Environmental Justice Metrics Contextualize the Preterm Birth Disparity in Allegheny County

by

Kathleen Shedlock

BS, Microbiology, University of Pittsburgh, 2018

Submitted to the Graduate Faculty of

the Department of Epidemiology

Graduate School of Public Health in partial fulfillment

of the requirements for the degree of

Master of Public Health

University of Pittsburgh

2019

UNIVERSITY OF PITTSBURGH

GRADUATE SCHOOL OF PUBLIC HEALTH

This essay is submitted

by

Kathleen Shedlock

December 13, 2019

and approved by

Essay Advisor:
Evelyn O. Talbott, DrPH, MPH
Professor
Epidemiology
Graduate School of Public Health
University of Pittsburgh

Essay Reader:
LuAnn Brink, PhD, MPH
Chief Epidemiologist, Deputy Director
Allegheny County Health Department
Adjunct Assistant Professor
Epidemiology
Graduate School of Public Health
University of Pittsburgh

Essay Reader:
Noble A-W Maseru, PhD, MPH
Professor
Behavioral and Community Health Sciences
Graduate School of Public Health
University of Pittsburgh

Evelyn O. Talbott, DrPH, MPH

Environmental Justice Metrics Contextualize the Preterm Birth Disparity in Allegheny County

Kathleen Shedlock, MPH

University of Pittsburgh, 2019

Abstract

The Environmental Justice movement began in the South as a response to toxic waste dumping in disproportionately black communities. Today, it encompasses the many inequities and social injustices concentrated in largely black and low-income populations. This disproportionate burden may aid in understanding the lack of birth equity between white and black mothers where individual behaviors fail to fully explain the disparity. This study presents a cross-sectional, ecologic analysis of Environmental Justice metrics and preterm birth in Allegheny County, PA. Overall, areas with the highest level of housing vacancies had significant increases in preterm birth incidence (IRR 1.43, 95% CI 1.22, 1.67). However, race stratified models show a disproportionate impact of diesel particulate matter on preterm birth incidence among black women (IRR 2.20, 95% CI 0.99, 4.87), compared to white women. Ultimately, this analysis contributes a piece to untangling the complex and multifactorial relationship between neighborhood, preterm birth, and race, a matter of great public health significance.

Table of Contents

List of Tables

List of Figures

Preface

I would like to thank my parents, Robert and Lynne Shedlock, my sister, Elizabeth Shedlock, and my partner, Dylan Galper, for all their support and encouragement throughout graduate school. In addition, a special thanks to two of my classmates, Adrianna Gradisek and Hannah Kupets, for their unending optimism and great friendship.

1.0   Introduction

1.1   Environmental Justice and Historical Context

Environmental justice has roots that stretch far beyond its storied beginning of waste dumping in the southern United States. Historically, black and lower income communities have been constructed around higher density traffic, commercial, and industrial areas leaving residents subject to greater levels of environmental pollutants[1-3]. During the industrial age, towns were built around manufacturing centers to allow for an easy commute for white workers[4]. However, as industry jobs moved from urban centers, white workers moved on to suburban areas with loans provided by the federal government[5]. Only then, were black populations afforded the opportunity to move into these higher density areas. Without the economic stimulus from industry, communities collapsed and were ignored by local government[5-7]. Often, leaving these areas for better environment and opportunity is not an option. Many lacked the financial stability to afford rent in better areas or were excluded from mortgage lending based on race[8]. Infrastructure was neglected, and many communities were effectively cut off from all opportunity and access to resources required to thrive.

That isolation and racial exclusion has continued today. Poverty is concentrated in areas that once were economic boons of industry, and most residents are trapped within a system constructed against them. These communities are the living example of institutional racism;

historical actions both implicitly and explicitly discriminatory restricted the growth of black communities[4, 5]. Now, communities still bear the burden of historical policy through lack of opportunity, disproportionate environmental degradation, and increased negative health outcomes. Though environmental justice began as a response to an environmental concern it has expanded to become a home for issues pertinent to the spaces and places where people work, live, and play, and how those spaces may impact health or quality of life[9].

The environmental justice movement was born in the 1980's in the southern US out of controversy surrounding disproportionate toxic waste dumping in primarily African American communities[10, 11]. Specifically, in 1982 an illegal dump by a local North Carolina company had left the state to dispose of 30,000 gallons of contaminated soil[12, 13]. The state chose to build a landfill in the community of Afton, a lower income area with a population that was 65% black[13]. Protests from the community and other environmental groups delayed the construction, but ultimately the state went forward with the development and put an entire community at risk of contaminated drinking water[13]. Though unsuccessful, the protests marked the beginning of a fight for environmental protections in the black community[9, 10]. Reports that followed built upon the fledgling movement and quantified the scope of environmental degradation felt by many primarily black and low-income communities. One such report by The United Church of Christ concluded, at the time, that the greatest predictor for the location of commercial hazardous waste facilities was the mean minority percentage of an area. Communities with a waste facility had up to twice the proportion of minority residents than areas without such a facility[14].

Consequently, the inequities in neighborhood environment has come into greater focus in light of the many health disparities between the black and white population[15]. Across the board, black populations have rates of chronic and noncommunicable disease and adverse birth

outcomes that often far exceed that of their white counterparts[16]. Despite wide-scale effort and some progress, many gaps in health persist. Researchers have begun to give more focus to analysis that incorporates higher level indicators of health to cover the gaps that remain after taking individual level factors into account[15, 17]. Socio-demographic characteristics, pollution levels, and measures of the built environment have all come into play to evaluate and remediate health disparities.

1.2   Preterm Birth

Preterm birth is defined as birth as less than 37 weeks of gestation, extensive study has shown that preterm births accounts for a third of all infant deaths and is the largest direct cause of global neonatal deaths[18, 19]. In the United States the preterm birth rate has risen since 1990 among all live births; at the same time the percent of black infants born preterm has remained consistently higher than the percent of white infants born preterm (Table 1)[20]. More recently, rates have alarmingly risen each year between 2014 and 2017[21]. Nationally and locally, the preterm birth rate is utilized to identify serious pockets of inequity, particularly among lower income populations and populations of color. Since the mid 1900s, it has been recognized that there exists a pervasive lack of birth equity in the United States[22]. Much like issues of environmental justice, the disparity in preterm birth between white and black women is not a mere difference in behavior. Instead, it is borne out of a long history of social injustice and widespread racial exclusion and inequity that has persisted today; and is evident in the disparity in preterm birth. Nationally, black infants are born preterm 60% more frequently than white infants, and associated complications account for 42.5% of infant deaths among black infants,

but only 30.8% of infant deaths among white infants[18]. Often, infants who were born preterm have lasting effects through childhood, adolescence, and adulthood[23].

