

Low Birth Weight and Neighbourhood of Residence: A Multi-level Analysis

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By

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ABSTRACT

Low birth weight (LBW) is most often measured at an individual level. However, increasingly, it has been shown that other factors, which are not directly tied to the individual, can influence low birth weight. Specifically, factors such as family income, education level, place of residence, and health care benefits may influence a child's health. Through the database available, I will test the hypothesis that low birth weight is an outcome that can be influenced by the macro-level environment.

The objective of this study is to understand the relationship between neighbourhood level factors and LBW in a population of children. It is well known that individual level risk factors influence low birth weight. What is less known is the extent to which a potential determinant of LBW - such as neighbourhood of residence influences low birth weight in a birth cohort in a small prairie city. The main study question is as follows; **Do factors related to neighbourhood of residence increase the risk of low birth weight children?**

The study was comprised of a birth cohort of 5,643 children born in 1992-1994, in Saskatoon, Saskatchewan, Canada. It was found through logistic regression models that the following variables contributed significantly to the prediction of low birth weight; sex (OR=1.75, 95% CI=1.27-2.41), financial

assistance (OR=1.5, 95% CI=1.05-2.14), and gestational age (OR=85.8, 95% CI=54.02-136.35). There were also significant interactions between gestational age and parity and gestational age and stillborn births. Neighbourhood characteristics that were related to LBW (unadjusted) were; proportions of residents <grade9 (p=0.056), dwellings owned (p=0.03), median income (p=0.018), park space (p=0.015), total number of person <\$10,000/year (p<0.001), one parent households (p=0.001), and total number of aboriginal persons (p=0.005).

Lastly, previously mentioned individual and neighbourhood level variables were combined in a multi-level model. It was found that once all significant individual level predictors were in the model, all neighbourhood level variables studied were no longer significant.

In this study, I found that individual level variables were the best predictors of low birth weight. Efforts at prevention of LBW should focus on individual level variables.

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For my parents,
who made everything possible
and then made me feel as though
anything could be

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CHAPTER 1: INTRODUCTION

Low birth weight (LBW) is a common and preventable public health concern. Since the early 1970s low birth weight has been widely studied, and its significance in causing childhood handicap, infant mortality and morbidity is widely accepted.(1, 2) In the United States, low birth weight accounts for \$5.5 to 6 billion dollars more per year in health care spending than if the children had been born "normal" weight.(3) There are many risk factors associated with low birth weight that have also been well documented. What is interesting, however, is whether there are other risk factors that are more ecologic in nature, which contribute to increased low birth weight.

Low birth weight is generally described as less than 2500 grams (or 5 pounds 8 oz).(1) Low birth weight risk factors are most often measured at the individual level. However, it has been shown that other factors, which are not directly tied to the individual, can influence low birth weight. Such aggregate measures can include access to care, services available, and the socio-demographic profile of people. Neighbourhood of residence is an excellent proxy for many of these aggregate measures. Specifically, factors such as family income, education level, place of residence, and health care benefits

may influence a child's health. In this respect, research into children's health is also family and child health research.

The present study will utilize data from Saskatchewan Health on Saskatoon births from 1992-1994. Saskatoon is a prairie city located in South Central Saskatchewan with a population of 212,660.(4) The city is supplied with water by the South Saskatchewan River, which is the conventional division between the East and West sides of the city. The Eastside of the city is comprised of thirty-seven neighbourhoods, which includes University land, one industrial area, and development areas. University land, industrial areas and development areas are not generally included in population analyses, as they are not residential. The Westside of the city is comprised of forty-three neighbourhoods, which include eight industrial areas, and management/development areas that are not included in analysis.(5, 6)

Neighbourhood analyses are increasingly becoming part of the epidemiological landscape. In the search for risk factors and cause and effect, traditional epidemiology has focused primarily on individual risk factors. As neighbourhood analyses, ecologic studies, and other macro level environment studies increase in frequency our understanding of causation of morbidity and mortality will only increase.

Neighbourhoods differ in many ways, for example, access to groceries, access to alcohol, housing prices, green space, schools and average income.(6) It is thought that these differences contribute to the differing health outcomes of

its residents. It will be interesting to understand what specific aspects of Saskatoon neighbourhoods contribute to the differences in low birth weight of its children - or if there are differences at all.

1.1 RATIONALE FOR STUDY

Besides being a preventable public health concern, low birth weight is also associated with childhood mortality and morbidity. Recent literature regarding low birth weight, as well as other adverse birth outcomes, have focused on individual level factors. This focus has the inherent limitation of ignoring important macro-level influences. While there have been many studies which examine individual level factors and macro-level factors separately, few examine them together. Clearly, if one was to analyze both levels *together*, a better picture of the problem can be elicited.

In studies where both macro and micro level considerations have been taken, there are many problems. Not all studies utilize the appropriate statistical technique for analyzing this kind of data. Many studies use simple regression models with both individual and aggregate level variables, when multi-level modeling is much more appropriate. Problems such as interviewer bias, proxy response, recall bias and sampling bias plague many of these studies, due to the source of the data.

The present study will attempt to redress these issues. By utilizing an administrative database, which has been found reliable and valid for some

research purposes, problems of interviewer bias, proxy response, recall bias and sampling bias are greatly minimized; however administrative databases have other limitations of their own. Also, this study will use a relatively new statistical technique in order to incorporate both individual and neighbourhood level variables into the same model. This technique is known as multi-level modeling.

1.2 STATEMENT OF OBJECTIVES

The objective of this study is to understand the relationship between neighbourhood level factors and LBW in a population of children. It is well known that individual level risk factors influence low birth weight. What is less known is the extent to which a potential determinant of LBW, such as neighbourhood of residence, influences low birth weight in a birth cohort in a small prairie city.

The main study question is as follows:

Do factors related to neighbourhood of residence increase the risk of low birth weight children?

Secondarily to the main objective, this study would like to demonstrate that taking into account individual level factors, neighbourhood factors are still independently related to LBW. For example, even amongst those individuals with a history of stillborn births, lower income, and higher parity -

neighbourhood of residence will still play a role in understanding the risk factors associated with low birth weight.

