Association between Neighborhood-Level Racial Segregation and Low Birth Weight among
Black Infants: A Systematic Review and Meta-Analysis

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With gratitude to my loving family and friends and dedicated to my beloved grandmothers and

uncles

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CHAPTER 1

INTRODUCTION

Rationale

Low birth weight is a leading contributor of infant mortality in the United States and a source of long-term morbidity into adulthood (Baker, Olsen, & Sorensen, 2008; Institute of Medicine, 1985) making it a significant public health issue. Compared to other races, Black infants are disproportionately affected by low birth weight (Collins & David, 2009). In 2013, the prevalence of low birth weight for Black infants was 13.1% in comparison to 7% for Whites (Child Trends, 2015). Clinical efforts to reduce low birth weight outcomes have centered on modifying health behaviors of expecting mothers especially as they concern abstaining from smoking and utilizing prenatal care. Although these strategies have been associated with decreases in low birth weight, they and other individual-level interventions do not fully account for Black women's increased odds of having a low birth weight infant (Berg, Wilcox, & d'Almada, 2001; Collins & David, 2009). To investigate this unexplained variance and to formulate more rigorous, empirically-based community health research in the future, understanding relationships between low birth weight and neighborhood-level phenomena is essential to assessing how everyday ecological exposures may influence human development.

Prior systematic, meta-analytic reviews (Metcalfe, Lail, Ghali, & Sauve, 2013; Ncube, Enquobahrie, Albert, Herrick, & Burke, 2016) have found statistically significant associations

between neighborhood deprivation and low birth weight (OR = 1.11, 95% CI [1.02, 1.20]; OR = 1.17, 95% CI [1.10,1.25] respectively). While these meta-analytic studies contribute greatly to social epidemiological knowledge, attention specifically to racial residential segregation is warranted. Compared to other minority groups, Blacks have experienced the highest levels (i.e., hypersegregation) and proportions of racial segregation historically and contemporarily, and empirical evidence suggests that residential patterns post-Civil Rights movement continue to be driven in part by discriminatory housing practices as well as Whites' neighborhood preferences (Cashin, 2004; Massey & Denton, 1993). Concordantly, Black segregated neighborhoods tend to be more socio-economically diverse than other racially segregated communities (Darden, Bagaka's, & Ji, 1997; Massey & Denton, 1993) so that when economic shifts occur poverty becomes more concentrated and confined with effects that extend to individuals of all socioeconomic levels (Massey & Denton, 1993). Empirically, neighborhood racial residential segregation has been linked to racial health disparities with positive associations for mortalities across the lifespan including infant mortality (Acevedo-Garcia & Lochner, 2003; Schulz, Williams, Israel & Lempert, 2002). Theoretically, racial residential segregation is hypothesized to impact health by limiting opportunities to education and economic resources, increasing exposures to physiological stressors as well as environmental hazards in the built and social environment, and restricting access to healthy foods and preventive health services (Collins & Schulte, 2003; Geronimus, 1991; Schulz et al., 2002; Williams and Collins, 2001).

Conventionally, health research has primarily used percentages, densities, and compositions to measure segregation. However, these measures are too general to capture the spatial particularities of racial residential segregation (Oka & Wong, 2014; Reardon, 2006; White & Borrell, 2011). For instance, knowing that a neighborhood is 70% Black gives no information

about how dissimilar the social environment or how isolated that neighborhood is from other surrounding racialized groups or how spatially clustered or dispersed the population is throughout an area unit. Additionally, studies examining low birth weight and racial segregation, operationalized as the percentage of Black persons within an area, do not provide a clear consensus about the statistical significance of this association (Baker & Hellerstedt, 2006; Jaffee & Perloff, 2003; Madkour, Harville, & Xie, 2014; Richard, 2006).

Assessing and synthesizing studies that have employed methodological advancements in the measure of racial residential segregation is key to clarifying possible statistically significant associations. Sociologists have traditionally operationalized racial residential segregation according to six dimensions (Massey & Denton, 1988). More recently, however, there is some consensus that racial isolation, the probability of interracial interaction at the neighborhood level, and racial evenness, the extent to which local groups are evenly dispersed or clustered, are sufficiently equipped to describe and measure racial residential segregation (Johnston, Poulsen, & Forrest, 2007; Oka & Wong, 2014; Reardon & O'Sullivan, 2004). Additionally, these different segregation dimensions may be differently associated with health outcomes and imply different mechanisms and pathways (Acevedo-Garcia & Lochner, 2003; Kramer & Hogue, 2009). Several spatial segregation indexes capable of measuring such intricacies exist (e.g., Reardon and O'Sullivan's Isolation Index (2004), Wong's Local Spatial Isolation Index (2002)), and by assessing a neighborhood's segregation level (i.e., isolation or evenness) with that of its neighbors, these indexes allow for the mathematical representation of racial interaction across space. Interested readers should consult Oka and Wong (2014), Reardon (2006), and Reardon and O'Sullivan (2004) for more in-depth explanations of racial residential segregation spatial indexes.

Objectives

     This study aimed to examine the association between low birth weight and neighborhood-level racial segregation among Black infants by analyzing studies that operationalized segregation by spatial dimension. This research is expected not only to provide the first quantitative synthesis of this research question known to the author but also to assess how consistent these results are when comparable measures of segregation are synthesized. Additionally, this study examines if the association between racial segregation and low birth weight varies by ethnicity or segregation dimension. Answers to both of these secondary research questions are intended to advance future research by pinpointing more adversely affected populations and disentangling segregation dimensions according to their associated health impacts.

CHAPTER 2

METHODS

Eligibility Criteria

To be included in the review, studies had to examine low birth weight among Black-identified infants born within the United States and neighborhood-level racial residential segregation. Infant births outside the United States or within a United States territory made a study ineligible due to expected differences in the social history of racial residential segregation. Only cross-sectional studies analyzing birth weight reported at time of birth and linked with neighborhood identifiers were eligible. Studies that measured racial residential segregation as a neighborhood composition (i.e., percentage, density) were ineligible as these measures ignore the spatial distribution of populations. Interventions to reduce adverse birth outcomes and non-empirical or qualitative studies were also excluded because their results would either yield no effect sizes comparable to those estimated from eligible studies. Racial residential segregation measured at levels other than neighborhood were not eligible for inclusion (i.e., metropolitan statistical areas) to avoid threats to internal validity. No limits were placed on publication type or dates.

Identification of Studies

A comprehensive literature search was conducted to identify all relevant articles reporting the association between neighborhood-level racial residential segregation and low birth weight. To capture all relevant articles, the search broadly covered terms related to birth outcomes, segregation, and neighborhoods across disciplines with special attention to epidemiology, sociology, and geography. The search was performed in four stages from September 23, 2015 to December 3, 2015. First, a university medical librarian was consulted about designing the search process and locating journal resources. Seven major databases (i.e., PubMed, EMBASE, PsycINFO, ProQuest Dissertations and Theses, ProQuest Sociology, ProQuest Social Science, and CINAHL) were then searched using relevant MeSH/controlled vocabulary terms for each database and following this format:

Population: (Blacks OR Black* OR African?American* OR "ethnic*") AND

Segregation: (Social Integration OR dissimilar* OR isolat* OR cluster* OR concentrat* OR density OR exposure OR "racial* segrega*" OR "residential segrega*" OR   segrega* OR segregat* OR "Racial and Ethnic Differences" OR "Race and Ethnic Discrimination" OR "racism" OR "racial disparities" OR "Health Disparities" OR Disadvantaged) AND

Birth Outcomes: ("Birth Weight" OR Low Birth*Weight OR "Premature Birth" OR "Pregnancy Outcomes" OR "Small for Gestational Age" OR "gestational age" OR "preterm" OR "premature" OR "birth outcome*") AND

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Neighborhoods: (Neighborhoods OR "census tract*" OR residen* OR social

environment)

Asterisks (*) and question marks (?) were used to capture variations in terms. Only filters for

human were used with no other restrictions.

