape, assault, or robbery reported within the nine counties of metro Atlanta, GA in 2013 (DeKalb, Gwinnett, Cobb, Clayton, Coweta, Douglas, Fayette, and Henry). Data was taken from various police agencies in the metro Atlanta area from 2013. Crime rates for each block group were calculated by dividing the total number of crimes in a block group by the population of that block group as determined from the 2017 5 year-American Community Survey conducted by the U.S. Census Bureau. A one unit change in crime reflects a change in one standard deviation for each measurement of crime.

[e] Residential crime is defined as violent crime at the census block group level

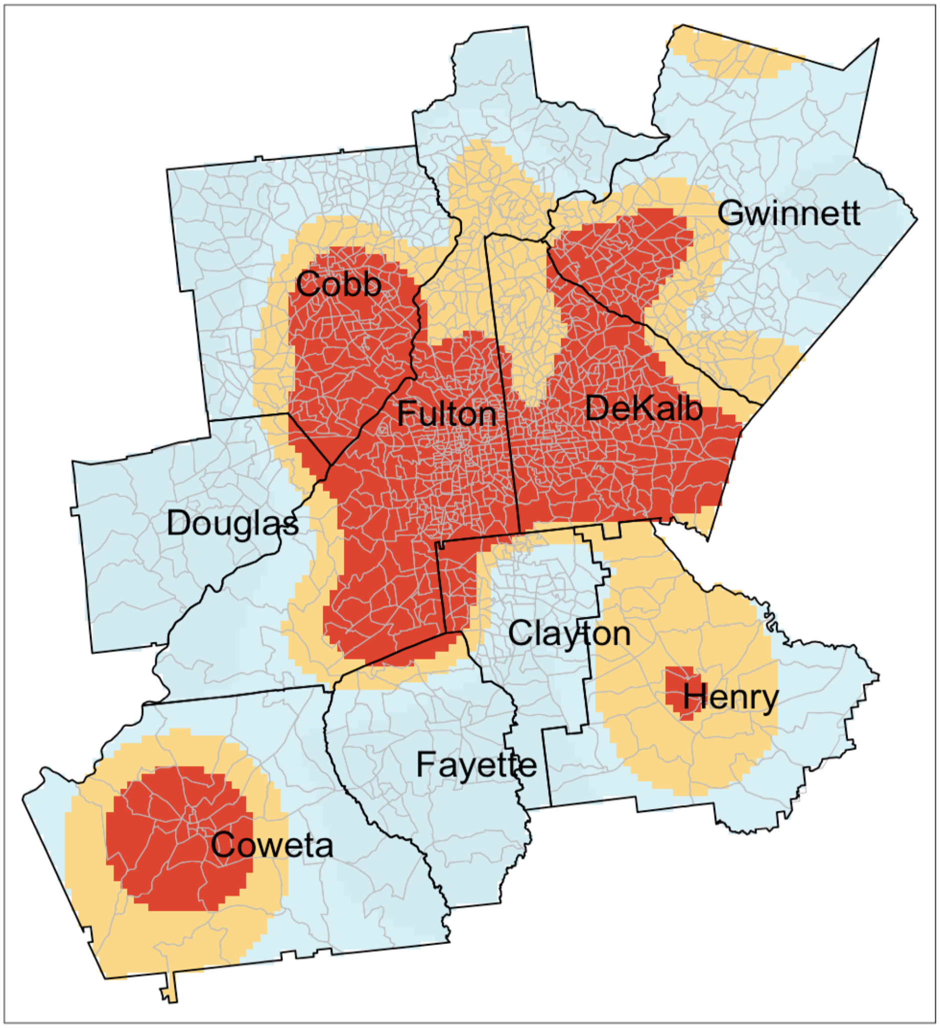
[f] Activity space crime is defined as violent crime accounting for individual mobility

[g] Activity space crime adjusted for time is defined as violent crime accounting for individual mobility in minutes per day

[h] Activity space crime adjusted for frequency is defined as violent crime accounting for individual mobility in visits per week