Table 1 Percent of all Live Births Born Preterm in the US Overall and by Race for 1990, 2000, and 2010.

Year	Overall	Black	White
1990	10.62	17.0	7.3
2000	11.64	15.3	8.4
2010	11.99	17.12	10.77

The preterm birth disparity is pervasive and equivocal. Many studies that focused on individual level risk factors such as smoking status, inter gestational period, education, previous preterm births, or adequate prenatal care failed to fully explain the disparity[24]. More recent research has begun to examine preterm birth as a multifactorial issue and has incorporated both individual and community level factors, hypothesizing that accumulated stress from individual circumstance, neighborhood quality, and environmental toxins contribute to the widening gap[19, 25, 26]. One prominent theory is the concept of weathering, where life-long exposure to racism, poor environment, and other daily stressors accumulate and increase allostatic load, resulting in poorer health over time[27]. A study of generational mobility among black and white women found that a majority of black women resided in lower income areas across generations, whereas white women largely resided in higher income areas across generations[27]. Results indicated that the black women experienced weathering in rates of small for gestational age and low birth weight, but not preterm birth, however the study did not incorporate neighborhood context outside of income. Another study considered "metropolitan statistical areas" (MSA) in terms of segregation, income, educational attainment, and very preterm birth. The MSAs were grouped by

size, 100,000-500,000, 500,000-1 million, or million plus, and region, Northeast, Southeast, Midwest, and West. The only instances of overlap between very preterm rates between black and white infants occurred in the "very best" city for black women and the "very worst" city for white women[19]. Again, this study did not consider environmental factors, and the unit of analysis was large and may contain a vast amount of heterogeneity that can be lost in aggregate.

Much like past environmental justice research, other studies have incorporated environmental characteristics into their analysis of neighborhood structures and adverse birth outcomes. In California, $PM_{2.5}$ concentrations accounted for 3.1% of the difference in PTB rates and 4.5% of the difference in very PTB rates between black and white mothers[28]. These values were on par with many other individual and neighborhood level factors such as age at delivery, explaining 4.6% of the difference, or zip code level of unemployment, explaining 3.8% of the difference[28]. However, the study used zip code as the unit of analysis which are large and often heterogenous and may not reflect accepted community boundaries.

Circumstances in Allegheny County mirror that of the state and the nation. Though overall Allegheny is on track to exceed the Healthy People 2020 goal for rate of preterm births, there is a significant portion of the population trailing behind. African Americans comprise 13% of the population in Allegheny County, yet they accounted for 30% of all preterm births between 2015 and 2017[29, 30]. In the same period, black women were 80% more likely to experience preterm birth than white women[29]. Furthermore, due to Allegheny County's unique history and geography, African Americans tend to be isolated in neighborhoods with a higher concentration of poverty, environmental toxins, and poor built environment[31]. Compared to eight other counties of a similar size and racial composition, Allegheny had the second highest racial disparity in preterm birth[29].

Furthermore, due to Allegheny County's unique history and geography, African Americans tend to be isolated in neighborhoods with a higher concentration of poverty, environmental toxins, and poor built environment. The Allegheny County 2017 Environmental Justice Index found that of the ten areas with the highest environmental justice score, a composite score factoring in socio-demographics and environmental characteristics of an area, eight of them had at least 30% racial minorities[31]. Moreover, they concluded that no one variable drove the overall score, but that the highest need areas had consistently higher scores across each category.

1.3   Public Health Significance

Preterm birth has lasting effects on both mothers and infants. Mothers who've had a previous preterm birth are 15-50% more likely to have an additional preterm birth or experience other birth complications[32]. Infants born preterm are at a higher immediate risk of mortality; through adolescence and adulthood, individuals born preterm are at higher risk of asthma, learning disabilities, attention deficit disorder, and emotional problems[23]. Women who themselves were born preterm are at a higher risk of adverse birth outcomes and most salient, there is evidence that that women who themselves were born preterm in a low-income area and later moved to a high income area are at an increased risk (RR 1.72; 95% CI 0.54, 5.64) of having an infant born preterm, though not statistically significant[33].

Infants born preterm come at a high societal cost. Recent estimates from 1444 Ohio births born preterm found an annual cost of $93 million in initial hospital costs alone[34]. The study also found that costs continue throughout life, and an extension of the data calculated a loss of over

$300 in annual earnings among local adults born preterm. A similar study conducted in Michigan measured the excess costs associated with the racial gap in preterm birth. Researchers found that the increased rate of preterm birth among black infants was associated with a lifetime cost of $352 million[35]. Thus, preterm births include not only the discrete costs of initial hospitalization and increased care, but also continue to grow throughout life. Furthermore, the Michigan study illustrates not only the discrete excess costs attributed to the racial disparity, but also that the burden of indirect costs continues in lifetime morbidities associated with preterm birth.

Altogether, current and past research on both preterm birth and environmental justice indicate that the two are inextricably linked, complex issues. Analysis of individual factors alone fails to contextualize experiences of women during pregnancy that have been shown to affect birth outcomes. Preterm birth and its subsequent complications have great public health significance in both societal cost and long-term health, and gaps in literature exist that fail to fully incorporate neighborhood context and environmental justice with preterm birth and its racial disparities. This analysis seeks to add a piece of evidence to the growing body of research that environmental and neighborhood factors impact preterm birth, and disproportionately impact the preterm birth rates of black infants.