It is hoped that the results of this study will provide important information to Saskatoon District Health, and add to the body of literature on low birth weight and aggregate level influences. It is also hoped that the results will be able to add to the current understanding of the risk factors of low birth weight.

CHAPTER 2: LITERATURE REVIEW

The following is a literature review of the significant issues relevant to the present study. I will first provide the definition of low birth weight, the risk factors known to be associated with it and the effects of low birth weight subsequently in life. Following this, a discussion of socio-economic factors associated with low birth weight will be presented. The next section will cover neighbourhood analysis in general, with a brief look at multi-level modeling in particular. Following this an overview of administrative data, and its use in health research will be presented. This chapter will conclude with a brief discussion of limitations and gaps in the present understanding and highlight directions for future research.

3.1. DEFINITION OF LOW BIRTH WEIGHT

Low birth weight is defined as less than 2500 grams (5 pounds 8 ounces) at birth.(1, 2) Less than 2500g is a universally accepted threshold for LBW, as below this threshold neonatal mortality has been observed to rise sharply.(2) Many longitudinal studies have been conducted in order to elucidate the affects

LBW has on the child subsequently in life. Although not an empirical aim of the present study, a brief review of these effects is presented.

2.2 THE EPIDEMIOLOGY OF LOW BIRTH WEIGHT

An important study, which examined the risk factors of LBW, is Kramer's meta-analysis of LBW published by the World Health Organization in 1987.

Meta-analysis is a unique method of compiling the results of different studies.

(7) Through statistical manipulation, the author(s) of a meta-analysis are able to combine the effects of many studies aimed at looking at the same question. In this way, it is hoped that a clearer picture of the problem is presented. For developed countries, based on a review of many studies, Kramer concluded that the following to be risk factors for LBW: infant sex (female babies are more likely to be born of low birth weight), racial/ethnic origin, maternal height, pre-pregnancy weight, paternal weight and height, maternal birth weight, parity, history of prior low-birth-weight infants, gestational weight gain and caloric intake, general morbidity and episodic illness, malaria, cigarette smoking, alcohol consumption, and tobacco chewing. (2)

The description of risk factors for having a child of low birth weight can be most easily divided into medically related and psychosocially related risk factors.(8) As the present study is attempting to amalgamate individual and macro-level factors, consideration of this distinction will also be made.

2.2.1 MEDICALLY RELATED RISK FACTORS

The incidence of prematurity is an important confounder in the study of low birth weight. (2, 8, 9,10,11) Low birth weight children are often born premature; conversely, premature children are often of low birth weight. (12,13) Prematurity is defined as a gestational age of less than thirty-seven (37) weeks. (11) In an analysis of 11 regions in developed countries and 25 areas in developing countries, Villar and Belizan conclude that LBW in developing countries is due to intra-uterine growth retardation and in developed countries it is due to prematurity. (10) Kramer notes that in developed countries, LBW is most often associated with prematurity - and prevention of pre-maturity by further studying genital tract infection, antenatal care, maternal employment and physical activity, and stress and anxiety is needed. (2)

Mothers of low birth weight children are more likely to have had previous stillborn deliveries, both spontaneous and induced. (40,11,2) Previous stillborn births, then, is an important confounder to control for in an analysis of low birth weight children.

The number of children a woman gives birth to in her lifetime also affects the incidence of low birth weight. (9, 12,14,15) This measure is referred to as parity. For the purposes of the present study parity includes the study child. Higher parity decreases the relative risk of low birth weight. (9,12,16) However, age can confound the relationship between parity and LBW - as younger

women tend to be nulliparous. For this reason, Kramer recommends controlling for age and assessing age-parity interactions in LBW studies.

A significant individual level risk factor for low birth weight is maternal smoking. (2, 9,11) Additional individual level risk factors that significantly effect low birth weight in Canada are maternal nutritional status and pregnancy induced hypertension. (11) Unfortunately, none of these measures can be controlled for in the present study, as the administrative database does not include information on these factors.

In previous studies, the affect of age on birth weight has been inconsistent. (17, 18, 2, 19, 20, 14, 21-23) However, in regard to Canadian data, Statistics Canada reports, "low birth weights are more common among very young or older mothers". (24) This pattern is true for many adverse birth outcomes. (11)

The main factor that hinders the consistency of studies based on age and birth weight is stratification based on race. Different racial/ethnic backgrounds show different risks associated with age and birth weight. (18) Rather than present the entire literature surrounding this issue, only those studies that focus on the difference between aboriginal and non-aboriginal persons will be presented, as this is the only racial information available for the present study.

In a prospective cohort design of 96 Aboriginal and 96 non-aboriginal women in Australia, Humphrey and Holzheimer compared neonatal outcomes,

including birth weight. The Aboriginal neonates were on average almost 450 grams lighter than non-Aboriginals. (25)

The issue of low birth weight and aboriginal ancestry is a complicated one, as aboriginal peoples in Saskatchewan have a higher proportion of diabetes compared to non-aboriginal persons. (26, 27, 28) The effect of gestational diabetes significantly increases the weight of the baby. (29) For this reason, studies attempting to examine the relationship between low birth weight and aboriginal ancestry must be aware of the potential interaction between gestational diabetes and LBW in the data.

New research has also suggested that there may be a medically related link between outcomes in children and mother's environment. This link between mother's environment affecting the fetal life is called microchimerism. It refers to the phenomenon of maternal cells and fetal cells transferring in the womb; this transfer can trigger immune reactions and exchange. This may explain how a mother's environment can affect disease in children. (30)

2.2.2 PSYCHOSOCIALLY RELATED FACTORS

When investigating the link between psychological factors and adverse birth outcomes, research from a decade ago (and longer), tended to focus on behavioural factors and "parental blaming". (8) Today, researchers tend to look at poverty, socio-economic status, education and macro-level influences as contributing to inequities in health more so than behavioural choices. (31-35)

Maternal education levels have been shown to affect low birth weight. (18, 8, 36, 37) In a large sample comprising over 20,000 live births from 12 hospitals in Virginia and Connecticut, the effect of maternal education on low birth weight was found to be differential between black and white women. Black women showed a consistent benefit across all levels of educational attainment, whereas white women showed a surprising negative impact of very advanced education (>16 years) in the risk of low birth weight. (18) These results were controlled for maternal age (19+ and 23+). However, these results must be read with caution, as the study is very non-representative of the population at large, and only a handful of confounders were adjusted for.