To find grey literature and unpublished articles, the investigator searched two academic

journals (e.g., Maternal and Child Health Journal) through hand searching, two internet searches

(e.g., ResearchGate), six conference proceedings (e.g., American Public Health Association),

seven governmental agencies (e.g., US Department of Health and Human Services), two

professional membership organizations (e.g., American Academy of Pediatrics), six non-profit

organizations (e.g., RAND), four foundations (e.g., Robert Wood Johnson), and performed

forward and backward citation searching of all eligible articles. Last, six content experts were

contacted to inquire about their work and relevant articles.

Study Selection

All retrieved articles underwent a title and abstract screening process by the principal

investigator. A conservative approach was taken capturing any article mentioning any adverse

birth outcome (i.e., low birth weight, preterm, small for gestational age) associated with any

neighborhood-level characteristic (i.e., neighborhood deprivation, segregation) among any racial

group. All articles for which these characteristics could not be determined from the title or abstract

moved into the full text screening process along with those fulfilling these criteria. The full-text

screening process selected articles that met all eligibility requirements. Although all studies

addressing the research question were included in the systematic review, only those that allowed for the extraction of statistically comparable effects sizes were included in the meta-analysis.

Variables

A total of ten variables were coded; four served as analytic variables (i.e., low birth weight, neighborhood racial residential segregation, segregation dimension, ethnicity) and the remaining six acted as descriptive variables to provide a narrative depiction of all eligible studies and to describe research quality.

Low Birth Weight. An infant was considered low birth weight if they weighed less than 2500 grams or 5.5 pounds at the time of birth.

Neighborhood Racial Residential Segregation. As previously discussed, there is a wide variety of methods used to measure racial segregation. This study defined racial residential segregation as the distribution of one population in comparison to another measured spatially (e.g., Wong's (2002) Local Segregation Index). In general, spatial indexes calculate segregation dimensions by creating a moving average from each composite areal unit (i.e., a focal neighborhood and its adjacent neighborhoods) and the total population of the study area or composite areal unit. Although indexes exist that can quantify segregation among three or more populations, this study was only interested in indexes measuring segregation among two groups — Blacks and Whites, or Blacks and all other racial groups. Within the residential segregation literature, neighborhoods are most often operationalized as those at the census tract level or the block group level. This study follows this convention but also allowed the inclusion of any new

emerging techniques for neighborhood measurement (e.g., surface-density, Kramer et al., 2010; automated zone-matching, Grady, 2010).

Segregation Dimensions. This study made further distinctions between categories of neighborhood-level racial residential segregation to assess differences in association by different segregation types. For the purposes of this study, segregation dimensions defined by Reardon and O'Sullivan (2004) were used. These dimensions were spatial isolation, "the extent that members of one group encounter members of another group…in their local spatial environments" (Reardon & O'Sullivan, 2004, p.125), and spatial evenness, "the extent to which individuals of different groups occupy or experience different social environments" (Reardon & O'Sullivan, 2004, p.138).

Ethnicity. An infant's ethnicity was defined as one's familial country of cultural origin (e.g., African American, Haitian). The underlying assumption was that different ethnicities may live in statistically different social and physical environments.

Additionally, sample size and geographic location were recorded to ascertain generalizability of the results. Potential confounders (e.g., smoking, nativity, neighborhood poverty) at both the individual and neighborhood level were coded to assess internal validity. Descriptions of strategies authors took to ensure quality were also coded and included the following: testing for systematic differences between incomplete records (e.g., missing racial or geographic data) and complete records, excluding records when they belonged to women with permanent addresses outside the study area, and providing an empirical or conceptual justification for handling edge effects. Coding for these descriptions assessed the extent to which attrition and misclassification threatened internal validity namely the extent to which incomplete, and thus excluded records skewed the analytical sample, the extent to which the analytic sample featured only women exposed to the study area, and the extent to which index values for each neighborhood

in the study area reflected appropriate calculations. Edge effects, a problem associated with boundary making, occur in spatial data because values at the edges inherently have missing neighbors and thus missing information. Because spatial indexes are based on composite neighborhoods, not correcting for edge effects could possibly bias calculations (Anselin, 1998; Darmofal, 2015). For the purposes of this study, the use of edge effects corrections is only noted to describe the analytic processing of the data given that it was not possible to determine the extent or direction of any bias due to the lack of edge effects corrections.

Analytical Plan

Where possible, log odds ratio (LOR) effect sizes were calculated from studies to quantify the magnitude of the association between residential segregation and low birth weight (using formulas from the Cochrane Collaboration (2011)). A full listing of formulas can be found in the Appendix: Figures. Whenever possible effect sizes were taken from the most appropriately adjusted model (i.e., adjusting for socioeconomic status). All effect sizes were coded such that positive effect sizes indicated a positive association between higher isolation and low birth weight, and negative effect sizes indicated a negative association between higher isolation and low birth weight.

A random effects meta-analysis was used to synthesize effect sizes across studies, to estimate the average association of low birth weight and neighborhood-level racial residential segregation, using an alpha level of 0.05 for statistical significance testing. A random effects model was chosen over a fixed effect model as both sampling error and true variation between studies was expected. An assessment of heterogeneity was also planned to determine whether moderator

analysis could be conducted to explore potential variability in effects across studies. The Q statistic was used to test for homogeneity, the I^2 statistic was used to quantify the amount of true heterogeneity, and the τ^2 statistic was used to assess the variability of true effect sizes around the mean of the effect size distribution. Prediction intervals were also estimated to quantify predicted effect size dispersion for future studies. To test for statistically significant associations by ethnicity and segregation dimension, a mixed effects meta-regression was planned. An inspection of publication bias using a funnel plot, a Peter's test, and a trim and fill test were conducted, as well as a sensitivity analysis to examine the potential impact of outliers. Outliers were defined as those points outside the 95% confidence interval of a Galbraith plot. All analyses were executed in Stata IC version 14.1 using such commands as metan, metareg, metafunnel, metabias, and metatrim.

