UNDERSTANDING RACIAL DISPARITIES IN LOW BIRTHWEIGHT IN PITTSBURGH, PENNSYLVANIA: THE ROLE OF AREA-LEVEL SOCIOECONOMIC POSITION AND INDIVIDUAL-LEVEL FACTORS

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Background: Low birthweight (LBW, <2500g) is a leading cause of infant mortality, and disparities exist between Blacks and Whites. About 11% of Pittsburgh births in 2003 were LBW, and the racial difference was wide: 8.4% of LBW infants were born to Whites, whereas 16.0% were born to Blacks. Studies suggest an association between contextual factors and LBW—lower levels of area-level socioeconomic position (SEP) are associated with increased LBW risk. The dissertation's main research hypotheses are whether 1) area-level SEP predicts LBW, 2) racial difference in LBW is partially explained by area-level SEP, and 3) racial difference is explained after controlling for area-level SEP and individual-level factors.

Methods: Using U.S. Census 2000 data, area-level SEP measures were created for Pittsburgh: overall neighborhood disadvantage (OND_{ijk}), material and economic deprivation (MED_{ij}), and concentrated disadvantage (CD_{ij}). LBW and other individual-level data from 10,830 birth records were obtained from the 2003-2006 Allegheny County birth registry. Multilevel logistic regression was utilized to examine the association between SEP measures and LBW.

Results: OND_{ijk} was a significant predictor of LBW (OR: 1.306, p<0.001), remained significant after controlling for race (OR: 1.10, p<0.03), but was no longer significant after controlling for individual-level disadvantage (OR: 1.05, p=0.27). In addition, 74% of Blacks resided in disadvantaged neighborhoods, compared to 13% of Whites. In the unadjusted race model, Blacks were at increased odds of LBW compared to Whites (OR: 2.119, $p<0.001$), and the race OR decreased after adjusting for OND_{ijk} (OR: 1.917, $p<0.001$) and individual-level disadvantage (OR: 1.56, $p<0.001$). Due to the lack of variability of LBW at the block group level, there was insufficient power to test the association between LBW and CD_{ij} and MED_{ij}.

Conclusions: Findings suggest that contextual factors are associated with LBW: knowing one's race and neighborhood may help predict one's risk for LBW. Public health significance includes using OND_{ijk} as an indicator of areas with higher levels of LBW risk and targeting these neighborhoods for interventions to improve birth outcomes. In addition, understanding racial differences in neighborhood conditions may help further understand the social determinants that contribute to health disparities in LBW between Blacks and Whites.

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1.0 INTRODUCTION

Exploring the relationship between where one lives and health outcomes is not new in public health. In the mid-1800s, John Snow, the father of epidemiology, mapped out locations of cholera cases and discovered that location of residence was associated with mortality due to cholera in London, England. Households whose water source was the Broad Street pump had relatively more cases of cholera. To prevent further cases, Snow broke off the water pump handle; his efforts stopped the further spread of cholera (Gordis, 1996). Almost 150 years later, attention continues to focus on the relationship between residential environment and health outcomes (Diez Roux, 2001, 2004; Kawachi & Berkman, 2003), especially in relation to health disparities. Some local residential areas demonstrate clustering of social problems, concentration of poverty, and paucity of resources, and these characteristics may be associated with local area-level differences in health outcomes (such as cardiovascular disease, self-reported health status, pre-term birth), risk factors (obesity, smoking), and behaviors (physical activity and diet) (Diez-Roux, 2000; Farley, et al., 2006; Morenoff, 2003; Sampson, Raudenbush, & Earls, 1997). Current thinking in public health has recognized that there are social determinants of health, and factors at multiple levels, ranging from the individual to the global, that contribute to health. This thinking, coupled with the improved accessibility of powerful statistical software, has augmented researchers' capability to examine more closely the contextual factors that are associated with health status (Diez-Roux, et al., 2001; Gee & Payne-Sturges, 2004; A. Schulz & Northridge, 2004). Similar to efforts employed by John Snow, examining differences between local areas as well as individual-level factors may eventually lead to the formulation of more effective interventions and policies that reduce social inequalities in health.

Low birth weight (LBW), defined as having a birthweight of less than 2500 g, is an important public health problem. LBW is a leading cause of infant mortality in the United States and contributes to developmental delays in children. In 2006, 8.3% of all live births in the United States were LBW. More so, differences exist in the risk of LBW between Blacks and Whites. In 2006, a higher proportion of Blacks (13.6%) gave birth to LBW infants, more so than Whites (7.2%). Some studies suggest that other risk factors associated with LBW, such as lower individual-level SEP, higher smoking rates, and access to prenatal care are more prevalent in Blacks, thus contributing to these differences. However, several studies show that after controlling for these factors, disparities in LBW continue to persist.

From a multilevel perspective examining social determinants of health, factors beyond the individual may be associated with the higher risk of LBW in Blacks. One such perspective is the fundamental cause theory that suggests that social and contextual factors may be contributing to these differences (Link & Phelan, 1995). In this context, policies, laws, and economic structures have contributed to the confluence of neighborhoods that are racially segregated, and in turn have lower levels of SEP. These areas are deprived of resources that may contribute to an environment at higher risk of LBW.

Recent studies have suggested that neighborhood socioeconomic position (SEP) may be associated with adverse birth outcomes, such as low birth weight (LBW) (Buka, Brennan, Rich-Edwards, Raudenbush, & Earls, 2003; Messer, Laraia, et al., 2006; Morenoff, 2003; Pickett, Collins, Masi, & Wilkinson, 2005; Rauh, Andrews, & Garfinkel, 2001; Schempf, Strobino, &

O'Campo, 2009). More so, although disparities persist between Blacks and Whites after controlling for individual-level factors, understanding neighborhood-level factors may help further explain the differences in LBW between Blacks and Whites. Thus, to further examine these differences, the main objective of the dissertation is to test whether an association exists between area-level SEP and birth weight of infants born to Black and White mothers residing in Pittsburgh, Pennsylvania from 2003-2006 (n=10,830). More specifically, using measures of area-level SEP that I constructed in my masters thesis (overall neighborhood disadvantage (OND_{ijk}), block concentrated disadvantage (CD_{ij}), block group material and economic deprivation (MED_{ij}), I will test the following hypotheses:

1) Area-level SEP predicts positively LBW

2) Blacks have a higher risk of LBW infants than Whites

   a) Area-level SEP explains some of the difference

   b) Racial differences are not fully explained by individual-level factors

3) Race differences in LBW are attenuated by area-level SEP, after controlling for individual-level factors

To address these research questions, this paper will:

- ♦ Summarize birth weight of infants born in Pittsburgh from 2003-2006.
- ♦ Summarize individual characteristics (race, age, education, marital status, health care access, health behaviors) of women who gave birth to infants born in Pittsburgh, Pennsylvania from 2003 to 2006.
- ♦ Summarize characteristics of neighborhood and block group socioeconomic position (SEP) of women who gave birth to infants born in Pittsburgh, Pennsylvania from 2003 to 2006.

- Using multilevel logistic regression, examine the relationship between neighborhood and block SEP factors and LBW.
- Using multilevel logistic regression, examine relationship between individual-level factors (race, socio-demographic characteristics, health care access, and health behaviors) and LBW.
- Examine relationship between neighborhood and block group SEP factors and LBW after controlling for individual-level factors.

There are several research and policy implications of the study. The main research and policy implications are that 1) this study will add to the literature that focusing on factors beyond the individual are warranted in order to address health disparities in LBW between Blacks and Whites and 2) the findings may potentially guide policymakers in developing effective policies that address the social determinants of health and move towards the goal of eliminating health disparities.

2.0 REVIEW OF THE LITERATURE

The following section is divided into seven sub-sections. The first section describes LBW, including trends, prevalence, risk factors associated with LBW, especially race. The second section will describe conceptual frameworks and theories that can help our understanding of why neighborhoods are an important level in which to examine factors associated with LBW and how to examine area-level factors and LBW. The third and fourth sections describe domains of SEP and methods used to create composite measures of SEP. The fifth section describes the U.S. Census data as a source to construct area-level measures of SEP. The sixth section describes the studies that have examined area-level SEP factors and LBW, and racial differences in LBW. The final section will describe multilevel logistic regression, an analytical approach to examine how area-level SEP and individual-level factors predict individual-level LBW.

2.1 LOW BIRTH WEIGHT

2.1.1 Defining Low Birth Weight

Low birth weight (LBW), defined as having a birthweight of less than 2500g, is an important indicator of population health, more specifically the health of infants and also the potential health status of children and adults (Sastry & Hussey, 2003). LBW is a leading cause of infant mortality and contributes to developmental delays in children. In 2006, the most recent year for which data is available, 8.3% of all live births in the United States were LBW (Martin, et al., 2009).

Recent data show that the current rate of LBW in the United States is the highest in the past 40 years and continues to increase (Martin, et al., 2009). In the early 1980s LBW percentage was 6.8%, increased to 7.0% in 1990, to 7.6% in 2000, and to 8.3% in 2006. Increases in LBW rates are partially due to a larger percentage of births that are multiple births: more than 50% of multiple births produce LBW infants. However, when focusing only on singleton births, LBW rates continue to show an increase over time. In 1990 the LBW percentage was 5.90%, and 6.49% in 2006.

In parallel to increasing percentage of LBW over time in the United States, recent data have suggested a plateauing in the declining rates of infant mortality that has been observed in the United States since the 1950s. MacDorman and Mathews (2009) suggest that a contribution of this leveling is due to an increase in the number of low birthweight infants, especially infants with very low birth weights (less than 1000g): in 2005, 50% of infant deaths were of infants weighing less than 1000 grams at birth, although these LBW infants comprised 0.8% of total births. In addition, infant mortality rates for infants weighing less than 1500g was 250.0 per 1000 live births, compared to a much lower rate of 2.3 deaths per 1000 live births in infants weighing more than 2500g (MacDorman & Mathews, 2009). Thus, one way to reduce infant mortality rates in the United States is to focus interventions in reducing LBW infants.

2.1.2 Risk Factors Contributing to Low Birth Weight

The Institute of Medicine's (IOM) Committee on Preventing Low Birthweight (1985) reviewed the risk factors contributing to LBW and categorized risk factors into six categories:

demographics risks, medical risk prior to pregnancy, medical risks during current pregnancy, behavioral and environmental risks, health care risks, and new or evolving concepts of risks. These factors are related to each other and identifying one sole factor contributing to LBW is difficult (Institute of Medicine (U.S.). Committee to Study the Prevention of Low Birthweight., 1985). Demographics risks include age (< 17 years or >34 years), race (Black), low SEP, unmarried, and low level of education. Medical risks include diabetes, hypertension/preeclampsia, previous abortion, multiple pregnancies (such as having twins or triplets), and infections of either the fetus (e.g., cytomegalovirus infection) or mother (Chlamydia). Behavioral and environmental risks include smoking status, alcohol use, and poor nutrition. Health care risks include late or no prenatal care. Given the topic of this paper, race as a risk factor will be the focus of this section,

2.1.3 Racial Disparities in Low Birth Weight

An important risk factor of LBW is race, and a wide disparity exists between Blacks and Whites. In 2006, a much higher proportion of Black births are LBW (13.6%), compared to the proportion of White births (7.2%) (Martin, et al., 2009). More so, Allegheny County Health Department (2006) report higher percentages compared to national data: 11.4% of total live births in Pittsburgh, Pennsylvania in 2003 were LBW, and the difference in percentage of LBW infants between Blacks and Whites was wide: 8.4% of LBW infants were born to White mothers, whereas 16.0% of LBW infants were born to Black mothers in 2003.

Some argue that disparities exist between the two groups because Blacks have lower individual-level SEP, higher smoking rates, and/or less likely to access prenatal care than Whites. Recent national data (Martin, et al., 2009; National Center for Health Statistics (U.S.).

2009) and studies (Goldenberg, et al., 1996; Shiono, Klebanoff, Graubard, Berendes, & Rhoads, 1986; Teitler, Reichman, Nepomnyaschy, & Martinson, 2007) however, demonstrate that even after controlling for these two types of factors, disparities between Blacks and Whites continue to exist. In terms of age and education, Table 1 and Table 2 show that in 2006, Blacks still had a higher LBW percentage than Whites within the same age group and same education level (Martin, et al., 2009; National Center for Health Statistics (U.S.). 2009).

In addition, several studies show that disparities existing between Blacks and Whites are not explained by individual-level SEP or behaviors (Goldenberg, et al., 1996; Shiono, et al., 1986; Teitler, et al., 2007). Using nationally representative birth cohort data from the Early Childhood Longitudinal Survey-Birth Cohort, Teitler and colleagues (2007) adjusted for gender, SES (as measured by household poverty level, education, and employment status during pregnancy) and healthy behaviors (received prenatal care, smoker status). The unadjusted LBW percentage for non-Hispanic Whites was 4.6%, compared to 10.3% in non-Hispanic Blacks. However, the difference between Blacks and Whites was only partially explained after adjustment of gender, SES and behaviors. Adjusted LBW percentages were 4.6% for non-Hispanic Whites and 9.8% for non-Hispanic Blacks. In a low-income population, Goldenberg and colleagues (1996) found a significant association between LBW and individual-level characteristics: maternal demographics, medical, and behavioral characteristics, such as height, weight, smoking, hypertension, and diabetes. However, these characteristics did not explain the differences between Blacks and Whites. When race alone was included in the model, the average weight of Blacks infants was 200 grams more than White infants. However, when adding other risk factors, Blacks infants still weighed less than their White counterparts (139g or less), suggesting that only about 33% of the difference between Blacks and Whites was explained by these individual-level factors. Similarly, another study showed that unadjusted odds ratios for LBW of Blacks compared to Whites did not change after adjusting for risk factors (Shiono, et al., 1986).

The inability of SEP and behaviors to explain differences between Blacks and Whites may suggest that different mechanisms may be occurring between the racial groups. Nepomnyaschy (2009) showed that although SEP measures (maternal education, income, wealth) were significantly associated with LBW in White mothers, no association existed between SEP and LBW in Black mothers. Other factors may be playing a role in explaining these differences in LBW risk between Blacks and Whites. One set of factors are the conditions of one's residential environments, or area-level factors. The following section sets up the conceptual framework in which to understand these factors.

Table 2-1 Percentage LBW in Each Category by Race, United States, 2006

Age Group	White Non-Hispanic %	Black Non-Hispanic %
<15 years	12.3	16.7
15-19	8.9	14.5
20-24	7.4	13.6
25-29	6.7	13.3
30-34	6.9	13.9
35-39	7.9	15.3
40-44	9.9	18.0
45-54	20.4	19.5

Source: (Martin, et al., 2009)

Table 2-2 Percentage of LBW in Each Education Attainment by Race, United States, 2006

Maternal Education (in years)	White Non-Hispanic %	Black Non-Hispanic %
No HS/GED	9.9	15.8
HS/GED	8.0	14.1
Some College	6.9	12.9
Bachelor's Degree or More	6.3	11.7

Source:(National Center for Health Statistics (U.S.). 2009)

2.2 CONCEPTUALIZING THE RELATION BETWEEN AREA-LEVEL FACTORS AND LOW BIRTH WEIGHT

To understand how area-level factors are associated with low birth weight, a review of the conceptual framework, theories, and conceptual models proposed in the research literature are described below. This summary will help guide and organize one's understanding of area-level factors that predict LBW and the racial/ethnic disparities associated with LBW.

2.2.1 Conceptual Framework, Theories, and Conceptual Models

A brief overview of conceptual frameworks, theories, and conceptual models in the literature will be presented. Adapting from Carpiano and Daley's (2006) work, *conceptual frameworks* are at the highest and broadest level and "identifies a set of variables and relations among them that are presumed to account for a set of phenomena," but they do not explain how variables explain a phenomenon. A *theory* is more specific and "explicates a more dense and logically coherent set of relationships." A *conceptual model* is at the lowest level and "are developed and used to make specific assumptions about a limited set of parameters and variables." Models may draw upon several theories (Carpiano & Daley, 2006).

2.2.1.1 Conceptual Frameworks

Two conceptual frameworks are used to guide one's understanding of the association between neighborhood-level factors and LBW: the multilevel approach to epidemiology and the social determinants of health. The multilevel approach to epidemiology serves as a conceptual framework that can be used as a guide to identify the various levels that factor into health (Institute of Medicine, 2000). The framework broadens the scope of potential risk factors of LBW by focusing on factors beyond the individual. Unlike individual-focused models, this model (see Figure 2-1) acknowledges that several factors on various levels (ranging from biological mechanisms to policies) and dimensions (life course and environment), may contribute to health outcomes. These levels can be grouped into the socioecological levels outlined by McLeroy and colleagues (1988): individual characteristics (genetics, age), intrapersonal or interactions with other individuals (social support), community-level factors (neighborhoods), and aspects at the policy-level.

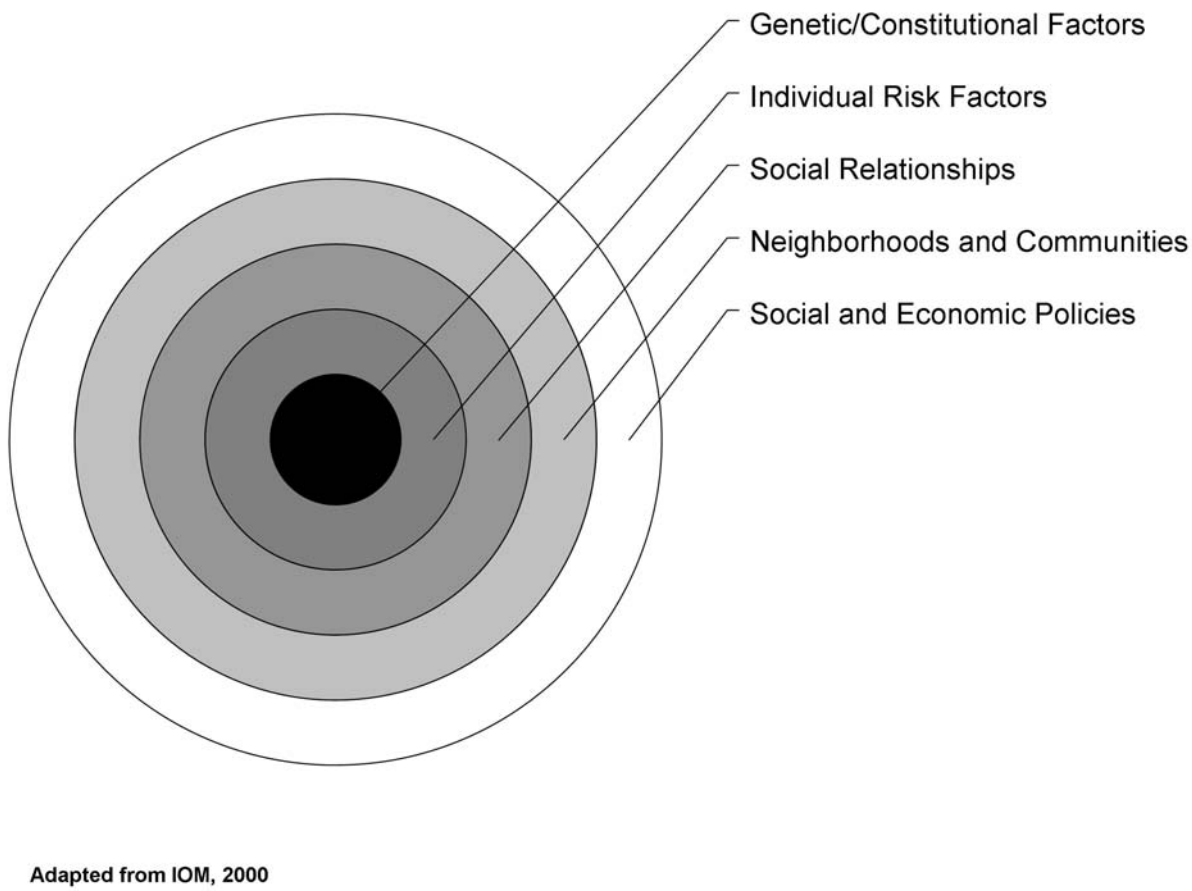

Figure 2-1 A Multilevel Approach to Epidemiology

Whereas the multilevel approach helps identify what levels to examine, the social determinants of health helps identify the type of factors to focus on that contribute to disparities in health outcomes. In a recent WHO report (2008), the Commission on Social Determinants of Health state the following:

"The Commission takes a holistic view of social determinants of health. The poor health of the poor, the social gradient in health within countries, and the marked health inequities between countries are caused by the unequal distribution of power, income, goods, and services, globally and nationally, the consequent unfairness in the immediate, visible circumstances of peoples lives – their access to health care, schools, and education, their conditions of work and leisure, their homes, communities, towns, or cities – and their chances of leading a flourishing life. This unequal distribution of health-damaging experiences is not in any sense a 'natural' phenomenon but is the result of a toxic combination of poor social policies and programmes, unfair economic arrangements, and bad politics. Together, the structural determinants and conditions of daily life constitute the social determinants of health and are responsible for a major part of health inequities between and within countries" (p.1).

Based on this WHO report, the source of health inequalities are poor policies and decisions that contribute to inequities in the distribution of financial resources and power. These factors in turn contribute to disparities in health. These social inequalities can be observed within neighborhoods.

2.2.1.2 Why Neighborhoods?

Recent studies have focused on the neighborhood as one level in which to examine health outcomes (Diez Roux, 2001; Kawachi & Berkman, 2003; Sampson, Morenoff, & Gannon-Rowley, 2002). According to Sampson and colleagues (2002),

> "a neighborhood is "a collection of both people and institutions occupying a spatially defined area influenced by ecological, cultural and sometimes political forces….[with] boundaries…defined by either outsiders and/or residents" (p. 445).

Neighborhoods may be an important level where social and physical characteristics coexist to promote an environment with increasing levels of LBW infants. Social problems, poverty, and lack of resources vary greatly among neighborhoods (Sampson, et al., 2002). For example, findings suggest that neighborhoods with lower wealth and higher proportion minorities had more crime, less social support, more fast food restaurants, poorer food choices, less access to supermarkets, less access to physical activity resources, and poorer dietary behavior (Algert, Agrawal, & Lewis, 2006; Block, Scribner, & DeSalvo, 2004; Diez-Roux, et al., 1999; Diez Roux, et al., 2007; Lewis, et al., 2005; Moore & Diez Roux, 2006; Morland, Wing, & Diez Roux, 2002; Morland, Wing, Diez Roux, & Poole, 2002; Powell, Slater, Chaloupka, & Harper, 2006; Powell, Slater, Mirtcheva, Bao, & Chaloupka, 2007; Zenk, Schulz, Hollis-Neely, et al., 2005; Zenk, Schulz, Israel, et al., 2005). These findings suggest that neighborhoods may be an important level in which to examine the factors associated with health disparities. The multilevel approach to epidemiology and the social determinants of health identify that the neighborhoods may be a level in which to understand how social inequalities play a role in health disparities, specifically LBW. Although conceptual frameworks help lay what pieces to examine, their purpose is not to explain how neighborhood factors contribute to low birth weight. One step further towards elucidating the relationship between neighborhoods and LBW is through theories and conceptual models.

2.2.1.3 Theories and Theoretical Models

Theories can be used to help explain how neighborhood factors are associated with LBW. Two such theories are the psychosocial theory and fundamental cause theory.

The psychosocial theory posits that factors in the social environment impact an individual's susceptibility to disease by turning on stress functions maintained by the neuroendocrine system within the individual. Stressors in the social environment are psychosocial factors which are created through human interaction, such as social support and social disorganization (Krieger, 2001). For example, a study by Messer and colleagues (2006) showed a positive association between neighborhood crime levels, an aspect of social disorganization, and pre-term births. Schempf and colleagues (2009) found that a composite indicator of neighborhood risk that included violent crime rate, percent Black, percent poverty, and percent boarded-up housing was positively associated with birth weight Adjustment of stress levels, perceived locus-of-control, and social support, reduced the effect of neighborhood risk by 12%. These studies suggest that environmental hazards in neighborhoods may be associated with LBW risk. However, although the psychosocial theory helps identify the potential factors in the environment that effect health, the fundamental causes theory helps identify the sources that are contributing to these environmental hazards in the neighborhood.

A seminal paper in medical sociology is the work by Link and Phelan (1995) that proposes the fundamental causes theory. Link and Phelan (1995) state to have an impact in improving population health, there is a need to 1) focus on the context of individual-level risk factors, and 2) emphasize that "social factors such as socioeconomic status and social support are likely 'fundamental causes' of disease (p.80). To disregard these fundamental causes and to continue emphasizing on individual-risk factors in the absence of context would perpetuate the social inequalities that we see in health, especially between Blacks and Whites, or as Krieger (2001) states that "economic and political institutions and decisions that create, enforce, and perpetuate economic and social privilege and inequality are root—or fundamental—causes of social inequalities in health" (p.670).

A conceptual model in which to apply this theory more specifically to low birth weight is through the work by Schulz and Northridge (2004) (Figure 2-2). This model goes beyond the mechanisms proposed in the psychosocial theory by positing that fundamental causes contribute to aspects in the built environment, the psychosocial environment, and other middle-level factors, that then contribute to health outcomes, including birth outcomes. The figure shows that fundamental factors of health disparities include the natural environment, macrosocial factors (such as racism, historical conditions), and socioeconomic inequalities. Intermediate and proximate factors include the built environment (housing codes), social context (community investment in police services), stressors (crime), health behaviors, and social integration and social support.

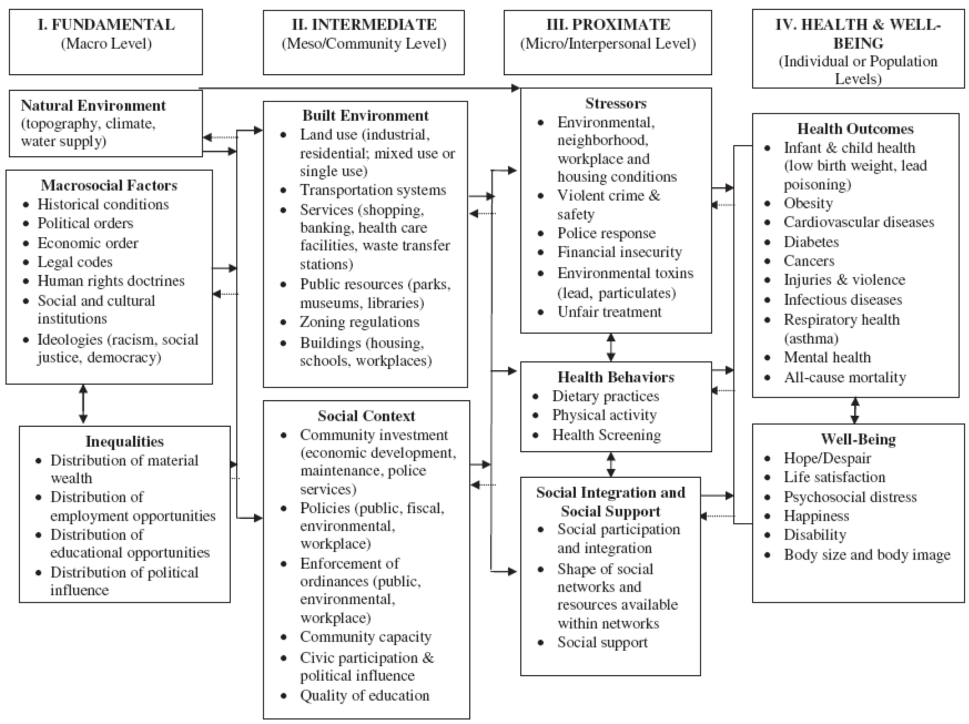

Figure 2-2 Fundamental Causes in Schulz and Northridge's Social Determinants of Health Conceptual Model

Schulz and Northridge's (2004) conceptual model includes the social context in which fundamental factors may affect stressors, health behaviors, and social relationships which can then influence health outcomes. This social context is similar to what Sampson and colleagues (2002) term "social processes" which are mechanisms [that] provide accounts of *how* neighborhoods bring about a change in a give phenomenon of interest" (p. 447). The inclusion of social processes along the pathway towards LBW is important because it depicts a potential mechanism in which LBW may occur: how people interact with each other within a neighborhood may impact health outcomes.