Socioeconomic status is associated with proportions of LBW. (36, 15, 29, 38-41, 35, 42) Socio-economic status (SES) is a term used extensively in social science research and related fields. While a strict definition is not available, as different authors use different variables to define SES, generally SES refers to a person's place in the social hierarchy, (43, 44) and is intrinsically tied to the distribution of occupations, income, wealth, and education. (45)

Social class is related to health. (36, 43, 45, 46, 44, 42, 47) Much literature has been produced which demonstrate a strong link between individual social class relating to individual health; with higher social classes consistently experiencing better health outcomes.(48, 44)

In a literature review of published articles, Adler *et al* reviewed the association between SES and health outcomes. They found a consistent

relationship in the literature of lower SES correlating to adverse health outcomes - even in countries with universal health care. The authors conclude that, "health insurance coverage alone is not likely to reduce significantly SES differences in health". A rather bold statement, and one may hazard a guess that the authors conducted this study in opposition to those in favour of adopting a universal health care system in the United States, thus depreciating the credibility of results.

Further, Krieger, *et al* call for concise and definitive definitions of SES. Most importantly, however, is their recognition of the need to include neighbourhood level variables when defining SES. (45) Krieger *et al* also call for the measurement of social variables in routine databases; something the present study would have benefited enormously from.

LBW differs among differing income levels. (9, 16, 36, 45, 46, 49-51, 47, 52) The reasons for this are not completely known. Many studies point to the cause and effect between poor maternal nutritional status and income. (9) Many others however, merely attempt to find a correlation between income and poor child health. (36, 45, 46, 47)

Using a medical birth registry linked to census information in Stockholm Sweden, Ericson *et al* divided their study group into two clearly defined socio-economic classes based on occupation/ education, cohabitation and citizenship, those that are underprivileged and those that are privileged. Their results show that the underprivileged group had higher proportions of low birth weight

compared to the privileged group; even *after* controlling for maternal smoking habits (Odds ratio (OR)=1.92, 95%CI=1.66-2.20 before stratification based on smoking, OR=1.69, 95%CI=1.44-1.98 after stratification). The caution in this study is in how the authors classified privileged versus non-privileged using unconventional variables to define them. However, one can argue that even in this unconventional method of defining socio-economic status, it is a more regimented and accurate description.(50)

Similarly, in a study conducted by Hirve and Ganatra in India, lower socio-economic status was associated with an (unadjusted) relative risk of 1.71 for low birth weight.(16) Socio-economic status also had a substantial attributable risk percent for LBW of 41.4%. The authors conclude in their study, that maternal education was the single most important socio-economic risk factor for LBW and preventative measures should be aimed at increasing the level of education among mothers in Pune, India. (16)

In a slightly different approach to the study of low birth weight and socio-economic status, Collins *et al* looked at positive and negative income incongruity. Positive income incongruity occurs when one lives in a wealthier community than expected for ones educational attainment and marital status. Negative income incongruity occurs when one lives in a poorer community than expected for their education and marital status. (49) Collins and his colleagues suggest that income incongruity may be a better indicator of socio-economic inequalities than socio-economic status alone. The authors conclude that there

exists a racial stratification in regards to income incongruity in a community. Both African-Americans and Whites who experienced positive income incongruity were more likely to have very-low-birth weight children (OR=0.7, 95%CI=0.5-0.9 and OR=0.6 95% CI=0.5-0.9, respectively). Interestingly, though, the authors do not use a person's income to define income incongruity.

In a worrisome article on the temporal trends in LBW amongst the Samoan women in Hawaii, Baruffi *et al* look at changing pregnancy outcomes. The Samoan traditionally have low proportions of LBW despite their low levels of SES.(53) However, from 1979-1994 there exists a trend of increase percentage of LBW infants born to Samoan mothers in Hawaii; from 2.6% to 3.8%. The authors found this to be true, even when adjusting for SES in multivariate analyses. The authors do not offer an explanation for this trend, rather the article calls for further research on psychosocial variables, including acculturation-related stresses. (53)

In an interesting cohort study of 259,462 singleton babies born in Scotland from 1981-1984, de Sanjose and Roman attempt to look at the correlation between social class and low birth weight, small-for-gestational-age and prematurity.(47) The results indicate that, even when parity, maternal age, adverse reproductive history, and father's social class are controlled for, mother's social class predicts adverse birth outcomes. The authors state an important dilemma in this type of research, is that we may never truly know the

cause and effect of poverty and morbidity; given the unethical nature of randomizing groups into poor and non-poor. (47)

Clearly, socioeconomic status plays an important role in shaping a child's health. (54) Most studies, however, focus on an individual's socioeconomic status as the key indication of income. A recent shift in the literature has been the use of macro-level considerations of adverse health risk, rather than individual ones. (55, 40, 48, 49, 56-60) It stands to reason, that if macro-level differences are associated with the incidence of LBW – neighbourhood of residence may be a crucial piece of the puzzle.

2.2.3 SHORT AND LONG TERM AFFECTS OF LOW BIRTH WEIGHT

The most common short-term effect of LBW cited by most is increased hospitalizations within the first year. (9) In the late part of the 1980s and early into the 1990s, the emphasis of LBW research changed to look more at the longitudinal effects LBW could have on an individual later in life. (8, 61, 62)

The first groundbreaking epidemiological study to look at this connection was performed by David Barker at the University of Southampton, England. Barker noticed that areas with higher than average infant mortality proportions also had correspondingly higher incidence of adult cardiovascular disease. Because of the accepted connection between low birth weight and infant mortality, Barker hypothesized that a baby's birth weight could be contributing to the development of cardiovascular disease later in life. (61, 63, 64) He further

hypothesized that this effect is due to poor nutrition of the mother, contributing to poor nutrition of the fetus and subsequent effect later in life on the development of chronic disease (specifically, cardiovascular disease and diabetes). (61) Other studies have gone on to further associate LBW with cardiovascular disease risk later in life, and as Irving notes in his article, "Adult cardiovascular risk factors in premature babies", even babies born at term but still low weight predict cardiovascular disease risk. (64)