CHAPTER 3

RESULTS

Search Selection

The identification stage of the literature search yielded a total of 6,212 articles (see Figure 1 for PRISMA flow chart). After removing duplicates and evaluating titles and abstracts, a total of 75 articles were assessed at the full-text stage for eligibility. Sixty-eight articles were excluded. The majority of these were ineligible because they had no eligible measures of residential segregation (e.g., no variable measuring segregation or measuring segregation as a percentage). Despite assistance from librarians, one rogue article was not retrieved and thus excluded. Seven eligible articles[1] were found. Six were identified from major database searches and one from backward citation searching. Only four of these seven total articles had independent study samples[2] (n=9) because multiple articles used birth records from New York City in 2000 as their study population. Although all eligible articles are included within the qualitative synthesis, only three articles (Anthopolos, James, Gelfand, & Miranda, 2011; Debbink & Bader, 2011; Grady & McLafferty, 2007) had independent study samples with comparable effect sizes that could be synthesized in the meta-analysis. Anthopolos et al. (2011) investigated five independent samples,

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[1] Report or article refers to a physical document (i.e., journal article). Reports can have multiple studies embedded within them.
[2] Study samples or samples refers to independent samples of participants. Multiple studies can be embedded within a study report.

Debbink and Bader (2011), one, and Grady and McLafferty (2007), two. Therefore, a total of eight

study samples were identified and quantitatively synthesized in the meta-analysis.

Figure 1. **Flow chart of literature search process and results.**
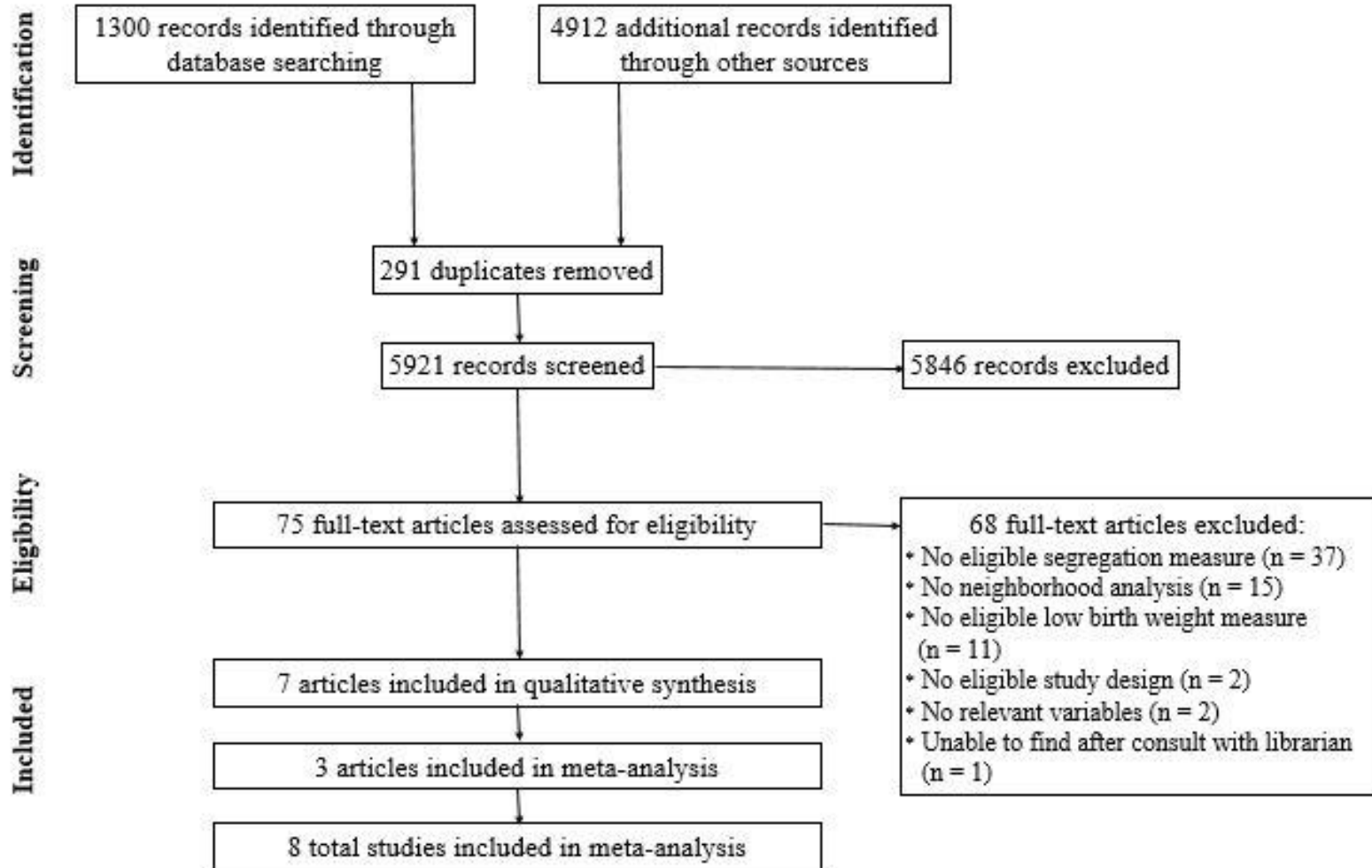
Performed 9/23/2015 to 12/3/2015

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Study Characteristics

All seven articles were similar across a number of characteristics. Each used a case control study design extracting birth weight and neighborhood location for singleton births from state birth certificates and U.S. Census demographic data resulting in a combined sample size of n = 126,755 Black infants across n = 6,936 areal units. Two articles, Grady (2005) and Grady (2006), included n = 60,244 White infants for comparison purposes. Low birth weight was defined as less than 2,500g regardless of gestation for the majority of articles. Grady (2005) additionally required infants to be less than 37 weeks. Every article measured segregation as isolation. Debbink (2011) also measured racial evenness. All but one article (Anthopolos et al., 2011) used a multi-level modeling approach nesting infants within neighborhoods (i.e., census tracts or block groups). Although all articles defined Black by mothers' self-reported race, two defined Black as non-Hispanic (Anthopolos, et al., 2011; Debbink and Bader, 2011), three included Hispanic Blacks (Grady, 2005; Grady, 2006; Grady & McLafferty, 2007), and the remaining two (Debbink, 2011; Grady & Ramirez, 2008) made no mention of ethnic specifications. Generally, birth records were excluded if residential information, race, or birth weight data were missing or unclear and if permanent addresses resided outside the study area. Three articles (Anthopolos, et al., 2011; Debbink, 2011; Debbink and Bader, 2011) also excluded records where infants were born with congenital anomalies. Only one article with two studies (Grady & McLafferty, 2007) provided effect sizes that disaggregated Blacks (i.e., U.S.-born and foreign-born). No study provided associations of low birth weight and racial isolation by ethnicity.

Four of these seven articles were excluded from the quantitative synthesis (meta-analysis). These articles were excluded due to differences in measurement that precluded effect size calculations, or because they used the same study sample reported in other articles. The remaining

three articles (Anthopolos, et al., 2011; Debbink & Bader, 2011; Grady & McLafferty, 2007) were included in the meta-analysis. They comprised a total of eight independent studies of n = 72,416 Black infants across n = 4,882 areal units, operationalized segregation as Black isolation, and used cutoff values to compare the odds of low birth weight in neighborhoods with highest isolation versus those with the lowest isolation. For three of these studies, Massey and Denton's (1988) theoretical and empirical cutoff points were used to bound racial isolation (i.e., Debbink and Bader, 2011: cutoff = 0.60; Grady and McLafferty, 2007: cutoff = 0.70). The measurement of racial isolation in the included studies therefore shifted the focus of the meta-analysis away from the original focus on quantifying the association between segregation and low birth weight, to instead address the question of how low vs. high Black isolation was associated with low birth weight. Descriptions of study characteristics for these articles can be found in Table 1. A summary of each study follows.