To better conceptualize these social processes, a brief summary of Sampson and colleagues (2002) review of studies on neighborhood and health follows. They identified several indicators of these neighborhood social processes that have been examined in the literature: social capital, collective efficacy, and institutional resources. *Social capital* is defined as the resource resulting from social relationships, or the "quality and quantity of social resources" (Cohen, Finch, Bower, & Sastry, 2006; Kawachi, 1999; Sampson, et al., 2002). An example would be the number of social interactions between neighbors or the number of friendships within neighborhoods (Sampson, et al., 2002). Through these social networks, healthy behaviors and social norms may be diffused throughout the neighborhood. For example, family social support throughout one's pregnancy may encourage individuals to attend prenatal care visits or to assist expectant mothers in finding transportation to attend those visits. The second type, and closely related to social capital is *collective efficacy*, defined as "the linkage of mutual trust and shared willingness to intervene for the public good" among neighborhood residents or "the norms and networks that enable collective action" (Cohen, et al., 2006; Sampson, et al., 2002). Studies have measured collective efficacy through the capacity for informal social control and social cohesion within neighborhoods. An example is that neighborhood residents may be less likely to help each other where there is high mistrust and fear between neighbors. For example, high levels of mistrust may affect levels of social support among neighborhoods in encouraging or assisting expectant mothers in attending prenatal services. The third type of social processes is the presence of *institutional resources*, specifically the quality, quantity, and diversity of institutional resources in neighborhoods that addresses resident's needs. Institutional resources include not only the number or presence of medical facilities that offer prenatal care services, but also those that offer recreational activities, the existence of libraries, police stations, transportation services, and resident participation in neighborhood organizations. High levels of these indicators may result in high levels of social support, less crime, and sufficient capacity to promote a healthier and safer environment that is associated with a broader definition of prenatal care. However, although social processes may be one way to understand how neighborhoods impact health, caveats exist. One is that high social capital, for example, is not always beneficial. Tight social networks may lead to exclusion of racial minorities, for example (Sampson, 2003). Second, consensus is lacking in how to define some of these social processes, and third, efforts are needed to accurately measure some of these social mechanisms at the neighborhood-level (Kawachi & Berkman, 2003; Sampson, 2003).

Applying the fundamental cause theory to LBW is as follows: race, as a social construct, over time has influenced the policies, laws, and economic structures in which neighborhoods have been created. From these policies, laws, and economic structures, certain minority groups, more specifically Blacks, have been segregated to specific neighborhoods in a city. The economic viability of these neighborhoods may decrease due to institutional racism. These areas may then be more likely to experience high levels of neighborhood socioeconomic disadvantage. Neighborhood residents may be less likely to exert control over their neighborhood conditions, which leads to deteriorating neighborhood quality, such as lack of road or sidewalk improvements, decreased spending on public outdoor spaces, lower demand for healthier food establishments, increase in drug trafficking, cigarette smoking, and crime throughout the community, and exposure to toxins (Boslaugh, Luke, Brownson, Naleid, & Kreuter, 2004;

McNeill, Kreuter, & Subramanian, 2006; A.J. Schulz, et al., 2005; A. J. Schulz, Williams, Israel, & Lempert, 2002). As the differences in the quality between neighborhoods widen, social norms are diffused within deprived neighborhoods and advantaged neighborhoods. In deprived neighborhoods, the levels of unhealthy behaviors, such as smoking, lack of physical activity, and lack of regular visits to health care providers are promoted as fear, mistrust, and stressors are fostered. Conversely, residents in advantaged neighborhoods may feel safer, engage in healthier behaviors, through easier access to physical activity resources, better restaurants, and quality grocery stores, and having the means to attend regular medical checkups and have health care providers. The culmination of these fundamental factors, and differences in SEP and social processes may then contribute to wider health disparities, such as in LBW rates, among and within neighborhoods.

2.2.2 Summary

Based on this summary, the fundamental cause theory helps identify factors that are the driving force of why health disparities exist, demonstrates the complexity in relating these factors, and shows the multilevel nature of factors contributing to LBW. More specifically, the theory suggests that the built environment, psychosocial factors, and socioeconomic factors are interrelated, and that social processes exist which may help explain how fundamental factors, more specifically racism, contributes to socioeconomic inequalities that later impact health.

Conceptual frameworks provide an orientation of the complexity and interrelatedness of neighborhood- and individual-level factors. Utilizing the conceptual frameworks in the public health literature helps identify that neighborhoods may be an important level in which to explore the impact of both group-level and individual-level factors on LBW. Although neighborhoods will be the focus of this review, it is important to keep in mind the interconnectedness of neighborhoods among other geographic levels (city, county, state) and other communities (school, work, church). Overall, the theories presented provide a way to organize the various aspects of the neighborhood that may be associated with LBW. With these theories and concepts in mind, the following describes dimensions of SEP and aspects of SEP that may provide insight on the contextual factors associated with LBW.

2.3 AREA-LEVEL SEP

According to Krieger and colleagues (1997), SEP is

> "An aggregate concept that includes both resource-based and prestige-based measures as linked to both childhood and adult social class position. Resource-based measures refer to material and social resources and assets, including income, wealth, educational credentials; terms use to describe inadequate resources include 'poverty' and 'deprivation.' Prestige-based measures refer to individual's rank or status in a social hierarchy, typically evaluated with reference to people's access to consumption of goods, services and knowledge, as linked to their occupational prestige, income, and education level."

Examining SEP provides a way to contextualize risk factors, provides a deeper understanding of why certain subpopulations are more likely to be unhealthy, and further elucidates the fundamental causes of disease (e.g., access to resources, specifically money, knowledge, power, prestige, and social connections) that contribute to health disparities (Link & Phelan, 1995). One way to examine this context is to examine area-level measures of SEP. Area-based measures, obtained by grouping individual-level measures of SEP into the geographic area of interest (e.g., such as census blocks, census tracts, or zip codes), can reflect single indicators of SEP (e.g., occupation class, education, income, wealth, poverty, housing) or combinations of these indicators (e.g., social and/or economic deprivation).

2.3.1 Domains of SEP

Krieger and colleagues (1997) and Galobardes and colleagues (2007; 2006a, 2006b) provide overviews of these domains. These are summarized below.

2.3.1.1 Occupation Class

Primarily used in the United Kingdom, occupation represents the social standing within a society that is based on one's employment and position within that employment. A higher occupation may be interpreted as having a higher income and easier access to resources such as health care and education. Limitations include whether occupation adequately captures differences in SEP (e.g., an executive secretary versus manager in a mid-size company) and excludes individuals outside the labor force (e.g., unemployed workers, retirees).

2.3.1.2 Education

Education represents the knowledge one may have to understand health messages and access to health services, as well as one's potential employment and income. Education can be measured continuously or categorically. As a continuous measure, more years of education suggest better health; as a categorical measure, groupings represent achievements that may represent higher SEP (e.g., professional/graduate degrees high school degrees versus). Limitations include changes in education attainment over time, such as birth cohort effects where older generations may be classified as less educated. Advantages are high response rates, ease in measurement, and inclusion of individuals not in the labor force.

2.3.1.3 Income

Income represents monetary resources available. Income may represent the ability to purchase direct/indirect health-related services and/or products (e.g., education, health insurance, gym membership) that would affect health and/or health behaviors. Income can be measured at the individual-level or at the household level. Limitations are that income is a sensitive topic and may yield low response rates. A strength is that income is considered the "best single indicator of material standards" (Galobardes, Shaw, Lawlor, Lynch, & Davey Smith, 2006).

2.3.1.4 Wealth

Wealth represents the accumulation of assets. Wealth may include savings, inheritance, and home and/or car ownership. Limitations are the low response rates and the feasibility of obtaining wealth information. Similar to income, wealth is "a direct measure of material circumstances" (Galobardes, et al., 2006, p. 58).

2.3.1.5 Poverty

Poverty is another dimension of SEP that is a relative measure of income: poverty is a normative construct judged to be the minimum income level at which one could survive. One limitation of this dimension is that dichotomizing income into either below or above the poverty level may mask the gradient of inequalities. Another way of measuring poverty is by relative need, i.e., the distance by which a family is below or above the poverty line. Limitations are that this measure fails to capture the dynamic experience of being in poverty (one may not be in poverty all the time) and is a subjective state.

2.3.1.6 Housing Characteristics and Housing Amentias

In addition to home ownership (included in the wealth dimension), another related dimension is housing conditions, specifically overcrowding (i.e., housing units with >1 person per room, not including kitchens or bathrooms) (Galobardes, Lynch, & Smith, 2007). Overcrowding of households may indicate inadequate economic resources. Housing amenities include the presence of refrigerators, indoor plumbing, and telephones, which may reflect material circumstances. A limitation is the difficulty in conducting comparisons, such as within the United States, where most of the population will have a refrigerator and indoor plumbing. Advantages include ease of data collection.

2.4 COMPOSITE INDICATORS

A broader approach to understanding the associations between SEP and health is to examine composite indicators, such as area-level economic deprivation or disadvantage. Deprivation indicators are comprised of a variety of measures representing several socioeconomic domains. The following section describes statistical methods to construct composite indicators and examples of three indicators used in health research studies: Townsend Index of Material Deprivation (Townsend, Phillimore, & Beattie, 1988), the Concentrated Disadvantage Index

(Sampson, Raudenbush, & Earls, 1997), and the Neighborhood Deprivation Index (Messer, Laraia, et al., 2006).

2.4.1 Statistical Methods to Develop Composite Indicators

Folwell (1995) summarized the main methodological approaches that have been used to create composite indicators. He categorized these approaches as simple additive indices, weighted index, and multivariate techniques.

2.4.1.1 Simple Additive Index

A simple additive index is created by standardizing the individual SEP measures (z_i) by subtracting off the mean, dividing this difference by the standard deviation, and summing the standardized values to create a z-score index, where

$$z_i = \frac{x_i - \bar{x}_i}{sd_i} \tag{2.1}$$

$$\text{Z-score index} = \sum_{i=1}^{n} z_i \tag{2.2}$$

Although the additive index is of a simple construction, it is difficult to interpret (Folwell, 1995). Measures that are combined to create an index contribute equally to the composite index. The equal weighting "…hides information rather than illuminates it." (Folwell, 1995, p. S5).

2.4.1.2 Weighted Index

A weighted index is similar in construction to the simple additive index, except that the standardized scores are multiplied by weights. Weights represent the relative contributions of measures to the index score: measures that are considered "more important" have larger weights than those deemed to be of less importance. The scores are summed to construct the weighted index:

$$\text{Weighted Index} = \sum_{i=1}^{n} w_i z_i \qquad (2.3)$$

A limitation of this measure is the subjective nature of the weighting scheme. For example, in creating a deprivation index that includes several SEP measures, it is unclear how one would weight one measure (e.g., unemployment) over another (e.g., education).

2.4.1.3 Multivariate Methods: Principal Component Analysis and Exploratory Factor Analysis

Composite indicators also can be created through two types of multivariate techniques: principal component analysis (PCA) and exploratory factor analysis (FA). Both methods are used to examine correlations between variables in a set and to form subsets that are relatively independent from each other (Tabachnick & Fidell, 2007). Combining variables within subsets reduces a large number of variables into a few factors (in FA) or components (in PCA) that are linear combinations of the original variables. Both techniques extract subsets of correlated variables to form factors or components. However, they differ mathematically and in the use of theory to form their construction (Fabrigar, 1999; Tabachnick & Fidell, 2007). Mathematically, PCA analyzes all of the variance in the variables. In contrast, FA analyzes only the shared variance among the variables and not variance due to error or that is unique to a specific variable. In PCA, variables are combined on the basis of empirical correlations to form components; there is no underling theory to explain the observed associations. In FA, the analyst examines combinations of variables and considers the theory that helps explain why certain variables are associated with each other. If theory suggests that an underlying factor represents a selected group of correlated variables, FA may be a more appropriate method to extract interpretable factors, especially in creating composite indicators that reflect underlying concepts like SEP.

In FA, several methodological decisions need to be made (Fabrigar, 1999; Tabachnick & Fidell, 2007). After measuring a set of variables and constructing the correlation matrix of these variables, a set of factors that represent a subset of correlated variables are extracted. The first decision is to select an extraction method. Several extraction methods exist, and one widely used and preferred method is maximum likelihood factoring (a summary of other extraction techniques, such as principal factors and principal components, can be found in Tabachnick and Fidell (2007, p. 633). A special feature of maximum likelihood factoring is the ability to test whether factors are significant, which is useful in confirmatory factor analysis, a more advanced type of factor analysis that involves theory testing (Tabachnick & Fidell, 2007). The second decision is to choose the number of factors to be extracted; the goal is a parsimonious and interpretable solution. One statistical approach to assess the number of factors is by examining a scree plot, a graph of the number of factors versus the corresponding eigenvalue (or variance of the factor). The scree plot usually is decreasing, and the optimal number of factors is based on where the slope of the line changes. For example, if a shift in the slope occurs after the first three factors, then three factors are extracted. In addition to the scree plot, the number of extracted factors should be interpretable (Fabrigar, 1999). Factor interpretation is easier when a factor has several variables correlated to it, and when those variables are correlated with only one factor. Variables that are correlated with more than one factor are considered “complex items” and are more difficult to interpret. In addition to interpretability, factors should make sense based on previous research and theory (Fabrigar, 1999; Tabachnick & Fidell, 2007). Third, if two or more factors are extracted, the solution is rotated. Rotation improves the interpretability of the factors. There are two types of rotations, depending on whether or not the factors are correlated. For factors that are not correlated, an orthogonal rotation is applied. An orthogonal rotation of the factors produces a loading matrix, where factors are not correlated. A common and widely used orthogonal rotation is varimax rotation. For correlated factors, an oblique rotation is applied. The loading matrix in factors that are rotated obliquely also is called the pattern matrix. Unlike the loading matrix of factors that are orthogonally rotated, the pattern matrix represents the unique relationships between each factor and each variable, ignoring the shared variance among correlated factors (Tabachnick & Fidell, 2007). One commonly used family of oblique rotations is direct oblimin, which allows for different degrees of correlation among factors (see p. 639 for additional techniques (Tabachnick & Fidell, 2007). In software statistical packages, a variable, delta, specifies the degree of correlation among factors. Values that are less than 0 become increasingly orthogonal; values that are zero or higher indicate correlation among the factors. Most programs default with a delta equaling zero.

Variables with loadings ≥0.30 from both rotations are interpreted (Comrey & Lee, 1992). Squaring the factor loading can provide a crude index of how much the variable's variance overlaps with the factor. For example, a variable with a factor loading of 0.30 had about 9 percent of its variance in common with the factor. Comrey and Lee (1992) suggest cutoffs to help interpret factor loadings: factor loadings >0.71 are excellent, >0.63 are very good, >0.55 are good, >0.45 are fair, and >0.32 are poor. Variables with factor loadings ≥0.30 are then summed together to create factor scores (Tabachnick & Fidell, 2007).

2.4.2 Examples of Composite Indices of SEP

Several composite indicators of area-level SEP have been used, especially in the United Kingdom, to help guide public policies and allocate public funding (e.g., Carstairs Deprivation Index, Jarman Underpriveleged Area Score (Shaw, 2007). For the purposes of developing a deprivation index relevant to LBW, the following three are described because of their wide recognition and use in health research (Townsend Index of Material Deprivation (Townsend, et al., 1988), incorporation of racial/ethnic composition of an area (Concentrated Disadvantage Index (Sampson, et al., 1997), and development specific to adverse birth outcomes (Neighborhood Deprivation Index (Messer, Laraia, et al., 2006) (Shaw, 2007). An advantage of composite indices is that they acknowledge the multi-faceted aspects of SEP; however, a limitation is that the number of variables used to create the index may make it difficult to identify the true target of subsequent policies.

The Townsend Index of Material Deprivation is widely used in the United Kingdom to reflect "material deprivation," defined as lacking "goods, services, resources, amenities, and physical environment which are customary, or at least widely approved in the society under consideration." (Shaw, 2007; Testi, Ivaldi, & Busi, 2004; Townsend, et al., 1988). The measure is a simple additive index and sums together the following percentages: unemployed, do not own a car, do not own a home, and overcrowded households.

Concentrated Disadvantage reflects the concept that economic changes in urban cities (e.g., Detroit and Pittsburgh) have contributed to the concentration of residents in areas with high levels of poverty, higher proportion of racial minorities and families headed by single females (Sampson, et al., 1997). Using FA with an oblique rotation, variables used to construct Concentrated Disadvantage were percentage below the poverty line, percentage on public assistance, percentage of female-headed families, percentage unemployed, percentage children, and percentage Black. This measure was developed to reflect disadvantage in Chicago neighborhoods (defined by researchers as aggregates of census tracts).

Variables used to construct the Neighborhood Deprivation Index were selected based reported associations between neighborhood SEP factors, racial disparities, and adverse birth outcomes (Messer, Laraia, et al., 2006). Because their interest was to summarize the total variance at the neighborhood level empirically rather than to confirm a factor that represents the measures, Messer and colleagues (2006) used PCA to construct their composite index of SEP. Of the 20 measures initially included in the analysis, eight factors were included in the final score. These are percent of males in management and professional occupations, percent crowded housing, percent of households under the poverty level, percent of female-headed households, percent of households receiving public assistance, percent of households earning less than $30,000 per year, percent with less than a high school education, and the percent unemployed. Item loadings were used to weight each measure to calculate the summary score, and the score was then standardized and divided into quartiles. The measure was used to examine how area-level measures were associated with adverse birth outcomes for census tracts in Baltimore City, Baltimore County, Montgomery County, and Prince Georges County in Maryland.

These three indices, Townsend Index, Concentrated Disadvantage, and the Neighborhood Deprivation Index, differ in the measures included to construct the measures and the statistical methods by which these indices were developed. The only common measure across the indices was percent unemployed. Percent crowding was included in both the Townsend and Neighborhood Deprivation Indices. The Concentrated Disadvantage and Neighborhood Deprivation Indices included percent in poverty, percent on public assistance, and percent female-headed households. The three indices were based on a total of 12 unique census measures.

2.5 THE U.S. CENSUS

2.5.1 Description and Datasets

Many health studies examining the association between area-level factors and health have utilized the U.S. Census as a source of data on SEP. The following section provides a general description of the U.S. Census, including a summary of four main datasets, describes corresponding SEP indicators found in the datasets, and examines different local area-levels (block group, census tract, and zip code) at which data can be aggregated.

The U.S. Census is a collection of data that provides characteristics on the U.S. population, including socioeconomic data. The U.S. Constitution mandates enumeration of the population every 10 years; the last U.S. census was obtained in 2000. Data from the U.S. Census have been used for congressional redistricting, allocating government funds, transportation planning, and informing the public about the area in which they live. In public health, many studies have used the U.S. Census to examine the relationship between local area level SEP and a variety of health behaviors (e.g., early sexual onset, violence, cigarette/alcohol use) and health outcomes (e.g., depression, cardiovascular mortality, adverse birth outcomes) (Browning, Leventhal, & Brooks-Gunn, 2004; Cutrona, et al., 2005; Diez Roux, Borrell, Haan, Jackson, & Schultz, 2004; Foshee, et al., 2008; Messer, Kaufman, et al., 2006).

The U.S. Census data are collected through two surveys: the short form and the long form (U.S. Census Bureau, 2002). The short form was administered to 5 of 6 households. The long form asked additional questions on a sample of the U.S. population (on average 1 in 6 households). Sampling units were housing units. Several sampling rates were applied based on the size of the smallest number of housing units in a specified census area (e.g., counties, cities, school districts, American Indian reservations). Sampling rates were 1-in-2, 1-in-4, 1-in-6, and 1-in-8 with an average sampling rate of 1-in-6. Sampling rates were applied in the following way: if an area included less than 800 housing units in a block, then the sampling rate for the housing units in the blocks of that area was 1-in-2. A sampling rate of 1-in-4 was applied when areas were composed of 800 to 1200 housing units in a block. If a block was not part of areas of either size, a 1-in-8 sampling rate was applied. For blocks that did not meet any of these categories, a 1-in-6 sampling rate was applied to housing units. Sample data collected from the long form are extrapolated to the population level using iterative ratio estimation. The estimation procedure was applied to "geographically defined weighting areas," which are areas within counties that are connected with each other and have least 400 people. For the sample of people, weights were adjusted in four stages to account for type of households (family with dependents, family no dependents, other housing units, people in group quarters), sampling rate, householder status, and age/sex/race/and Hispanic origin. For housing units, weights were adjusted in four stages to account for number of individuals in occupied housing units, sampling rate, race and Hispanic origin of householder/tenure, and the number of vacant housing units for rent or sale.

The four major datasets are: 1) Summary File 1 (SF1) (U.S. Census Bureau, 2001b). Based on the short form, data reflect responses to questions asked of the total population and all housing units. Data include sex, age, race/ethnicity, household relationship (family household residents versus non-relatives in the households), and housing information (occupancy status, owner/renter). 2) Summary File 2 (SF2) (U.S. Census Bureau, 2001a). Based on the short form, data reflect responses to questions asked of the total population and all housing units. In addition to the measures in SF1, the SF2 data include sex by age, average household size, household type, and housing characteristics (tenure) overall and for 250 population groups sub-defined by race/ethnicity. 3) Summary File 3 (SF3) (U.S. Census Bureau, 2002). Based on the long form, data reflect responses to questions asked of a sample of the total population and a sample of housing units. Data include population totals, educational attainment, employment status, occupation, income, and poverty status. Housing data include household size, the number of available vehicles, and home value. 4) Summary File 4 (SF4) (U.S. Census Bureau, 2003). Based on the long form, data reflect responses to questions asked of a sample of the total population and a sample of housing units. In addition to the data in SF3, SF4 data also include the same measures for 336 population sub-groups defined by race/ethnicity.

2.5.2 Local Area Levels

Census data are aggregated into different area levels from blocks all the way to the entire nation (See Figure 2-1). The smallest level at which socioeconomic data can be aggregated (from SF3) is at the block group level. Health studies examining local area levels have employed data at the block group level, and also the census tract level, and zip code level. Other studies have aggregated together block groups or census tracts to form “neighborhoods.”

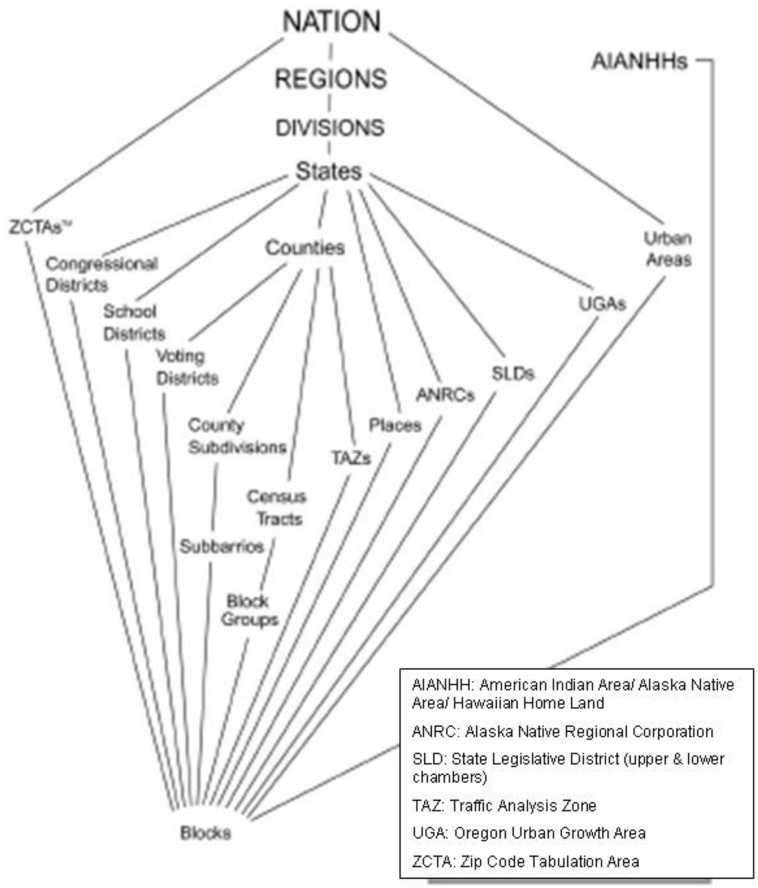

Figure 2-3 Standard Hierarchy of Census Geographic Entities (U.S. Census, 2000)

Understanding the differences between census tracts, census blocks, and zip codes can help determine the advantages and disadvantages of their use (Messer & Kaufman, 2006; U.S. Census Bureau, 2002). In general, census-defined areas are preferred to those defined by zip codes. Census tracts are defined by local or regional data users based on U.S. Census Bureau guidelines, contain an average of 4000 individuals (between 1,000 to 8,000 people) and are designed to contain units that are homogeneous. Boundaries can be geographic, legal, or defined by the government. Census tracts are an area with public health policy implications. To increase the availability of low-income housing in deprived census tracts, the Qualified Census Tract administered by the U.S. Department of Housing and Urban Development examines census tract household income to determine whether low-income housing in the census tract qualifies for tax credits. In addition, the Health and Resources Services Administration can designate census tracts as medically underserved areas that targets for the Health Professional Shortage area program and location for Community Health Centers (Department of Housing and Urban Development, 2006; Health Resources and Services Administration, 1995; Krieger, 2006).

Within census tracts are census blocks, which contain an optimal size of 1,500 individuals (between 600 and 3000 people). *Block groups* are a cluster of blocks, whose boundaries are streets, railroad tracks, streams, administrative boundaries (e.g., county lines). Block groups never cross census tract, state, county, or city boundaries. Block groups are identified with four numbers, with blocks in the same block group having the same first digit (e.g., Block group 3 has blocks of numbers from 3000 to 3999). Making up block groups are census *blocks*, which contain on average 75 individuals and are the smallest level at which data are collected. Boundaries include not only legal, geographic, or governmental boundaries, but also streets, roads, and railroad tracks. However, because of their small size, census blocks are more homogeneous than census tracts but, due to confidentiality issues, socioeconomic data are not available (Krieger, et al., 1997).

Zip code is another way to define the local area, but they are larger areas that contain up to 30,000 people. Zip codes are designed for mail delivery, not by population homogeneity. Zip codes are created by the U.S. Postal Service, and they do not have corresponding census-defined regions (Krieger, et al., 2002). However, in 2000 the U.S. Census created zip code tabulation areas (ZCTAs) to approximate U.S. Postal Service zip code areas (U.S. Census Bureau, 2000). ZCTAs are clusters of addresses in census blocks where the majority has the same zip code. However two major differences exists between ZCTAs and zip codes: zip codes are based on delivery routes along street networks or boundaries that may follow property lines or blocks, and may divide census blocks, and ZCTAs do not include most zip codes of P.O. boxes or companies that have been assigned their own dedicated zip codes. Approximately 10,000 zip codes are not included as ZCTAs (U.S. Census Bureau, 2001c). Zip codes should be considered a last resort for examining neighborhood socioeconomic factors (Krieger, et al., 2002).

2.6 STUDIES EXAMINING AREA-LEVEL FACTORS AND LBW

Several studies have examined the relationship between area-level factors and/or race, and LBW/birthweight. Table 2-3 summarizes the nine studies that have examined this association. These studies varied in the area level at which the analysis was conducted and the SEP indicators examined. First, studies used different area levels: one study used census block groups, four used census tracts, and four used neighborhoods which were defined as comprising more than one census tract. Second, studies used various SEP measures. Two studies used composite indicators of SEP. The most commonly used SEP measure was percent poverty (seven studies used this measure), followed by percent unemployment (three studies used this measure), followed by percent with a high school education and percent Blacks (two used studies used these measures). In addition, these studies were located in California, New York City, Chicago, North Carolina, and in Maryland. In general, these studies reported associations between area-level factors and LBW/birthweight, and more specifically that areas with lower SEP were associated with higher risk of LBW infants and infants with lower average birthweight.

Table 2-3 Studies Examining Area-Level SEP and Birthweight

Author	Area Level of Analysis	Local Area-Level SEP measures	Main Finding
(Buka, et al., 2003)	Neighborhood clusters comprised of 1 or more census tracts	*Economic Disadvantage* proportion residents below poverty proportion receiving public assistance proportion unemployed	For Black women only, mean birth weight decreased significantly as neighborhood economic disadvantage increased
(Grady, 2006)	Census tracts	% families below poverty	Higher neighborhood poverty was significantly associated with higher LBW after controlling for race and residential segregation
(Messer, Laraia, et al., 2006)	Census tracts	*Neighborhood Deprivation* % males in professional and management occupations % crowded housing % households in poverty % female-headed households % households on public assistance % households earning >$30,000/year % earning less than a high school education % unemployed	Increasing percentages of LBW associated with increasing deprivation
(Morenoff, 2003)	Neighborhood clusters comprised of 1 or more census tracts	% Blacks % Mexican origin % poor families % residents who lived at same location for at least 5 years % of owned homes	Black, poor families, and residential stability were significantly associated with LBW, except when after individual factors were added to the model
(Pearl, Braveman, & Abrams, 2001)	Census block groups	% family income below poverty level % males 16 years or older who were unemployed % individuals over age 25 with less than a high school education	High levels of poverty or unemployment result in LBW infants for Black and Asian women
(Pickett, et al., 2005)	Census tracts	Positive income incongruity* % Blacks	For women living in predominantly black census tracts, positive income incongruity was associated with lower risk of LBW. For women living in mixed areas, positive income incongruity was not associated with LBW.
(Rauh, et al., 2001)	Health areas composed of 4-6 census tracts	% of residents below poverty level	Black women in poorer communities were at higher risk for giving birth to infants with moderately LBW
(Rich-Edwards, Buka, Brennan, & Earls, 2003)	Neighborhood clusters comprised of 1 or more census tracts	% households below poverty level	Neighborhood poverty was a significant moderator of age in predicting LBW. LBW was higher in communities with higher percentage of households in poverty and with older women.
(Schempf, et al., 2009)	Census tracts	Structural Process Risk Index % Black % Poverty Violent crime rate (per 1000) % Boarded-up housing	After controlling individual-level socioeconomic characteristics, 1 SD increased in structural process risk index was associated with 76g decrease in birthweight

*positive income incongruity measures "whether or not Black women were living in a wealthier census tract than might be expected"

2.6.1 Studies Examining the Association between Area-Level Factors and LBW

Several studies examined the association between area-level SEP and LBW. Rich-Edwards and colleagues (2003) demonstrated that neighborhood poverty interacted with age and was a significant predictor of LBW, even after controlling for individual-level factors (OR: 1.00, 95% CI 1.00-1.00, NOTE: authors state that CI excluded 1.00 before being rounded to 2 decimal places). Messer and colleagues (2006) developed a neighborhood deprivation index and demonstrated that most of the sites showed a significant trend in higher levels of deprivation and higher percentage of LBW. Morenoff (2003) on the other hand examined several neighborhood variables, including percent Blacks, % family poverty, residential stability, violent crime rate, and level of exchange/voluntarism. Although initially, percent Blacks (OR: 1.50, $p<0.01$) and percent of family poverty (OR: 1.07, $P<0.001$) were significant, after controlling for other neighborhood factors and individual-level factors, these factors were no longer significant (OR Black: 1.01, p=NS; OR family poverty: 0.97, p=NS), and level of exchange/voluntarism (0.96, $p<0.05$) was now significant. Schempf and colleagues (2009) found that neighborhood SEP as measured by percent Black, percent poverty, rate of violent crime, and percent of boarded-up housing, was significantly associated with birthweight: after controlling for individual-level SEP. A one standard deviation (SD) increase in neighborhood SEP contributed to a decrease of 76 g in birthweight. Some of this decrease was partially explained once psychosocial factors such as stress and emotional support were included in the model.