Clearly, the risk of LBW can produce results beyond those experienced just at birth. The need to prevent and understand LBW only increases with these risks. Additionally, "Low birth weight is a key determinant of infant survival, health, and development. Low birth weight infants are at a greater risk of having a disability and for diseases such as cerebral palsy, visual problems, learning disabilities and respiratory problems".(1)

In an inception cohort follow-up study of 1,868 children of very-low-birth weight and normal weight, McCormick *et al* focused on the health and development status of the cohort from age 8 to 10 years. (65) The authors conclude that lower birth weight was associated with increased morbidity for all measures except the depression/anxiety likert score.(65) Interestingly, intelligence quotient score (IQ) was lower amongst lower socio-economic groups regardless of birth weight. One major caution of this study is the response proportion. Follow-up was preformed by telephone interviews and the authors report only a 65.1% response proportion. In a sample of non-

responders they were significantly different than responders in relation to socioeconomic status.

In an article published early 2002, Hack *et al* compared a cohort of 242 very-low-birth-weight survivors (<1500 grams) to 233 controls of normal weight. (66) These individuals were born between 1977 and 1979, thus providing the authors the unique opportunity to look at the outcomes in young adulthood for very-low-birth-weight children (VLBW). Interesting findings included; fewer VLBW children had graduated high school ($p=0.04$), VLBW men (not women) were less likely to attend post-secondary education ($p=0.002$), and VLBW adults had a lower mean IQ and lower academic achievement scores ($p<0.001$). The authors conclude, "educational disadvantage associated with VLBW persists into early adulthood".(66)

In a six year follow-up study of 201 low birth weight infants (<2000 grams) and 71 controls, Chaudhari *et al* concluded that the mean IQ of LBW infants was within normal limits (94.3), but was significantly lower than the controls (101.3). (55) This study also looked at prematurity and its relationship to the outcome measures and LBW, with preterm LBW children having the lowest mean IQ score across the groups. The authors also controlled for the housing conditions and SES of family. Mother's education and "spaciousness of the house" had a positive impact on IQ. The author's conclude that even though LBW children had mean IQ scores within normal limits, further research must

be done to understand the consistently lower IQ scores of LBW children compared to controls. (55)

In an interesting and controversial article, Sommerfelt concludes that the long term affects of LBW are still not known, as authors have failed to take into account confounding variables such as socio-economic status. He classifies the conditions researchers have focused on as the "new morbidities", including learning disabilities, behavioural problems, lower mean IQ, and motor clumsiness. He writes, "LBW may have many different etiologies, with varying relative frequency in different populations, which probably have different degrees of associated risk for impairment of later development". (67)

2.2.4 LOW BIRTH WEIGHT TRENDS IN CANADA

From 1970 to 1993 the proportion of low birth weight has been declining steadily in Canada. A small blip occurred in 1993, when the proportion increased for three years, then returned back to the 1993 level in 1996. (11) The reasons for this are not entirely known.

Among other industrialized nations, as of 1995, Canada falls close to the middle of the pack in terms of low birth weight. Finland leads the world with the lowest proportion (4.1%) compared to the highest in Japan (7.5%). (11) The United States is comparatively worse than Canada at 7.3% of all births occurring in hospital defined as low weight.

The incidence of low birth weight in Saskatoon and Saskatchewan are presented compared to the national proportion for 1996 (Fig 3.1). It is noted, that Saskatoon has a higher proportion of low birth weight than Saskatchewan and indeed, higher than the national proportion (not statistically significant). Following in step with the provincial and national trend, Saskatoon also displays a higher proportion of LBW for female children. (1)

REGION	TOTAL		MALE		FEMALE	
	Rate (%)	95% CI	Rate (%)	95% CI	Rate (%)	95% CI
Canada	5.8	5.8,5.8	5.4	5.4,5.5	6.2	6.1,6.3
Saskatchewan	5.3	5.1,5.5	5.1	4.8,5.4	5.5	5.2,5.8
Saskatoon	5.9	5.4,6.3	5.5	4.9,6.1	6.2	5.6,6.9

Figure 3.1: Incidence Rate of Low Birth Weight: Saskatoon, Sask. & Canada, 1996

2.3 SIGNIFICANCE OF AND APPROACH TO THE STUDY OF LOW BIRTH WEIGHT

As an epidemiological problem, low birth weight has been extensively studied in the 1970s and early 1980s. It is clear from these early studies that individual level risk factors, such as maternal smoking, nutritional status, ethnicity and family income contributed to an increased risk of low birth weight in newborns. (2, 8, 9, 68, 62)

Following these early works, there was an apparent decrease in research interest in low birth weight for a decade or so - until the middle 1990s brought

about the influx of ecologic and macro-level study designs. These recent studies attempt to focus on not individual level risk factors for low birth weight (LBW), but to look at more broad measures of public health (60, 69, 18, 49, 57). It is through these earlier works that a better understanding of macro-level risk factors for LBW began to emerge. These studies, in part, led to an understanding that individual level risk factors are not the only important determinants of LBW, but that other factors such as neighbourhood of residence and other characteristics are also important factors of LBW.

It is obvious that the reports of the relationship between neighbourhood of residence and LBW could have serious preventative policy implications. As Stevens notes in the article entitled "Low Birth weight Prevention Programs: The Enigma of Failure", prevention of low birth weight has failed, but the reasons are unknown. Perhaps, as the author suggests, the actual measurement of the relative success or failure of prevention programs is what is contributing to the "failure". However, another reason for the failure to prevent low birth weight, one that the authors do not suggest, could be the focus of preventative programs on individual level risk factors.

2.4 NEIGHBOURHOOD ANALYSIS

Neighbourhoods are not random designations of space. On the contrary, city planners spend years establishing neighbourhood boundaries, and

assessing the best way to organize urban locales. (5, 6, 70-76) What emerges is not only the infrastructure of the urban landscape, but also the social network of the area individuals chooses to live in. Is it the neighbourhood that has the potential to cause poor health outcomes - or is the aggregation of similar people; people with similar socioeconomic characteristics? Whatever the reason, if there exists a substantial difference amongst neighbourhoods, health policy and service providers should ultimately recognize these differences.