2.0   Methods

2.1   Study Design

This is a cross-sectional, ecologic study evaluating preterm birth data from 2015-2017 in Allegheny County as it relates to community health and structure during the same period. It includes 205 Allegheny County neighborhoods and municipalities that had complete data for both outcomes data and environmental justice indicators

2.2   Environmental Justice Evaluation

The Environmental Justice Index's goal was to identify and highlight areas of higher environmental need based on a series of community health metrics. In 2017, the Allegheny County Health Department met with a series of local stakeholders to determine what metrics they felt best represented community health[31]. In the end, they decided on three main categories with a total of ten metrics: diesel particulate matter, particulate matter, miles of railroad track coverage, proximity to greenspace, housing vacancy, median household income, educational attainment, traffic density, and percent minority population. For the purpose of this analysis, the report was updated with all of the same metrics except for traffic density and stream impairment. Because diesel particulate matter's main source is automobile traffic it can approximate traffic

density in a similar fashion. All the data were originally at the census-tract level but were aggregated to reflect Allegheny County neighborhood and municipality boundaries using a health department document to correspond the geography. Some census-tracts overlapped in multiple areas and so those areas were combined in analysis, see Appendix for the full list of areas with census tract overlap. A map of the distribution of overall EJ scores was created in ArcGIS.

2.3   Overview of Data Sources

2.3.1   Sociodemographic Data

We obtained socio-demographics data: median household income, educational attainment, and percent minority population, from the American Community Survey[30]. All data sets were three-year estimates for the years 2015-2017. For areas containing more than one census tract, the average median household income was used as the income in that area. Educational attainment was defined as the percent of individuals over 18 with a high school degree, in a given area. Percent minority population included all nonwhite residents in the numerator.

2.3.2   Built Environment

Built environment variables included housing vacancy, proximity to greenspace, and miles of railroad track coverage. Railroad track coverage and proximity to greenspace were both

initially calculated using spatial analysis software for the original EJ evaluation[31]. Given that little change in either has occurred over the past few years, the original estimates were included in this analysis, reaggregated to reflect municipal and neighborhood boundaries as opposed to census-tracts. Proximity to greenspace was defined as the percent of total homes in an area that were located within 0.25 miles of greenspace, such as a park. Railroad track coverage was calculated as the miles of total track divided by the total area of a location in square miles. The US Postal Service provided the vacancy data[36]. For this analysis, vacancy was calculated over a three-year period, 2017-2017, and reflects the average annual percent of homes vacant in any quarter in a given area.

2.3.3   Air Quality

Both $PM_{2.5}$ and DPM variables reflected air quality in Allegheny County. National Air Toxics provided the 2014 DPM data and the $PM_{2.5}$ data came from the original Environmental Justice Evaluation in 2017[31, 37].

2.3.4   Preterm Birth

Allegheny County Health Department vital statistics provided the estimates for preterm birth for the years 2015-2017[38]. All live singleton births were considered for analysis. Three variables were created for assessment: number of white preterm births, number of black preterm births, and preterm births overall. Race was determined by mother's self-reported race on the birth record and aggregated by mother's municipality or neighborhood.

2.4 Statistical Analysis

All statistical analyses were conducted in SAS 9.4. Three models were created to assess preterm birth and neighborhood in order to detect effects of environmental justice indicators on preterm birth overall and among racial groups.

For baseline analysis, we constructed tertiles of preterm birth rates, and calculated mean and standard deviation for each variable within each tertile. Analysis of variance distinguished differences in the covariates across levels of preterm birth. Pearson's correlations were calculated to illustrate the strength and direction of the linear relationship between each variable and preterm birth overall and stratified by race.

Each model was a negative binomial model. Like a poisson model, the negative binomial models count data, but is used when the variance is not equal to the mean to avoid overdispersion. In order to model rates, negative binomial models require an offset term that is the natural log of the outcome denominator. Otherwise, models of absolute counts would not reflect the difference in total live births. For the overall birth model, areas with less than 10 preterm birth events were suppressed to avoid small numbers issues in the regression. However, given the smaller number of events when stratifying by race, the suppression threshold was dropped to 5 for the white and black models to gather enough observations for regression.

We constructed univariate models for overall preterm birth with each of the eight EJ variables. The final model included minority percent, diesel particulate matter, housing vacancy, median household income, railroad track coverage, educational attainment, and proximity to greenspace. Because $PM_{2.5}$ levels are relatively ubiquitous throughout the region, it was not retained in the final model. To assess differential by race, the variables in the final overall model

were ran against stratified preterm birth estimates. For each model, we visually assessed fit and

checked model diagnostics within the set parameters.

3.0 Results

Baseline tables show a disparity in preterm birth rates between black and white mothers (Table 2). Overall, between 2015 and 2017 of 47,100 live births 8.1 % were born prior to 37 weeks gestation. Among black mothers, 11.4% of 10,755 infants were born preterm, and 6.3% of 31,504 white infants were born preterm (Table 4). Bivariate analysis illustrated statistically significant differences across tertiles of preterm birth rates for all environmental justice variables, except for $PM_{2.5}$ (Table 4). Because the concentration of $PM_{2.5}$ was largely uniform throughout Allegheny County and essentially the same across levels of preterm birth rates, it was not retained in the full negative binomial models.

Pearson's correlations showed the strength and significance of linear relationships with preterm birth, stratified by race (Table 3). Among blacks, minority percent, $PM_{2.5}$, and housing vacancy, were all significantly positively associated with preterm birth. Conversely, educational attainment and median household income were significantly negatively associated with preterm birth. Among whites, minority percent, DPM, railroad track coverage, vacancy, and proximity to greenspace were all negatively associated with preterm birth. Educational attainment and median household income were both positively associated with preterm among white preterm birth. Overall, DPM, railroad track coverage, and proximity to greenspace were negatively associated with preterm birth.

Table 2 Descriptive statistics within Allegheny County.

Variable	Mean ± SD	Range
Live births, % preterm		
Overall	47100, 8.1	-
Black	10755, 11.4	-
White	31504, 6.3	-
Minority %	24.89 ± 25.5	0 – 99.6
DPM ng/m^3	0.538 ± 0.2	0.253 – 1.17
PM$_{2.5}$ ng/m^3	11.54 ± 0.25	10.6 – 12.0
Railroad Track Coverage per mi^2	7.11 ± 9.6	0 – 71.4
Housing Vacancy %	4.68 ± 4.37	0 – 29.5
Proximity to Greenspace %	67.31±26.1	4.4 – 100
Educational Attainment %	92.51 ± 4.4	76.8 – 100
Median Household Income	54669 ± 2717	13358 – 162054

Distribution of all EJ variables, given by mean, standard deviation, and range; and preterm birth, given by number of live births and percent born preterm. Birth data includes all births between the years 2015-2017, sociodemographics data covers the years 2015-2017, air quality data covers 2014, housing vancancy includes the years 2015-2017, and both railroad track coverage and proximity to greenspace includes data from 2017.