Although studies demonstrate an association between area-level SEP and LBW, differences in this association between Blacks and Whites may exist. The following three studies demonstrated a significant association between area-level SEP and birthweight for Blacks, but not for Whites. In Buka and colleagues (2003) study, 1 SD increase in neighborhood economic disadvantage corresponded to a 13.1g decrease in birthweight for Black mothers, which was significant ($p<0.0005$). Although a decrease in birthweight was also observed for White mothers as neighborhood economic disadvantage increased, the association was not significant. Similarly, Pearl and colleagues (2001) showed that higher levels of neighborhood unemployment ($p<0.05$) were significantly associated with decreasing levels of birthweight for Blacks, but not for Whites. Rauh and colleagues (2001) showed a significant association between neighborhood SEP (as measured as neighborhood poverty level) for Blacks ($\beta=0.08$, 99% CI=0.02-0.13), after controlling for individual-level maternal SEP and characteristics (education, marital status, smoking, age, birth order, receipt of Medicaid, marital status, smoking, education substance abuse). For Whites, there was no significant association between neighborhood poverty and LBW ($\beta=0.03$, 99% CI=-0.05-0.12) These findings suggest that area-level SEP may be operating differently between Blacks and Whites in relation to LBW.

2.6.2 Relationship among Race and LBW Risk

In addition, the following studies examine the risk of LBW by comparing Blacks to Whites in the same model. Buka and colleagues (2003) showed that the mean birthweights of Blacks was significantly lower than Whites and the variability of birthweights between neighborhoods was significant, although the proportion of the variance between neighborhoods was small (0.57 for Blacks and 0.93 for Whites). After controlling for SEP (as measured by proportion of residents living below poverty, receiving public assistance, and employment), 81% of the between neighborhood variance for Blacks and 76% of the between neighborhood variance for Whites was explained. In addition, Buka and colleagues (2003) found in the unadjusted model, differences between birthweights between Blacks and Whites was 273 grams, followed by 154g after controlling for maternal characteristics, such as, age, marital status, education, prenatal care, parity, and number of cigarettes smoked. After controlling for neighborhood SEP, the birthweight difference between Blacks and Whites decreased to 121 g.

Differences may be explained by the interaction between race and maternal age. Geronimus' (1992) "weathering hypothesis" posits that early stressful events may have an impact on women's and infant's health and that the cumulative effects of social inequalities, such as racism and discrimination, are manifested as such that disparities between Blacks and Whites are widest in the older age groups. Rich-Edwards and colleagues (2003) found a significant interaction between Black and age: the risk of LBW was higher for Blacks as age increases, more so than Whites (OR: 1.05, CI=1.04-1.06) in unadjusted models. In addition, the interaction between age and neighborhood poverty was significant. Results demonstrated that in neighborhoods with higher levels of poverty (50% of households) versus neighborhoods with lower levels of poverty (1% of households), the odds ratio for LBW in the 20 years age group was 1.00 (95% CI, 0.91-1.10) compared to 1.34 (95% CI: 1.13 to 1.56) in the 40-year age group. However, after controlling for individual-level factors, neighborhood factors, and interactions with individual-level and area-level factors with age, LBW risk was higher as maternal age increased, regardless of race. As the authors noted, LBW risk increased with maternal age for unmarried women who smoked, lived in impoverished neighborhoods, and did not receive adequate prenatal care for both White and Black mothers. However, in contrast Rauh and colleagues (2001) found no interaction between age and community-level poverty. The only significant interaction term was age and Medicaid status, and significant differences continued between Blacks and Whites. The adjusted odds ratio for moderately LBW between Blacks and

Whites was 1.8 at age 20, 2.2 at age 30, and 2.6 at age 40. For very LBW, the odds ratio between Blacks and White ranged from 2.5 to 4.2 from age 20 to 40.

Another difference may be due to the proportion of minorities in the neighborhood and its association with relative measures of neighborhood SEP. Pickett and colleagues (2005) studied this relationship in a group of single infants born to Black women living in Chicago. The association between LBW and "positive income incongruity," or a measure of whether the woman lived in a wealthier census tract than an average Black woman with the same education and marital status, was compared in census tracts comprised predominantly of Blacks (≥90%) or mixed (<90%). The association between positive income incongruity was not significant for LBW, although the trend suggests a protective effect of positive income incongruity in predominantly AA-tracts versus mixed tracts. For women living in predominantly AA-tracts, the odds of LBW was 0.91 (p=0.2) for women who had positive income incongruity. In contrast, in mixed areas, the odds of LBW was 1.04 (p=0.63) for women with positive income incongruity. In a similar study, but set in Wake and Durham counties of North Carolina, a less racially segregated area than Chicago, authors (Vinikoor, Kaufman, MacLehose, & Laraia, 2008) found similar, albeit not significant results. In areas with high proportion of Blacks, the odds for LBW for women with positive income incongruity was 0.90 (95% CI, 0.80-1.01). In contrast, in areas with low proportion of Blacks, the odds of LBW for women with positive income incongruity was 1.00 (95% CI: 0.76-1.33).

Other studies suggest neighborhood differences in LBW can be explained by residential segregation or the "physical separation of the races in residential contexts" (Williams & Collins, 2001), p. 404) more so than neighborhood poverty levels. In a study of LBW in New York City, Grady found that the odds ratio for LBW comparing Blacks to Whites decreased from 1.54 (95%

CI, 1.46-1.64) to 1.40 (95% CI, 1.32-1.50) after adding a measure of residential segregation, to 1.53 (95% CI, 1.44-1.62) after adding a measure of neighborhood poverty, and to 1.40 (1.32-1.50) after adding both residential segregation and neighborhood poverty to the model, after controlling for marital status, education, Medicaid, smoking status, substance abuse, maternal age, and foreign-born status. In addition, neighborhood and Black were considered random effects in the model. In the model with only individual-level variables, the variance of the intercept and Black were significant, suggesting that there were significant differences in LBW among neighborhoods and the effect of Black on LBW among neighborhoods was different. However, differences among neighborhoods and Blacks were no longer significant ($p<0.10$) after adding residential segregation to the model but remained significant after adding neighborhood poverty into the model ($p<0.05$). This suggests that the differences between neighborhoods and among Blacks were explained by residential segregation.

In summary, measures of neighborhood SEP, measured in various ways ranging from neighborhood poverty to composite measures of SEP showed a positive association with birthweight and LBW risk. In addition, some studies have suggested that the association between area-level SEP and LBW may be operating differently between Blacks and Whites. The different mechanisms could be due to differences in the impact of racism within Blacks and Whites, manifested as culmination of life course events (weathering hypothesis) or racial residential segregation.

2.7 MULTILEVEL ANALYSIS

In interpreting results that represent data on multiple levels, two fallacies may occur. The first type of fallacy is the ecological fallacy, where higher level results are interpreted at the individual level. For example, block group data are aggregated to the neighborhood level to examine neighborhood differences in SEP. Interpretation of the aggregated data must be made at the neighborhood level, not at the block group level. Aggregating the data results in decreased power given that some information is lost when block group data are aggregated to the neighborhood level (Tabachnick & Fidell, 2007). Another fallacy is the atomistic fallacy, where lower level results are interpreted at the higher level. For example, block group results cannot be interpreted at the neighborhood level.

2.7.1 Multilevel Analysis

One method to take into account multiple area levels of the census data and to reduce the likelihood of committing the aforementioned fallacies is multilevel analysis (Tabachnick & Fidell, 2007). In a two-level study, for example, parameters at level 1 (the lower level at which data are available, e.g., individuals) and parameters at level 2 (higher level at which data are available, e.g., neighborhoods) are analyzed simultaneously to predict health outcomes. For dependent variables where the outcome is dichotomous (for example, 1 = success and 0 = failure), typical equations for multilevel logistic regression would look like the following.

At level 1, the equation is:

$$\log it\ (P_{ij}) = \beta_{0j} + \beta_{1j}(X_{ij}) \qquad (2.4)$$

where,

i is level 1 data (e.g., individual level data) and *j* is level 2 data (e.g., neighborhood level data).

P_{ij} = The observed dependent dichotomous variable at level 1 for the jth group
X_{ij} =The independent variable or predictor at level 1 for the jth group.
β_{0j} = The intercept for the dependent variable in group j.
β_{1j} = The slope or the relationship between the independent variable and the dependent variables within group j.
logit is the function or link that transforms the dichotomous outcome (P_{ij}, 0 or 1) into a continuous variable (-∞ to +∞) with linear parameters.

At level 2, the equations are:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} z_j + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + u_{1j} \qquad (2.5)$$

γ_{00} = The grand mean of the dependent variable across all groups when predictors are zero.
γ_{01} = The overall regression coefficient for the relationship between the level 2 predictor and the dependent variable
γ_{10} = The overall regression coefficient for the relationship between level 1 predictor and the dependent variable
z_j = The predictor at level 2
u_{0j} = The random error for the deviation of the intercept of level 2 from the overall intercept
u_{1j} = The deviation of the group slopes from the overall slope.

Combining these two levels, the final model would look like the following:

$$\log it(P_{ij}) = \gamma_{00} + \gamma_{01} z_j + \gamma_{10} * x_{ij} + u_{0j} + u_{1j} * x_{ij} \qquad (2.6)$$

To interpret the relationship between the predictor variables and the outcome, the coefficients can be transformed into odds ratios. For example, transforming γ_{01}, the equation would be

$$odds\ ratio = \frac{\exp(\gamma_{00} + \gamma_{01} + \gamma_{10})}{\exp(\gamma_{00} + \gamma_{10})} = \exp(\gamma_{01}) \qquad (2.7)$$

and would be interpreted as the odds of observing $P_{ij}=1$ if $z_j=1$ versus if $z_j=0$. To determine whether a significant association exists between predictor and outcome would be based on the z-test of the fixed parameters or a Wald's test of the random effects.

It is important to note that unlike multilevel linear regression, variance at the level-1 does not include a residual or error term because as Hox states (2002), "In the binomial distribution, the variance of the observed proportion depends only on the population proportion. As a consequence, the lowest level variance is determined completely by the predicted value for π_{ij}, and it does not enter the model as a separate term" (p.114). This will have implications on the calculation of the intraclass correlation coefficient (ICC) which measures the contribution of the variance between neighborhoods to the total variance at the neighborhood and individual group levels (Hox, 2002). For multilevel linear regression, the ICC is calculated:

$$ICC = \frac{\tau^2_{neighborhoods}}{\tau^2_{neighborhoods} + \sigma^2_{indiviuals}} \tag{2.8}$$

In the formula, $\tau^2_{neighborhoods}$ is the between neighborhood variance, $\sigma^2_{individuals}$ is the individual-level variance. Together they sum to the total variance. The ICC can range from zero to one (Reise, Ventura, Nuechterlein, & Kim, 2005). For example, in a two-level analysis with individuals and neighborhoods, an ICC of 0 means that all of the variation is occurring between block groups within neighborhoods, but not between neighborhoods. On the other hand, an ICC of 1 means that all of the block group variation is due to neighborhood differences. A z-test statistic can be used to assess the significance of the variances at each of the levels.

However, because in multilevel logistic regression, the outcome is dichotomous, not continuous, and there is no direct measure of the level-1 variance, Snijders and Bosker (1999) use an estimate of the level-1 variance as $\pi^2/3$ or 3.29. An ICC for multilevel logistic regression is:

$$ICC = \frac{\tau^2_{neighborhoods}}{\tau^2_{neighborhoods} + \frac{\pi^2}{3}} \tag{2.9}$$

Other measures can be calculated to help in interpretation: autocorrelation statistic and the explained proportion of the variance (R^2). Spatial similarity between neighboring areas, such as neighborhoods, can be measured by an autocorrelation statistic. One common autocorrelation statistic is the Moran's I statistic (Bailey & Gatrell, 1995; Chaix, Merlo, & Chauvin, 2005; Pfeiffer, 2008):

$$I = \frac{N\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\left(\sum_{i=1}^{N}(y_i - \bar{y})^2\right)\left(\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\right)} \tag{2.10}$$

$$where\, i \neq j$$

In this formula (using neighborhoods as an example), N represents the number of neighborhoods, $y_i - \bar{y}$ is the neighborhood-level residual, and w_{ij} is a weight that depends on the distance between neighborhood i and neighborhood j. The weight provides greater value to areas that are closer in distance to each other than those areas that are farther away from each other (Pfeiffer, 2008). A commonly used weight is "queen contiguity" which puts more weight on areas that share a border or corner with each other. The statistic is similar in interpretation to a Pearson's correlation coefficient: 0 indicates no clustering, +1 indicates positive spatial autocorrelation (adjacent areas cluster and are similar), and -1 indicates negative spatial autocorrelation (adjacent areas are dissimilar). Significance is estimated using Monte Carlo randomization.

R^2 proposed by Snijders and Bosker (1999) is an extension of McKelvey and Zavonia (1975) measure. The measure captures the amount of variation is explained by inclusion of variables into the model. To calculate R^2, the following formula is used:

$$R^2 = \frac{\sigma^2_{variance\ of\ \hat{Y}_{ij}}}{\sigma^2_{variance\ of\ \hat{Y}_{ij}} + \tau^2_{neighborhoods} + \frac{\pi^2}{3}} \qquad (2.11)$$

where $\sigma^2_{variance\ of\ \hat{Y}_{ij}}$ is the explained part of the variance, and the other variances are the unexplained variance in the model. Snijders and Bosker (1999) note that for logistic models, this R^2 will be less than its counterpart for continuous outcomes.

In summary, there are several elements that will help in interpreting results of a multilevel logistic regression model. First, the ICC can help determine if there is high level of variation between neighborhoods that would warrant a multilevel analytical approach. Second, interpretation of significance tests can help determine if an association exists between the predictor and outcome. Third, to understand the magnitude of the association between the predictor and the outcome, an odds ratio can be calculated to further help interpret the relationship between the two variables. Fourth, variance components can also be interpreted to examine whether the predictor is contributing to explaining the variation among neighborhoods. Fifth, spatial autocorrelation is a descriptive measure to help summarize spatially how similar neighboring areas are. Sixth, the explained variance can help describe how much of the variation is being explained by including variables in the model.

3.0 METHODS

3.1 DATA FOR PITTSBURGH, PENNSYLVANIA

3.1.1 Units of Analysis

Two levels of geographic areas are available for analysis: census tracts and census block groups, as defined in the U.S. Census, and neighborhoods, which are combinations of census tracts defined by the City of Pittsburgh. A total of 90 neighborhoods exist in Pittsburgh, Pennsylvania (see Appendix A for map of Pittsburgh) and are used by the City of Planning Department for planning purposes. These neighborhoods are comprised of 140 census tracts, which are then composed of 343 block groups (see Figure 3-1). For example, four of the 90 neighborhoods in Pittsburgh are West Oakland, North Oakland, Central Oakland, and South Oakland. One to two census tracts and one to four census block groups make up these neighborhoods. For this paper, levels in the analysis are defined as in the following: three-level analysis encompasses individuals at level 1, block groups at level 2, and neighborhoods at level 3.

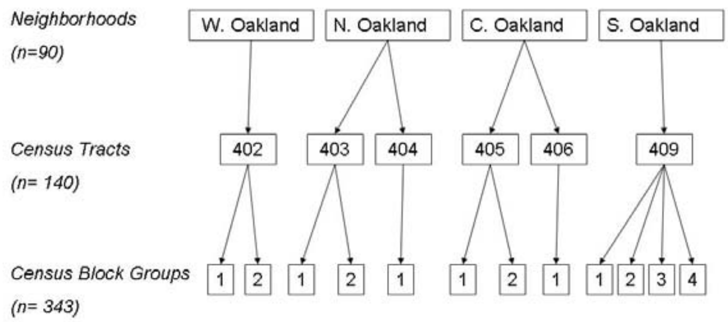

Figure 3-1 Example of Area Levels in Pittsburgh, Pennsylvania

3.1.2 LBW

LBW proportion was defined as the number of LBW infants (<2500g) divided by the total number of singleton births. Geocoded birth data were obtained from Allegheny County Birth Registry Data for 2003 to 2006. There were a total of 52,551 births born to Black non-Hispanic or White non-Hispanic mothers in Allegheny County. Observations were excluded if mothers resided outside of Pittsburgh (38,913), race information was missing (1315), mother delivered multiple births (447), birthweight was missing (18), census tract information was missing (632), and individual-level covariates were missing (397). Because no birth data were available for Chateau neighborhood (which includes one census block and one census tract) and for one census tract and block group in the Marshall-Shadeland neighborhood, these areas were excluded from the final analysis. The final analysis included data on 341 block groups, 139 census tracts, and 89 neighborhoods. On average, the range of individuals living in neighborhoods was 1 to 538, with a mean number of 121.6 (SD: 105.3), and a median of 94 (25^{th}:75^{th} percentile; 42:185).

The range of individuals living in block groups was 1-135, with a mean of 31.8 (SD: 18.8), and a median of 28 (25^{th}:75^{th} percentile: 20:39). The range of block groups per neighborhoods was 1 to 15, with a mean of 3.8 (SD: 3.16) and a median of 3 (25^{th}: 75^{th} percentile: 1:5). Twenty-five neighborhoods were comprised of one block group.

3.1.3 Area-Level SEP

Measures of SEP for block groups and neighborhoods were developed by Almario Doebler (2009). In summary, U.S. Census data at the census block group level were extracted for Allegheny County (in which Pittsburgh is located) from the U.S. Census 2000 SF3 file. These SEP measures were based on those included in the Neighborhood Deprivation Index (Messer, Laraia, et al., 2006), Concentrated Disadvantage (Sampson, et al., 1997), and Townsend Material Deprivation Index (Townsend, et al., 1988) collectively. Measures are percentages of individuals or households with the following characteristics: are unemployed, do not own a car, are living in crowded households, are renters, are professionals, are in poverty, are in female-headed households, receive public assistance, earn low income, have a low education, are Black, or are under 18 years of age. Raw data at the block group level were summed to create corresponding measures at the census tract and neighborhood levels (i.e., census sampling weights were ignored). The linkage between census block groups and census tracts were provided in the U.S. Census data. The linkage between census tracts and neighborhoods is defined by the city (City of Pittsburgh Department of City Planning, 2000) (see also Appendix B). All analyses are limited to data for Pittsburgh, Pennsylvania. Multilevel factor analysis was used to create factors at the block group and neighborhood levels.

To calculate factor scores, variables with negative factor loadings were reverse coded. For within neighborhood factor scores, raw values of the SEP variables whose factor loadings were ≥0.30 were added together then divided by the number of variables with factor loadings ≥0.30. For between neighborhood factor scores, computations were similar to within neighborhood factor score computations, but with an additional step: the mean of SEP variables was calculated for each neighborhood to create between neighborhood factor scores.

Three measures were created: Overall Neighborhood Disadvantage (OND_{ijk}), Block Group Concentrated Disadvantage (CD_{ij}), and Block Group Material and Economic Deprivation (MED_{ij}). For additional description of the methods, see Almario Doebler (2009).

Table 3-1 Factor Loadings of Items in Area-Level SEP Measures

	MED_{ij}	CD_{ij}	OND_{ijk}
% Unemployment	.05	.15	**.78**
% of Households with No Car	**.75**	-.04	**.94**
% of Crowded Households	.18	.23	**.46**
% Renters	**.75**	-.09	**.61**
% in Professional Occupation	-.25	-.12	**-.45**
% of Households in Poverty	**.60**	.24	**.87**
% Female Headed Households	.12	**.82**	**.75**
% on Public Assistance	**.35**	**.53**	**.73**
% with Income < $30K	**.90**	-.04	**.93**
% with < High School Education	.29	.08	**.74**
% Black	.22	**.47**	**.76**
% Under 18 Years of Age	-.20	**.84**	**.42**

3.1.4 Individual-Level Covariates

Individual-level sociodemographic, health care access, and health behaviors are obtained from Allegheny County Birth Registry. A summary of all variables included the analysis are listed in Table 3-2. Due to high percentage of missing (15%), prenatal care utilization, health insurance status, and pre-pregnancy weight were excluded from the analysis. Variables selected were identified in the literature as having a significant association with LBW. WIC was included as a proxy for health care access. WIC, or Special Supplemental Nutrition Program for Women, Infants, and Children is a grant program funded by the Federal government to provide services and food to low-income pregnant, postpartum, breastfeeding women, and children up to age 5 who are at "nutrition risk." Individuals who fall below the poverty line or receive public assistance automatically meet the income requirement. Those who have poor pregnancy outcomes, are anemic, or have inappropriate dietary practices meeting "nutrition risk" (USDA, 2010).

Table 3-2 Variables Included in Analysis

Variables	Values
Independent Variables (Individual-Level)	
Sociodemographic	
Race	Black White
Maternal Age	Continuous
Education	No College Some College
Marital Status	Married Not Married
Infant Sex	Male Female
Birth Order (Previous Births)	1 2_3 >=4
Health Care Access	
WIC	Yes No
Health Behaviors	
Any cigarette smoke during pregnancy	Yes No
Area Level Factors	
OND_{ijk}	Continuous
MED_{ij}	Continuous
CD_{ij}	Continuous

3.2 STATISTICAL METHODS

The following data analysis strategy will be employed: data exploration, multilevel logistic regression analysis, and diagnostics. The data exploration step will examine the distribution of the outcome and covariates of interest, including by neighborhoods and block group. Data exploration will also include calculation of the ICC to determine whether the variation of LBW differs significantly among neighborhoods. Multilevel logistic regression will used to examine differences between Blacks and Whites in LBW, and also differences after controlling for individual-level covariates and area-level measures of SEP. Diagnostics will identify potential outliers and examine their influence on the results.

3.2.1 Data Exploration

Data exploration summarizes the distribution of the covariates of interest (listed in Table 3-2) and LBW, and compares differences in the covariates between Blacks and Whites. Differences were tested using chi-square. Using ARCGIS, maps were created for Pittsburgh for LBW and area-level SEP, including a map that overlays neighborhood LBW percentages on top of levels of area-level SEP at the block group and neighborhood levels. GeoDa 0.9.5-I was used to calculate Moran's I statistic for LBW and area-level SEP At block groups and neighborhoods. Queen contiguity was used as the weight matrix, and inferences were based on Monte Carlo simulation with 999 permutations and $p<0.05$ as indicating statistical significance (Anselin, 2004). In addition, given the relationship among race, cigarette smoke, and age, an interaction among all three are tested.

3.2.2 Multilevel Logistic Regression: Individual-Level Covariates

Each of the individual-level covariates were regressed on LBW. A multilevel approach was used to account for clustering and the block and neighborhood levels. Random intercept at the neighborhood level was indicated. Iterated generalized least squares was used to generate initial starting estimates for the model, then Bayesian estimation using Markov Chain Monte Carlo was used to for final analysis to provide final estimates. Interactions were also examined for the following: race*cigarette smoke, race*maternal age, maternal age*cigarette smoke, and race*cigarette smoke*maternal age.

3.2.3 Multilevel Logistic Regression: Individual-Level Covariates and Area-Level SEP

Multilevel logistic regression is used to regress area-level SEP and individual-level factors on LBW, and fives sets of models are analyzed, which are listed in Table 3-3. The null model, absent of predictors is the first model. This model provides the average estimate of LBW, absent all the predictors. Preliminary analysis demonstrated that the three-level ICC that included the variance at the individual, block group, and neighborhood levels resulted in a very small contribution of the total variance at the block group level. Based on the lack of variability at the block group level, further analysis retained the nested structure of the data (individuals within block groups within neighborhoods), but included a random intercept only at the neighborhood level. In addition, random effects of slopes were tested but were found to be non-significant. Models included only a random intercept at the neighborhood level.

The second set of models includes area-level SEP measures only. The third set of models included race and area-level SEP. The fourth set of models included race and individual-level factors. The fifth set combines the third and fourth sets by running race, individual-level factors, and area-level SEP in predicting LBW. The sixth model only included individual-level disadvantage (no education, not married, and receipt of WIC services) and OND_{ijk}. Individual-level disadvantage is reflective of some of the individual SEP measures included in $OND_{ijk.}$

Table 3-3 Sets of Models in Analysis

Sets	Model Parameters
1	Null model (intercept-only)
2	Area-level SEP
3	Race + Area-level SEP
4	Race + individual-level covariates
5	Race + individual-level covariates + Area-level SEP
6	Race + individual-level SEP + OND_{ijk}

To understand the components of the model, the logistic regression mixed model with effects on level-1 are presented, followed by the effects on level-2. This section concludes with a presentation of the full model that incorporates both main effects on level-1 and level-2 and interaction terms of factor scores between the two levels. Level-1 model is written as follows:

$$\log it(P_{ij}) = \beta_{0j} + \beta_{1j}(X_{1ij} - \overline{X}_{2j}) \quad (3.1)$$

where P_{ij} is the probability that an individual *i* gives birth to a LBW infant given X_{1ij} in neighborhood *j*; β_{0j} is the intercept; β_{1j} and β_{2j} are the slopes for the relationship between and individual-level covariate, such as education) and LBW. More specifically, β_{1j} is the association between the education-level and LBW for individuals within a neighborhood; X_{1ij} is the value education at the individual level. The logit is transformation so that the parameters are a linear regression equation.

The neighborhood level equations are written as follows:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * (Z_j - \overline{Z}) + \mu_{oj} \quad (3.2)$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} * (Z_j - \overline{Z}) \quad (3.3)$$

where, γ_{00} is the average log odds of LBW for neighborhoods with an average disadvantage score; γ_{01} is the regression coefficient of overall neighborhood disadvantage predicting LBW; γ_{10} is the average regression coefficients for neighborhood SEP with the proportion of LBW at the mean overall neighborhood disadvantage across neighborhoods; γ_{11} quantify the extent to which neighborhood disadvantage moderates the association between individual-level education and LBW; μ_{oj} is the random deviation of a neighborhood's intercept from the overall intercept. The variance of this random effects is τ_{00}. Between neighborhood factor scores were grand mean centered by subtracting the mean between factor score for all neighborhoods from the between factor scores of each block group.

The full model is

$$\log it(P_{ij}) = \gamma_{00} + \gamma_{01} * (Z_j - \overline{Z}) + \gamma_{10} * \left(X_{1ij} - \overline{X}_{1j}\right) + \gamma_{11} * \left(Z_j - \overline{Z}\right) * \left(X_{1ij} - \overline{X}_{1j}\right) + \mu_{oj} \tag{3.4}$$

Although the coefficients provide us whether an association exists between neighborhood and individual-level predictors, understanding the magnitude of the association can be done by transforming the coefficients into odds and calculating an odds ratio of having a LBW infant among individuals with, for example, no college degree versus the odds of having a LBW infant among individuals with a college degree. .This is done by taking the inverse of logit, or exponentiating the right hand of the model. In this example, the odds of giving birth to a LBW infant given that one has no college education versus those who do have a college education

$$Odds\ Ratio = \frac{\exp(\gamma_{00} + \gamma_{01} + \gamma_{10} + \gamma_{11})}{\exp(\gamma_{00} + \gamma_{01} + \gamma_{11})} = \exp(\gamma_{10}) \tag{3.5}$$

In addition the variance of the random effect (μ_{oj}) is also interpreted to examine whether significant variation among neighborhoods continue to exist after adding covariates. Significant associations were determined by a $p<0.05$.

Multilevel logistic regression analysis used MLWIN version 2.17 (Rasbash, Charton, Brown, Healy, & Cameron, 2009). Models are specified with a logit link and binomial distribution. Random effects were indicated for the neighborhood intercept only. Iterated generalized least squares was used to generate initial starting estimates for the model, then Bayesian estimation using Markov Chain Monte Carlo was used to for final analysis to provide final estimates (Browne, 2009). In addition to focusing on the association between area-level SEP and LBW, the association between race and LBW, specifically odds ratio of race in the unadjusted model (model 6) was compared to models adjusting for individual-level and area-level factors.