In geographical and urban planning literature, theories of neighbourhood organization are abound. In relating to the organization of the city of Chicago, author L. John Wright, describes how the *physical* environment dictated the formation of the city. As the city is on the waterfront, the expansion occurred in a semi-circle surrounding the central business district on the waterfront. Developing outwards from the central business district was residential areas of increasing wealth as one reached the commuter areas farthest away. (77)

Another theory of neighbourhood development uses historical evidence to determine how neighbourhoods of differing income levels arose. Tom Muir uses England at the height of the industrial revolution to explain the existence of slums; "...it [the industrial revolution] polarized residential districts. The wealthy industrialists usually chose to live in the west end of the cities (up-wind of their factories); the factory workers and urban poor lived in a tight right around their places of employment, in slum conditions". (78)

Perhaps *both* the physicality of the environment and the logistic considerations of urbanization can explain the development of neighbourhoods with differing income levels.

Recent studies have noted the correlation between neighbourhood of residence and individual health outcomes. (57, 79-81) Poverty is the main factor that consistently is related to the correlation between individual health outcomes and the area of residence. (42) In a study looking at survival proportions for cystic fibrosis patients, Britton showed an independent effect of area of residence (as well as for social class and sex). The independent odds of death at above the median age varied significantly among regions of residence by a ratio of up to 2.67. (35)

International comparisons of infant mortality proportions present a revealing picture. In Canada even our *poorest* neighbourhoods have an infant mortality proportion lower than the American *national* average. While this may seem promising, in comparison to European proportions, Canada falls short. In Canada, even our *richest* neighbourhoods have an infant mortality proportion similar to the Swedish *national* average. (1)

Researchers Ross and Dunn have shown consistent relationships between neighbourhood of residence and health outcomes (including adverse birth outcomes). These researchers feel that neighbourhoods provide a "self-sorting" mechanism for individuals with different levels of risk for health conditions;

thereby grouping similar individuals and creating a neighbourhood effect for health. (82, 58, 83, 84)

Diez-Roux discusses neighbourhood boundaries very well. Her explanation for using neighbourhoods as the aggregate level in research, is based on what the research is for. She contends that when research is political in nature, other boundaries (such as administrative or enumeration areas) should be used. However, when the problem is more on a social cohesion level, neighbourhoods are the best choice of boundary. (85)

Neighbourhood perception is an important component of neighbourhood cohesion. (86) By one's own perception of the geographical area they call home, a community is born. Jorgenson et al, discuss this notion by using a concept from sociology; sense of place (SOP). They feel that SOP does not arise out of the actual physical setting of the neighbourhood, but in the human interpretation of that setting. (87)

Conceptualization of a neighbourhood leads to the operationalization of its traits. Health is one aspect of society that is manifested at the neighbourhood level. Differences in neighbourhood creates residential segregation, which in turn creates different health. (85) Also, community level factors affect the health of its residents, such as socioeconomic status. (88, 89)

An interesting meta-analysis by Pickett et al in 2001, found a consistent relationship between neighbourhood level factors and individual level health, despite widely different variables, methodology and analytic

techniques.

Neighbourhood analysis specifically looking at health issues involves many complex problems. Diez-Roux discusses the notion of neighbourhood level effects diminished by the large effect of macro-level health factors.

She further attests to the challenge researchers face by looking at interactions between levels (individual and neighbourhood). (85) In the present study, interactions between levels were not considered, although future studies may well benefit from exploring this complex phenomenon.

2.4.1 MULTI-LEVEL ANALYSIS

Multi-level analysis allows the researcher to use both micro and macro level variables in one model. (90, 91) In this way, it is statistically possible to simultaneously control for the known individual level predictors of low birth weight, and look at the significance of neighbourhood characteristics.

Aitken *et al* performed a study that is generally regarded to be the first study to illustrate the importance of multi-level modeling, and combining macro and micro level variables in 1981. (92) In the 1970's Bennett performed a study in which he utilized a standard logistic regression model to compare elementary school students' performance in reading. Students subjected to a "formal" style of teaching progressed better in reading level (statistically significant at $p < 0.05$). (93) However, Aitken *et al.* reanalyzed this data accounting for different teachers, hypothesizing that different teachers would teach differently, but

individual students within one particular classroom are taught the same (a good example of clusters). In this analysis, the student's progress was not statistically significant. Clearly it is important to account for the students grouping into different classrooms, and hence different teachers. Using the individual student's level of progress ignores a crucial element – and using each teacher is a more appropriate unit of analysis.

Given the complexity of the statistical technique, multi-level analyses are not always performed correctly. A common mistake is to employ multivariate techniques rather than true multi-level models. (94)

Incorrect techniques aside, many studies have shown that both neighbourhood and individual level risk factors contribute to risk for infant health. (94, 69, 49) In a linked study of birth and death records matched with county-level data in Upstate New York, Matteson *et al* found that neighbourhood factors, specifically the “number of per capita primary care physicians and local government expenditures on health care services and hospitals are positively linked to an increase in the probability of infant death”. (94)

Multi-level analysis is a unique opportunity to analyze two very different levels of data simultaneously and correctly.

2.5 LOW BIRTH WEIGHT AND NEIGHBOURHOOD ANALYSIS

A small number of studies have been published which focus on *both* low birth weight and neighbourhood of residence (36, 57, 60, 69, 95). These studies have all been conducted in the United States or the United Kingdom, each have utilized differing individual and neighbourhood level variables, and do not always include a definition of low birth weight (though one could most likely safely assume that these studies would have used the standard definition).

In Canada, a joint project of Statistics Canada and Health and Welfare Canada produced a report on birth outcomes and infant mortality in urban Canada in 1991 (using 1986 census data). In this report, census tracts, along with postal code matching and percentage of residents below the low-income cutoff measure (LICO), were used to create urban neighbourhoods characterized by income levels. The data showed a consistent relationship between low-income neighbourhoods and adverse birth outcomes (including low birth weight). (52)

In a March 1997 article published in the American Journal of Public Health, Collins *et al* studied the effects of ethnicity, median neighbourhood income and very low birth weight (VLBW). In this study, VLBW is defined as infants born less than 1500 grams. The authors concluded from the results of their study that positive income incongruity is associated with African American proportions of VLBW. (49)

Eric Roberts employed a backward stepwise regression model for combining individual risk factors and neighborhood variables to predict LBW in Chicago neighborhoods. Of the individual level variables, ethnicity of the mother most strongly predicted LBW. (69) Using self admittedly crude neighborhood variables, Roberts found that of these variables, community socioeconomic status, crowded housing and high percentages of young and African-American residents were negatively associated with low birth weight.