Table 3 Pearson's Correlations, Environmental Justice Metrics and Preterm Births from 2015-2017, by Race.

EJ Variable	Pearson's Correlations to Preterm Birth Rate		
	Black	White	Overall
Minority %	0.49 **	-0.31 **	0.036
DPM ng/m^3	0.097	-0.27 **	-0.15 *
PM$_{2.5}$ ng/m^3	0.21 *	-0.011	0.095
Railroad Track Coverage per mi^2	0.027	-0.21 *	-0.15 *
Housing Vacancy %	0.34 **	-0.28 **	-0.044
Proximity to Greenspace %	0.031	-0.39 **	-0.27 **
Educational Attainment %	-0.32 **	0.21 *	< 0.0001
Median Household Income	-0.33 **	0.24 *	0.012

Bivariate relationships using Pearson's Correlations between each EJ variable and the preterm birth rate, stratified by race.

* p=0.05
** p < 0.0001

Table 4 Bivariate Analysis Across Tertiles of Preterm Birth, 2015-2017, among Allegheny County Locales.

Mean ± SD	Low, n=61	Moderate, n=67	High, n=67
Total Births, % Preterm	11230, 5.16	27592, 8.12	8278, 12.09
Minority % **	13.93 ± 12.8	21.36 ± 20.6	39.03 ± 31.8
DPM ng/m^3 *	0.49 ± 0.1	0.51 ± 0.1	0.58 ± 0.2
PM$_{2.5}$ ng/m^3	11.49 ± 0.2	11.55 ± 0.3	11.58 ± 0.3
Railroad Track Coverage per mi^2 *	5.93 ± 7.6	5.60 ± 7.3	9.30 ± 12.1
Housing Vacancy % **	2.61 ± 2.5	4.20 ± 3.9	6.74 ± 4.2
Proximity to Greenspace % **	62.9 ± 29.3	61.8 ± 23.6	76.0 ± 23.2
Educational Attainment % **	94.9 ± 2.5	92.8 ± 3.7	89.7 ± 4.7
Median Household Income **	69251 ± 31885	56784 ± 23326	38914 ± 15837

This represents the differences in means of EJ variables across tertiles of the overall preterm birth rate. The tertiles are based on the distribution of preterm birth, with 61 areas designated as low preterm birth, 67 as moderate, and 67 as high. ANOVA tests were run to detect differences in the means of EJ metrics across tertiles of preterm birth.

* p=0.05
** p < 0.0001

Negative binomial models included 205 of the 220 Allegheny County locales where there were at least 10 preterm births overall (Table 5). All independent variables, except for DPM, were divided into tertiles for entry into the model and given values 0, 1, or 2, indications the lowest to highest tertile, respectively. In initial model building, algorithms only converged when DPM was entered as a continuous variable, so it was retained as continuous for final analysis. As mentioned above, PM$_{2.5}$ was not included in the final models due to a lack of variation throughout Allegheny County. Initial models showed paradoxical relationships between median household income and preterm birth rates. Current literature has questioned the use of median household income as an aggregate measure in studies of adverse birth outcomes, particularly among black women[39, 40]. Thus, median household income measures were dropped from the

models to best estimate the impact of other factors that provide a better measure of neighborhood status and need in aggregate.

Moderate and high levels of housing vacancy were associated 32% and 68% higher rates of preterm birth incidence, overall (IRR 1.32, 95 % CI 1.20-1.47; IRR 1.68, 95% CI 1.52-1.86). Following adjustment, the relationship was attenuated, but still statistically significant (IRR 1.21, 95% 1.07, 1.37; IRR 1.43, 95% CI 1.22, 1.67). In the crude model, the highest tertile of percent minority population was associated with a 48% increase in preterm birth rates (IRR 1.48, 95% CI 1.31-1.67). Adjusted models showed no relationship to preterm birth and percent minority population at either the moderate or high level. DPM was not associated with preterm birth in the crude model, but after adjustment there was a nonsignificant association indicating a 37% increase in the incidence of preterm birth with a one unit increase in DPM (IRR 1.37, 95% CI 0.89-2.09). In crude models, railroad coverage was associated with a 35% increase in preterm birth at higher levels, with no significant relationship at the moderate level (IRR 1.35, 95% CI 1.17-1.57). Adjusted models showed a weakened relationship between railroad coverage and preterm birth rates at the highest tertile, indicating a 14% increase (IRR 1.14, 95% CI 1.01, 1.28). Moderate and low tertiles of educational attainment were associated with 22% and 56% increases in the preterm birth rate, that were null following adjustment (IRR 1.22, 95% CI 1.08, 1.38; IRR 1.56, 95% CI 1.37-1.78). Finally, proximity to greenspace was associated with a 21% and 27% reduction in preterm birth rates among moderate and low tertiles, respectively (IRR 0.79, 95% CI 0.67, 0.94; IRR 0.73, 95% CI 0.62, 0.86). However, following adjustment there was no significant association.

Table 5 Negative Binomial Crude and Adjusted Models of Preterm Birth, 2015-2017, within Allegheny County Locales.

EJ Variable	IRR of Preterm Birth (95% CI)	
	Crude (n=205)	Adjusted (n=205)
Housing Vacancy		
Low	Ref.	Ref.
Moderate	1.32 (1.20-1.47) *	1.21 (1.07-1.37) *
High	1.68 (1.52-1.86) *	1.43 (1.22-1.67) *
Minority %		
Low	Ref.	Ref.
Moderate	1.05 (0.93-1.19)	0.98 (0.88-1.09)
High	1.48 (1.31-1.67) *	1.04 (0.91-1.19)
DPM ng/m^3	1.01 (1.00-1.02)	1.37 (0.89-2.09)
Railroad Track Coverage per mi^2	Ref.	Ref.
Low	0.95 (0.83-1.08)	1.02 (0.92-1.13)
Moderate	1.35 (1.17-1.57) *	1.14 (1.01-1.28) *
High		
Educational Attainment		
High	Ref.	Ref.
Moderate	1.22 (1.08-1.38) *	1.03 (0.93-1.15)
Low	1.56 (1.37-1.78) *	1.09 (0.94-1.25)
Proximity to Greenspace		
High	Ref.	Ref.
Moderate	0.79 (0.67-0.94) *	0.95 (0.92-1.10)
Low	0.73 (0.62-0.86) *	1.02 (0.89-1.01)

This represents the crude models of all the EJ variables included in the final model, the tertiles are based on the distribution of each variable. The adjusted model includes every variable listed above.