The following models were tested:

Table 3-4 Models Tested

Model	Model Parameters
1	Null model (intercept-only)
2	OND_{ijk} only
3	MED_{ij} only
4	CD_{ij} only
5	ALL SEP
6	Black only
7	Black + OND_{ijk}
8	Black + MED_{ij}
9	Black + CD_{ij}
10	Black + ALL SEP
11	Black + Individual-level sociodemographics
12	Black + Individual-level sociodemographics + Health Care Access
13	Black + Individual-level sociodemographics + Health Care Access + Health Behavior
14	Black + Individual-level sociodemographics + Health Care Access + Health Behavior + Interactions
15	Black + Individual-level sociodemographics + Health Care Access + Health Behavior + Interactions + OND_{ijk}
16	Black + Individual-level sociodemographics + Health Care Access + Health Behavior + Interactions + MED_{ij}
17	Black + Individual-level sociodemographics + Health Care Access + Health Behavior + Interactions + CD_{ij}
18	Black + Individual-level sociodemographics + Health Care Access + Health Behavior + Interactions + ALL SEP
19	Black + Individual SEP
20	Black + Individual SEP + OND_{ijk}

3.2.4 Example Neighborhoods

To better understand the association between the predictors and the predicted LBW proportion, four neighborhoods (East Liberty, Garfield, Shadyside, and Squirrel Hill North) were selected to examine OND_{ijk} levels, predicted LBW, and observed LBW based on the models with OND_{ijk} alone and with OND_{ijk} and race included in the model.

3.2.5 Diagnostics

Residuals of the model were checked using caterpillar plots and diagnostics were used to identify potential influential points. Sensitivity analysis was conducted by comparing regression results from the original model to model where outlying neighborhoods were excluded. Coefficients and standard errors of fixed effect parameters, and estimates and standard errors of random effects were compared between the original model and model excluding potential outliers.

4.0 RESULTS

4.1 DESCRIPTIVE ANALYSIS

4.1.1 Summary of LBW in Pittsburgh

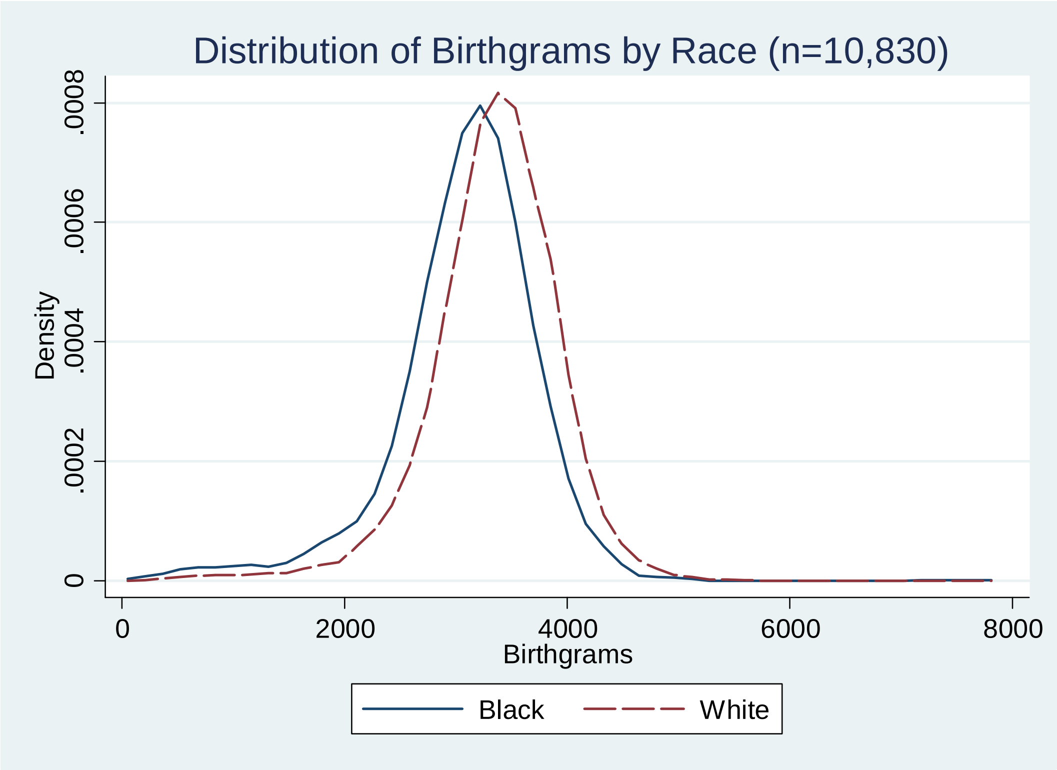

Figure 4-1 Distribution of Birthweight by Race

The overall mean birthweight was 3241.6 g. Figure 4-1 shows the distribution of birthweight by race. The mean for Whites was 3346.8g, and the mean for Blacks was 3087.5g, which were significantly different from each other (t(1)=-21.4, p<0.001). In terms of LBW, Figure 4-2 shows a higher proportion of Blacks gave birth to LBW infants than Whites ($\chi2(1)$=135.8, p<0.001).

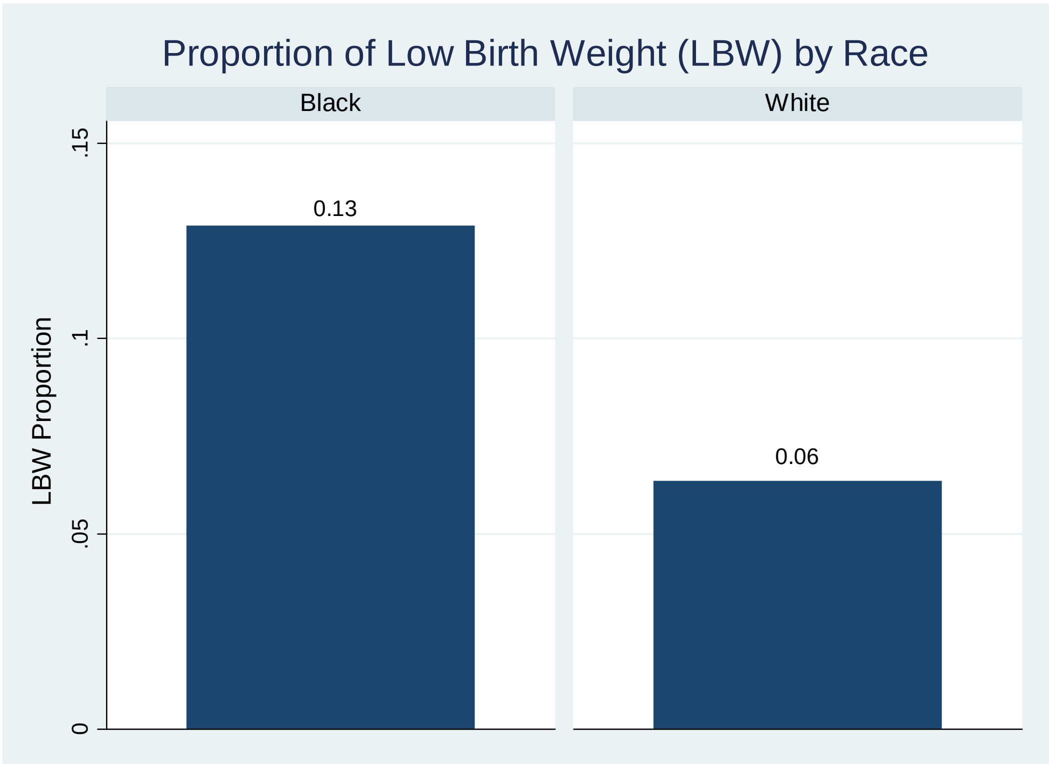

Figure 4-2 Proportion of LBW by Race

4.1.1.1 LBW by Neighborhood and Block Group

To understand the distribution of LBW by neighborhood and block groups, Figures 4-3 and 4-4 depict the proportion of LBW infants by neighborhoods and block groups, respectively. In these maps, the proportion of LBW is divided into quartiles with darker shades indicating areas with higher proportion of LBW whereas areas lighter shades depict areas with lower LBW proportions. Figure 4-3 shows LBW proportion by neighborhoods, and Figure 4-4 shows LBW proportion by block groups. Darkest shades are indicated towards the eastern part of Pittsburgh (Homewood North 41, Homewood South 42, and Homewood West 43), Lincoln-Lemington-

Belmar 46, Homewood neighborhoods), central Pittsburgh (Bluff 11, Central Oakland 19, Middle Hill 51, North Oakland, 19, and Terrace Village 81), and northwest (California Kirkbride 15, Central Northside 18, Manchester 49, Marshall-Shadeland 50, Northview Heights 58, Perry South 62). Lighter shade include Squirrel Hill North (77) and Shadyside (69) to the east. The northwest includes Brighton Heights (13). Similar patterns were observed for LBW by block groups (Figure 4-4), and some neighborhoods varied by block groups. For example, different proportions of LBW were observed within Homewood and Shadyside. The observed proportion of LBW for all neighborhoods is listed in Appendix C.

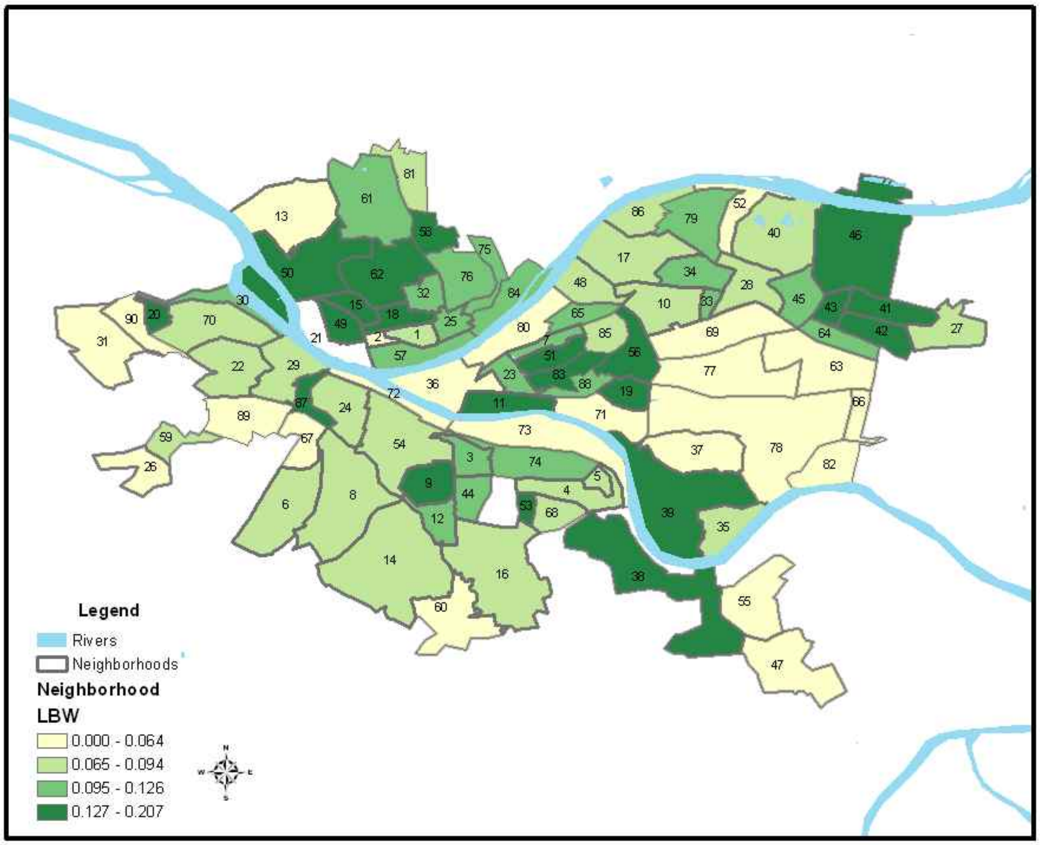

Figure 4-3 Proportion of LBW by Pittsburgh Neighborhoods

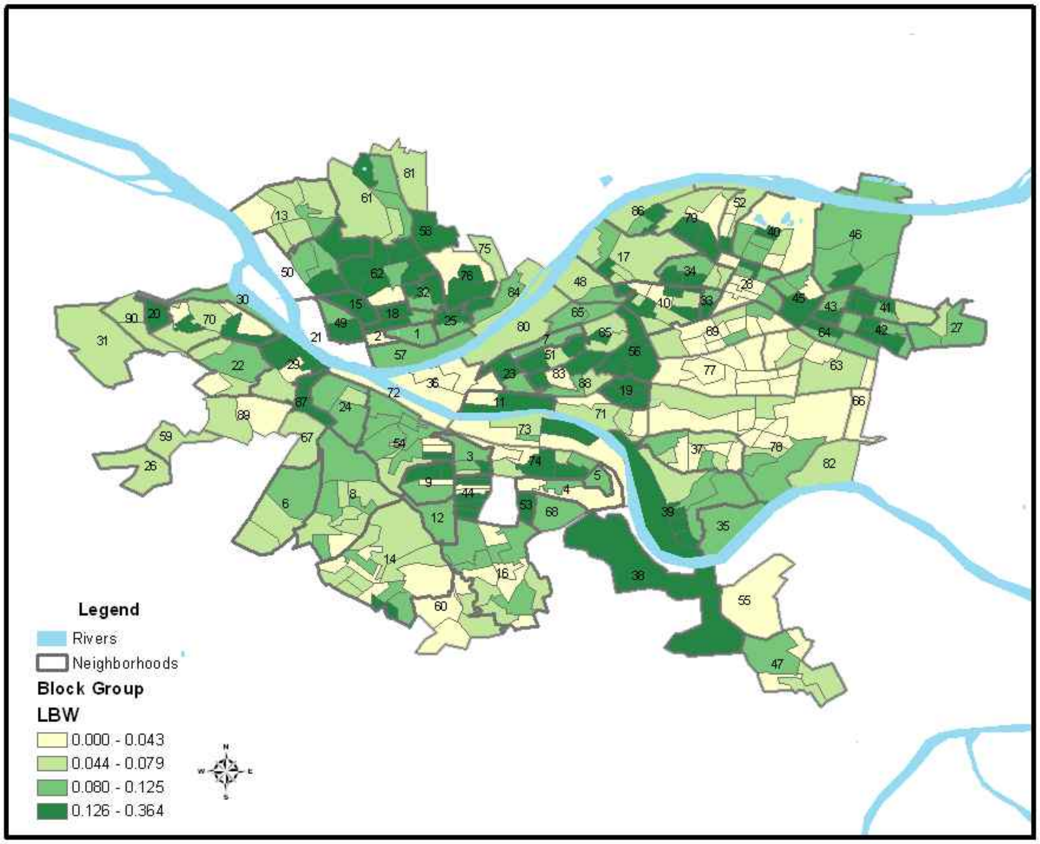

Figure 4-4 Proportion of LBW by Pittsburgh Block Groups

The spatial autocorrelations of LBW among neighboring areas were calculated. Table 4-1 includes the Moran's I statistic for LBW at the block group and neighborhood levels. Overall, values are positive, indicating that adjacent areas are similar. However, as aggregation increases from block group level to neighborhood level, Moran's I statistic decreases. For example, spatial autocorrelation for LBW was higher at the block group level (0.23) than at the neighborhood level (0.14), suggesting that LBW among neighboring block groups are more similar than neighboring neighborhoods.

Table 4-1 Moran's Statistic by Area Level

Variables	Block Group		Neighborhoods	
	Moran's I Statistic	*p-value*	*Moran's I Statistic*	*p-value*
LBW	0.23	<0.01	0.14	<0.05
OND_{ijk}	--	--	0.24	<0.01
MED_{ij}	0.62	<0.01	--	--
CD_{ij}	0.45	<0.01	--	--

4.1.2 Summary of Area-level SEP

Table 4-2 summarizes the measures of OND_{ijk}, MED_{ij}, and CD_{ij}. Example neighborhoods close to the mean/median of these measures are Bloomfield (OND_{ijk}: 26.5), Highland Park ($MED_{ij:}$ 29.6), and Mount Washington (CD_{ij}: 12.3). Appendix C includes the OND_{ijk} measures by neighborhoods.

Table 4-2 Summary of Area-Level SEP

	OND_{ijk}	MED_{ij}	CD_{ij}
Mean (SD)	27.6 (10.3)	30.9 (15.0)	18.3 (14.7
Median (25^{th}: 75^{th} Percentile)	25.0 (20.3-34.0)	28.0 (19.8: 38.0)	11.0 (7.3:29.6)

Figures 4-5. 4-6, and 4-7 show the distribution of area-level SEP measures by Pittsburgh neighborhoods and block groups. For OND_{ijk}, darker areas towards the North Side (Manchester (49) and California Kirkbride (15), central Pittsburgh (Bedford Dwellings (7) and Terrace Village (83), and towards the East End (East Liberty (28) and Garfield (34). Lighter areas include Shadyside (69), and Squirrel Hill (77). For MED_{ij} and CD_{ij}, which depict SEP at block group levels, similar areas are shaded darker and lighter as in the OND_{ijk} map. However, some neighborhoods varied by block groups. For example, Shadyside (69) has pockets of darker block

groups closer to North Oakland (56) and East Liberty (28) in the MED_{ij} map. In contrast for CD_{ij}, there was not as much heterogeneity with block groups by neighborhoods.

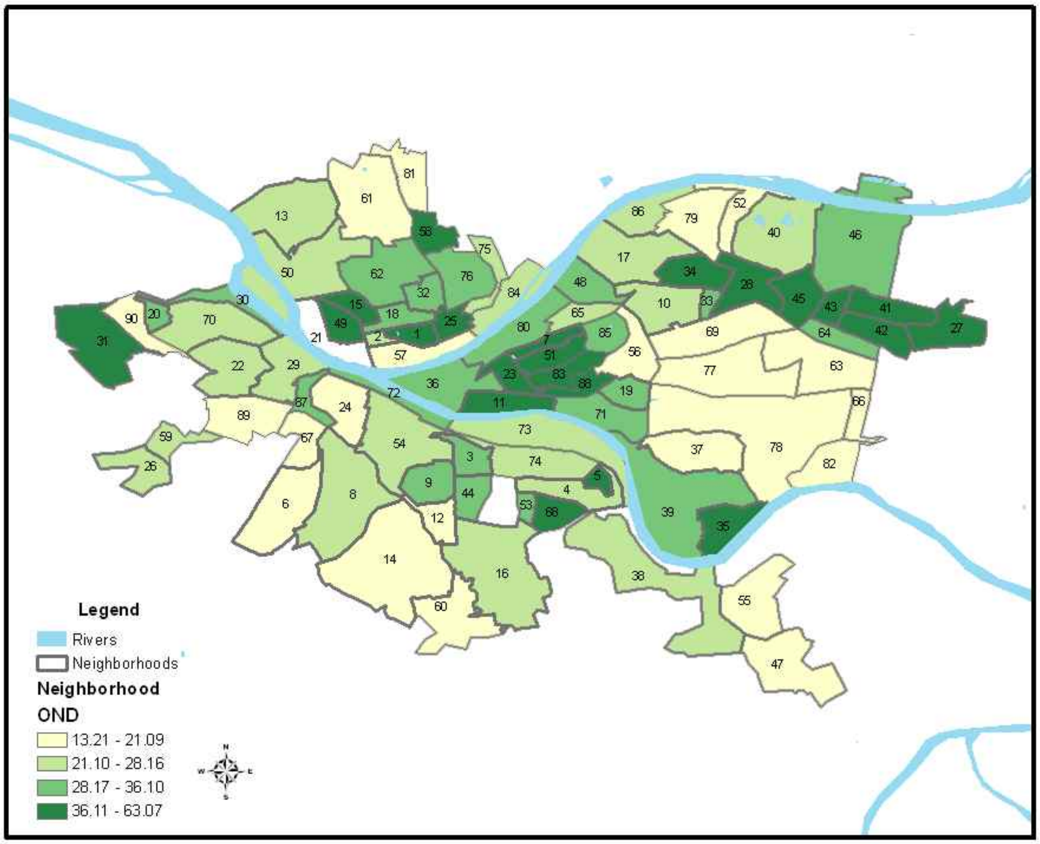

Figure 4-5 OND_{ijk} by Pittsburgh Neighborhoods

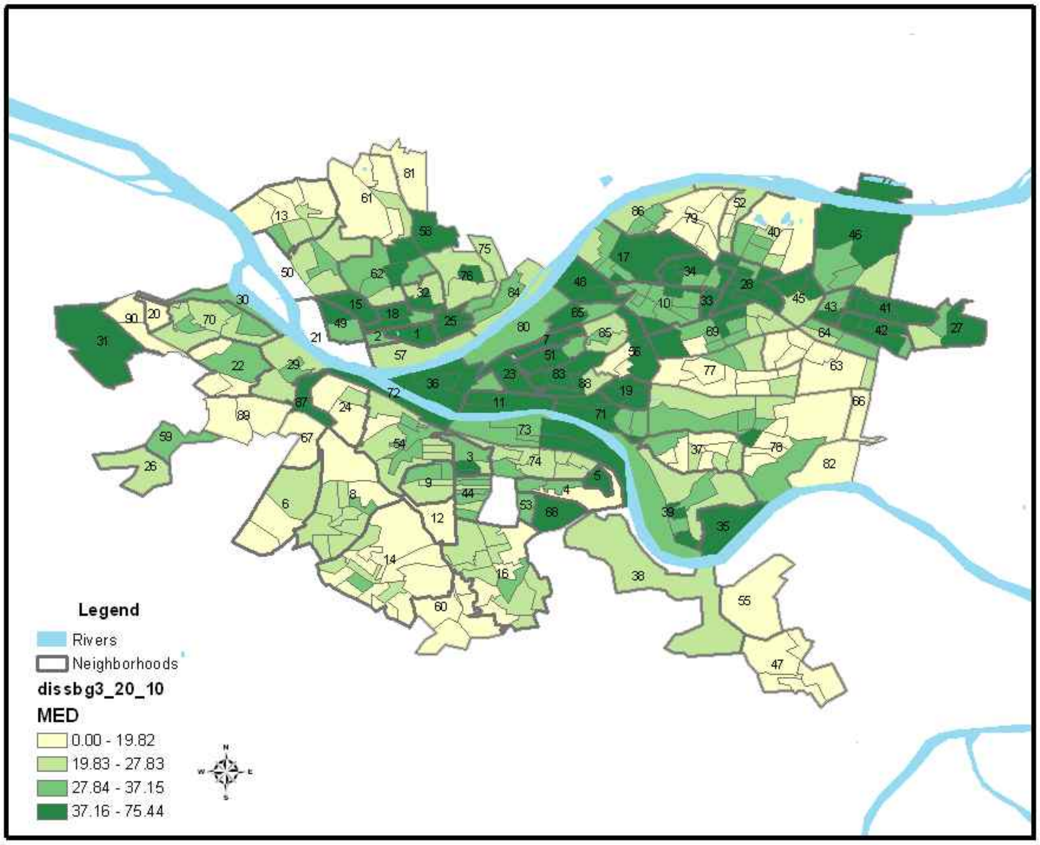

Figure 4-6 MED_{ij} by Pittsburgh Block Groups

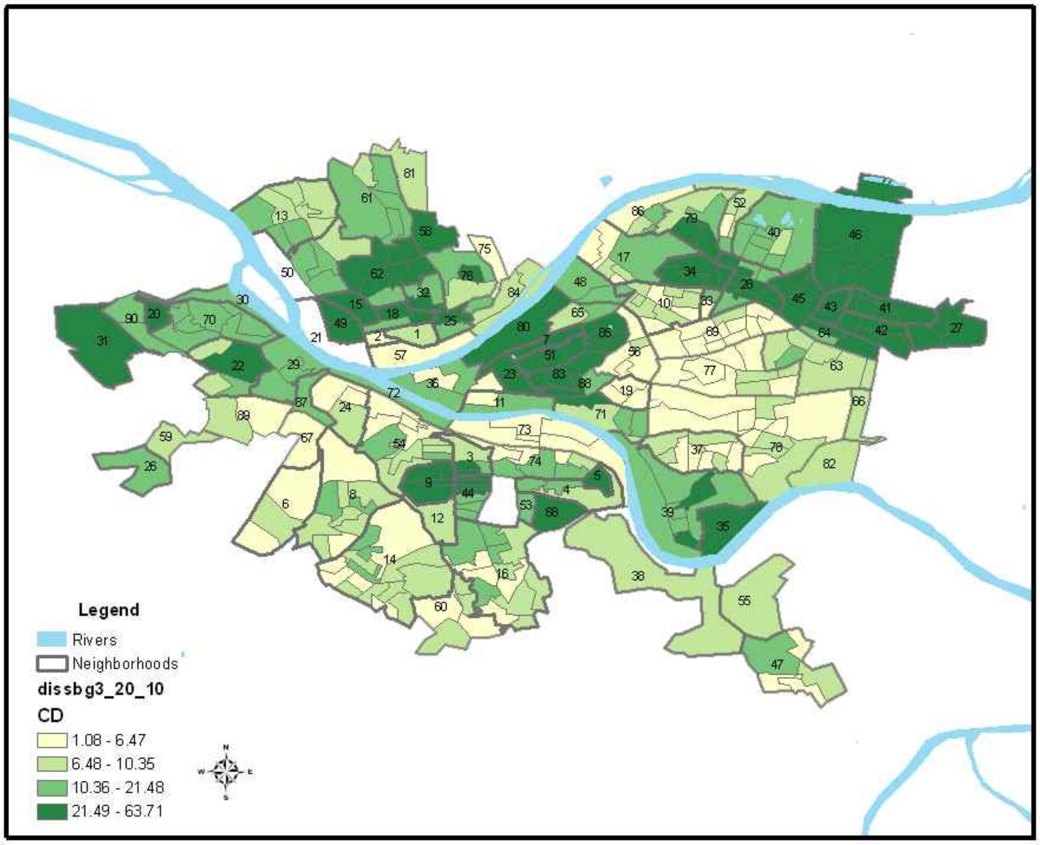

Figure 4-7 CD_{ij} by Pittsburgh Block Groups

Moran's I statistic for OND_{ijk} at the neighborhood level and MED_{ij} and CD_{ij} at the block group levels were calculated. Results are shown in Table 4-1. Similar to LBW, values are positive, indicating that adjacent areas are similar. In addition, spatial autocorrelation for OND_{ijk} (0.24) was lower than the spatial autocorrelation for MED_{ij} (0.62) and CD_{ij} (0.45). This suggests that MED_{ij} and CD_{ij} among neighboring block groups are more similar than OND_{ijk} of neighboring neighborhoods.

4.1.2.1 Area Level SEP by Race

By race, the mean OND_{ijk} for Blacks was 35.5 (SD 10.6) versus Whites was 22.3 (SD: 5.5). Table 4-3 shows the distribution of OND_{ijk} divided into quartiles by race. Almost 75% of Blacks are residing in neighborhoods with the most disadvantage (quartiles 3 and 4), whereas 87% of Whites resided in areas with the least disadvantage. Only 3% of Whites lived in the most deprived neighborhoods, and only 6% of Blacks lived in the least deprived neighborhood.

Table 4-3 OND_{ijk} categories by Race

	Black		**White**	
OND_{ijk} Quartiles	*n*	*%*	*n*	*%*
Quartile 1 (13.21-21.09)	255	5.80	2,808	43.63
Quartile 2 (21.10-28.16)	890	20.25	2,789	43.33
Quartile 3 (28.17-36.10)	1,020	23.21	653	10.15
Quartile 4 (36.11-63.07)	2,229	50.73	186	2.89
Total	4394	100	6436	100

4.1.2.2 Area Level SEP and LBW by Race

Figure 4-9 graphs the distribution of OND_{ijk} by the proportion of LBW in Pittsburgh neighborhoods. Overall, as OND_{ijk} increases, so does the proportion of LBW in neighborhoods.