The neighbourhood variables used in this study were "economic hardship", "socioeconomic status", median rent, crowded housing proportion, percentage of African American residents and percentage of young residents. One could argue that these variables do not accurately describe truly macro level influences at the neighbourhood level, such as, park space, availability of services, commercial space, etc. Roberts concludes that "the traditional focus on individual risk factors for low birth weight limits our understanding". (69) However, the logistic regression models serve only to reinforce the literature beginning from the early 1970s - individual level data predicts low birth weight. Additionally, Roberts used a regression model that does not take into account both macro and micro level variables as a multi-level model would do.

In an often referenced study, Patricia O'Campo *et al* studied neighborhood risk factors for LBW in Baltimore. This multi-level analysis provided an analytical method correctly employing both individual and macro-level variables for the prediction of low birth weight. (59) The author's main

conclusions were that both individual and macro level are associated with LBW, and they interact with one another. More importantly though is the author's conclusion that multi-level modeling is an important tool for research and "should play a larger role in the formulation of public health policies".

Another leading child health and neighbourhood researcher, Jeanne Brooks-Gunn, concluded in her 1998 study, neighbourhood of residence does indeed make a difference. Children in poor and middle-income families had increased emergency department visits than their affluent counterparts. Also, children from middle-income neighbourhoods experienced more physician visits than either the poor or affluent. (57)

More recently, in 2002, Sims *et al* conducted a study of LBW and VLBW by neighbourhood in Milwaukee, Wisconsin. Census-block data and Vital statistics data were both used to look at the difference between African American and white babies by neighbourhood and birth weight. African American women lived in less desirable, more segregated neighbourhoods than white women. The proportions of LBW and VLBW were almost double for African American women compared to white women, and African American women were eight times more likely to have inadequate prenatal care. (95) The study, however, did not employ a multi-level analysis (or even simple regression) to manage both micro and macro level variables.

Another study looking at the effects of low birth weight and neighbourhood of residence was conducted in the United Kingdom. This study

is very interesting, in that it attempts to statistically “attribute” LBW to social inequity. In other words, the authors claim that 12% of LBW (using a different cut-off of <3500g) could be averted if the child lived in a neighbourhood of higher SES. (40)

Studies involving infant mortality and neighbourhood of residence have also been documented. In Nicaragua, Pena *et al* found that infant mortality was associated with social inequity, defined as the difference between the household income and the predominant social class of the neighbourhood (RR=1.74, 95% CI=1.12-2.71). (96)

In an interesting harm reduction effectiveness study, Reguero and Crane analyzed Project MotherCare in New Haven, Connecticut. The authors found that the very high infant mortality proportion in New Haven was most associated with complications due to low birth weight stemming from inadequate prenatal care. Project MotherCare was developed to provide adequate prenatal care to underserved neighbourhoods, where the highest proportions of infant mortality were. Clearly, infant mortality and neighbourhood of residence were related in New Haven. (97)

In 2000, DiLiberti found that children living in the least advantaged counties in the United States had a much higher infant mortality proportion than those children living in more advantaged counties. Sadly, this association persists despite trends of declining infant mortality proportions for the country since 1968. (98)

There have been a few studies looking at both LBW and neighbourhood of residence. These studies, however, have been primarily executed in the United States. The present study will attempt to improve on this understanding by using administrative data. A unique aspect of this study will be the use of both individual and neighbourhood level data. The data allows for records of all births and subsequent health outcomes, as well as some information on the families socio-economic status. Generally, it is difficult to ascertain the families' exact household income - rather social assistance proportions are used as a measure of convenience.

2.6 USE OF ADMINISTRATIVE DATA

Increasingly, epidemiological studies are utilizing routinely collected databases in order to elicit cause/effect and descriptive data. There has been many articles published which look at the nature of administrative data and its advantages and disadvantages. (99-101, 81, 102-105) Specifically, there have been articles in the literature that have looked at the relative advantages and disadvantages of administrative data from Saskatchewan Health. (106-117)

Administrative data from Saskatchewan Health offers several advantages. These include, a unique patient identifier in order to facilitate data linkage, verified data, and universal coverage exists across the province. It is important to note that these valuable statistics arose almost as a by-product of universal health care coverage. The database is for insurance purposes, not

research, and as a result important individual level variables that may be pertinent to many studies are not available in this administrative database. However, the powerful possibilities that exist for research within such a comprehensive complete and computerized database have been recognized here and elsewhere. (106, 115)

The main disadvantage of using routinely collected data from Saskatchewan Health for research purposes is that the data is not intended for research - rather it is a database maintained for administrative and insurance purposes. Because of this, many interesting variables, in a research sense, are not recorded. Also, many individual level factors specific to the present study are not included. In the present study, these include maternal smoking status, nutritional status, pre-natal care and pre-pregnancy maternal weight.

However, one major limitation often cited in the literature regarding routinely collected databases is not a limitation in this study. That is, many American studies utilize Medicare data for research purposes, and fall into the problem of non-universality. (99) Saskatchewan Health databases do not have this same problem, as Saskatchewan Health covers all Saskatchewan residents, and all have a unique identifying number - which facilitates health research. (exceptions include status Indians, inmates, Canadian armed forces personnel, and Royal Canadian Mounted Police personnel).