* p=0.05
** p < 0.0001

Largely the models stratified by race showed few significant associations with environmental justice variables and preterm birth (Table 6). However, among black preterm births, a one unit increase in DPM was associated with a 220% increase in the rate of preterm birth at a p-value of 0.051 (IRR 2.19, 95% CI 0.99, 4.87). Additionally, moderate and low tertiles of educational attainment were both associated with an approximately 20% non-significant

increase in black preterm birth (IRR 1.18, 95% CI 0.80, 1.87; IRR 1.16, 95% CI 0.78, 1.85). Both moderate and high tertiles of minority percent and housing vacancy were associated with non-significant reductions in the risk of preterm birth among black women. Like in the overall model, education attainment moderate and high tertiles were associated with increases in preterm birth risk, though non-significant. Proximity to greenspace showed no relationship.

Table 6 Negative Binomial Adjusted Models of Preterm Birth, 2015-2017, within Allegheny County Locales, Stratified by Race.

EJ Variable	IRR of Preterm Birth by Race (95% CI)	
	Black (n=69)	White (n=102)
Housing Vacancy		
Low	Ref.	Ref.
Moderate	0.74 (0.41-1.34)	1.20 (1.03-1.39) *
High	0.66 (0.36-1.23)	1.49 (1.19-1.86) *
Minority %		
Low	Ref.	Ref.
Moderate	0.70 (0.34-1.42)	0.91 (0.81-1.03)
High	0.62 (0.29-1.23)	0.88 (0.73-1.06)
DPM ng/m^3	2.20 (0.99-4.87) *	1.15 (0.64-2.08)
Railroad Track Coverage per mi^2	Ref.	Ref.
Low	1.08 (0.84-1.40)	1.02 (0.90-1.17)
Moderate	1.15 (0.93-1.42)	1.25 (1.05-1.51) *
High		
Educational Attainment		
High	Ref.	Ref.
Moderate	1.18 (0.80-1.87)	0.99 (0.87-1.13)
Low	1.16 (0.78-1.85)	1.09 (0.90-1.33)
Proximity to Greenspace		
High	Ref.	Ref.
Moderate	0.93 (0.91-1.19)	1.16 (0.92-1.47)
Low	0.94 (0.75-1.18)	1.13 (0.87-1.46)

Negative binomial models were run with only black and only white preterm births, and only areas with > 5 preterm births were included in the model.

* p=0.05
** p < 0.0001

Among white preterm births, housing vacancy was associated with increases in the risk of preterm birth like those in the overall model at moderate and high tertiles (IRR 1.20, 95 % CI 1.02, 1.39; IRR 1.49, 95% CI 1.19, 1.86). Similar results to the overall model were also seen in the lack of a significant relationship to educational attainment and minority percent. Among the high tertile of railroad track coverage, the relationship was slightly stronger than in overall models, with a 25% significant increase in risk (IRR 1.25, 95% CI 1.05, 1.51). The relationship to DPM was slightly attenuated and nonsignificant. Finally, proximity to greenspace remained nonsignificant but showed slight increases in preterm birth risk among white mothers.

Figure 1 illustrates the spatial distribution of overall environmental justice scores and tertiles of preterm birth rates. Only areas with at least 10 preterm births have calculated rates. It can be seen that the darkest areas tend to be along the rivers and in central Allegheny County, within the Pittsburgh Municipality. These same areas also tend to have preterm birth rates in the second or third tertiles. Only one area in the lowest quintile of environmental need included an area in the second level of preterm birth
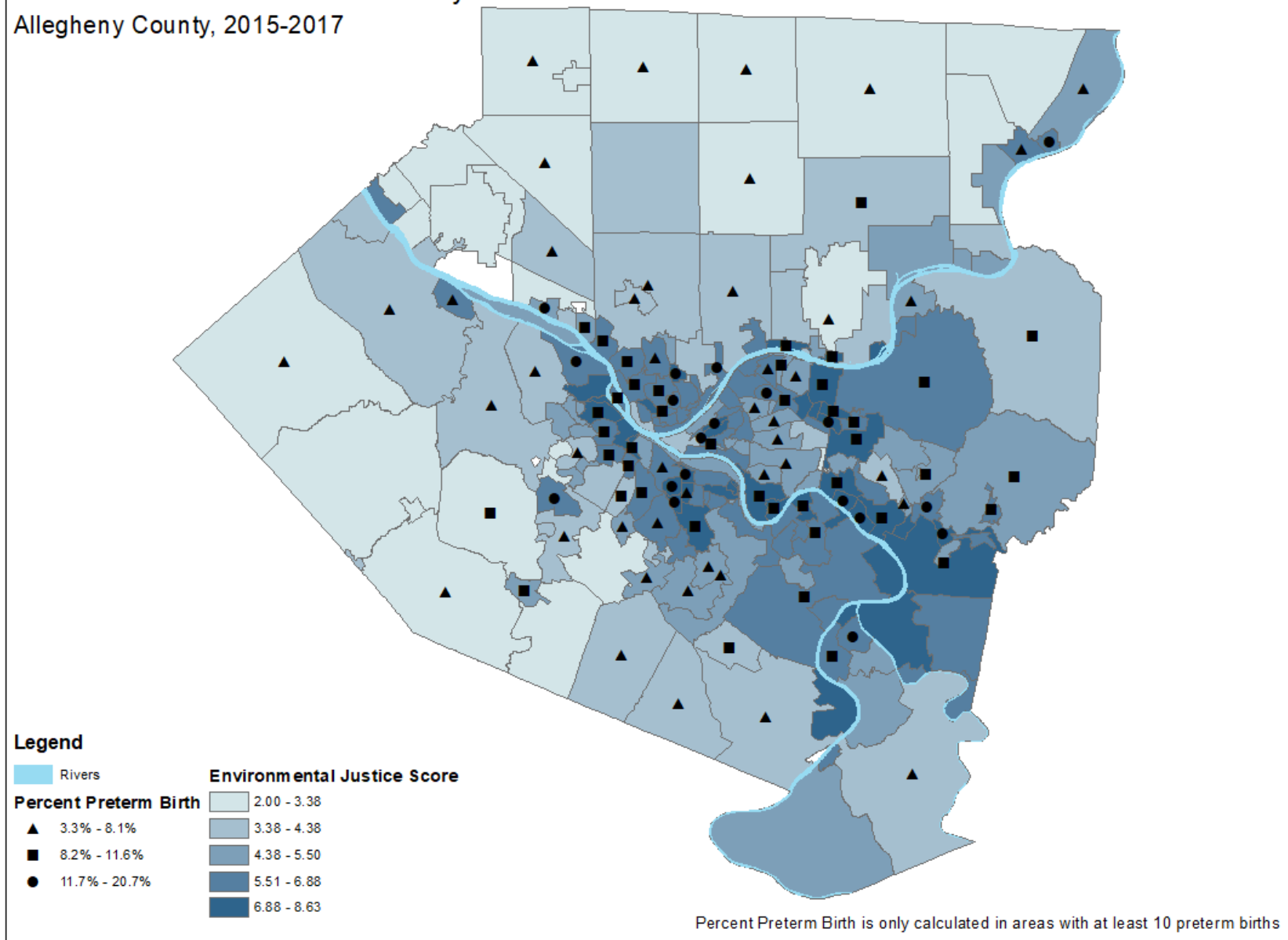
.