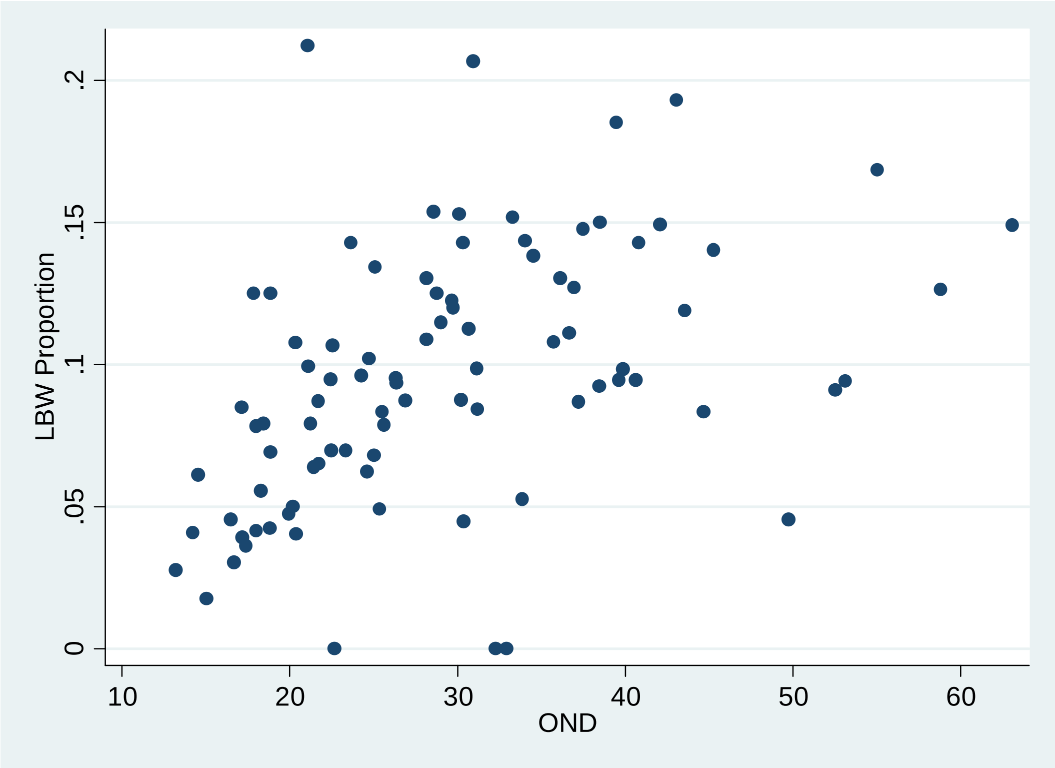

Figure 4-8 OND_{ijk} by LBW proportion in Pittsburgh Neighborhoods

Table 4-4 shows the distribution of LBW infants by race for each of the quartiles of OND_{ijk}. For Blacks, 5.7% of all LBW infants are born in the first quartile (or areas with lower OND_{ijk}/less deprived areas), versus 50.7% in the 4th quartile (or areas with higher OND_{ijk}/more deprived areas). For Whites, there was higher percentage of LBW infants born in the first quartile (32.8%) than in the fourth quartile (2.7%). However after controlling for size of the sample in each quartile by race, the proportion is similar across quartiles. Table 4-5 shows the range of LBW proportion is higher for Blacks (0.11-0.14) than White (0.05-0.09). Overall, a smaller percentage of LBW infants are born in the first quartile (5%) than in the fourth quartile (12%). However, between Blacks and Whites, the percentage was slightly different across quartiles. In the least deprived and most deprived neighborhoods, the LBW difference between Blacks and Whites was highest (difference of 0.7 to 0.08) than in areas that are less extreme in their level of ND (differences were 0.04 to 0.05).

Table 4-4 LBW proportion by Race for Each OND_{ijk} Quartile

	Total		Black		White	
OND_{ijk} Quartiles	*n*	%	*n*	%	*n*	%
Quartile 1 (13.21-21.09)	166	17.03	32	5.65	134	32.76
Quartile 2 (21.10-28.16)	310	31.79	102	18.02	208	50.86
Quartile 3 (28.17-36.10)	201	20.62	145	25.62	56	13.69
Quartile 4 (36.11-63.07)	298	30.56	287	50.71	11	2.69
Total	975	100	566	100	409	100

Table 4-5 LBW Proportion by Race for Each OND_{ijk} Quartile, Controlling for Sample Size in Each Quartile

OND_{ijk} Quartiles	Total	Black %	White %	Difference
Quartile 1 (13.21-21.09)	5.0	13.0	5.0	8.0
Quartile 2 (21.10-28.16)	8.0	11.0	7.0	4.0
Quartile 3 (28.17-36.10)	12.0	14.0	9.0	5.0
Quartile 4 (36.11-63.07)	12.0	13.0	6.0	7.0

Figure 4-9 overlays the proportion of LBW in each neighborhoods on top of the measures of OND_{ijk} for each neighborhood. In general, darker green areas, representing higher levels of OND_{ijk} correspond to higher percentage of LBW. For example, the Homewood neighborhoods (41, 42, 43) correspond to areas with higher LBW percentage (around 13%). Some anomalies do exist, however. For example, neighborhood of North Oakland (56) had an OND_{ijk} value of 20.9, near the average, while LBW percentage was relatively higher (14.5%).

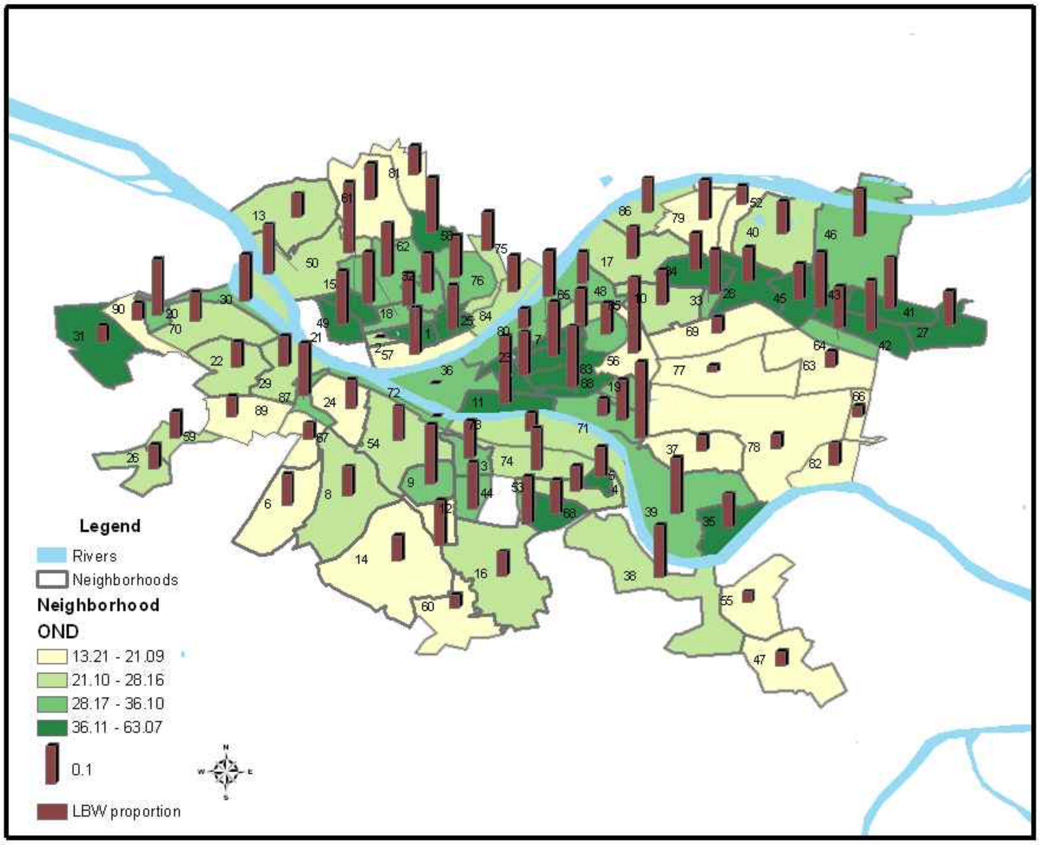

Figure 4-9 OND_{ijk} of Pittsburgh Neighborhoods by LBW Proportion

4.1.3 Summary of Individual-level Covariates and Area SEP by Race

Table 4-6 shows the distribution of individual-level characteristics by race. Differences between racial groups were significant, except for female infant. Overall, compared to Whites, Blacks were significantly younger, a higher proportion had no college education, were not married, received WIC, and smoked during pregnancy ($p<0.001$). A higher percentage of Blacks also were giving birth to at least their second infant.

Table 4-6 Summary of Characteristics by Race

Characteristics	Total (10,830)	Black (n=4394)	White (n=6436)	p-value
Individual-Level Characteristics				
Maternal Age, Mean (SE)	21.1 (0.06)	24.5(0.09)	28.9 (0.07)	<0.001
No College, % (n)	42.7 (4,619)	61.6 (2,707)	29.7 (1,912)	<0.001
Not Married, % (n)	53.6 (5,806)	83.2 (3,657)	33.4 (2,149)	<0.001
Female Infant, % (n)	48.9 (5,299)	49.5 (2,174)	48.6 (3,125)	0.34
Birth Order, % (n)				<0.001
1	44.4 (4,813)	37.9 (1,667)	48.9 (3,146)	
2_3	44.3 (4,795)	44.9 (1,971)	43.9 (2,824)	
>=4	11.3 (1,222)	17.2 (756)	7.3 (466)	
Receive WIC, % (n)	45.5 (4,926)	67.8 (2,978)	30.3 (1,948)	<0.001
Smoke During Pregnancy, % (n)	23.9 (2,593)	25.8 (1,133)	22.7 (1,460)	<0.001
Area-Level SEP				
MED_{ij}, Mean (SE)	30.9 (0.14)	40.7 (0.24)	24.1 (0.12)	<0.001
CD_{ij}, Mean (SE)	18.3 (0.14)	30.3 (0.22)	10.1 (0.09)	<0.001
OND_{ijk}, Mean (SE)	27.6 (0.10)	35.5 (0.16)	22.3 (0.07)	<0.001
OND_{ijk} Quartiles				<0.001
Quartile 1 (13.21-21.09)	28.28 (3,063)	5.80 (255)	43.63 (2,808)	
Quartile 2 (21.10-28.16)	33.97 (3,679)	20.25 (890)	43.33 (2,789)	
Quartile 3 (28.17-36.10)	15.45 (1,673)	23.2 (1,020)	10.15 (653)	
Quartile 4 (36.11-63.07)	22.3 (2,415)	50.73 (2,229)	2.89 (186)	
Birth Outcomes				
Birthgrams, Mean (SE)	3241.6 (6.0)	3087.5 (9.8)	3347.1 (7.2)	<0.001
LBW, % (n)	9 (975)	12.9 (566)	6.4 (409)	<0.001

4.2 ASSOCIATION BETWEEN INDIVIDUAL-LEVEL COVARIATES AND LBW

Table 4-7 shows the association between individual-level covariates and LBW. Overall, there was an increased odds of LBW for those who were Black, with no college education, who were not married, the sex of the baby was female, the birth order was higher, and for those who smoked any cigarettes during their pregnancy ($p<0.05$). There was also no association between WIC and LBW ($p=0.88$). Interactions among race, cigarette smoke, and maternal age were also tested.

Table 4-7 Association between Individual-Level Covariates and LBW (n=10,830)

Individual Covariates	Parameter	SE	Z-statistic/Wald Statistic	p-value	OR	95% CI L	95% CI U
Black	0.7507	0.0747	10.0495	0.00	2.1183	1.9719	2.2647
Intercept	-2.6798	0.0581	-46.1239	0.00			
Random Effect (Neighborhood)	0.0244	0.0169	2.0845	0.15			
Maternal Age (Neighborhood Centered)	0.0018	0.0056	0.3214	0.75	1.0018	0.9908	1.0128
Intercept	-2.3132	0.0561	-41.2335	0.00			
Random Effect (Neighborhood)	0.1333	0.0385	11.9878	0.00			
No College	0.3841	0.0723	5.3126	0.00	1.4682	1.3265	1.6099
Intercept	-2.4984	0.0616	-40.5584	0.00			
Random Effect (Neighborhood)	0.0861	0.0317	7.3771	0.01			
Not Married	0.8683	0.0799	10.8673	0.00	2.3826	2.2260	2.5392
Intercept	-2.8561	0.0672	-42.5015	0.00			
Random Effect (Neighborhood)	0.019	0.0174	1.1924	0.27			
Female Infant	0.2168	0.0686	3.1603	0.00	1.2421	1.1076	1.3765
Intercept	-2.4263	0.0675	-35.9452	0.00			
Random Effect (Neighborhood)	0.1366	0.0404	11.4324	0.00			
Birth Order							
1	REF						
2_3	-0.1774	0.0775	-2.2890	0.02	0.8375	0.6856	0.9894
>=4	0.2406	0.1052	2.2871	0.02	1.2720	1.0658	1.4782
Intercept	-2.2746	0.0686	-33.1574	0.00			
Random Effect (Neighborhood)	0.1264	0.0382	10.9488	0.00			
WIC	0.0107	0.0732	0.1462	0.88	1.0108	0.8673	1.1542
Intercept	-2.3151	0.0657	-35.2374	0.00			
Random Effect (Neighborhood)	0.1322	0.0407	10.5505	0.00			
Cigarette Smoke During Pregnancy	0.7486	0.0732	10.2268	0.00	2.1139	1.9704	2.2573
Intercept	-2.5376	0.0595	-42.6487	0.00			
Random Effect (Neighborhood)	0.1026	0.0346	8.7931	0.00			

Two-way interaction terms were tested between race and cigarette smoke, race and maternal age, and maternal age and cigarette smoke. In addition, a three-way interaction among race, cigarette smoke, and maternal age was also tested. Table 4-8 shows that each of the two-way interactions alone was significantly associated with LBW. Table 4-10 shows these results. For the race*cigarette smoke interaction term, the odds of a LBW for Black smokers was 1.894, and the odds was 2.562 for Whites demonstrating that the odds ratio comparing blacks to Whites was 0.74 (95% CI: 0.473-1.006). Black smokers were less likely to give birth to a LBW infant than White smokers. For the race*mage (centered by neighborhoods) showed that the odds for LBW for was 1.022 for Blacks and 0.999 for Whites. In other words, Blacks were at increased odds for giving birth to a LBW infant for every unit increase in the maternal age (OR: 1.033, 95% CI: 1.010-1.056) compared to Whites. Finally, for the mage*cigarette smoke interaction term, the odds of LBW for smokers was 1.034 for every unit increase maternal age. In contrast, the odds of LBW for non-smokers was 0.986. In other words, as a woman's age increase, smokers were at increased risk for LBW than non-smokers. Adding all three two-way interactions in the model resulted in nonsignificant results for the race*Mage term (p=0.09), but significant associations for race*cigarette smoke ($p<0.05$ and mage*cigarette smoke ($p<0.001$). Finally, the three-way interaction term for race*maternal age*cigarette smoke term was borderline significant (p=0.05). The odds for LBW infant for a Black smoker was 1.057 for increasing unit in maternal age. The odds for a White smoker was 1.006. This resulted in an increased odds of LBW for Black smokers with increasing maternal age, compared to White smokers (OR: 1.051, 95% CI: 1.001-1.099).

Table 4-8 Association between Interaction Terms and LBW (n=10,830)

Individual Covariates	Parameter	SE	Z-statistic/Wald Statistic	p-value	OR	95% CI
Race*Cig						
Intercept	-2.9798	0.0675	-44.1452	0.00		
Black	0.8655	0.0857	10.0992	0.00	2.3760	2.2080-2.5440
CigAny	0.9411	0.1019	9.2355	0.00	2.5625	2.3628-2.7623
Race*Cigany	-0.3023	0.1359	-2.2244	0.03	0.7391	0.4728-1.0055
Random Effect (Neighborhood)	0.0122	0.0121	1.0166	0.31		
Race*Mage						
Intercept	-2.6817	0.0579	-46.3161	0.00		
Black	0.7681	0.0749	10.2550	0.00	2.1555	2.0087-2.3023
Mage	-0.0104	0.0091	-1.1429	0.25	0.9897	0.9718-1.0075
Race*Mage	0.0322	0.0118	2.7288	0.01	1.0327	1.0096-1.0558
Random Effect (Neighborhood)	0.0197	0.0178	1.2249	0.27		
Mage*Cig						
Intercept	-2.5437	0.0604	-42.1142	0.00		
Mage	-0.0146	0.0073	-2.0000	0.05	0.9855	0.9712-0.9998
Cig	0.7467	0.075	9.9560	0.00	2.1099	1.9629-2.2569
Mage*Cig	0.0479	0.0116	4.1293	0.00	1.0491	1.0263-1.0718
Random Effect (Neighborhood)	0.0963	0.0322	8.9442	0.00		
Race*Cig*Mage						
Intercept	-2.9739	0.0692	-42.9754	0.00		
Black	0.8663	0.0917	9.4471	0.00	2.3779	2.1982-2.5576
Mage	-0.0151	0.0104	-1.4519	0.15	0.9850	0.9646-1.0054
CigAny	0.9469	0.1105	8.5692	0.00	2.5775	2.3609-2.7940
Race*Cigany	-0.3449	0.1487	-2.3194	0.02	0.7083	0.4169-0.9998
Race*Mage	0.0195	0.0116	1.6810	0.09	1.0197	0.9970-1.0424
Mage*Cig	0.0377	0.0118	3.1949	0.00	1.0384	1.0153-1.0615
Random Effect (Neighborhood)	0.0115	0.0127	0.8200	0.37		
Race*Cig*Mage						
Intercept	-2.9802	0.0676	-44.0858	0.00		
Black	0.866	0.0906	9.5585	0.00	2.3772	2.1996-2.5547
Mage	-0.003	0.0131	-0.2290	0.82	0.9970	0.9713-1.0227
CigAny	0.9419	0.105	8.9705	0.00	2.5646	2.3588-2.7704
Race*Cigany	-0.3464	0.1447	-2.3939	0.02	0.7073	0.4236-0.9909
Race*Mage	0.0007	0.0162	0.0432	0.97	1.0007	0.9689-1.0325
Mage*Cig	0.0088	0.0189	0.4656	0.64	1.0088	0.9718-1.0459
Race*Cig*Mage	0.049	0.025	1.9600	0.05	1.0502	1.0012-1.0992
Random Effect (Neighborhood)	0.0084	0.0079	1.1306	0.29		

Figure 4-10 shows the relationship between race, cigarette smoke, and LBW proportion, controlling for age from the three-term interaction model. Figure 4-10 shows the observed and predicted LBW proportion are similar. In general, Black smokers had the highest predicted proportion of LBW infants (0.187), followed by White smokers (0.115), Black non-smokers (0.108), and then White non-smokers (0.047). Overall Black non-smokers had the same LBW risk as White smokers.

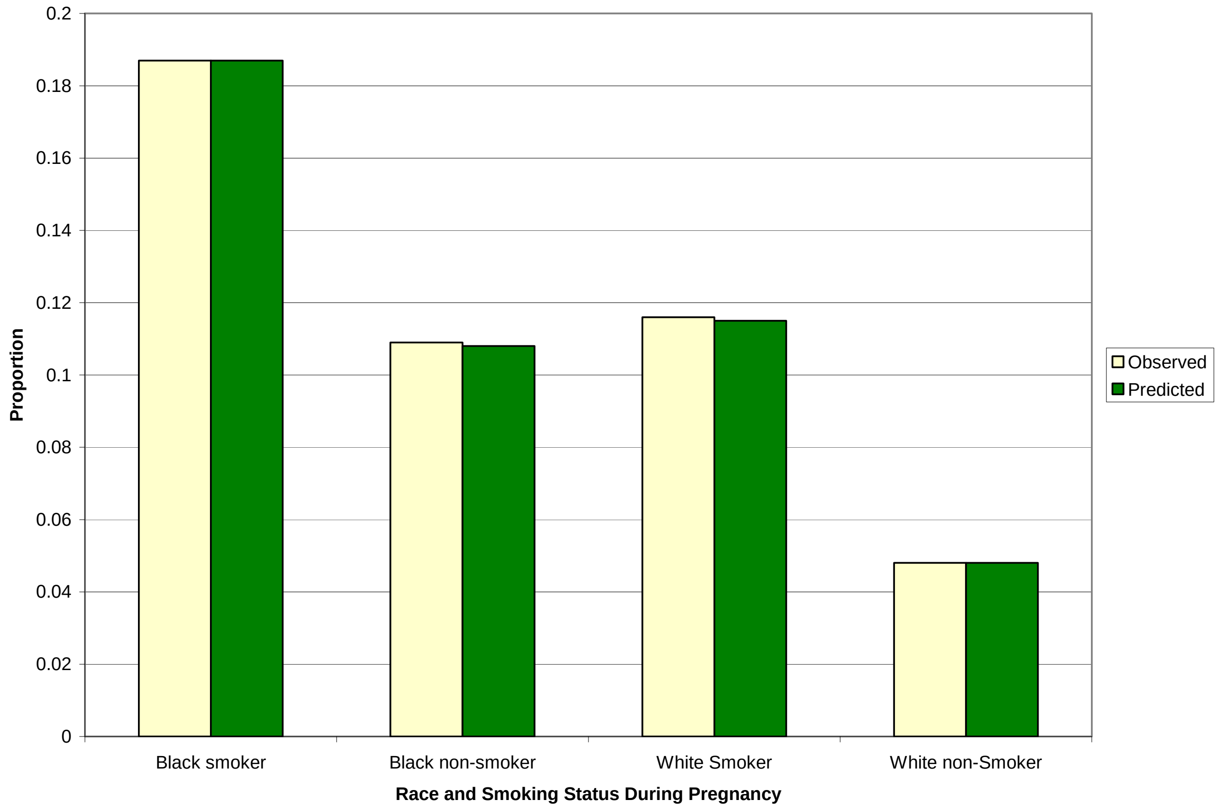

Figure 4-10 Predicted LBW by Race and Cigarette Smoking Status During Pregnancy

Figure 4-11 shows the predicted LBW proportion by race and cigarette smoking status over age categories. Overall, Blacks had higher predicted LBW proportions than Whites. However, in general, LBW proportion remains constant for the Black non-smokers, White non-smokers, and White smokers. In contrast, for Black smokers, the LBW proportion increases from 0.120 in the <18 age group to 0.305 in the >=35 year age group. Over time, the difference between Blacks and Whites increases, which seems to be augmented by smoking status for Blacks.

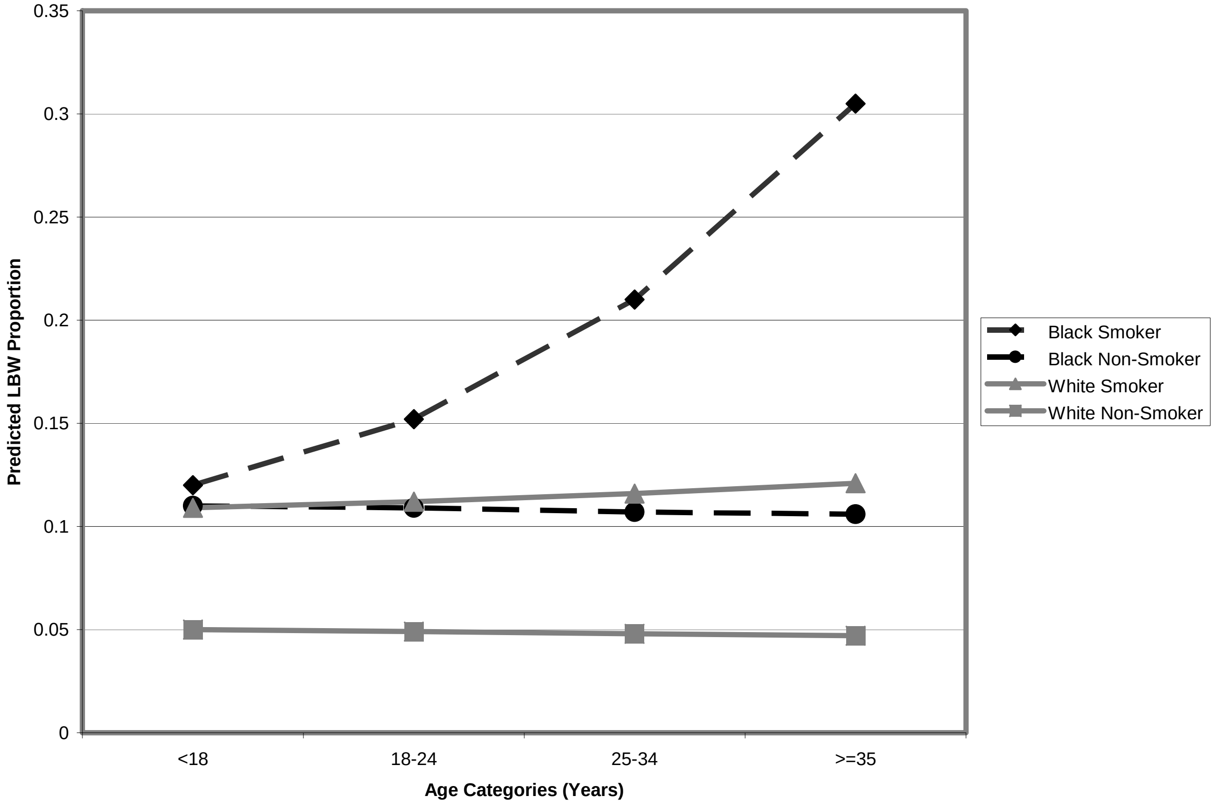

Figure 4-11 Predicted LBW Proportion Over Maternal Age by Race and Cigarette Smoke Status During Pregnancy

4.3 RESULTS OF MULTILEVEL LOGISTIC REGRESSION

Results of multilevel logistic regression are presented. The initial null model included random intercepts at the neighborhood and block group level. However, the variance at the block group level was close to zero, so further analysis included a random intercept at the neighborhood-level only. Based on variance estimated from the null model, the neighborhood ICC was 0.039, suggesting that there was enough variation of LBW between neighborhoods to employ multilevel analysis.

4.3.1 Association Between Area-Level SEP and LBW

Table 4.9 shows results of multilevel logistic regression for the null model (model 1) and each area-level SEP measure (models 2-5). In the null model, the random effect of neighborhood is significant suggesting significant variation in LBW among neighborhoods. When OND_{ijk} is added to the model, the magnitude of the effect is reduced, but remains borderline significant (p=0.05). For MED_{ij} and CD_{ij}, the variation at the neighborhood level remains significant, so adding these area-level SEP measures does not explain the variation of LBW among neighborhoods. In terms of association, the OR for OND_{ijk} is 1.027 (1.019-1.035) suggesting a significant positive association between OND_{ijk} and LBW. Converting the odds ratio to a 10 point scale, the OR of OND_{ijk} is 1.31, which means that for every 10 point increase in OND_{ijk}, the odds for LBW increases by 31%. MED_{ij} alone was also significantly associated with LBW (OR: 1.011, 95% CI: 1.001-1.022), but the variation among neighborhood remained significant. For every 10 point increase in MED, the odds for LBW increases by 12%. CD_{ij} was not significantly associated with LBW. In the model with all SEP measures, only OND_{ijk} remained significant (OR: 1.027, 95% CI: 1.019-1.034), and the random effect at the neighborhood level was no longer significant (p=0.08).

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Table 4-9 Regression Results for Area-Level SEP, Models 1-5

	Null (Model 1)						**OND_{ijk} (Model 2)**					
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI***	***Parameter***	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% C***
Fixed Effects												
Intercept	-2.3110	0.0571	-40.4729	0.00			-2.3077	0.0423	-54.5556	0.00		
OND_{ijk}							0.0267	0.0038	7.0263	0.00	1.0271	1.0196-1.0345
MED_{ij}												
CD_{ij}												
Random Effects												
Neighborhood	0.1326	0.0394	11.3265	0.00			0.0422	0.0219	3.7131	0.05		

	MED_{ij} (Model 3)						**CD_{ij} (Model 4)**					
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI***	***Parameter***	***SE***	***z/Wald's statistic***	***p-value***	*OR*	***95% CI***
Fixed Effects												
Intercept	-2.3255	0.0554	-41.9765	0.00			-2.3249	0.0543	-42.8158	0.00		
OND_{ijk}												
MED_{ij}	0.0113	0.0052	2.1731	0.03	1.0114	1.0012-1.0216						
CD_{ij}							0.0119	0.0065	1.8308	0.07	1.0120	0.9992-1.0247
Random Effects												
Neighborhood	0.1297	0.0386	11.2903	0.00			0.1350	0.0387	12.1687	0.00		

	ALL SEP (Model 5)					
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	*OR*	***95% CI***
Fixed Effects						
Intercept	-2.3171	0.0439	-52.7813	0.00		
OND_{ijk}	0.0262	0.0038	6.8947	0.00	1.0265	1.0191-1.0340
MED_{ij}	0.0065	0.0064	1.0156	0.31	1.0065	0.9940-1.0191
CD_{ij}	0.0053	0.0081	0.6543	0.51	1.0053	0.9894-1.0212
Random Effects						
Neighborhood	0.0404	0.0229	3.1124	0.08		

4.3.2 Association Between Race and LBW

Table 4.10 shows model regression results for models with race (model 6) and race and area-level SEP (models 7-10). In the first model, when adding race to the model, the random effects of neighborhoods is no longer significant (p=0.15) suggesting that addition of race into the model helps explain the variation in LBW among neighborhoods. The association between race alone and LBW is significant and shows an increased risk for Blacks. The odds of Blacks giving birth to a LBW infant was 2.11 higher than Whites (95% CI: 1.97-2.26).