Without access to an administrative database for information, child health researchers are forced to rely on proxy responses of health status from the

primary parent/guardian. (118, 105) In a sample of 608 pre-term low birth weight children from the Infant Health and Development Program in the United States, Scholle *et al* compared maternal-reported measures of growth, morbidity, functioning and health care status (using several different scales) compared to the actual measurements. The authors found a significant difference between the two, and conclude that for researchers "none of the [scales] seems to serve as a proxy for health care utilization or morbidity". (118)

There have been several studies that have looked at the reliability and validity of Saskatchewan's administrative database. (104, 108, 110-112, 114) Most have found greater than 90% agreement between raw and computerized data; those where agreement was lower were outcomes requiring clinical judgment. Muhajarine *et al* found an overall agreement between survey and computerized data for hypertension to be moderate to high, meaning 82-85%. Rawson and Malcolm, in a study looking at ischemic heart disease chronic obstructive pulmonary disease, found the concordance proportions between the computerized database and chart records to be at least 95% for chart number, first and last name, health care number, sex, date of birth, residence and discharge date. The authors note that this is epidemiologically realistic. Similarly, Edouard, in studying the reliability of the recording of hysterectomies in Saskatchewan found that "Saskatchewan health care utilization datafiles provide a source of valid data for research and evaluation studies". (117)

That said, however, there are significant problems associated with the use of administrative databases in research. Administrative data is not infallible, and is can be plagued with human error. Physician's are human and are subject to misjudgment, recording errors, and errors of omission. (108) Also, those who record medical records into the database are subject to the same errors. (102) When discussing the reliability and validity issues in administrative data, Rawson and D'Arcy make a very important point. What the data is representing is the reality of the clinical situation, where human error occurs. (108)

However, in the present study, the data used in analysis are quantitative (e.g.) birth weight, gestational age, and these variables are less likely to be plagued with human judgment error. (103, 111) Miskeyed and misrepresented information can still occur. For this reason, authors Roos et al, have studied the Manitoba health database and have determined that a substantial amount of checks and balances, need to occur to minimize these errors. (102, 103)

Administrative data is not perfect. When designing any type of study one must make compromises based on the reality of the research situation. However, for the present study, administrative data offers a cost effective, large sample and good data within a realistic time frame.

2.7 CONCLUSIONS

It is clear that LBW is a significant indicator of public health, and an important risk factor for many adverse outcomes in children. Additionally, it is clear that neighbourhood level analysis provides researchers with a relatively novel way to elicit new understandings of complex phenomenon. This study proposes to utilize neighbourhood analysis and multi-level modeling techniques, in the hope that a better understanding of LBW in Saskatoon will be achieved.

While LBW has been the focus of many studies in the past, I would argue that the present study is still needed in the body of literature surrounding LBW and neighbourhood of residence.

A study that looks at the effects of area of residence and neighbourhood characteristics on the incidence of low birth weight using multi-level analysis has not, to the best of my knowledge, been done in Canada. Many of the preceding articles call for a need for epidemiologists to be aware of contextual effects, such as neighbourhood of residence, on the health of people. Low birth weight is a reliable and easily measurable indicator of population health. Given the richness of the empirical dataset at hand, the availability of neighbourhood level data, and the ease of access to complicated analysis software packages, this analysis will provide a unique opportunity to study contextual effects of low birth weight on a medium sized prairie city.

The most persistent gap in the above literature is the use of self-reported data from US studies. My study does not rely on self-reported measures, therefore reducing this type of bias (although there are several other issues surrounding administrative data, please see above).

Using area-based measures is a very useful method to track etiology of disease. In so far as low birth weight is an outcome, this method is very useful, particularly because birth is a snapshot of one point in time, which can be a problem for chronic conditions over time and the mobility of residences within an area.

As far as the analysis technique is concerned for the present study; many so-called "multi-level" studies in the literature simply use an extended hierarchical logistic regression technique, thereby losing the power of a truly multi-level analysis. This study aims to improve on this technique.

Given these issues, as well as the unique dataset that exists in Saskatchewan, and the ability to combine both individual and neighbourhood level variables, I feel that a study of this nature is very much needed.

CHAPTER 3: METHODOLOGY

This chapter will describe all data sources and methods used in the study. First, there will be a discussion of the study design, and of the larger study from which this analysis is a part of. A description of the study subjects, including exclusion criteria, will follow. Next, there will be a description of the data sources, both individual and neighbourhood level variables. A description of the four separate parts of the analysis will follow. The chapter will conclude with an indication of the software programs used and the ethics approval obtained for the present study.

3.1 STUDY DESIGN

The present study utilizes routinely collected administrative data from Saskatchewan Health. Additionally, Canada census-based neighbourhood level variables were obtained from the City of Saskatoon Planning Department. All babies born to mothers residing in the Saskatoon District Health area from April 1st to March 31st 1994 were included in the analysis. Please see section 3.2.1 for detailed information on the exclusion criteria employed in this study.

The present study is a small part of a larger study entitled the "Adverse Birth Outcomes Study" (Principal investigator Dr. Nazeem Muhajarine and Co-

investigator Dr. Carl D'Arcy). The larger study encompasses many different data files from the Saskatchewan Health databases. The present study, however, utilizes only two Saskatchewan Health data files. These two files contained, 1) information on the babies' birth and birth outcome and, 2) information on the demographic factors of the family.

In the present study, Saskatchewan Health has divided and amalgamated Saskatoon neighbourhoods slightly differently than the standard neighbourhood divisions of the City of Saskatoon. This is due to the size of the study population in certain neighbourhoods. Those neighbourhoods with few children born during the study years are grouped together with other neighbourhoods to protect the confidentiality of the health information of the children.

A set of variables were used to characterize each neighbourhood in Saskatoon. These include: occupational categories, education level attained, average family income, family structure, percentage of houses owned and rented, neighbourhood park space per person, ethnicity (aboriginal vs. non-aboriginal) and density of development. (6)

3.2 STUDY SUBJECTS

This study includes all 5,643 children born in Saskatoon from April 1st 1992- March 31st 1994. For each child, neighbourhood of residence at study entry (i.e. birth) was within Saskatoon city. These children are representative of

the population of children at the time, as they represent all births in the study years.

3.2.1 EXCLUSION CRITERIA

Of the 6,466 children born between 1992-1994 in Saskatoon and covered under Saskatchewan Health insurance, 823 (12.7%) were excluded from the study. Detailed explanations of these exclusions follow.

First, 149 children were excluded because they lived in areas in the city that are predominantly non-residential. These areas were: Airport industrial, Confederation Industrial, North Industrial, Agriplace, and South-West Industrial areas. This group also included some children for whom a residential neighbourhood was not easily assigned, such as, post office boxes, retired postal codes, rural routes not accounted for, non-Saskatoon address, and University land.