Figure 1 Environmental Justice Scores and 3-year Preterm Birth Percent, Allegheny County, 2015-2017.

20

4.0   Discussion

This study presents a cross-sectional, ecologic analysis of the relationship between different environmental justice variables and preterm birth in Allegheny County. We found evidence for positive relationships between many of the EJ metrics and preterm birth. Most salient, housing vacancy remained positively significantly associated with preterm birth after adjustment for other variables. After stratifying by race, we also found differential impacts of EJ indicators on preterm birth. In particular, both housing vacancy and minority percent were protective in black women, though non-significant, while DPM concentration had a much stronger, statistically significant, positive relationship than in the overall or white models. Conversely, the white models largely mirrored the overall models with some variations in the strength of associations.

Much of existing literature has focused on the interplay between individual factors and neighborhood characteristics[28, 33, 41, 42]. The goal of this analysis was to determine which environmental justice factors may have a disproportionate impact on preterm birth both overall and among black women. Given that black women in Allegheny County are 1.8 times as likely to have an infant born preterm, and Allegheny County's high preterm birth racial disparity in comparison to other similar counties, it is important to identify actionable targets for intervention. This analysis cannot replace interventions that target individual behavior, quality of care, or other psychosocial social factors that are essential to achieving birth equity[22]. Rather, it

functions with the understanding that many of these characteristics fail to fully explain the disparity in preterm birth, and analyses that contextualize the relationship between health and neighborhood are needed to supplement work on the individual level.

Both the baseline findings and crude models indicated relationships between EJ variables and preterm birth that were expected given previous work. This illustrates overall that neighborhood characteristics may play a part in preterm birth, especially at the highest levels of preterm birth where the largest difference in means was found. Furthermore, Pearson's correlations stratified by race indicated that these variables may impact black and white preterm birth rates differently. A few of the variables indicated paradoxical relationships in unexpected directions, which may reflect the nature and distribution of the data more than true relationships.

There has been a lot of study regarding the potential relationship between air quality and adverse birth outcomes. Studies have identified $PM_{2.5}$ in particular as a potential indicator for increased rates of preterm birth, though the results have been mixed[28, 43]. Allegheny County's unique history with the past and current relationship to the steel industry, in addition to its unique geography have made $PM_{2.5}$ nearly ubiquitous through the region. Bivariate analysis indicated no significant difference across levels of preterm birth. However, diesel particulate matter did vary throughout the region enough to include in analysis. DPM is a constituent of PM2.5 that comes largely from diesel engines like those in buses, freight trains, and trucks[44].

Overall, the results of bivariate analysis as well as crude and adjusted models were mixed on the overall relationship between DPM and preterm birth. However, among black women, there was a much stronger positive relationship to DPM unseen in the white or overall models. These results fit into both the spatial distribution of the region, as well as prior literature that indicates a differential in exposure to air pollution may explain a portion of the gap in black and

white preterm birth[28]. Allegheny County's black population resides largely in the center of the county where there is a denser system of roadways and railroad track coverage. These are the major sources in of the pollutant and black populations are thus exposed more frequently and at greater concentration than more disperse and majority white areas. Unfortunately, residence in these higher density areas is often not a choice for many who may be unable to afford to move outside of the region, who rely on the public transportation within the area, or who may have been historically excluded from residence[4, 8]. In addition, the results of the race stratified models must be interpreted with caution given the small number of observations after censoring areas with less than 5 black preterm births.

Many of the other EJ variables that appeared to relate to rate of preterm birth in both bivariate analysis and crude models were attenuated or null following adjustment. Given the complex interactions between many of these factors, it is not surprising to see a reduction in the strength of the relationship weakened in aggregate. However, two variables remained significant following adjustment: housing vacancy and railroad track coverage. Given that freight trains produce large amounts of diesel, it is unsurprising that higher levels of coverage would be positively associated with preterm birth. Housing vacancy, however, represents a slightly more complex relationship. Ancillary analyses investigating potential collinearity between variables did not find any concerning relationships that indicate housing vacancy measures the same thing as income or other socio-demographic characteristics, though they may occur in the same areas. Instead, housing vacancy may reflect the growing body of literature implicating stress as a factor in adverse birth outcomes[25, 27, 33]. It is difficult to obtain objective measurements for the stress of an area, and often rates of crime and homicide may act as proxies[45, 46]. It's possible that a higher

density of vacant homes in an area illustrates overall neighborhood quality and how safe or comfortable an individual may feel there.