One study, reported in four articles (Grady (2005), Grady (2006), Grady and McLafferty (2007), and Grady and Ramirez (2008)) sampled Black mothers giving birth in the year 2000 across all New York City neighborhoods. As reported in Grady (2006), an association of OR = 1.09, 95% CI [1.05, 1.14], $p = 0.00$ was estimated after adjusting for nativity, marital status, education, Medicaid, smoking, substance abuse, maternal age, and race at the individual level as well as tract level poverty. This equated to a relative odds of 1.18 as isolation increased by one standard deviation. A White comparison group was included to investigate the role of race as social construct. After controlling for individual factors and neighborhood poverty, racial isolation was the only variable across models to fully explain differences in tract-level means of low birth weight ($\tau^2 = 0.07$, $p = 0.12$) by tract and race ($\tau^2 = 0.05$, $p = 0.13$) at the neighborhood level. At the individual level, however, neighborhood poverty fully reduced statistically significant variations

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by race (OR = 1.14, 95% CI [0.99, 1.32]). Examining differences in association by nativity, Grady and McLafferty (2007) also reported that for U.S.-born Black mothers the odds of having a low birth weight infant significantly increased with higher levels of racial isolation (OR = 1.10; 95% CI [0.99, 1.22], p = 0.04). For foreign-born mothers, the odds (OR = 1.02; 95% CI [0.91, 1.16], p = 0.35) did not reach statistical significance. Notably, the odds of a low birth weight birth infant for foreign-born mothers only failed to reach significance when region/country of origin was added to the analysis. Geographies of origin where the odds of low birth weight births remained statistically significant after controlling for racial isolation and poverty included South America, Haiti, Trinidad, the Dominican Republic, and the West Indies. Conversely, infants of African, Central American, and Jamaican mothers did not have statistically significant odds after such adjustments.

While not primarily addressing the research question under review, additional analyses reported in subsequent articles from this study (Grady, 2005; Grady and Ramirez, 2008) provide more insight surrounding the association between racial isolation and low birth weight. Although chronic hypertension, pregnancy-related hypertension, and preeclampsia were statistically significant mediators (z-score = 2.15, 95% CI [0.01, 0.27], $p < 0.05$; z-score = 2.12, 95% CI [0.01, 0.16], $p < 0.05$; z-score = 2.07, 95% CI [0.01, 0.25], $p < 0.05$ respectively) of the association between racial isolation and low birth weight, racial isolation remained significantly associated with low birth weight even after these adjustments (OR = 1.05, 95% CI [1.01, 1.10], $p < 0.05$; and OR = 1.05, 95% CI [1.01, 1.09], $p < 0.05$; OR = 1.05, 95% CI [1.01, 1.09], $p < 0.05$). For this sample, however, other pre-pregnancy (e.g., anemia, cardiac disease, chronic diabetes, lung disease, STDs, renal disease) and pregnancy-related (e.g., pregnancy-related diabetes, eclampsia, hydramnios) medical conditions were not statistically significant mediators of this association.

More generally, across these various analyses, there were more high poverty tracts (n = 704, 31.75%) than those that were racially isolated (n = 229, 10.32%), and while these neighborhood characteristics were not completely geographically aligned, there was a statistically significant correlation between them ($r = 0.31$, $p = 0.01$). Testing for systematic differences between residence identifiable and unidentifiable records was not reported for these articles. Descriptively, however, Grady (2005) stated that the New York City 2000 dataset had only a small number of records missing geographic identification which may suggest that attrition may not have posed a substantial threat to internal validity for the above articles. Edge effects corrections followed a similar pattern. Grady (2005) explained that because segregated tracts did not lie along the edges of the city, edge effects corrections were not performed. Although not mentioned, this justification would also most likely apply to Grady (2006), Grady and McLafferty (2007), and Grady and Ramirez (2008) given the use of the same census dataset. Permanent residence was generally restricted to the study area. Overall, all of the articles from this study adjusted for pertinent variables at the individual level (e.g., smoking, maternal age, Medicaid), and all but one (i.e., Grady, 2005) adjusted for tract-level poverty. Controlling for neighborhood poverty, in particular, within models aimed at predicting low birth weight from racial segregation helped to disentangle these two contextual variables.

In the second eligible study, among Black infants born across Los Angeles county neighborhoods from 2000 to 2004, Debbink (2011) found statistically significant results (OR = 1.13, 95% CI [1.02, 1.25], $p < 0.05$) for the association between low birth weight and Black-White isolation, but failed to find statistically significant results for the association between low birth weight and high or low evenness (OR = 1.10, 95% CI [1.00, 1.22] and OR = 0.91, 95% CI [0.77, 1.07] respectively). There were no statistically significant associations with Black-Hispanic

isolation (OR = 1.020, 95% CI [0.87, 1.20]) or neighborhood poverty (OR = 0.97, 95% CI [0.84, 1.12]) when accounting for Black-White isolation and other tract and individual-level variables. The census tracts under study were less structurally confounded for neighborhood characteristics. For Black-White isolated tracts, only 54.24% had high levels of neighborhood poverty compared to 45.76% that did not. The rate of low birth weight differed by neighborhood characteristics as well. Census tracts that were non-poor and Black-White isolated had the highest rates of low birth weight (5.93%) as compared to other racially isolated and non-racially isolated tracts with varying poverty levels (p. 53). Adjustments for appropriate confounders at the individual level (e.g., nulliparity, pregnancy complication, degree of prenatal care usage) and the neighborhood level (e.g., poverty, residential turnover, women's disadvantage) were made given the characteristics of the sample. Tests for systematic differences between records with geographic identification and those without, and thus excluded from the analysis, were conducted and were not found to be significant. Exclusion requirements for permanent residence of women at time of birth were less restrictive including all women, regardless of permanent residence, who gave birth in Los Angeles County. Corrections for edge effects were not discussed.

In the third included study, Anthopolos et al. (2011) examined neighborhoods in five North Carolina counties (i.e., Durham, Forsyth, Guilford, Mecklenburg, Wake) from 1998 to 2002 for associations between low birth weight and racial isolation and found statistically significant associations for two counties (i.e., Forsyth, OR = 1.37, 95% CI [1.10, 1.71], $p < 0.01$; Wake, OR = 1.28, 95% CI [1.08, 1.51], $p < 0.01$). Methodologically, Anthopolos et al. (2011) is notable for the use of cluster corrected standard errors, block group neighborhood designations instead of census tracts, and percentile cutoffs for racial isolation (i.e., isolated as the 90th percentile and non-isolated as the 10th percentile). Additionally, all five studies of this article corrected for edge

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effects. Common confounders at the individual level for mothers included maternal age, marital status, and education level. There were no common confounders at the neighborhood level or discussion of checks for permanent residence outside the focal area.

In the fourth included study, Debbink and Bader (2011) examined the association between low birth weight and racial isolation for both Blacks and Whites in Michigan metropolitan neighborhoods in 2000; however, because the associations for these analyses were not specific to Black infants, the effect size for Blacks had to be estimated from a descriptive table within the article. Thus, although the article adjusted for both individual and neighborhood level variables, the effect size included in the current meta-analysis remained unadjusted. Both low birth weight and racial isolation were analyzed as binary variables. The resulting effect size was OR = 1.11, 95% CI [1.04, 1.20], $p < 0.05$. Among racially isolated tracts 46.74% had high proportions of families living below the poverty level. Checks for systematic differences between included and excluded cases due to missing address information were performed, and none were found. Discussions about edge effect corrections or restrictions on permanent addresses outside the study area were missing from the research protocol description.