4.3.3 Association Between Race and LBW, after Controlling for Area-Level SEP

Additional models in Table 4.10 add area-level SEP measures to the model. Inclusion of each of the area-level SEP measures with race further reduced the significance of the random effects, suggesting that variability in LBW among neighborhoods is further reduced by adding area-level SEP to the model. In the Black and OND_{ijk} model (model 8), OND_{ijk} is significantly associated with LBW, after controlling for race (OR: 1.009, 95% CI: 1.001-1.018). Converting this OR on a 10 point scale resulted in an OND_{ijk} OR of 1.0975, which translates to a 9.8% increase in the odds of LBW for every 10 point increase in OND_{ijk}, after controlling for race. The association between race and LBW remains with a slight attenuation (OR: 1.917, 95% CI: 1.739-2.094). MED_{ij} and CD_{ij} are no longer significant when added to the race model (MED_{ij} OR: 1.003, 95% CI: 0.993-1.013; CD_{ij} OR: 0.999, 95% CI: 0.987-1.012). When adding all area-level SEP measures to the model along with race, only OND_{ijk} remains significant (OR: 1.009, 95% CI: 1.001-1.017). The race OR becomes slightly attenuated (1.906, 95% CI: 1.730-2.082).

Table 4-10 Regression Results for Race and Area-Level SEP, Models 6-10

	Race (Model 6)						**Race + OND_{ijk} (Model 7)**					
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI***	***Parameter***	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI***
Fixed Effects												
Intercept	-2.6798	0.0581	-46.1239	0.00			-2.6304	0.0623	-42.2215	0.00		
Black_NH	0.7507	0.0747	10.0495	0.00	2.1183	1.9719-2.2647	0.6506	0.0906	7.1810	0.00	1.9166	1.7390-2.0941
OND_{ijk}							0.0093	0.0042	2.2143	0.03	1.0093	1.0011-1.0176
MED_{ij}												
CD_{ij}												
Random Effects												
Neighborhood	0.0244	0.0169	2.0845	0.15			0.0205	0.0160	1.6416	0.20		

	Race + MED_{ij} (Model 8)						**Race + CD_{ij} (Model 9)**					
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	*OR*	***95% CI***	***Parameter***	***SE***	***z/Wald's statistic***	***p-value***	*OR*	***95% CI***
Fixed Effects												
Intercept	-2.3255	0.0554	-41.9765	0.00			-2.6807	0.0577	-46.4593	0.00		
Black_NH	0.7455	0.0765	9.7451	0.00	2.1073	1.9574-2.2573	0.7545	0.0745	10.1275	0.00	2.1264	1.9804-2.2724
OND_{ijk}												
MED_{ij}	0.0030	0.0049	0.6122	0.54	1.0030	0.9934-1.0126						
CD_{ij}							-0.0006	0.0063	-0.0952	0.92	0.9994	0.9871-1.0117
Random Effects												
Neighborhood	0.0241	0.0178	1.8331	0.18			0.0211	0.0187	1.2732	0.26		

	Race + ALL SEP (Model 10)					
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	*OR*	***95% CI***
Fixed Effects						
Intercept	-2.6275	0.0593	-44.3086	0.00		
Black_NH	0.6453	0.0898	7.1860	0.00	1.9064	1.7304-2.0824
OND_{ijk}	0.0093	0.0041	2.2683	0.02	1.0093	1.0013-1.0174
MED_{ij}	0.0042	0.0062	0.6774	0.50	1.0042	0.9921-1.0164
CD_{ij}	-0.0031	0.0082	-0.3780	0.71	0.9969	0.9808-1.0130
Random Effects						
Neighborhood	0.0162	0.0157	1.0647	0.30		

4.3.4 Association Between Race and LBW, After Controlling for Individual-Level Covariates

Tables 4-11 and 4-12 show results from models with race and individual-level covariates added to the model (model 11-14). For each of these models, the random effect of neighborhood is not significant suggesting that variation among neighborhoods in LBW is explained including race and individual-level covariates to the model. The Black OR decreased from 2.118 (95% CI: 1.972-2.264) (model 6) in the adjusted model to 1.556 (95% CI: 1.400-1.712) after adding sociodemographic characteristics to the model. Adding WIC to the model with sociodemographic characteristics, the Black OR increased slightly to 1.637 (95% CI: 1.472-1.802). Comparing the 95% CI confidence intervals of all three of these models show that there is no overlap between the unadjusted model 6 and adjusted models (model 11 and 12), suggesting that the addition of sociodemographic characteristics and WIC contributed to a significant reduction in the Black OR from the unadjusted model. However, after adding cigarette smoke during pregnancy, and interaction terms to the model, the OR for Black increased to 1.846 (95% CI: 1.679-2.014) and 2.085 (95% CI: 1.874-2.296), respectively. The 95% CI intervals of these ORs overlap with the 95% CI of the OR in the models 11 and 12, suggesting that the differences between Blacks and White were not further explained by adding cigarette status or interaction terms to the model.

For the individual-level covariates, all the terms remained significant and did not change, except for birth order (>=4), which was not significant in model 11 and 12 but was significant after adding cigarette smoke (model 13) and interaction terms (model 14) to the model. In addition, no college was significant in the first two models, but was not significant in models 13 and 14. Finally, maternal age and interactions terms were not significant in model 14.

Table 4-11 Regression Results for Race and Individual-Level Covariates, Models 11-12

	Race + Sociodemographics (Model 11)						Race + Sociodemographics + Health Care Access (Model 12)					
	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*	*Parameter*	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*
Fixed Effects												
Intercept	-3.0651	0.0846	-36.2305	0.00			-3.0053	0.0941	-31.9373	0.00		
Black_NH	0.4421	0.0798	5.5401	0.00	1.5559	1.3995-1.7123	0.4931	0.0842	5.8563	0.00	1.6373	1.4723-1.8023
Socio-demographic Characteristics												
Maternal Age (neigh-centered)	0.0362	0.0067	5.4030	0.00	1.0369	1.0237-1.0500	0.0343	0.0068	5.0441	0.00	1.0349	1.0216-1.0482
No College	0.1650	0.0778	2.1208	0.03	1.1794	1.0269-1.3319	0.2147	0.0792	2.7109	0.01	1.2395	1.0842-1.3947
Not Married	0.7651	0.0940	8.1394	0.00	2.1490	1.9648-2.3333	0.8860	0.1027	8.6271	0.00	2.4252	2.2239-2.6265
Female Infant	0.2147	0.0686	3.1297	0.00	1.2395	1.1050-1.3739	0.2139	0.0716	2.9874	0.00	1.2385	1.0981-1.3788
Birthorder												
2_3	-0.2959	0.0776	-3.8131	0.00	0.7439	0.5918-0.8960	-0.3005	0.0779	-3.8575	0.00	0.7405	0.5878-0.8932
>=4	-0.0974	0.1129	-0.8627	0.39	0.9072	0.6859-1.1285	-0.1251	0.1166	-1.0729	0.28	0.8824	0.6539-1.1110
Health Care Access												
WIC							-0.3676	0.0777	-4.7310	0.00	0.6924	0.5401-0.8447
Behavior												
Cigarette during Pregnancy												
Interaction Terms												
Race*Cig												
Race*Mage												
Mage*Cig												
Race*Cig*Age												
Random Effects												
Neighborhood	0.0071	0.0083	0.7317	0.39			0.0097	0.0083	1.3658	0.24		

Table 4-12 Regression Results for Race and Individual-Level Covariates, Models 13-14

	Race + Sociodemographics + Health Care Access + Behaviors (Model 13)						Race + Sociodemographics + Health Care Access + Behaviors + Intxns (Model 14)					
	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*	*Parameter*	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*
Fixed Effects												
Intercept	-3.0486	0.0890	-34.2539	0.00			-3.0694	0.0917	-33.4722	0.00		
Black_NH	0.6131	0.0854	7.1792	0.00	1.8460	1.6786-2.0134	0.7348	0.1075	6.8353	0.00	2.0849	1.8742-2.2956
Socio-demographic Characteristics												
Maternal Age (neigh-centered)	0.0306	0.0068	4.5000	0.00	1.0311	1.0177-1.0444	0.0192	0.0127	1.5118	0.13	1.0194	0.9945-1.0443
No College	0.1096	0.0819	1.3382	0.18	1.1158	0.9553-1.2763	0.105	0.0797	1.3174	0.19	1.1107	0.9545-1.2669
Not Married	0.6967	0.1009	6.9049	0.00	2.0070	1.8092-2.2047	0.6354	0.1009	6.2973	0.00	1.8877	1.6899-2.0854
Female Infant	0.2233	0.0668	3.3428	0.00	1.2502	1.1192-1.3811	0.2285	0.071	3.2183	0.00	1.2567	1.1175-1.3958
Birthorder												
1	REF											
2_3	-0.3816	0.0813	-4.6937	0.00	0.6828	0.5234-0.8421	-0.3707	0.0815	-4.5485	0.00	0.6903	0.5305-0.8500
>=4	-0.2540	0.1183	-2.1471	0.03	0.7757	0.5438-1.0076	-0.2912	0.1221	-2.3849	0.02	0.7474	0.5081-0.9867
Health Care Access												
WIC	-0.3811	0.0785	-4.8548	0.00	0.6831	0.5293-0.8370	-0.409	0.0811	-5.0432	0.00	0.6643	0.5054-0.8233
Behavior												
Cigarette during Pregnancy	0.6758	0.0789	8.5653	0.00	1.9655	1.8108-2.1201	0.828	0.1212	6.8317	0.00	2.2885	2.0510-2.5261
Interaction Terms												
Race*Cig							-0.2805	0.1538	-1.8238	0.07	0.7554	0.4540-1.0569
Race*Mage							0.0005	0.0155	0.0323	0.97	1.0005	0.9701-1.0309
Mage*Cig							0.0041	0.0178	0.2303	0.82	1.0041	0.9692-1.0390
Race*Cig*Age							0.0452	0.0239	1.8912	0.06	1.0462	0.9994-1.0931
Random Effects												
Neighborhood	0.0094	0.0090	1.0909	0.30			0.0066	0.0065	1.0310	0.31		

4.3.5 Association between Race and LBW after Controlling for Individual-Level Covariates and Area-Level SEP

Tables 4-13 and 4-14 show results of models that include race, individual-level covariates, and area-level SEP in predicting LBW (models 15-18). The random effects of LBW among neighborhoods remain non-significant in each of the models. Each of the area-level SEP by themselves and altogether were not significant predictors of LBW after controlling for individual-level covariates. In addition, the race OR in each of the models was similar to the unadjusted race OR. This suggests that addition of both individual-level factors and area-level SEP did not help explain the difference between Blacks and Whites in terms of LBW risk.

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Table 4-13 Regression Results for Race, Individual-Level Covariates, and Area-Level SEP, Models 15-16

	Race + Ind + OND_{ijk} (Model 15)						Race + Ind + MED_{ij} (Model 16)					
	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*	*Parameter*	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*
Fixed Effects												
Intercept	-3.0850	0.1004	-30.7271	0.00			-3.0700	0.0898	-34.1871	0.00		
Black_NH	0.7428	0.1132	6.5618	0.00	2.1017	1.8798-2.3235	0.7302	0.1097	6.6563	0.00	2.0753	1.8603-2.2904
Area-Level SEP												
OND_{ijk}	-0.0013	0.0043	-0.3023	0.76	0.9987	0.9903-1.0071						
MED_{ij}							-0.0008	0.0049	-0.1633	0.87	0.9992	0.9896-1.0088
CD_{ij}												
Individual-Level Covariates												
Socio-demographic Characteristics												
Maternal age (neigh-centered)	0.0204	0.0125	1.6320	0.10	1.0206	0.9961-1.0451	0.0182	0.0122	1.4918	0.14	1.0184	0.9945-1.0423
No college	0.1101	0.0814	1.3526	0.18	1.1164	0.9568-1.2759	0.1049	0.0823	1.2746	0.20	1.1106	0.9493-1.2719
Not married	0.6447	0.1049	6.1459	0.00	1.9053	1.6997-2.1109	0.6413	0.1001	6.4066	0.00	1.8988	1.7026-2.0950
Female infant	0.2276	0.0703	3.2376	0.00	1.2556	1.1178-1.3933	0.2281	0.0694	3.2867	0.00	1.2562	1.1202-1.3922
Birthorder												
1	REF											
2_3	-0.3689	0.0828	-4.4553	0.00	0.6915	0.5292-0.8538	-0.3671	0.0784	-4.6824	0.00	0.6928	0.5391-0.8464
>=4	-0.2882	0.1214	-2.3740	0.02	0.7496	0.5117-0.9876	-0.2866	0.1201	-2.3863	0.02	0.7508	0.5154-0.9862
Health Care Access												
WIC	-0.4034	0.0814	-4.9558	#####	0.6681	0.5085-0.8276	-0.4122	0.0797	-5.1719	0.00	0.6622	0.5060-0.8184
Behaviors												
Cigarette smoke during pregnancy	0.8268	0.1139	7.2590	0.00	2.2858	2.0626-2.5090	0.8292	0.1208	6.8642	0.00	2.2913	2.0545-2.5281
Interaction Terms												
Race*Cig	-0.2836	0.1475	-1.9227	0.05	0.7531	0.4640-1.0422	-0.2803	0.1486	-1.8863	0.06	0.7556	0.4643-1.0468
Race*Mage	0.0000	0.0151	0.0000	1.00	1.0000	0.9704-1.0296	0.0021	0.0150	0.1400	0.89	1.0021	0.9727-1.0315
Mage*Cig	0.0032	0.0177	0.1808	0.86	1.0032	0.9685-1.0379	0.0058	0.0178	0.3258	0.74	1.0058	0.9709-1.0407
Race*Cig*Age	0.0464	0.0231	2.0087	0.04	1.0475	1.0022-1.0928	0.0427	0.0238	1.7941	0.07	1.0436	0.9970-1.0903
Random Effects												
Neighborhood	0.0095	0.0079	1.4461	0.23			0.0072	0.01	0.7901	0.37		

Table 4-14 Regression Results for Race, Individual-Level Covariates, and Area-Level SEP, Models 17-18

	Race + Ind + CD_{ij} (Model 17)						Race + Ind + All SEP (Model 18)					
	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*	*Parameter*	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*
Fixed Effects												
Intercept	-3.0763	0.0893	-34.4490	0.00			-3.1087	0.1002	-31.0250	0.00		
Black_NH	0.7329	0.1056	6.9403	0.00	2.0809	1.8740-2.2879	0.7717	0.1173	6.5789	0.00	2.1633	1.9334-2.3932
Area-Level SEP												
OND_{ijk}							-0.0017	0.0042	-0.4048	0.69	0.9983	0.9901-1.0065
MED_{ij}							0.0008	0.0062	0.1290	0.90	1.0008	0.9886-1.0130
CD_{ij}	-0.0025	0.0065	-0.3846	0.70	0.9975	0.9848-1.0102	-0.0036	0.0084	-0.4286	0.67	0.9964	0.9799-1.0129
Individual-Level Covariates												
Socio-demographic Characteristics												
Maternal age (neigh-centered)	0.0211	0.0125	1.6880	0.09	1.0213	0.9968-1.0458	0.0214	0.0126	1.6984	0.09	1.0216	0.9969-1.0463
No college	0.1082	0.0817	1.3244	0.19	1.1143	0.9541-1.2744	0.1179	0.0824	1.4308	0.15	1.1251	0.9636-1.2866
Not married	0.6422	0.1020	6.2961	0.00	1.9005	1.7006-2.1005	0.6462	0.1000	6.4620	0.00	1.9081	1.7121-2.1041
Female infant	0.2289	0.0703	3.2560	0.00	1.2572	1.1194-1.3950	0.2350	0.0689	3.4107	0.00	1.2649	1.1298-1.3999
Birthorder												
1	REF											
2_3	-0.3704	0.0795	-4.6591	0.00	0.6905	0.5347-0.8463	-0.3741	0.0822	-4.5511	0.00	0.6879	0.5268-0.8490
>=4	-0.2891	0.1234	-2.3428	0.02	0.7490	0.5071-0.9908	-0.2974	0.1226	-2.4258	0.02	0.7428	0.5025-0.9831
Health Care Access												
WIC	-0.4043	0.0827	-4.8888	0.00	0.6675	0.5054-0.8296	-0.4080	0.0814	-5.0123	0.00	0.6650	0.5055-0.8246
Behaviors												
Cigarette smoke during pregnancy	0.8328	0.1161	7.1731	0.00	2.2996	2.0720-2.5271	0.8481	0.1196	7.0911	0.00	2.3350	2.1006-2.5694
Interaction Terms												
Race*Cig	-0.2875	0.1491	-1.9282	0.05	0.7502	0.4579-1.0424		-0.3055	0.1532	0.88	1.0000	1.5988-0.4012
Race*Mage	-0.0016	0.0158	-0.1013	0.92	0.9984	0.9674-1.0294	-0.0005	0.0156	-0.0321	0.97	0.9995	0.9689-1.0301
Mage*Cig	0.0019	0.0183	0.1038	0.92	1.0019	0.9660-1.0378	0.0026	0.0178	0.1461	0.88	1.0026	0.9677-1.0375
Race*Cig*Age	0.0478	0.0248	1.9274	0.05	1.0490	1.0003-1.0976	0.0463	0.0238	1.9454	0.05	1.0474	1.0007-1.0940
Random Effects												
Neighborhood	0.0079	0.0079	1.0000	0.32			0.0078	0.0093	0.7034	0.40		

4.3.6 Association between Race and LBW after Controlling for Individual-Level Disadvantage and OND_{ijk}

In addition, models 19 and 20 presented in Table 4-15 included only individual-level disadvantage (no college, not married, and receipt of WIC services), along with OND_{ijk}. The random effects in both models were not significant suggesting addition of these factors further decreased the LBW variability across neighborhoods. Model 19 includes only individual-level disadvantage variables. Not married and receipt of WIC were significantly associated with LBW, although no college was not a significant predictor (p=0.08) after controlling for the other individual factors. Those who were not married were 2.209 odds (95% CI: 2.009-2.409) more likely to give birth to a LBW infant than those were married. In addition, those who received WIC were less likely to give birth to a LBW infant (OR: 0.673, 95% 0.520-0.827). Blacks were at increased risk for giving birth to LBW infants than Whites (1.643, 95% CI: 1.482-1.805). OND_{ijk} was no longer a significant predicted when added to the model. However, the OR for race decreased slightly to 1.563 (95% CI: 1.385-1.741). Translating the OND_{ijk} OR to a 10 point scale, resulted in an OR of 1.046, which means that or for every 10 point increase in OND_{ijk}, the odds for LBW increases by 4.6%.

Table 4-15 Regression Results for Race, Individual-Level Disadvantage, and OND_{ijk}

	Race + Education + Not Married + WIC (Model 19)					
	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*
Fixed Effects						
Intercept	-2.9304	0.7170	4.0870	0.00		
Black_NH	0.4968	0.0823	6.0365	0.00	1.6434	1.4821-1.8047
Area-Level SEP						
OND_{ijk}						
Individual-Level Disadvantage						
No College	0.1349	0.0758	1.7797	0.08	1.1444	0.9958-1.2930
Not Married	0.7925	0.1019	7.7772	0.00	2.2087	2.0090-2.4085
WIC	-0.3958	0.0783	-5.0549	0.00	0.6732	0.5197-0.8266
Random Effects						
Neighborhood	0.0118	0.0111	1.1301	0.29		

	Race + Education + Not Married + WIC + OND_{ijk} (Model 20)					
	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI*
Fixed Effects						
Intercept	-2.8895	0.0766	37.7219	0.00		
Black_NH	0.4466	0.0907	4.9239	0.00	1.5629	1.3851-1.7407
Area-Level SEP						
OND_{ijk}	0.0045	0.0041	1.0976	0.27	1.0045	0.9965-1.0125
Individual-Level Disadvantage						
No College	0.1200	0.0769	1.5605	0.12	1.1275	0.9768-1.2782
Not Married	0.7849	0.0964	8.1421	0.00	2.1920	2.0031-2.3810
WIC	-0.3979	0.0770	-5.1675	0.00	0.6718	0.5208-0.8227
Random Effects						
Neighborhood	0.0121	0.0104	1.3536	0.24		

4.3.7 Summary of Results for OND_{ijk}

Because of the significant association between OND_{ijk} and LBW, even after controlling for race, Table 4-16 summarizes results for race and OND_{ijk} in models 2, 6, 7, 15, and 20. First the association between race and LBW will be described, followed by the association between OND_{ijk} and LBW. In the unadjusted model, the OR for race was 2.118 (95% CI: 1.972-1.265), and decreased to 1.916 (95% CI: 1.739-2.094) when OND_{ijk} was included in the model. However when adding individual-level covariates, the OR increased to 2.101 (95% CI: 1.880-2.324). When individual-level disadvantage was included in the model, the OR for race decreased to 1.563 (95% CI: 1.385-1.740).

In the unadjusted OND_{ijk} model, OND_{ijk} was significantly associated with LBW, suggesting that for every 10 point increase in OND_{ijk}, the odds for LBW increased by 31%. When race is added to the model, OND_{ijk} remained significant, suggesting that for every 10 point increase in OND_{ijk}, the odds for LBW increased by 10%. However, when adding either individual-level covariates to the model or individual-level disadvantage, OND_{ijk} is no longer significant. In the individual-level disadvantage model (model 20), for every 10 point increase in OND_{ijk}, the odds of LBW increases by 4.6%.

Table 4-16 Summary of Results for Race and OND_{ijk} in Predicting LBW (n=10,830)

Models	Parameter	SE	z/Wald's statistic	p-value	OR	95% CI
Model 6						
Black Only	0.7507	0.0747	10.0495	0.00	2.1183	1.9719-2.2647
Model 2						
OND_{ijk} Only$^{\pm}$	0.0267	0.0038	7.0263	0.00	1.3060	1.2123-1.4070
Model 7						
Black	0.6506	0.0906	7.1810	0.00	1.9166	1.7390-2.0941
OND_{ijk}±	0.0093	0.0042	2.2143	0.03	1.0975	1.0107-1.1916
Model 15*						
Black	0.7428	0.1132	6.5618	0.00	2.1017	1.8798-2.3235
$OND_{ijk}^{\pm}$	-0.0013	0.0043	-0.3023	0.76	0.9871	0.9073-1.0739
Model 20**						
Black	0.4466	0.0907	4.9239	0.00	1.5629	1.3851-1.7407
$OND_{ijk}^{\pm}$	0.0045	0.0041	1.0976	0.27	1.0460	0.9653-1.1335

± % Change on a 10 point scale
* Adjusted for individual-level covariates
**Adjusted for individual-level disadvantage

4.3.8 Explained Variance

Given the significance of OND_{ijk} in the race and OND_{ijk} model, Table 4.15 shows the explained variance for models that include race and/or OND_{ijk}. Adding race to the model explained 3.9% of the variation, and adding OND_{ijk} only to the model explained less of the variation (2.2%). Adding both race and OND_{ijk} to the model increased the proportion of variation explained to 4.3%. Race and individual-level covariates explained 11.1% of the variance. Adding OND_{ijk} to the model did not increase the proportion of the variance explained. However, in the individual-level disadvantage model, 7.3% of the variance was explained with only these variables and the proportion of the variance explained increased slightly to 7.4% after adding OND_{ijk} to the model. Overall, these findings suggest that adding individual-level factors, including race, increases the explained variance of the model, more so than $OND_{ijk.}$

Table 4-17 Explained Variance

Variables in Model	**Explained Variance (Psuedo R-squared)**
Black only (Model 6)	0.039
OND_{ijk} Only (Model 2)	0.022
Black + OND_{ijk} (Model 7)	0.043
Black + Individual-Level Covariates (Model 14)	0.110
Black + Individual-Level Covariates + OND_{ijk} (Model 15)	0.110
Black + Individual-level Disadvantage (Model 19)	0.073
Black + Individual-Level Disadvantage+ OND_{ijk} (Model 20)	0.074

4.4 EXAMINING PREDICTED VERSUS OBSERVED FOR FOUR EXAMPLE NEIGHBORHOODS

To provide a better understanding of the association among OND_{ijk}, race, and LBW, four neighborhoods were selected to examine their OND_{ijk}, predicted LBW, and observed LBW based on results from model 2 (OND_{ijk} only) and model 7 (race and OND_{ijk}). Figure 4-12 highlights the four example neighborhoods: Garfield (34), East Liberty (28), Shadyside (69), and Squirrel Hill North (77). Garfield and East Liberty have relatively higher levels of OND_{ijk} and Shadyside and Squirrel Hill have much lower levels of OND_{ijk}.

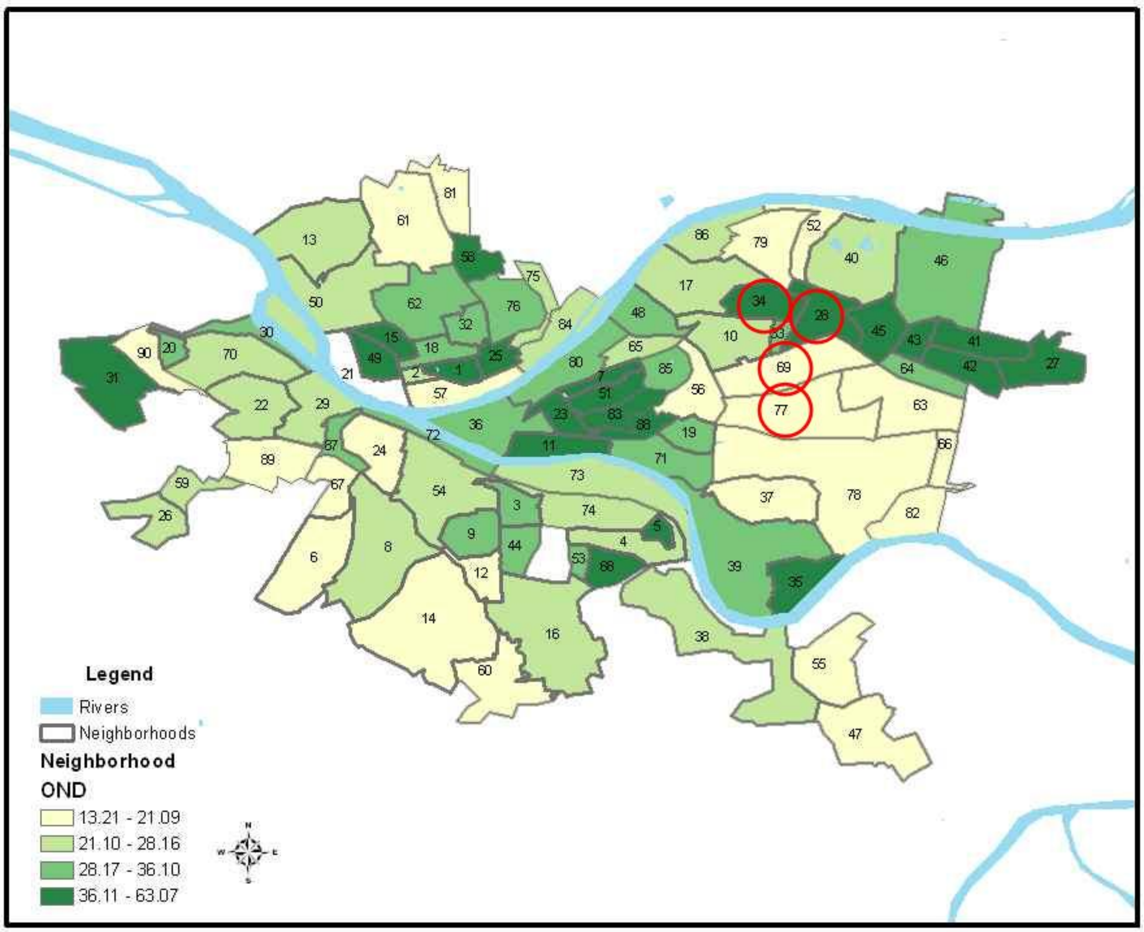


Figure 4-12 Specific Neighborhood Analysis

Table 4-18 shows OND_{ijk} and centered OND_{ijk} for each neighborhood, predicted LBW and observed LBW from the OND_{ijk} only model (model 2), and predicted LBW and observed LBW by race from the race + OND_{ijk} model (model 7). In general, in model 2, higher disadvantage neighborhoods were predicted and observed to have higher LBW proportion. In model 7, neighborhoods with higher OND_{ijk} did not necessarily predict areas with higher LBW. For Blacks, for example, a higher proportion of LBW was observed for Shadyside than East Liberty and Garfield. In addition, the LBW proportion predicted was higher than in observed. For Whites, the highest observed LBW was in Garfield. However, although East Liberty had a high OND_{ijk}, only a small percentage of Whites gave birth to LBW infants. In general, the predicted LBW proportion for White was higher than observed for each example neighborhood, except for Garfield.