Interestingly, the relationship between housing vacancy and preterm birth diverged in race-stratified models. The white model largely followed that of the overall model, showing a positive relationship with preterm birth and level of housing vacancy. However, the black models had a reversed relationship—higher levels of housing vacancy were associated with lower levels of preterm birth. Minority percent also followed a similar pattern, with relationships of the same strength showing protection against preterm birth. Past literature investigating redlining has shown that some highly segregated areas in Chicago had lower rates of preterm birth than would be expected and that, among black women, living within more redlined areas was protective[42]. It is possible that this model is showing a similar theme, where black women living within a majority black area may experience a benefit from social cohesion as opposed to a detriment that may come from isolation or lack of opportunity. Given that both minority percent and housing vacancy were protective in the black model, and that in the white model higher vacancy was a risk factor and minority percent was null, it may be a similar phenomenon.

This would confound the potential for housing vacancy to proxy social stress. Past literature has often shown that racial interactions may alter expected relationships, and it is difficult to fully untangle the complexities of a neighborhood environment[18, 42, 46]. A similar phenomenon may be seen in the paradoxical relationship to median household income seen in bivariate analysis among black preterm births. Research indicates that commonly income incongruity exists within an area where those who experience adverse birth outcomes are more likely to be of lower socio-economic status than the neighborhood where they reside. This phenomenon can confound the relationship calculated in models that do not account for

individual data[39, 40]. Though, it must also be noted that this is ecologic data within a small sample size and neither housing vacancy nor minority percent were statistically significant. Thus, it may be difficult to evaluate validity of relationships between these variables and preterm birth in the black model. However, it does present an interesting and notable difference that would benefit from further research on the individual level.

The spatial distribution of overall environmental justice scores and preterm birth shown in figure 1, support the notion that higher environmental need has implications for preterm birth rate. The darker the area, the higher the level of environmental need; darker areas in the center of the region appear to have more preterm birth rates in the second or third tertile of preterm birth. Conversely, lighter colored areas tend to have lower rates or numbers too small to calculate a rate. This fits into the story told by the statistical analysis and provides a visualization of the relationships. Historically, the steel industry was constructed along the rivers and communities, in turn, built up in those same areas. Over time as the industry began to collapse, so did the economies, infrastructure, and neighborhood quality of those areas[4]. Today, those regions tend to have the highest proportions of black residents and are exposed more frequently to pollutants from remaining industry as well as the major roadways and railroads producing higher levels of DPM.

Given the nature of this study, there are inherent limitations. Ecologic data is subject to the ecologic fallacy that may confound the true relationships at the individual level. This analysis did not incorporate other important indicators in the relationship between race and preterm birth such as quality or access to care, psychosocial behaviors, or other individual risk factors. In addition, cross-sectional data makes it impossible to prove causality due to a lack of temporality. Furthermore, the race stratified models should be interpreted with caution given the small sample

size, particularly in the model of only black preterm births. Finally, the variables included for analysis are not exhaustive and there may be residual confounding that exists within the relationships found in analysis.

Despite its limitations, this study also comes with numerous strengths. The variables included in analysis were those selected by community members to reflect their own idea of neighborhood health, and they are analyzed within accepted community boundaries as opposed to census tracts or zip codes. This lends a certain authenticity to the variables' ability to accurately measure neighborhood health and experience. Furthermore, stratifying the models by race allows the analysis of differential effects by race unable to be seen in a single model. Finally, the results support and build upon existing literature that incorporate environmental justice with the understanding that preterm birth is a complex problem that cannot be solved by looking at individual factors alone.

5.0   Conclusion

In summary, we found that not only does neighborhood context and need have the potential to explain a portion of the relationship to preterm birth, but also that the relationships may vary by race. Preterm birth, and in particular the nationwide disparity between black and white women, has been and remains a significant, unsolvable public health issue. Though not all-encompassing, it is evident from this analysis that neighborhood level intervention should be considered to reduce the preterm birth rate overall and among black women. Future efforts should take action to encourages technology improvement to reduce the level of diesel exhaust from trucks, buses, and trains; and create programs to improve neighborhood quality through community centered development, and the reduction of vacant housing. However, it must be noted that there currently exists a vast body of literature examining structural racism and its manifestations in health inequities[47]. Ultimately, the only successful policy and interventions to address this matter of great public health significance will be those that acknowledge historical inequities and actively confront the racism inherent in most present-day policy making.

Appendix Census Tract Overlap

Census-Tracts	Neighborhood/Municipality
42003563300	Sewickley Heights/Sewickley Hills
42003563900	Forest Hills Borough/ Chalfant Borough
42003564000	North Fayette Township/McDonald Borough
42003564100	Thornburg Borough/Rosslyn Farms Borough
42003564200	South Versailles Township/White Oak Borough
42003564400	North Versailles Township/Wall Borough
42003562700	Allegheny Center/Allegheny West
42003561600	Arlington/Arlington Heights
42003562400	Beltzhoover/Bon Air
42003563000	Chartiers City/Fairywood/Wind Gap
42003562300	Glen Hazel/Hazelwood
42003562800	East Carnegie/Oakwood
42003561700	Mt. Oliver/St. Clair
42003563200	North Shore/East Allegheny
42003563100	Ridgemont/Westwood

Bibliography

1. Williams DR. Miles to go before we sleep: racial inequities in health. *Journal of health and social behavior.* 2012;53(3):279-295.
2. Pulido L. Geographies of race and ethnicity II: Environmental racism, racial capitalism and state-sanctioned violence. *Progress in Human Geography.* 2017/08/01 2016;41(4):524-533.
3. Bullard R. The Mountains of Houston Environmental Justice and the Politics of Garbage. *Cite 93.* 2014.
4. Rothstein R. *The Color of Law*. New York, NY: Liveright 2017.
5. Taylor HL. The Hidden Face of Racism. *American Quarterly.* 1995;47(3):395-408.
6. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. *Public Health Rep.* Sep-Oct 2001;116(5):404-416.
7. Kasarda JD. Urban Industrial Transition and the Underclass. *The Annals of the American Academy of Political and Social Science.* 1989;501:26-47.
8. Rheingold I, Fitzpatrick M, Hofeld A, Jr. From Redlining to Reverse Redlining: A History of Obstacles for Minority Homeownership in America. *Clearinghouse Review.* 2000-2001 2000(Issues 9-10):642-654.
9. Brown P. Race, class, and environmental health: a review and systematization of the literature. *Environmental research.* 1995;69(1):15-30.
10. Cutter SL. Race, class and environmental justice. *Progress in Human Geography.* 1995;19(1):111-122.
11. Bullard R. *Dumping in Dixie: Race, Class and Environmental Quality* New York Routledge; 2000.
12. Carolinians Angry Over PCB Landfill *New York Times*, 1982.
13. Geiser K, Waneck G. PCBs and Warren County. *Science for the People.* 1983(July/August):13-17.
14. United Church of Christ. *Toxic Wastes and Race in the United States* 1987.
15. Williams DR, Priest N, Anderson NB. Understanding associations among race, socioeconomic status, and health: Patterns and prospects. *Health psychology : official journal of the Division of Health Psychology, American Psychological Association.* 2016;35(4):407-411.
16. CDC Health Disparities and Inequalities Report *Morbidity and Mortality Weekly Report.* 2013;62:1-187.
17. Feldman PJ, Steptoe A. How neighborhoods and physical functioning are related: the roles of neighborhood socioeconomic status, perceived neighborhood strain, and individual health risk factors. *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine.* 2004;27(2):91-99.