Overall, many studies suggested that racial isolation is positively associated with low birth weight for Black infants with some evidence from Grady and McLafferty (2007) that the association is particularly large for infants of mothers who were born within the United States or from particular geographical areas outside the States (e.g., South America, West Indies). Only Debbink (2011) investigated Black-Hispanic isolation and racial evenness, and each failed to yield statistically significant results. Across a number of neighborhood locations throughout the United States including New York City, Los Angeles County, Michigan metropolitan areas, and several North Carolina counties, statistically significant results were found. Generally, geographical

overlap between racial isolation and neighborhood poverty varied across tracts. While these characteristics seemed to converge more in New York City, they appeared to be less confounded across Los Angeles and Michigan metropolitan areas. Methodologically diverse, these studies used various measures for racial isolation (i.e., Wong's Local Spatial Isolation Index (2002), Krivo et al. Isolation Index (2007), and Reardon and O'Sullivan's Isolation Index (2004)) and different levels of measurement (i.e., categorical, dichotomous, and continuous) for racial isolation. Low birth weight was usually measured dichotomously.

Table 1. **Study Characteristics for the Association of Racial Neighborhood Segregation and Low Birth Weight**

Article	Independent Samples	Sample Sizes	Locations, Year	Segregation Dimension	Effect Sizes	Confounders	Sample and Tract Misclassification
Anthopolos et al. (2011) [A]	Yes	n=838[B] n=2,777[B] n=1,732[B] n=3,610[B] n=3,346[B]	North Carolina, 1998-2002 Five counties with the most populous cities	Reardon and O'Sullivan Isolation Index (2004)	OR 1.20; CI (0.94, 1.54) OR 1.37; CI (1.10, 1.71) * OR 1.16; CI (0.97, 1.38) OR 1.13; CI (0.98, 1.30) OR 1.28; CI (1.08, 1.51) *	Individual Level: (for all five counties) maternal age, first born infant, nativity, education, marital status, logit coefficient isolation, logit coefficient for isolation x Black	Corrected for edge effects; No description of check for missing data or checks for address misclassification
Debbink (2011)	Yes	n=54,098	Los Angeles County, 2000-2004	Krivo et al. Isolation Index (2007) Wong's Local Spatial Entropy Index (2002)	Black-White Isolation OR 1.13; CI (1.02, 1.25) * Black-Hispanic Isolation OR=1.02; CI (0.87, 1.20) Entropy (Diversity, Evenness) OR 1.10; CI (1.00, 1.22) OR 0.91; CI (0.77, 1.07)	Individual Level: infant's sex, mother's age and education, nulliparity, pregnancy complications, type of insurance coverage, and degree of prenatal care usage at the individual level Tract level: poverty, residential turnover, women's disadvantage, immigrant residency	Found no systematic birth outcomes differences between included cases and those excluded due to missing data; Included all births occurring in LA county regardless of permanent address; No mention of edge effects corrections
Debbink and Bader (2011) [A]	Yes	n=23,716	Michigan, 2000 Nine metropolitan areas including Detroit	Krivo et al. Isolation Index (2007)	OR 1.11; CI (1.04, 1.20) * [B]	Unadjusted model (synthesized effect size to retrieve a comparable effect for meta-analysis)	Found no systematic birth outcomes differences between included cases and those excluded due to missing data; No mention of edge effects corrections or whether records with permanent addresses beyond the study area were included
Grady (2006)	No, shares samples with other Grady articles	n=96,882[C]	New York City, 2000	Wong's Local Spatial Isolation Index (2002)	OR 1.09; CI (1.05, 1.14) *	Individual Level: nativity, marital status, education, Medicaid, smoking, substance abuse, maternal age, race Tract Level: poverty	No mention of checks for misclassification of addresses, edge effect corrections, or systematic differences among missing data
Grady and McLafferty (2007) [A]	No, shares samples with other Grady articles	US-born n=17.938 Foreign-born n=18,459	New York City, 2000	Wong's Local Spatial Isolation Index (2002)	US Born Mothers OR 1.10; CI (0.99, 1.22) * Foreign Born Mothers OR 1.02; CI (0.91, 1.16)	Individual Level: (for US Born analysis) maternal age, marital status, education, Medicaid, smoking, substance use (for Foreign Born analysis) maternal age, marital status, substance use Tract Level: (for all analysis) poverty	Excluded records with addresses outside of study area; No description of checks for missing data or edge effects corrections

[A] Article was included in meta-analysis; [B] Estimated or synthesized from data in article; [C] Included a White comparison group within analysis; * p>0.05

Note: Grady (2005) and Grady and Ramirez (2008) are omitted as these articles primarily provide additional analyses related to but beyond the scope of the central research question and already accounted for by Grady (2006) and Grady and McLafferty (2007).

Synthesis of Results

Effect sizes indexing the association between racial isolation and low birth weight were synthesized across the eight independent studies for which they could be estimated (see Figure 2). The resulting random-effects mean effect size for these studies indicated a positive statistically significant association between racial isolation and low birth weight among Black infants (OR = 1.13, 95% CI [1.07, 1.19], $p = 0.00$). Namely, the odds of low birth weight were 1.13 times higher among Black infants residing in racially isolated neighborhoods, relative to Black infants residing in non-isolated neighborhoods.

Heterogeneity

There was minimal heterogeneity in the eight effect sizes included in the meta-analysis ($Q = 8.34$, df = 7, $p = 0.30$; $I^2 = 16.1\%$; $\tau^2 = 0.00$). And indeed, the 95% prediction interval around the mean odds ratio was [1.03, 1.25], indicating that 95 out of 100 times a future study would be expected to find that racial isolation was associated with significantly higher odds of low birth weight among Black infants. Given the minimal heterogeneity across effect sizes, there was not sufficient variance to conduct the moderator analyses that were planned a priori (i.e., to examine ethnicity and segregation dimensions, and research design as moderators).
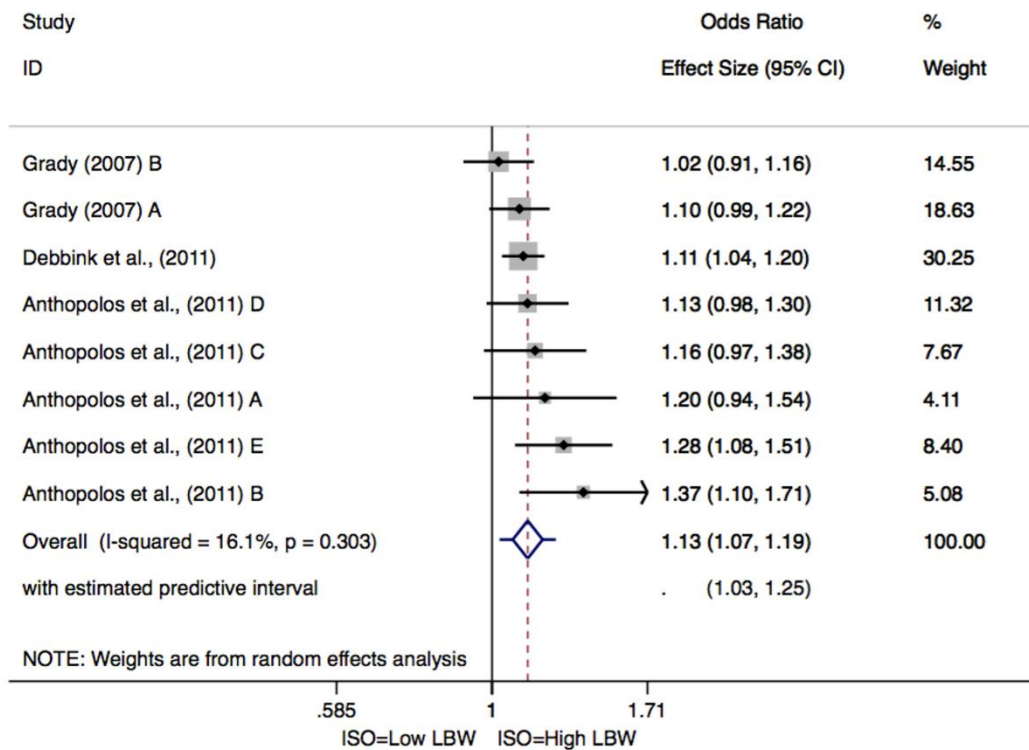
Figure 2. Forest plot of meta-analysis of the assocation between Black isolation and low birthweight.