Table 4-18 Predicted versus Observed LBW proportion in Four Example Neighborhoods

			Low Birth Weight Proportion					
			OND_{ijk} only Model (Model 2)		**Race + OND_{ijk} Model (Model 7)**			
			Total		**Black**		**White**	
Neighborhood Name (# on Map)	**OND_{ijk}**	**Centered OND_{ijk}**	**Observed**	**Predicted**	**Observed**	**Predicted**	**Observed**	**Predicted**
East Liberty (28)	39.62757	10.28649	0.0943396	0.105473	0.105263	0.122165	0.027027	0.067694
Garfield (34)	39.8526	10.51152	0.1007752	0.10894	0.102459	0.123206	0.071429	0.068307
Shadyside (69)	20.38206	-8.959021	0.0397112	0.059186	0.129032	0.102314	0.028455	0.056129
Squirrel Hill North (77)	15.03123	-14.30985	0.0173913	0.048364	0	0.094112	0.017621	0.051417

4.5 DIAGNOSTICS

4.5.1 Caterpillar Plots

Caterpillar plots were created for the null model (model 1), the OND_{ijk} only mode (model 2), and the race only model (model 6). In the null only model, Figure 4-13 shows several neighborhoods whose 95% CI were below zero or above 0, indicating that LBW was significantly below or above average. Neighborhoods that were below average included Greenfield (map number 36), Point Breeze (62), Shadyside (68), Squirrel Hill North (76), Squirrel Hill South (77). Neighborhoods that were above average were Hazelwood (38) and Terrace Village (82). However, after adding race and/or OND_{ijk} (Figures 4-14, 4-15) to the model these neighborhoods were no longer significantly different from the other neighborhoods.

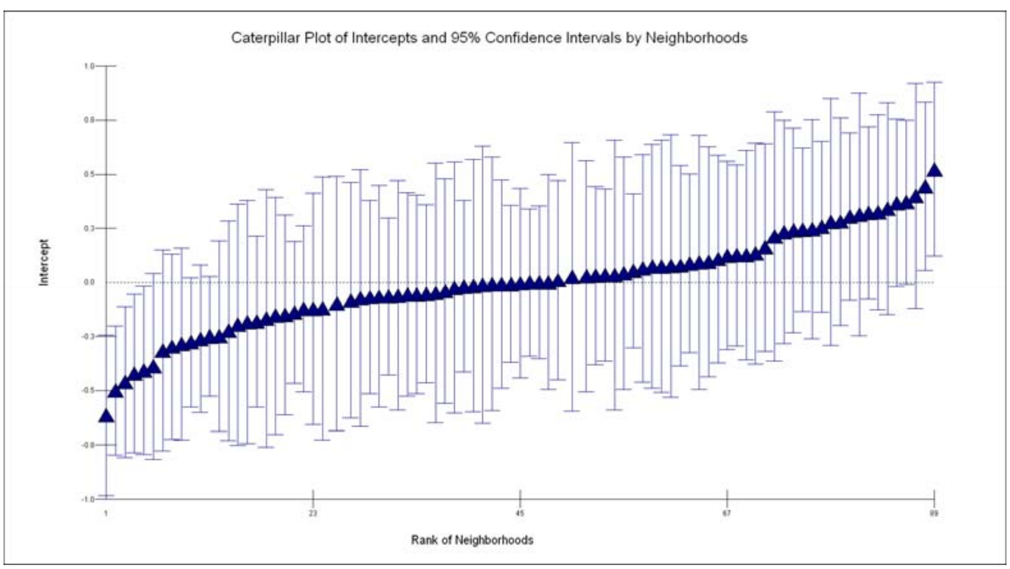


Figure 4-13 Caterpillar Plot of Residuals for Null Model (Model 1)

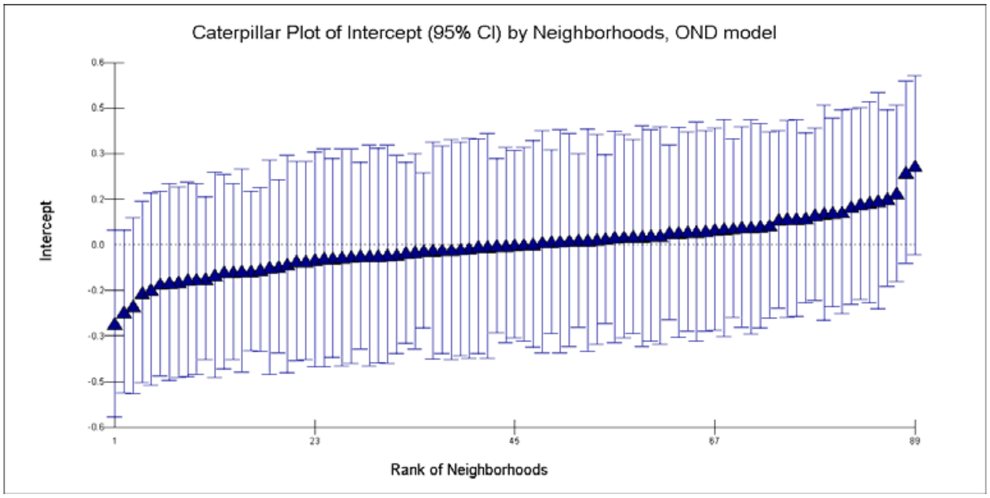


Figure 4-14 Caterpillar Plots for OND_{ijk} Model (Model 2)

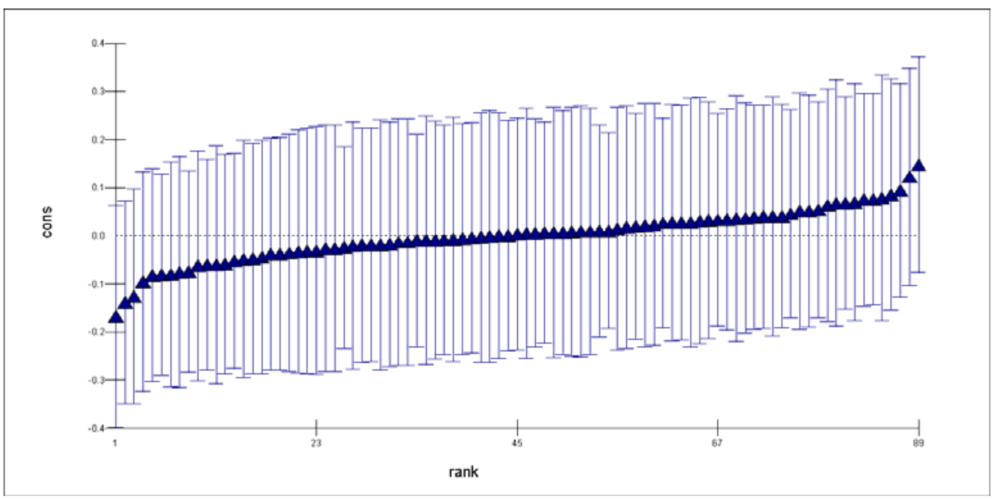


Figure 4-15 Caterpillar Plots for Race Only Model (Model 6)

4.5.2 Identifying Potential Influential Points

To identify potentially influential points, diagnostics were conducted on the following models: OND_{ijk} only (model 2), race only (model 6), race + OND_{ijk} (model 7), race + OND_{ijk} + individual-level covariates (model 15), Black + OND_{ijk} + individual disadvantage (model 20). In the OND_{ijk} only model (model 2) (Figure 4-16, Table 4-19), race only model (model 6, Figure 4-17, Table 4-

20), and race + OND_{ijk} + individual-level covariates model (model 15, Figure 4-19, Tables 4-22 and 4-23), Central Oakland and North Oakland were potential outliers. However, after removing these neighborhoods from the analysis, results were similar. In the race + OND_{ijk} model (model 7, Figure 4-18. Table 4-21), Squirrel Hill North, Marshall-Shadeland, and Hazelwood were potential influential points. Results were similar when these neighborhoods were removed. Finally, in the race + individual-level disadvantage + OND_{ijk} (model 20, Figure 4-20, Table 4-24), after removing Central Oakland, North Oakland, and Squirrel Hill North, results were similar. Overall, these outliers were not influential on the results of the models.

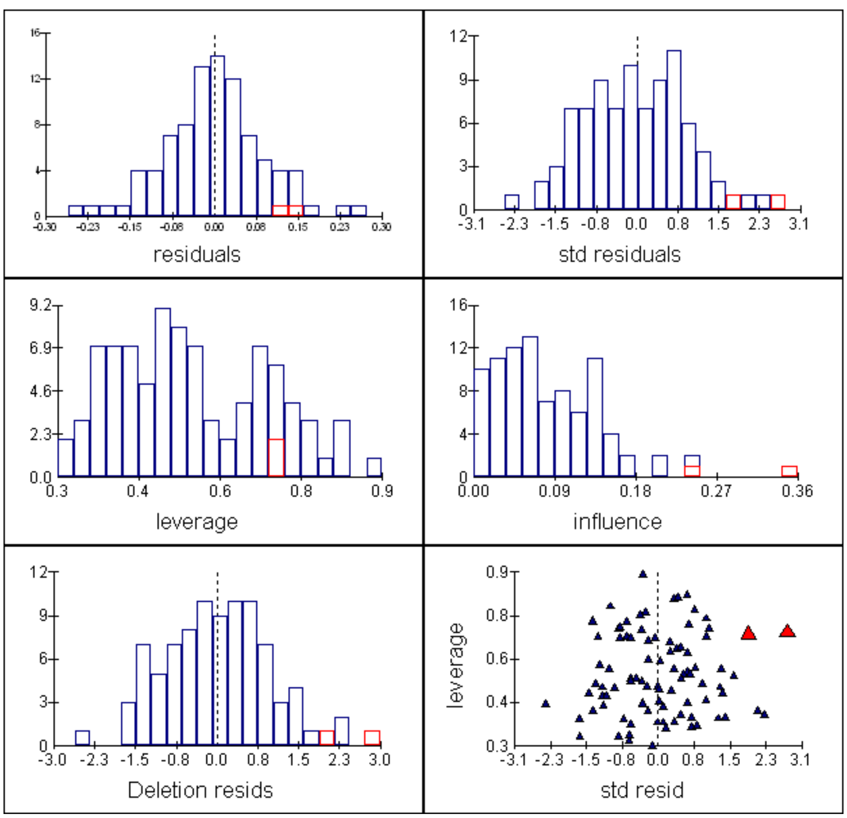


Figure 4-16 Diagnostics of OND_{ijk} Model

Table 4-19 Comparing Model With and Without Potential Influential Neighborhoods, OND_{ijk} Model

Without Neighborhoods Central Oakland (19) and North Oakland (56)

	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI L*	*95% CI U*
Fixed Effects							
Intercept	-2.3174	0.0423	-54.7849	0.00			
OND_{ijk}	0.0271	0.0038	7.1316	0.00	1.0275	1.0200	1.0349
Random Effects							
Neighborhood	0.0356	0.0220	2.6185	0.11			

All Neighborhoods

	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI L*	*95% CI U*
Fixed Effects							
Intercept	-2.3077	0.0423	-54.5556	0.00			
OND_{ijk}	0.0267	0.0038	7.0263	0.00	1.0271	1.0196	1.0345
Random Effects							
Neighborhood	0.0422	0.0219	3.7131	0.05			

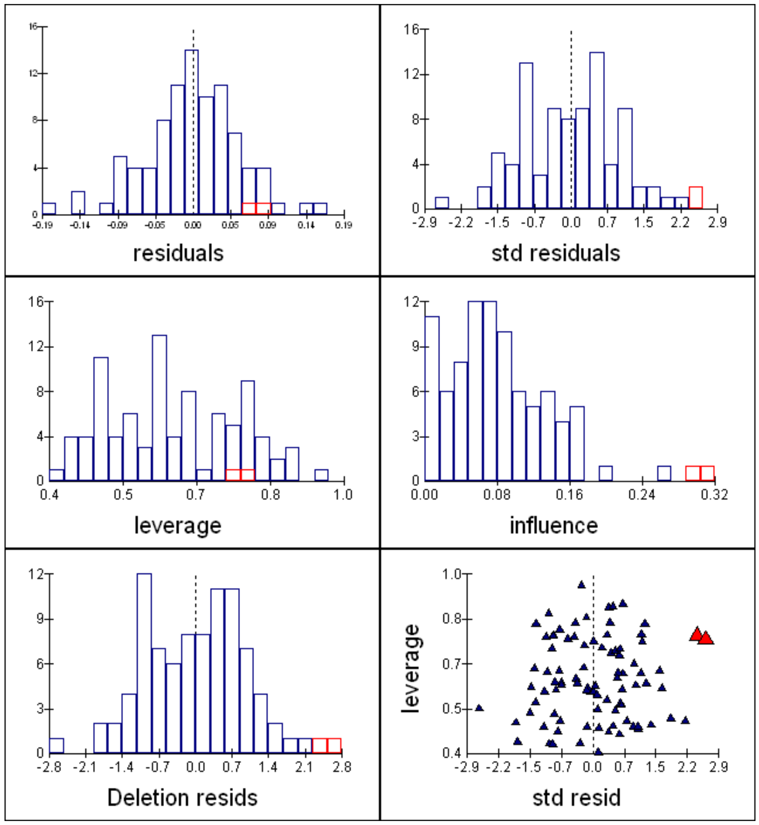


Figure 4-17 Diagnostics of Black Only Model

Table 4-20 Comparing Model With and Without Potential Influential Neighborhoods, Race Only Model

Without Neighborhood Central Oakland (19) and North Oakland (56)						
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI***
Fixed Effects						
Intercept	-2.7051	0.0561	-48.2193	0.00		
Black_NH	0.7779	0.0723	10.7593	0.00	2.1767	2.0350-2.3184
Random Effects						
Neighborhood	0.0182	0.0145	1.5755	0.21		
All Neighborhoods						
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI***
Fixed Effects						
Intercept	-2.6798	0.0581	-46.1239	0.00		
Black_NH	0.7507	0.0747	10.0495	0.00	2.1183	1.9719-2.2647
Random Effects						
Neighborhood	0.0244	0.0169	2.0845	0.15		

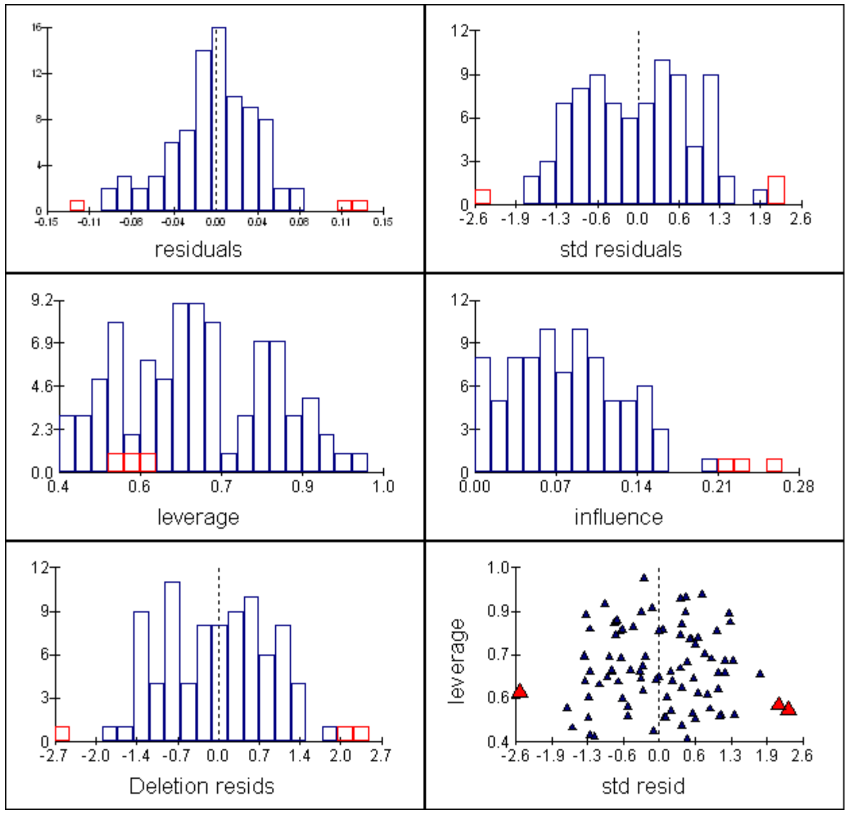


Figure 4-18 Diagnostics of Black + OND_{ijk} Model

Table 4-21 Comparing Model With and Without Potential Influential Neighborhoods, Race + OND_{ijk} Model

Without Neighborhoods Squirrel Hill North (76), Marshall-Shadeland (50), Hazelwood (38)							
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI L***	***95% CI U***
Fixed Effects							
Intercept	-2.6294	0.0616	-42.6851	0.00			
Black_NH	0.6360	0.0931	6.8314	0.00	1.8888	1.7063	2.0713
OND_{ijk}	0.0088	0.0041	2.1463	0.03	1.0088	1.0008	1.0169
Random Effects							
Neighborhood	0.0000	0.0000		NS			
All Neighborhoods							
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI L***	***95% CI U***
Fixed Effects							
Intercept	-2.6304	0.0623	-42.2215	0.00			
Black_NH	0.6506	0.0906	7.1810	0.00	1.9166	1.7390	2.0941
OND_{ijk}	0.0093	0.0042	2.2143	0.03	1.0093	1.0011	1.0176
Random Effects							
Neighborhood	0.0205	0.0160	1.6416	0.20			

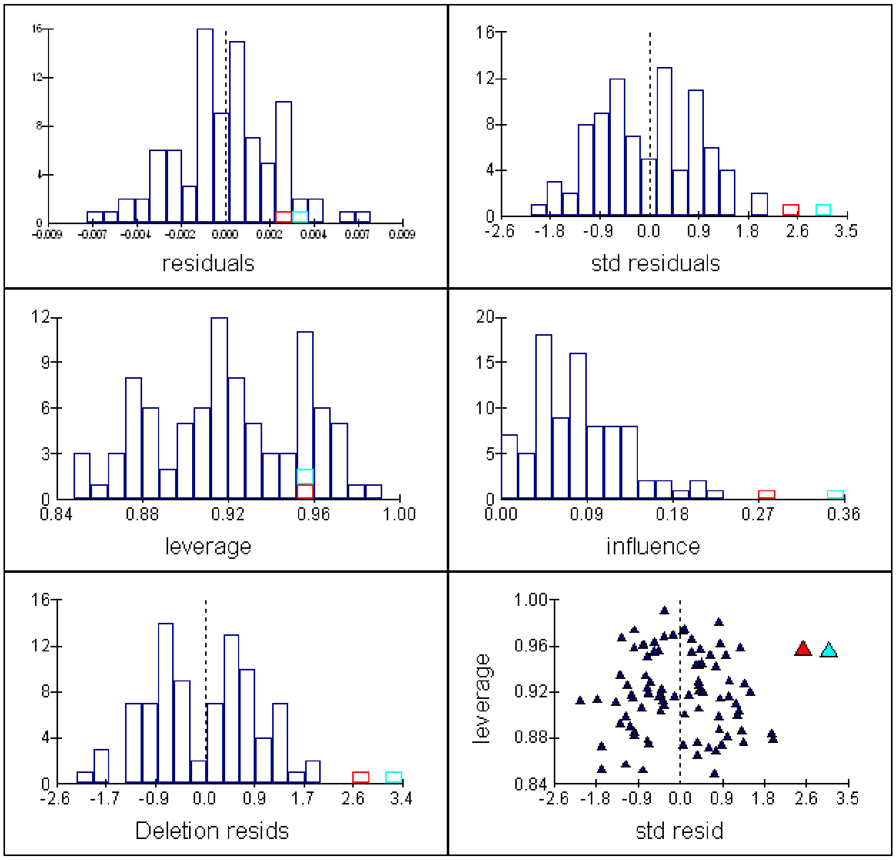


Figure 4-19 Diagnostics of Race + Individual-Level Covariates + OND_{ijk}

Table 4-22 Model Without Potential Influential Neighborhoods, Race+ OND_{ijk} + Individual-level Covariates Without Neighborhoods Central Oakland (19) and North Oakland (56)

	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI L*	*95% CI U*
Fixed Effects							
Intercept	-3.1049	0.0977	-31.7799	0.00			
Black_NH	0.7635	0.1150	6.6391	0.00	2.1456	1.9202	2.3710
Area-Level SEP							
OND_{ijk}	-0.0010	0.0041	-0.2439	0.81	0.9990	0.9910	1.0070
Individual-Level Covariates							
Socio-demographic Characteristics							
Maternal Age (neigh-centered)	0.0166	0.0137	1.2117	0.23	1.0167	0.9899	1.0436
No College	0.0971	0.0779	1.2465	0.21	1.1020	0.9493	1.2546
Not Married	0.6390	0.1023	6.2463	0.00	1.8945	1.6940	2.0950
Female Infant	0.2279	0.0700	3.2557	0.00	1.2559	1.1187	1.3931
Birthorder							
1	REF						
2_3	-0.3570	0.0804	-4.4403	0.00	0.6998	0.5422	0.8574
>=4	-0.2753	0.1168	-2.3570	0.02	0.7594	0.5304	0.9883
Health Care Access							
WIC	-0.4050	0.0802	-5.0499	0.00	0.6670	0.5098	0.8242
Behaviors							
Cigarette Smoke during Pregnancy	0.8605	0.1167	7.3736	0.00	2.3641	2.1354	2.5929
Interaction Terms							
Race*Cig	-0.3141	0.1483	-2.1180	0.03	0.7305	0.4398	1.0211
Race*Mage	0.0029	0.0159	0.1824	0.86	1.0029	0.9717	1.0341
Mage*Cig	0.0067	0.0195	0.3436	0.73	1.0067	0.9685	1.0449
Race*Cig*Age	0.0429	0.0247	1.7368	0.08	1.0438	0.9954	1.0922
Random Effects							
Neighborhood	0.0000	0.0000	--	NS			

Table 4-23 Model With Potential Influential Neighborhoods, Race+ OND_{ijk} + Individual-level Covariates

With All Neighborhoods							
	Parameter	***SE***	***z/Wald's statistic***	***p-value***	***OR***	***95% CI L***	***95% CI U***
Fixed Effects							
Intercept	-3.0850	0.1004	-30.7271	0.00			
Black_NH	0.7428	0.1132	6.5618	0.00	2.1017	1.8798	2.3235
Area-Level SEP							
OND_{ijk}	-0.0013	0.0043	-0.3023	0.76	0.9987	0.9903	1.0071
Individual-Level Covariates							
Socio-demographic Characteristics							
Maternal Age (neigh-centered)	0.0204	0.0125	1.6320	0.10	1.0206	0.9961	1.0451
No College	0.1101	0.0814	1.3526	0.18	1.1164	0.9568	1.2759
Not Married	0.6447	0.1049	6.1459	0.00	1.9053	1.6997	2.1109
Female Infant	0.2276	0.0703	3.2376	0.00	1.2556	1.1178	1.3933
Birthorder							
1	REF						
2_3	-0.3689	0.0828	-4.4553	0.00	0.6915	0.5292	0.8538
>=4	-0.2882	0.1214	-2.3740	0.02	0.7496	0.5117	0.9876
Health Care Access							
WIC	-0.4034	0.0814	-4.9558	0.0000	0.6681	0.5085	0.8276
Behaviors							
Cigarette Smoke during Pregnancy	0.8268	0.1139	7.2590	0.00	2.2858	2.0626	2.5090
Interaction Terms							
Race*Cig	-0.2836	0.1475	-1.9227	0.05	0.7531	0.4640	1.0422
Race*Mage	0.0000	0.0151	0.0000	1.00	1.0000	0.9704	1.0296
Mage*Cig	0.0032	0.0177	0.1808	0.86	1.0032	0.9685	1.0379
Race*Cig*Age	0.0464	0.0231	2.0087	0.04	1.0475	1.0022	1.0928
Random Effects							
Neighborhood	0.0095	0.0079	1.4461	0.23			

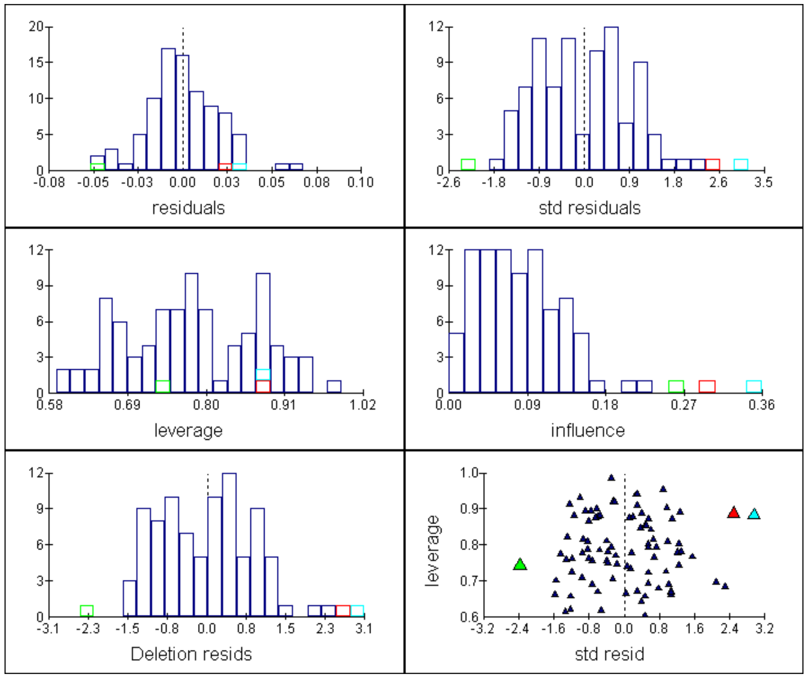


Figure 4-20 Diagnostics of Race + Individual-Level Disadvantage + OND_{ijk}

Table 4-24 Comparing Model With and Without Potential Influential Neighborhoods, Race + Individual-level Disadvantage+ OND_{ijk}

Without Neighborhoods Squirrel Hill North (77), Central Oakland (19), North Oakland (55)

	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI L*	*95 % CI U*
Fixed Effects							
Intercept	-2.8810	0.0783	36.7944	0.00			
Black_NH	0.4560	0.0909	5.0165	0.00	1.5777	1.3995	1.7558
Area-Level SEP							
OND_{ijk}	0.0035	0.0041	0.8537	0.39	1.0035	0.9955	1.0115
Individual-Level SEP							
No College	0.1163	0.0768	1.5143	0.13	1.1233	0.9728	1.2738
Not Married	0.7752	0.0935	8.2909	0.00	2.1709	1.9876	2.3541
WIC	-0.4009	0.0791	-5.0683	0.00	0.6697	0.5147	0.8248
Random Effects							
Neighborhood	0.0011	0.0036	0.0934	0.76			

All Neighborhoods

	Parameter	*SE*	*z/Wald's statistic*	*p-value*	*OR*	*95% CI L*	*95 % CI U*
Fixed Effects							
Intercept	-2.8895	0.0766	37.7219	0.00			
Black_NH	0.4466	0.0907	4.9239	0.00	1.5629	1.3851	1.7407
Area-Level SEP							
OND_{ijk}	0.0045	0.0041	1.0976	0.27	1.0045	0.9965	1.0125
Individual-Level SEP							
No College	0.1200	0.0769	1.5605	0.12	1.1275	0.9768	1.2782
Not Married	0.7849	0.0964	8.1421	0.00	2.1920	2.0031	2.3810
WIC	0.3979	0.0770	5.1675	0.00	1.4886	1.3377	1.6396
Random Effects							
Neighborhood	0.0121	0.0104	1.3536	0.24			

5.0 DISCUSSION AND CONCLUSIONS

5.1 SUMMARY

Three main hypotheses were tested, and results show that 1) areas with higher levels of neighborhood disadvantage are areas with higher risk of mothers giving birth to LBW infants, 2) Blacks have a higher risk of LBW than Whites in Pittsburgh, a) controlling for OND_{ijk} explains some of the difference between Blacks and Whites, and b) racial differences continue to exist even after controlling for individual-level factors. However, for the last hypothesis, 3) race differences were not attenuated by area-level SEP, after controlling for individual-level factors and OND_{ijk} was no longer associated with LBW. In a subsequent analysis that looked at individual-level disadvantage, although the race OR was attenuated, OND_{ijk} was not associated with LBW. Thus, although the differences between Blacks and Whites can be partially explained by adding OND_{ijk} to the model, racial differences were more explained by individual-level sociodemographic characteristics and individual-level disadvantage in models that include these individual-level covariate. This finding is supported by the non-significant association between . OND_{ijk} and LBW and yet the significant decrease of the Black OR from the unadjusted to the adjusted models.

This study's OND_{ijk} findings are consistent with results from Morenoff (2003) and Rich-Edwards and colleagues (2003). Although percent poor families, a measure of neighborhood poverty, in Morenoff's (2003) study and household income below the poverty level in Rich-Edwards and colleagues' paper (2003) were initially significantly associated with LBW, once individual-level covariates were added to the model, the magnitude of the association was greatly reduced to borderline significance or no-significance. In contrast, Grady's paper (2006) showed that neighborhood poverty remained significantly associated with LBW, even after controlling for individual-level covariates.