18. Manuck TA. Racial and ethnic differences in preterm birth: A complex, multifactorial problem. *Semin Perinatol.* Dec 2017;41(8):511-518.

19. Kramer MR, Hogue CR. Place matters: variation in the black/white very preterm birth rate across U.S. metropolitan areas, 2002-2004. *Public Health Rep.* Sep-Oct 2008;123(5):576-585.

20. Hamilton BE, Hoyert DL, Martin JA, Strobino DM, Guyer B. Annual Summary of Vital Statistics: 2010–2011. *Pediatrics.* 2013;131(3):548.

21. Martin JA OM. Describing the increase in preterm births in the United States, 2014–2016. *National Center for Health Statistics*.

22. March of Dimes. *Birth Equity for Moms and Babies.* Marchofdimes.org: March of Dimes Prematurity Collaborative; 2018.

23. Saigal S, Doyle LW. An overview of mortality and sequelae of preterm birth from infancy to adulthood. *Lancet.* Jan 19 2008;371(9608):261-269.

24. Collins JW, Jr., David RJ. The differential effect of traditional risk factors on infant birthweight among blacks and whites in Chicago. *Am J Public Health.* Jun 1990;80(6):679-681.

25. Pearl M, Ahern J, Hubbard A, et al. Life-course neighbourhood opportunity and racial-ethnic disparities in risk of preterm birth. *Paediatr Perinat Epidemiol.* Sep 2018;32(5):412-419.

26. Braveman P, Heck K, Egerter S, et al. Worry about racial discrimination: A missing piece of the puzzle of Black-White disparities in preterm birth? *PLoS One.* 2017;12(10):e0186151.

27. Love C, David RJ, Rankin KM, Collins JW, Jr. Exploring weathering: effects of lifelong economic environment and maternal age on low birth weight, small for gestational age, and preterm birth in African-American and white women. *Am J Epidemiol.* Jul 15 2010;172(2):127-134.

28. Benmarhnia T, Huang J, Basu R, Wu J, Bruckner TA. Decomposition Analysis of Black-White Disparities in Birth Outcomes: The Relative Contribution of Air Pollution and Social Factors in California. *Environ Health Perspect.* Oct 4 2017;125(10):107003.

29. Natality public-use data 2016-2018. In: Prevention CfDCa, ed. CDC Wonder September 2019.

30. 2015-2017 American Community Survey 3-year estimates. In: Bureau USC, ed. Census.gov.

31. Lewis JB, L. . *Identifying High Priority Communities in Allegheny County*: Allegheny County Health Department 2017.

32. Goldenberg RL, Culhane JF, Iams JD, Romero R. Epidemiology and causes of preterm birth. *Lancet.* Jan 5 2008;371(9606):75-84.

33. Ncube CN, Enquobahrie DA, Burke JG, Ye F, Marx J, Albert SM. Transgenerational Transmission of Preterm Birth Risk: The Role of Race and Generational Socio-Economic Neighborhood Context. *Matern Child Health J.* Aug 2017;21(8):1616-1626.

34. Hall ES, Greenberg JM. Estimating community-level costs of preterm birth. *Public health.* 2016;141:222-228.

35. Xu X, Grigorescu V, Siefert KA, Lori JR, Ransom SB. Cost of racial disparity in preterm birth: evidence from Michigan. *Journal of health care for the poor and underserved.* 2009;20(3):729-747.

36. Research OoPDa. Housing Vacancy Data. huduser.gov; 2019.

37. Agency USEP. 2014 Pollutant Specifc Results. epa.gov; 2018.

38. Health PDo. Birth Statistics Allegheny County Health Department 2015-2017.

39. Phillips GS, Wise LA, Rich-Edwards JW, Stampfer MJ, Rosenberg L. Income incongruity, relative household income, and preterm birth in the Black Women's Health Study. *Soc Sci Med.* Jun 2009;68(12):2122-2128.

40. Marengo L, Ramadhani T, Farag NH, Canfield MA. Should aggregate US Census data be used as a proxy for individual household income in a birth defects registry? *J Registry Manag.* Spring 2011;38(1):9-14.

41. Matoba N, Suprenant S, Rankin K, Yu H, Collins JW. Mortgage discrimination and preterm birth among African American women: An exploratory study. *Health Place.* Aug 23 2019;59:102193.

42. Mendez DD, Hogan VK, Culhane JF. Institutional racism, neighborhood factors, stress, and preterm birth. *Ethn Health.* 2014;19(5):479-499.

43. Wilhelm M, Ghosh JK, Su J, Cockburn M, Jerrett M, Ritz B. Traffic-related air toxics and preterm birth: a population-based case-control study in Los Angeles County, California. *Environ Health.* Oct 7 2011;10:89.

44. Rodriquez MZ, L. . *CalEnviroScreen 3.0.* California Office of Environmental Health Hazard Assessment 2017.

45. Brisson D, Roll S. The effect of neighborhood on crime and safety: a review of the evidence. *Journal of evidence-based social work.* 2012;9(4):333-350.

46. Matoba N, Collins JW, Jr. Racial disparity in infant mortality. *Semin Perinatol.* Oct 2017;41(6):354-359.

47. Hardeman RR, Medina EM, Kozhimannil KB. Structural Racism and Supporting Black Lives - The Role of Health Professionals. *The New England journal of medicine.* 2016;375(22):2113-2115.