Publication Bias

Inspection of a funnel plot inspection suggested a general lack of both nonsignificant studies with higher standard errors and significant studies with lower standard errors (see Figure 3). However, the Egger test for funnel plot asymmetry provided no strong evidence of small study bias ($b = 1.65$, $p = 0.11$). Results from the trim and fill test showed that results remained substantively similar even after the trimming and filling of four studies (OR = 1.10; 95% CI [1.04, 1.17], $p = 0.00$). Together these analyses provide strong evidence against the presence of publication bias.

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Figure 3. Funnel plot for assessing publication bias.
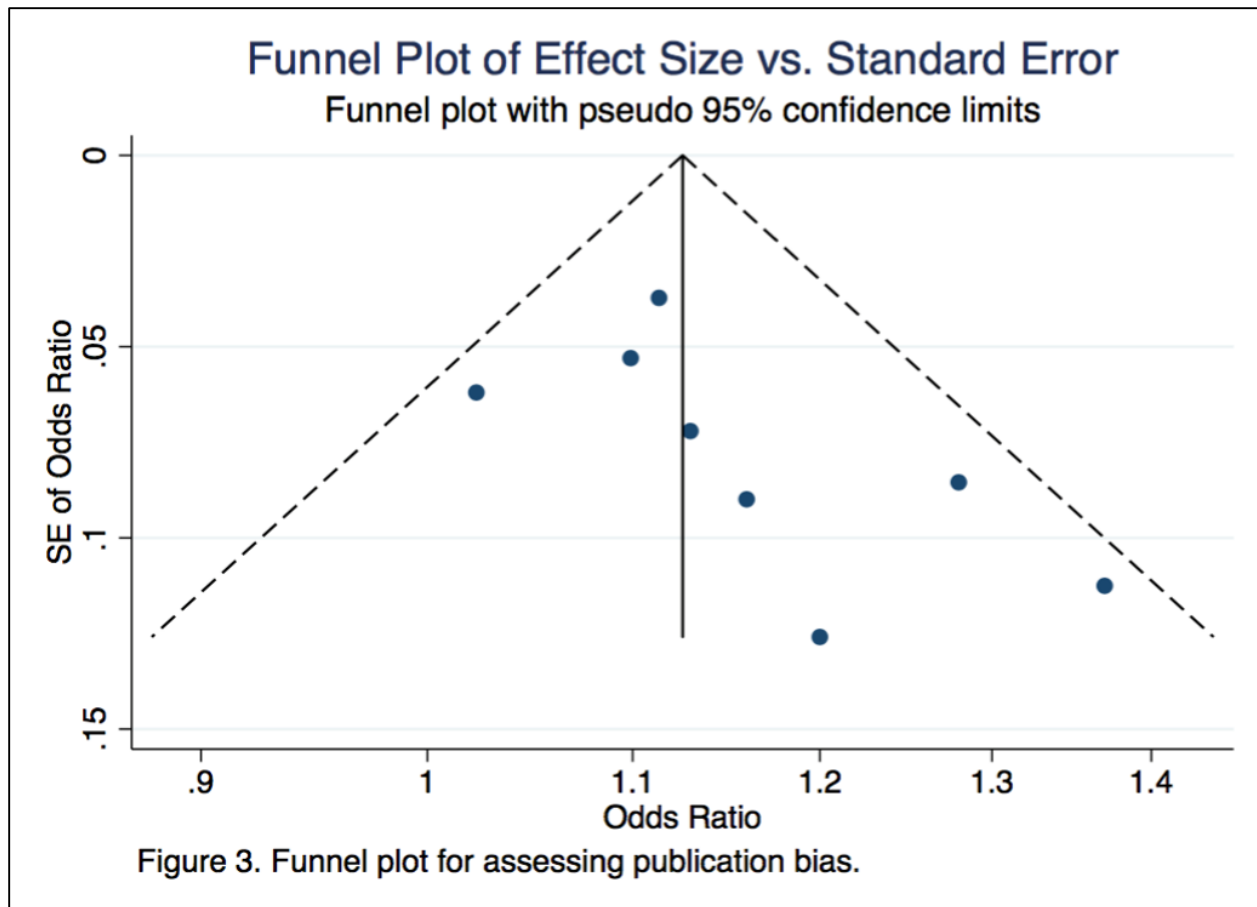
Sensitivity Analysis

A visual inspection of variability was performed using a Galbraith plot (Appendix: Figure 5) to locate outliers. None were found. Thus the planned sensitivity analysis of outliers was not possible due to a lack of outliers in the data. To assess the robustness of the results, a post-hoc analysis was done by dropping one study at a time from the analysis. Results remained robust and resulted in odds ratios ranging from 1.11 OR (95% CI [1.06, 1.17]) to 1.14 OR (95% CI [1.09, 1.20]).

CHAPTER 4

DISCUSSION

The importance of racial segregation, in particular racial isolation, to understanding low birth weight among Black infants cannot be overstated. Overall, studies within the systematic review provide evidence that a positive association exists between racial isolation and low birth weight. While this association may vary by mother's place of birth, statistically significant associations were found across diverse regional areas of the United States (i.e., Los Angeles, Michigan, New York, and North Carolina). Racial evenness, though very infrequently used, had no association with low birth weight. Results from the quantitative synthesis provided stronger support for an association between racial isolation and low birth weight and indicated that a mother from a racially isolated neighborhood had 1.13 higher odds of having a low birth weight infant relative to a mother from a less racially isolated neighborhood. This mean effect size is comparable to other meta-analytic findings for the association between low birth weight and contextual variables (i.e., pollution, Dadvand et al., 2013; Stieb et al., 2012; neighborhood deprivation, Metcalfe et al., 2013; Ncube el al., 2016) (Appendix: Tables).