Figures and Figure Legends

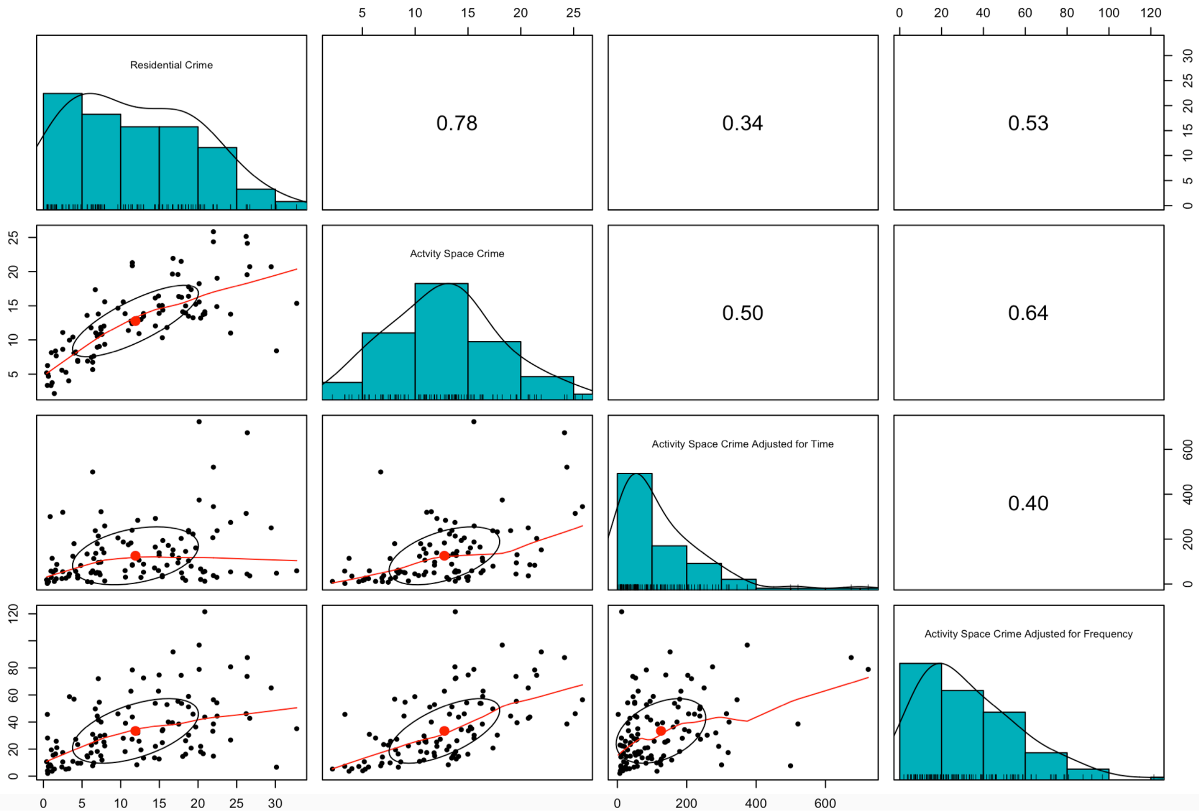
Figure 1. Risk density of violent crime[a] in block groups in metro Atlanta, GA



[a] Violent crime is defined as any instance of homicide, rape, assault, or robbery reported within the nine counties of metro Atlanta, GA in 2013 (DeKalb, Gwinnett, Cobb, Clayton, Coweta, Douglas, Fayette, and Henry). Data was taken from various police agencies in the metro Atlanta area from 2013. Crime rates for each block group were calculated by dividing the total number of crimes in a block group by the population of that block group as determined from the 2017 5 year-American Community Survey conducted by the U.S. Census Bureau. Crime numerators and denominators were at the block group scale, and these values were converted to points at the centroids. Kernel density estimation was used to produce a spatial continuous surface.

[b] Crime quartiles are based on distribution of women, not block groups. Q1 represents the lowest crime quartile.

Figure 2. Scatterplot matrix of residential crime[a] versus activity space crime[b], activity space crime adjusted for time[c], and activity space crime adjusted for frequency[d]



[a] Residential crime is defined as violent crime at the census block group level

[b] Activity space crime is defined as violent crime accounting for individual mobility

[c] Activity space crime adjusted for time is defined as violent crime accounting for individual mobility in minutes per day

[d] Activity space crime adjusted for frequency is defined as violent crime accounting for individual mobility in visits per week