There are several potential reasons why we found no association between OND_{ijk} and LBW, after controlling for individual-level covariates. First, attempting to control for individual-level covariates in examining the role of area-level factors and LBW is an artificial approach in separating out the contextual aspects of a neighborhood from the composition of that neighborhood (Diez-Roux, 2003). More specifically, living in a poor neighborhood may influence the socioeconomic status of its residents, or the socioeconomic status of the residents may contribute to level of disadvantage in a neighborhood. Thus, to tease out the unique contribution of OND_{ijk} versus individual-level characteristics may be difficult, given that the context of a neighborhoods interrelated to the composition of that neighborhood. As Diez-Roux (2003) quotes Macintyre "People make places, and places make people" (p.12). In addition, the use of U.S. Census data to create a measure that captures the context of an environment may actually be capturing the composition of that same environment. U.S. Census data are aggregated individual-responses, which may reflect more of the composition of an area, than the context. Studies that reflect more neighborhood context may tap into residents perception if neighborhood boundaries disadvantage (e.g., resident perception of safety, economic viability of the neighborhood (number of vacant storefronts), or the quality of schools) that may influence health outcomes. In addition, although we adjusted for individual-level covariates to control for potential confounders of the association of OND_{ijk} and LBW, these individual-level covariates may serve as mediators of the relationship between OND_{ijk} and LBW. In other words, the effect of OND_{ijk} on LBW may be indirect and mediated by factors, such as WIC services, education, and marital status. To test this directly, a path analysis approach under a structural equation framework would help tease out the indirect and direct relationships among OND_{ijk}, individual-level covariates, and LBW. Thus, although we found no association between OND_{ijk} and LBW, after controlling for individual-level factors, a path analysis approach may yield a better understanding of the indirect effect of OND_{ijk} on LBW, and whether that relationship is mediated by individual-level covariates.

Also, it is important to note that race OR increased unexpectedly when individual-level covariates and interaction terms were added to model. This behavior may have been due to suppressor effects of variables included in the model. Suppressor variables control for the "irrelevant elements" or random noise of a predictor, thereby contributing to a lower variance of that predictor (Maassen & Bakker, 2001). This can then produce the kind of elevated race ORs we observed when individual-level covariates were included in the model. Identifying suppressor variables are difficult, however, and includes running several models with combinations of variables and observing their effect on the race OR when they are removed or added to the model.

Despite our inability to reject the third hypothesis, results from individual-level analysis are worth noting, in particular results from the interaction analysis among race, cigarette smoke, and maternal age. Geronimus' (1992) "weathering hypothesis" suggests that an increase in maternal age increases the difference in LBW risk between Blacks and Whites. One notion is that cumulative contribution of stressors, manifested as racism, throughout one's life exacerbates the LBW risk, especially for older Black mothers. This perspective expands the notion of prenatal care in that care commences not at conception but at the mother's birth. Results in this study demonstrated an interaction among race, age, and cigarette smoke. Figure 4-11 shows the dramatic increased predicted LBW proportion for Black smokers as age increases. These findings suggest that an age and race interaction is occurring in Pittsburgh, which is exacerbated by smoking status of older Black women. The maternal age and race interaction was also found in papers by Rauh and colleagues (2001) and by Rich-Edwards and colleagues (2003). Both these studies found an increased difference in LBW risk and birthweight between Blacks and Whites as maternal age increased. For example, in Rauh and colleagues' study (2001) the OR for very LBW for Blacks was 2.45 at age 20, then jumped to 4.2 at age 40. Rich-Edwards and colleagues (2003) found that the OR for those who smoked during pregnancy was 1.94 (95% CI: 1.76-2.15) at age 20, but then jumped to 2.47 (95% CI: 2.19-2.79) at age 40. These findings suggest that cumulative effects of racism may be contributing to increased differences between Blacks and Whites in terms of LBW risk, especially as mothers increase in age.

5.2 LIMITATIONS

There were several limitations to this study. First, the lack of variability at the block group level limited our ability to conduct multilevel analysis at this level. Thus, although a lack of significance was found in most models between LBW and CD_{ij} or MED_{ij}, the inability to detect that difference was due to the lack of variability at this area-level. Future studies that have a higher number of LBW within a neighborhood or more individuals by race may help increase the variability at this level to examine this hypothesis more closely. A second limitation is that the structure of Pittsburgh neighborhoods in that 25 out of 89 neighborhoods were comprised of only 1 block group. In other words, 30% of neighborhoods serve as either block groups or neighborhoods in our analysis. This characteristic of the Pittsburgh neighborhoods may have also contributed to our inability to detect an association between block group disadvantage and LBW. Third, because of the lack of variability within neighborhoods, we were unable to test for cross-level interactions between, for example, race and OND_{ijk}. Studies have suggested that individuals with high-levels of disadvantage may experience the positive effects of living in neighborhoods with less disadvantage (Pickett, et al., 2005). Additional limitations of the study include: higher area level measures of SEP were aggregated by combining block group level data together, ignoring the different sampling weights at the block group, census tract, and neighborhood levels. Ignoring the sampling weights could potentially lead to inaccurate estimates of SEP measures at each of these levels. Fifth, SEP measures were based on U.S. Census from 2000. Findings from this study may not be applicable to the current conditions of neighborhoods where the makeup of residences have changed since 2000. Finally, SEP measures were developed specifically for Pittsburgh and are not generalizable to the experiences in other U.S. cities.

5.3 PUBLIC HEALTH IMPLICATIONS

The methodological approach and the findings from this study have implications on research examining area-level effects on health. A limitation in the literature on neighborhoods and health is the lack of consensus on which area-level to use (Diez Roux, 2001; Messer, 2007). Many studies have used areas defined by the U.S. Census, primarily census tracts. However, this study included area-level measures at the neighborhood and block group level. Although insufficient variation was found at the block group level to test the association between MED_{ij} and CD_{ij} and LBW, applying these measures to other areas or outcomes with more variability at the block group level may help identify different social processes or mechanisms operating at the block group level versus neighborhood level.

A second strength of this study is that it uses area-level SEP measures that were developed taking into consideration both theory and statistics to combine related measures that represent common SEP factors. This study goes one step further in the results presented in Almario Doebler, (2009) in that it examines the value of OND_{ijk} in predicting LBW at the individual level.

In terms of policy implications, this study found an association between OND_{ijk} and LBW. Maps showed an overlap between areas with high levels of OND_{ijk} and areas with high proportion of LBW. Thus, in the absence of individual-level characteristics, identifying one's neighborhood in Pittsburgh may help predict one's risk for LBW and develop interventions, such as increasing access to WIC services in these disadvantaged areas, which have shown to be protective of LBW.

Finally, if we take a life course perspective, or test the weathering hypothesis, that the cumulative effects early on in one's life may increase one's risk for adverse outcomes, especially for Blacks, results from Table 4-3 and depicted in Figure 5-1 show the startling patterns in Pittsburgh: that over half of Black infants are born in neighborhoods that are the most deprived and that almost 75% of these infants are born into neighborhoods with disadvantage in the upper two quartiles. In contrast only 13% of White infants are born in these neighborhoods. Thus, about 3350 Blacks infants, regardless if they are LBW or not, are born in disadvantaged neighborhoods, or as Acevedo-Garcia and colleagues' (2008) term, lacking access to “opportunity neighborhoods, ” and more likely these disadvantage neighborhoods are also lacking in high opportunity indicators, such as quality schools, healthy environments, safe neighborhoods, and access to quality health services. Overall trends presented in this study are consistent with national U.S. Census data that show that a typical Black child lives in neighborhoods with a high poverty rate, high percentage of renters, without a high school education, and unemployment. Policies recommended by Acevedo-Garcia and colleagues (2008) include people-based policies that help disadvantaged minorities find housing in more advantaged neighborhoods and place-based policies that help to improve the quality of the neighborhood environment. Overall, from a life course perspective, a targeted approach to improve child health may in the long term impact LBW risk

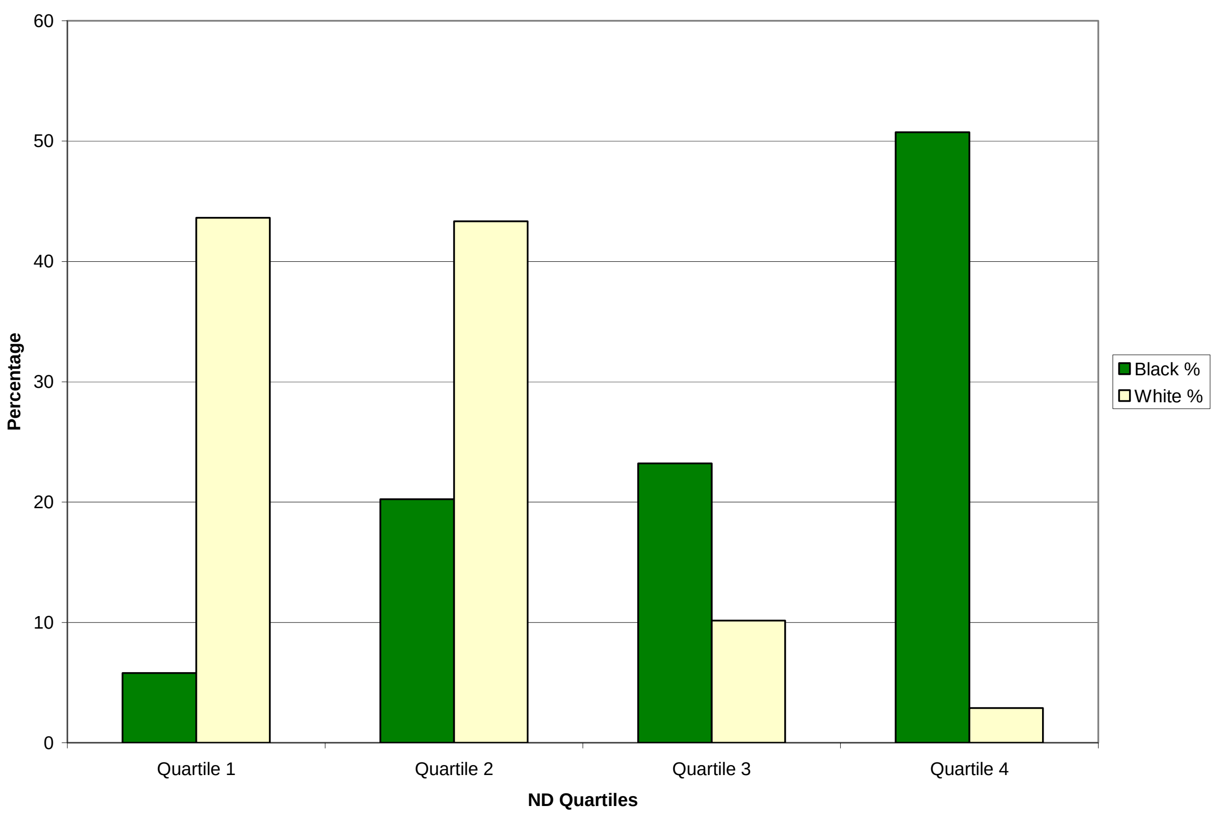


Figure 5-1 OND_{ijk} Quartiles by Race

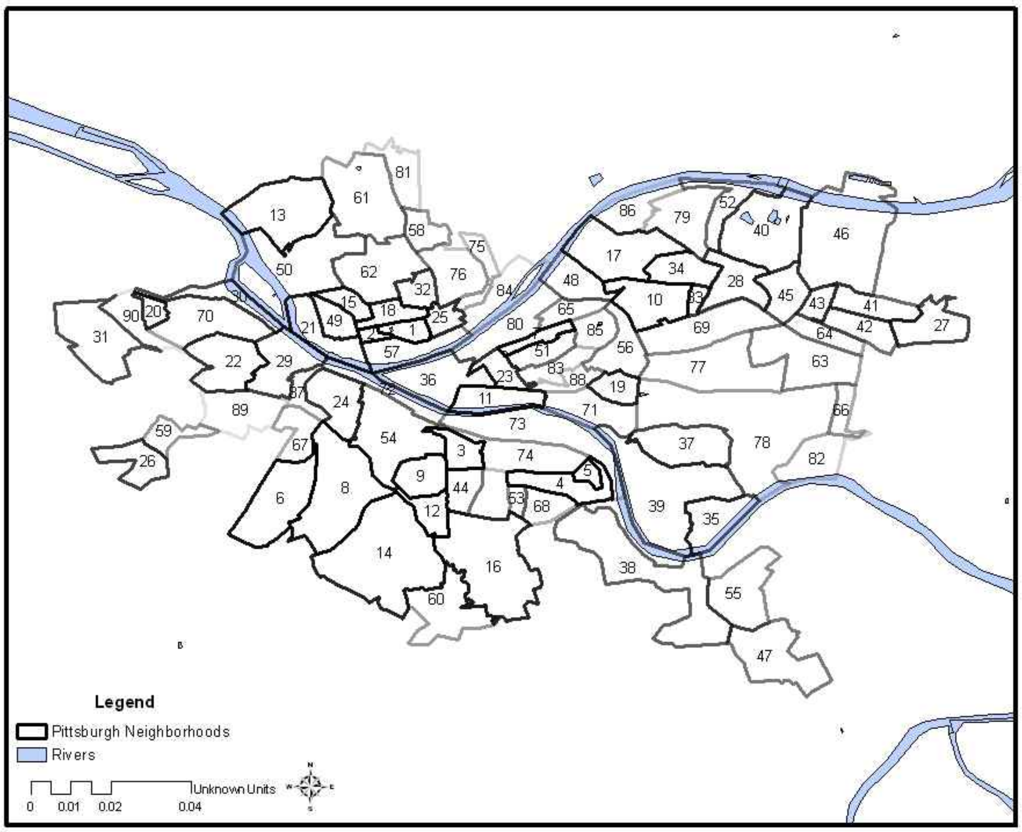
5.4 CONCLUSIONS

The study found an association between OND and LBW, even after controlling for race. In addition, the association between race and LBW was attenuated after adding OND to the model. However, the relation between OND and LBW was no longer significant after adding individual-level covariates to the model. Although an association between OND and LBW was not observed in this last model, limitations in the data (lack of variability of LBW within neighborhoods, use of aggregated Census data, and inability to tease apart the distinction between context and composition of an environment) contributed to our inability to detect an association between OND and LBW, after controlling for individual-level factors. However, an association between OND and LBW was found, and maps of Pittsburgh showing areas of high levels of OND and high proportion of LBW may be useful to policy-makers in identifying areas to target interventions to reduce LBW rates.

In addition, individual-level analysis suggested that an interaction existed among race, cigarette use, and age, providing evidence that differences between Blacks and Whites are increased at older ages. In addition the role of cigarette smoke during pregnancy exacerbated the differences between Blacks and Whites. This finding supports Geronimus' (1992) weathering hypothesis that suggests cumulative life stressors influences adverse health outcomes later on in life, such that differences in adverse birth outcomes are greatest between Blacks and Whites with advancing maternal age. Descriptive data also showed that a higher percentage of Black infants were residing in areas with higher disadvantage. Thus from a life course perspective or weathering hypothesis, improving disadvantaged neighborhoods, using people-based or place-based policies, may help reduce LBW risk later on in life.

APPENDIX A

PITTSBURGH NEIGHBORHOOD MAP



INDEX	NEIGHBORHOOD	INDEX	NEIGHBORHOOD	INDEX	NEIGHBORHOOD
1	Allegheny Center	31	Fairywood	61	Perry North
2	Allegheny West	32	Fineview	62	Perry South
3	Allentown	33	Friendship	63	Point Breeze
4	Arlington	34	Garfield	64	Point Breeze North
5	Arlington Heights	35	Glen Hazel	65	Polish Hill
6	Banksville	36	Golden Triangle	66	Regent Square
7	Bedford Dwellings	37	Greenfield	67	Ridgemont
8	Beechview	38	Hays	68	St. Clair
9	Beltzhoover	39	Hazelwood	69	Shadyside
10	Bloomfield	40	Highland Park	70	Sheraden
11	Bluff	41	Homewood North	71	South Oakland
12	Bonair	42	Homewood South	72	South Shore
13	Brighton Heights	43	Homewood West	73	South Side Flats
14	Brookline	44	Knoxville	74	South Side Slopes
15	California Kirkbride	45	Larimer	75	Spring Garden
16	Carrick	46	Lincoln-Lemington-Belmar	76	Spring Hill-City View
17	Central Lawrenceville	47	Lincoln Place	77	Squirrel Hill North
18	Central Northside	48	Lower Lawrenceville	78	Squirrel Hill South
19	Central Oakland	49	Manchester	79	Stanton Heights
20	Chartiers City	50	Marshall-Shadeland	80	Strip District
21	Chateau	51	Middle Hill	81	Summer Hill
22	Crafton Heights	52	Morningside	82	Swisshelm Park
23	Crawford Roberts	53	Mt. Oliver Neighborhood	83	Terrace Village
24	Duquesne Heights	54	Mount Washington	84	Herrs Island - Troy Hill
25	East Allegheny	55	New Homestead	85	Upper Hill
26	East Carnegie	56	North Oakland	86	Upper Lawrenceville
27	East Hills	57	North Shore	87	West End
28	East Liberty	58	Northview Heights	88	West Oakland
29	Elliot	59	Oakwood	89	Westwood
30	Esplen	60	Overbrook	90	Windgap

APPENDIX B

PITTSBURGH NEIGHBORHOODS AND CENSUS TRACT NUMBERS FOR 2000

Neighborhood	2000 Census Tracts
Allegheny Center	2204
Allegheny West	2201
Allentown	1803
Arlington	1603
Arlington Heights	1604
Banksville	2023
Bedford Dwellings	509
Beechview	1916, 1920
Beltzhoover	1809
Bloomfield	903, 809, 806, 802, 804
Bluff	103
Bonair	1806
Brighton Heights	2708, 2701, 2703
Brookline	1917, 3206, 1919, 1918
California Kirkbride	2507
Carrick	2901, 2902, 2904
Central Lawrenceville	901, 902
Central Northside	2503, 2206
Central Oakland	405,406
Chartiers City	2021
Chateau	2108
Crafton Heights	2814, 2815
Crawford Roberts	305
Duquesne Heights	1911
East Allegheny	2304
East Carnegie	2805
East Hills	1306
East Liberty	1113, 1115
Elliot	2020
Esplen	2017
Fairywood	2808
Fineview	2509
Friendship	807

Garfield	1016, 1017, 1114
Glen Hazel	1504
Golden Triangle	201
Greenfield	1516, 1517
Hays	3101
Hazelwood	1501, 1515
Herrs Island	2406
Highland Park	1106, 1102
Homewood North	1301, 1302
Homewood South	1303, 1304
Homewood West	1207
Knoxville	3001
Larimer	1204, 1208
Lincoln Place	3102
Lincoln-Lemington- Belmar	1201, 1202, 1203
Lower Lawrenceville	603
Manchester	2107
Marshall-Shadeland	2715, 2704
Middle Hill	501
Morningside	1014
Mount Washington	1903, 1914, 1807, 1915
Mt. Oliver Neighborhood	1607
New Homestead	3103
North Oakland	507, 403, 404
North Shore	2205
Northview Heights	2609
Oakwood	2812
Overbrook	3204, 3207
Perry North	2602, 2607
Perry South	2615, 2614
Point Breeze	1404, 1406
Point Breeze North	1405
Polish Hill	605
Regent Square	1410
Ridgemont	2016
Shadyside	708, 705, 709, 706, 703
Sheraden	2018, 2022
South Oakland	409
South Shore	1921
South Side Flats	1702, 1609
South Side Slopes	1608, 1706
Spring Garden	2412
Spring Hill-City View	2620
Squirrel Hill North	1402, 1401, 1403
Squirrel Hill South	1413, 1408, 1414
St. Clair	1606
Stanton Heights	1018, 1005
Strip District	203
Summer Hill	2612
Swisshelm Park	1411
Terrace Village	510, 511
Troy Hill	2406
Upper Hill	506

Upper Lawrenceville	1011
West End	2019
West Oakland	402
Westwood	2811
Windgap	2807

APPENDIX C

PREDICTED AND OBSERVED LBW FROM OND_{IJK} ONLY MODEL AND RACE AND OND_{IJK} MODEL

				All		Black		White	
Neighborhood	**#**	**OND_{ijk}**	**$cOND_{ijk}$**	**Observed LBW**	**Predicted LBW**	**Observed LBW**	**Predicted LBW**	**Observed LBW**	**Predicted LBW**
Allegheny Center	1	37.24	7.90	0.09	0.11	0.11	0.13	0.00	0.07
Allegheny West	2	22.64	-6.70	0.00	0.07	0.00	0.11	0.00	0.06
Allentown	3	31.17	1.83	0.10	0.10	0.14	0.12	0.06	0.07
Arlington	4	25.00	-4.34	0.07	0.08	0.04	0.12	0.08	0.06
Arlington Heights	5	44.68	15.34	0.08	0.13	0.09	0.13	0.00	0.08
Banksville	6	17.15	-12.19	0.08	0.07	0.50	0.11	0.07	0.06
Bedford Dwellings	7	58.83	29.49	0.13	0.16	0.13	0.15		
Beechview	8	21.26	-8.08	0.08	0.08	0.08	0.12	0.08	0.07
Beltzhoover	9	33.28	3.94	0.16	0.11	0.16	0.13	0.17	0.07
Bloomfield	10	26.35	-2.99	0.09	0.09	0.12	0.12	0.09	0.07
Bluff	11	39.48	10.14	0.19	0.12	0.24	0.14	0.00	0.08
Bonair	12	18.85	-10.50	0.12	0.07	0.00	0.11	0.13	0.06
Brighton Heights	13	21.42	-7.92	0.06	0.07	0.10	0.11	0.05	0.06
Brookline	14	18.83	-10.51	0.07	0.07	0.00	0.11	0.07	0.06
California Kirkbride	15	43.06	13.72	0.19	0.14	0.21	0.14	0.00	0.08
Carrick	16	21.75	-7.59	0.06	0.07	0.06	0.11	0.06	0.06
Central Lawrenceville	17	26.90	-2.44	0.09	0.09	0.05	0.12	0.10	0.07
Central Northside	18	34.50	5.16	0.14	0.11	0.14	0.13	0.13	0.07
Central Oakland	19	30.95	1.61	0.21	0.11	0.25	0.13	0.19	0.07
Chartiers City	20	28.57	-0.77	0.15	0.09	0.09	0.12	0.50	0.07
Crafton Heights	22	22.48	-6.86	0.07	0.07	0.09	0.11	0.06	0.06
Crawford Roberts	23	43.55	14.21	0.12	0.12	0.12	0.13	0.17	0.07
Duquesne Heights	24	18.42	-10.92	0.08	0.07	0.00	0.11	0.08	0.06
East Allegheny	25	36.94	7.60	0.13	0.11	0.16	0.13	0.10	0.07
East Carnegie	26	24.61	-4.73	0.06	0.08	0.50	0.12	0.00	0.06
East Hills	27	38.45	9.11	0.09	0.10	0.10	0.12	0.00	0.07
East Liberty	*28*	*39.63*	*10.29*	*0.09*	*0.11*	*0.11*	*0.12*	*0.03*	*0.07*
Elliot	29	25.52	-3.82	0.08	0.08	0.05	0.12	0.10	0.06
Esplen	30	28.77	-0.57	0.13	0.09	0.33	0.12	0.00	0.07
Fairywood	31	49.73	20.39	0.05	0.14	0.05	0.14	0.00	0.08
Fineview	32	35.76	6.41	0.11	0.11	0.12	0.13	0.09	0.07

				All		Black		White	
Neighborhood	**#**	**OND_{ijk}**	**$cOND_{ijk}$**	**Observed LBW**	**Predicted LBW**	**Observed LBW**	**Predicted LBW**	**Observed LBW**	**Predicted LBW**
Friendship	33	29.76	0.42	0.12	0.10	0.22	0.12	0.04	0.07
Garfield	*34*	*39.85*	*10.51*	*0.10*	*0.11*	*0.10*	*0.12*	*0.07*	*0.07*
Glen Hazel	35	52.52	23.18	0.09	0.15	0.10	0.14	0.00	0.08
Golden Triangle	36	32.28	2.94	0.00	0.09	0.00	0.12	0.00	0.07
Greenfield	37	18.82	-10.52	0.04	0.06	0.06	0.10	0.04	0.06
Hays	38	23.64	-5.70	0.14	0.08	0.00	0.12	0.17	0.07
Hazelwood	39	30.10	0.76	0.15	0.12	0.19	0.14	0.10	0.08
Highland Park	40	21.69	-7.65	0.09	0.08	0.15	0.11	0.05	0.06
Homewood North	41	40.79	11.45	0.14	0.13	0.14	0.14	0.13	0.08
Homewood South	42	45.28	15.94	0.14	0.13	0.15	0.14	0.00	0.08
Homewood West	43	38.50	9.16	0.15	0.12	0.14	0.13	0.25	0.07
Knoxville	44	29.67	0.33	0.13	0.11	0.13	0.13	0.12	0.07
Larimer	45	40.63	11.29	0.09	0.11	0.10	0.13	0.00	0.07
Lincoln-Lemington-Belmar	46	36.10	6.76	0.13	0.12	0.13	0.13	0.13	0.07
Lincoln Place	47	17.15	-12.19	0.04	0.06	0.33	0.11	0.03	0.06
Lower Lawrenceville	48	31.20	1.86	0.08	0.09	0.13	0.12	0.04	0.07
Manchester	49	37.49	8.15	0.15	0.12	0.16	0.13	0.00	0.07
Marshall-Shadeland	50	25.09	-4.25	0.13	0.10	0.16	0.13	0.11	0.07
Middle Hill	51	42.06	12.72	0.15	0.13	0.16	0.14	0.00	0.08
Morningside	52	20.17	-9.17	0.05	0.07	0.07	0.11	0.04	0.06
Mt. Oliver Neighborhood	53	28.17	-1.18	0.13	0.09	0.13	0.12	0.14	0.07
Mount Washington	54	22.43	-6.91	0.09	0.08	0.12	0.12	0.09	0.07
New Homestead	55	16.67	-12.67	0.03	0.06	0.00	0.11	0.03	0.06
North Oakland	56	21.04	-8.30	0.21	0.09	0.22	0.12	0.20	0.07
North Shore	57	17.86	-11.49	0.13	0.07			0.13	0.06
Northview Heights	58	63.07	33.73	0.15	0.18	0.15	0.16	0.00	0.09
Oakwood	59	23.35	-5.99	0.07	0.08	0.00	0.12	0.08	0.06
Overbrook	60	17.38	-11.96	0.04	0.06	0.00	0.10	0.04	0.06
Perry North	61	21.09	-8.25	0.10	0.08	0.19	0.12	0.05	0.07
Perry South	62	34.04	4.70	0.14	0.12	0.15	0.13	0.10	0.07
Point Breeze	63	14.23	-15.11	0.04	0.06	0.17	0.10	0.04	0.06
Point Breeze North	64	29.02	-0.32	0.11	0.10	0.14	0.12	0.05	0.07
Polish Hill	65	28.16	-1.18	0.11	0.09	0.07	0.12	0.13	0.07
Regent Square	66	13.21	-16.13	0.03	0.06	0.00	0.10	0.03	0.06
Ridgemont	67	16.49	-12.85	0.05	0.06	0.00	0.11	0.05	0.06
St. Clair	68	53.13	23.79	0.09	0.14	0.08	0.14	0.50	0.08
Shadyside	*69*	*20.38*	*-8.96*	*0.04*	*0.06*	*0.13*	*0.10*	*0.03*	*0.06*
Sheraden	70	25.65	-3.69	0.08	0.08	0.07	0.11	0.09	0.06
South Oakland	71	30.35	1.01	0.04	0.08	0.06	0.12	0.03	0.06
South Shore	72	32.91	3.57	0.00	0.10			0.00	0.07
South Side Flats	73	25.38	-3.97	0.05	0.07	0.18	0.11	0.04	0.06
South Side Slopes	74	22.53	-6.81	0.11	0.09	0.25	0.12	0.09	0.07
Spring Garden	75	24.71	-4.63	0.10	0.08	0.20	0.12	0.08	0.07
Spring Hill-City View	76	30.67	1.32	0.11	0.10	0.16	0.13	0.06	0.07
Squirrel Hill North	*77*	*15.03*	*-14.31*	*0.02*	*0.05*	*0.00*	*0.09*	*0.02*	*0.05*
Squirrel Hill South	78	18.02	-11.32	0.04	0.06	0.08	0.10	0.04	0.05

				All		Black		White	
Neighborhood	**#**	**OND_{ijk}**	**$cOND_{ijk}$**	**Observed LBW**	**Predicted LBW**	**Observed LBW**	**Predicted LBW**	**Observed LBW**	**Predicted LBW**
Stanton Heights	79	20.33	-9.01	0.11	0.08	0.17	0.12	0.06	0.07
Strip District	80	33.87	4.53	0.05	0.10	0.08	0.12	0.00	0.07
Summer Hill	81	17.99	-11.35	0.08	0.07	0.40	0.11	0.04	0.06
Swisshelm Park	82	14.53	-14.81	0.06	0.06	0.33	0.11	0.04	0.06
Terrace Village	83	55.03	25.69	0.17	0.17	0.17	0.15	0.00	0.09
Herrs Island - Troy Hill	84	24.26	-5.08	0.10	0.08	0.25	0.12	0.09	0.07
Upper Hill	85	30.23	0.89	0.08	0.09	0.06	0.12	0.25	0.07
Upper Lawrenceville	86	26.34	-3.01	0.09	0.09	0.13	0.12	0.07	0.07
West End	87	30.33	0.99	0.14	0.09	0.33	0.12	0.00	0.07
West Oakland	88	36.65	7.31	0.11	0.11	0.13	0.13	0.00	0.07
Westwood	89	18.28	-11.06	0.06	0.07	0.12	0.11	0.05	0.06
Windgap	90	19.96	-9.38	0.05	0.07	0.12	0.11	0.00	0.06

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