The greatest contribution this systematic and meta-analytic review makes is in finding a possible positive relationship between neighborhood racial isolation and low birth weight among Black infants, based on a synthesis of the current available research in the field. While previous individual studies have found mixed results for this association, this synthesis suggests that spatial

indexes of racial isolation may be more useful for measuring segregation than percentages and that racial isolation may be positively associated with adverse birth outcomes. Although these results imply that current spatial measures of isolation are methodologically promising, certain considerations should be taken into account. Researchers using these indices must consider the types of neighborhood units being incorporated, and theoretically and empirically decide when it is necessary to move beyond the conventional census tract demarcations. Although there is evidence that associations between birth outcomes and census tract derived segregation indexes are highly correlated with other measures such as surface-density estimated segregation indexes, the resultant associations quantitatively differ (Kramer et al., 2010). Additionally, Berry (2008) points out that all such indexes only partly estimate segregation given that segregation is conceptually more layered across time, structural systems, and socio-spatial norms and experiences. Advancements in methodology that examine spatial, temporal, structural, and embodied aspects of segregation can help improve internal and external validity and can inform researchers of how to better understand racial isolation and interpret analyses.

This systematic review also suggests that the association between racial isolation and low birth weight by ethnicity and nativity is complex with U.S. born Blacks as well as particular immigrant ethnicities being more greatly impacted than other similarly racially categorized groups (Grady & McLafferty, 2007). Though the reasons for this are unknown, understanding the experiences and accumulated exposures to racial isolation within spatial, historical contexts and the extent to which different populations experience similar neighborhoods is paramount to further investigation. Notable, too, is the strength of racial isolation's association with low birth weight at a neighborhood level and its ability to eliminate variance due to race (i.e., Black-White racialized differences) at the tract level (Grady, 2006) and suggests that racial isolation could help explain

statistically significant neighborhood differences in Black-White low birth weight outcomes. Additionally, for several studies (Debbink, 2011; Grady & McLafferty, 2007; Grady & Ramirez, 2008) neighborhood poverty failed to research significance when controlling for racial isolation. Although different forms of hypertension may serve as possible mediators of this association, medical conditions previous to and acquired during pregnancy do not seem to fully explain the relationship between low birth weight and racial isolation (Grady & Ramirez, 2008). Understanding racial isolation and as well as the discriminatory structures, practices, and relationships that foster it in relation to and independent of poverty must be seriously undertaken.

Although this study finds strong evidence for an association between racial isolation and low birth weight, it cannot provide any evidence regarding an ethnic density hypothesis (Bécares, Nazroo, & Stafford, 2009; Bécares et al., 2012; Pickett, & Wilkinson, 2008) that suggests that ethnic density may be associated with some health advantages (e.g., positive or reduced risk of mental health outcomes). As previously stated, ethnic density, measured by percentages and often conceptualized as social cohesion, is operationally distinct from racial isolation and many other important dimensions of racial segregation. Moreover, racial isolation conceptually pinpoints the probability of interracial interaction and, as Massey and Denton (1993) suggest, is linked to spatial manifestations of institutional racism.

The primary strength of these systematically reviewed articles resides in the coding of confounders. Unlike those eligible to be included in the meta-analysis, most systematically reviewed articles adjusted for individual and tract-level variables enabling some disentanglement of neighborhood poverty and racial isolation. Examining this association across a variety of locations was also useful to conceive of racial isolation's relationship with low birth weight generally. Yet in depth analysis of the particularities of different geographies is needed. Most

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articles used multilevel modeling which also improved the internal validity of these studies. Reports concerning corrections for edge effects and checks for address misspecification or systematic differences between included and excluded records were mixed. Because it is possible that researchers performed but did not report such quality measures or that such quality measures were not shown to be necessary (i.e., few excluded records), it is not possible to fully discuss these parameters. Describing the details of archival data processing and analytic justifications in the future may allow for more useful assessment.

At the primary level of analysis of the meta-analysis, the studies under review were limited in that they generally did not adjust for important confounders (i.e., smoking and neighborhood-level deprivation). Although this was largely due to the use of birth certificate data, which may report mother's smoking and socioeconomic level unreliably (Northam & Knapp, 2006), not adjusting for these variables threatens internal validity. Although multilevel modeling is considered to be more suitable than general regression to explicate individual and neighborhood variance and is recommended for examining associations between segregation and health (Acevedo-Garcia, Lochner, Osypuk, & Subramanian, 2003), only a few studies within this meta-analysis incorporated this methodological approach. Additional threats to internal validity at the primary study level were the overall lack of corrections for edge effects and of reports for missing data. Both may have systematically skewed results; however, there is no way to assess to what extent and in what direction. Greater transparency in the reporting of sample and population-level underlying distributions, especially of socio-economic characteristics, can help determine to what extent a study is examining similar populations in different environments. According to Messer, Oakes, and Mason (2010), this practice reduces structural confounding. Although a moderator analysis was planned for the current meta-analysis, there was no variation across included studies

by dimensions of segregation. Future research should expand investigations of evenness as well as isolation.

Several limitations also exist at the meta-analytic level. Although every effort was made to locate potential studies, one article was unable to be located despite consultations with university librarians. Additionally, only one researcher was involved in the screening and coding of articles in this research. It is possible, therefore, that eligible studies are missing or were screened out. Geographic coverage is another limitation. Although the eight reports represented here are from three distinct geographical areas (i.e., neighborhoods in New York City, Michigan metro areas, and North Carolina urban counties) and have a representative sample size (n = 72,416), they lack generalizability outside these study areas. Generalizability was also limited by the choice to analyze segregation within a primarily Black-White paradigm. Although it is important to understand the socio-historical trajectory for Blacks in the United States given this group's persistent patterns of segregation (i.e., slavery, Jim Crow), investigating racial residential segregation across multiple racial groups may further nuance our understanding of health and place particularly as it concerns the continuance and transformations of racial discrimination. Additionally, because ascertaining the generalizability of these findings within current demographic realities is difficult, this mean effect size applies to the years 1998 to 2002 for the geographic areas under review. These are the years for which birth data were collected.

Moderator analysis by ethnicity could not be performed due to infrequency of reporting associations by ethnicity. Choosing ethnicity as a moderator, while conceptually appropriate, may generally be logistically unsound given current the limits of birth certificate data. Finally, analyzing the length of exposure to Black isolation throughout mothers' lifetime, or weathering, (Geronimus, 1991) may be an important variable for understanding mediating factors contributing

to this association; however, this variable was missing from the current meta-analytic study design and cannot be accounted for using birth certificate data. Creating research designs, at the primary and synthesis level, that allow for the inclusion of these variables is essential to our knowledge about neighborhood racial isolation's association with low birth weight. Future studies must think intentionally about archival data and when and how to overcome limitations by changing study design.

Despite these limitations, this research synthesis provides the best estimate for the association of isolation and low birth weight among Black infants to date. By synthesizing findings from studies using the most advanced measures of segregation and given the inherent limitations of birth certificate, a mean effect size of 1.13 OR is the closest estimation for this association that current measures, study designs, and accumulated research allows.

CHAPTER 5

CONCLUSION

Overall, neighborhood-level racial residential isolation is associated with low birth weight outcomes for Black infants sampled within the geographies and time periods under study although this association may depend on mother's origin of birth. This positive association gives quantitative evidence consistent with what some scholars (Kramer & Hogue, 2009) have hypothesized about isolation as being a type of segregation associated with adverse health outcomes and helps to clarify this body of literature given its historically diverse measurements of segregation. Although these findings are the first quantitative synthesis of this relationship to the author's knowledge, limitations at the primary and meta-analytic study level suggest that more research is needed to evaluate these findings further.

Balancing advancements in measuring segregation dimensions spatially, attending to structural confounding at multiple levels of analysis (i.e., individual, neighborhood), and increasing measurement consistency within the literature is essential for producing knowledge capable of informing policy and intervention. Because limitations of birth certificate and census data are hard to overcome, funding for and incorporation of this research into large scale prospective study designs would allow for the assessment of ethnic differences and mothers' exposure to isolation — two variables difficult to ascertain under existing study design conventions. Overall, further causal and correlational investigation is needed across dimensions of

segregation, geographic regions, and racial/ethnic groups as well as in-depth qualitative methods examining the lived experiences within and structural development of racially isolated communities.

Most importantly, although the results of this study provide strong evidence of the association between racial isolation and low birth weight among Black infants, it does not in any way suggest that Black communities experience such adverse health outcomes by virtue of racial composition. It would be incorrect to assume from this study that ethnic concentration may not have protective associations with health. This research, however, does conceptualize racial isolation as a manifestation of multidimensional processes by which racial discrimination is facilitated and becomes embedded within Black residential communities and population health. Future research and policy efforts must continue to more clearly and critically examine these processes that establish, maintain, and exacerbate racial disadvantage residentially. Conceptual frameworks that clarify the dimensions of spatial, structural, and experiential isolation across time are needed. Such work must take an interdisciplinary approach and integrate the work of sociologists, geographers, and demographers.

Additional Tables

Table 2. **Meta-analysis results for articles of random effect model associations of low birth weight and other contextual variables.**

Study	n	Contextual Variable	Mean Effect Size	C.I.	I^2
Dadvand et al. (2013)	n = 13	Particulate air pollution, PM (2.5)	OR = 1.10	1.03, 1.18	89.7%
Stieb et al. (2012)	n = 7	Particulate air pollution, PM (10)	OR = 1.10	1.05, 1.15	15.9%
Metcalfe et al. (2011)	n = 6	Neighborhood deprivation	OR = 1.11	1.02, 1.20	89.2%
Ncube et al. (2016)	n = 9	Neighborhood deprivation	OR = 1.17	1.10, 1.25	34.4%
Wilfong (2016)	n = 8	Neighborhood Black isolation	OR = 1.13	1.07, 1.19	16.1%

Figure 4. **Conversion Formulas**

Estimating Odds Ratio
OR = (A x D)/(C x B)

Estimating Standard Error of Log Odd Ratio
Standard Error = sqrt (1/A + 1/B + 1/C + 1/D)

Estimating Log Odds Ratio
LOR = ln(OR)

Estimating Lower Confidence Limit (LCL) of a Log Odds Ratio
LCL = LOR - (1.96 x Standard Error)
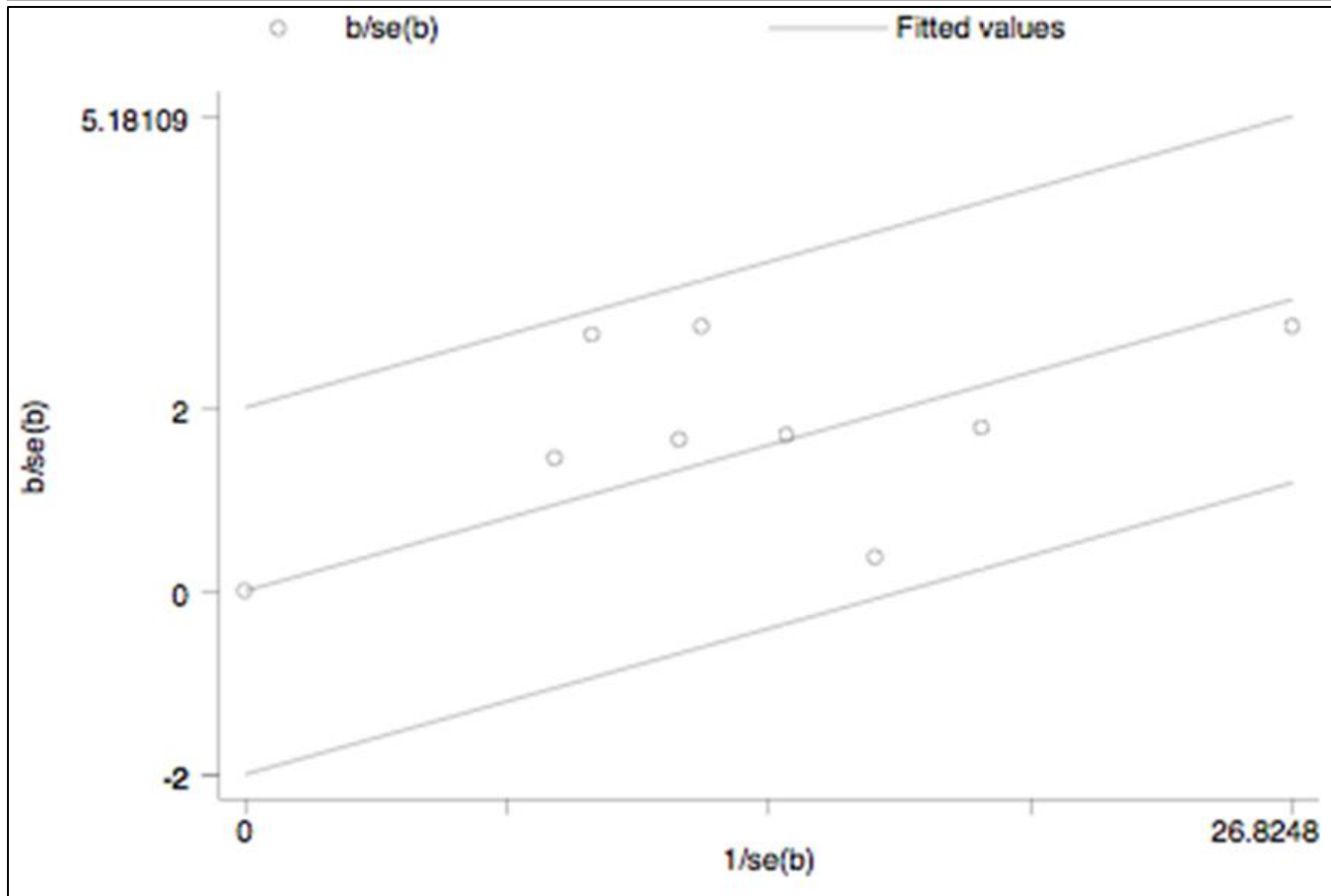
Estimating Upper Confidence Limit (UCL) of a Log Odds Ratio
UCL = LOR + (1.96 x Standard Error)

Estimating the Standard Error of a Log Odds Ratio using LCL and UCL of Log Odds
Standard Error = (UCL – LCL) / 3.92

Figure 5. **Galbraith plot assessing outliers.**

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