Second, 356 children were excluded for whom there were missing values for neighbourhood of residence or were residents of Corman Park rural municipality residents.

Third, 174 children living in rural municipalities (other than Corman Park residents who were accounted for above), were excluded. These children were residents of one of Bayne, Dundurn, Montrose, Harris, Whitecap Dakota Sioux First Nations, Lost River, Vanscoy, Perdue, Grant, Aberdeen, Great Bend, Mayfield, Laird, Rosedale, Colonsay, and Blucher.

Without a neighbourhood of residence reported, it is not possible to perform analysis that will take into account both individual and neighbourhood level variables. Rural residents were excluded in order to limit the study to the city of Saskatoon and allow analysis at the neighbourhood level. Obviously, rural residents cannot be assigned a Saskatoon neighbourhood, and therefore not included in further analyses. Also, the same data that was available for the city neighbourhoods was not available for the rural municipalities. The concept of neighbourhood within a larger city, as it has been operationalized in this study, is not applicable to rural areas, as these rural geographical entities do not often exist within a larger city. Rural municipalities may be alternatively considered as an entity unto itself, with common attributes being shared amongst them. However, due to both conceptual and practical reasons, focus of this study was the city of Saskatoon and not the surrounding rural municipalities.

Lastly, 144 children were excluded who were born of multiple births, which included twins. In studies of low birth weight, this exclusion criterion is common; children of multiple births are almost always born of low birth weight. (2) The sharing of placenta and uterus often result in a smaller birth size, and often prematurity. To be consistent with the literature on the topic, and to control for the over inflation of the proportion of LBW children in the study, multiple births were excluded. (2)

Due to the exclusion criteria employed in this study, the results are generalizable to singletons, born within medium sized Canadian urban cities, and whose mother lives in residential neighbourhoods within cities.

3.3 DATA SOURCES

Most variables in the database were recoded to facilitate analysis. The following is a detailed description of this process, as well as a description of the data sources used. Several variables were not retained from the original file for various reasons, due mostly to missing values and not being relevant to the present analysis.

3.3.1 INDIVIDUAL LEVEL VARIABLES

Within Canada's Medicare system, medically necessary services provided to Saskatchewan residents are covered under the provincial health insurance. Saskatchewan residents are covered, within some limits, even if health care were received elsewhere. Saskatchewan Health has compiled and maintained health statistics for almost fifty years; for most databases centralized electronic access is available from 1970 to the present. (109, 119)

The present study utilizes data from the Vital Statistics file through Saskatchewan Health. The Vital Statistics Office "administers and maintains a province-wide system for registering births, deaths, marriages, stillbirths and changes of name that occur in the province of Saskatchewan. The Office also

issues certificates as legal proof of these vital events and provides statistical information for agencies and the public". (120)

The variables that pertain to both mother and child, obtained from Vital Statistics through Saskatchewan Health, make up individual level data. These variables are: Marital Status of Mother, Age of Mother, Parity, Number of Previous Stillborn children, Financial Assistance, Sex of Child, Neighbourhood of Residence Upon Study Entry, Gestational Age, and Birth Weight (which is the dependant variable).

Individual level variables not considered for the present study (but were available in the database) include: Father's Age, Rural Municipality of Residence, Date of Birth, and Neighbourhood of Residence Upon Study Exit.

Father's age was excluded from the analysis due to the large number of missing values. This often occurs in studies involving babies at birth, as the identity of the father, location, and involvement at the time of birth is not consistent. Ignoring this variable in favour of mother's age is a common practice in the literature, due to missing values. (2)

From Saskatchewan Health, marital status was given in five categories: never married, married, divorced, widowed and unknown. In order to simplify this variable somewhat, as it was clear that the majority of the study subjects were in one of two categories, the variable was changed to a dichotomous outcome of "never married" and "married and other". Unknown marital status was placed in the category "married and other".

Given the inconsistencies in the literature surrounding mother's age and low birth weight, it was felt that this variable needed special consideration. Several ways of organizing this variable were tried including age groupings, and young vs. old, but ultimately the cut point determining the threshold for high and low risk age groups was identified. This was determined through a combination of Statistics Canada guidelines for high-risk pregnancies and quartile grouping of the data. (24) Women who were either less than 20 or 35 years and older were considered "high risk"; all others were considered "low risk".

Parity and previous stillborn births were both recoded as dichotomous outcomes. Parity was recoded as one child, or more than one child. The variable, previous stillborn births, was recorded as either a previous stillborn child was born or no previous stillborn children had been born. Strictly speaking, we were not able to capture miscarriage proportions, as all women with miscarriages may not always reach hospital, or recorded in Vital Statistics data. For this study, "stillborn births" was defined as, a potentially viable fetus that was delivered not alive after 28 weeks gestation in hospital.

Gestational age and birth weight were given as continuous variables. In order to simplify analysis and create meaningful associations, these variables were dichotomized. Birth weight was dichotomized into less than 2500 grams (low) or greater than or equal to 2500 grams (normal). Gestational age was dichotomized into less than 37 weeks and greater than or equal to 37 weeks.

As a proxy measure of income status amongst the study families, indicators of whether or not the family was receiving income assistance under various plans were obtained. Financial assistance information is not technically from Saskatchewan Health's vital statistics files, but for organizational clarity it is presented here. Several changes were made to arrive at the final financial assistance variable.

First, it was determined which of the various plans families with children would be able to access. These were: Saskatchewan Assistance Plan (SAP), Family Income Plan (FIP) and the Saskatchewan Child Benefit Plan (SCB). The FIP was ultimately replaced by the SCB by 1999, but for the study period there was a transitional phase of both plans in use. Information for all other plans was considered superfluous and deleted. These were: Government Income Supplement (GIS) and the Saskatchewan Income Plan (SIP). Second, only the study years of 1992, 1993 and 1994 were used, as these were the years for which birth outcomes were included in this study. Third, frequencies for each variable representing the three plans were examined and a summary measure derived. Fourth, the summary measure was recoded as a variable with "1" indicating "yes" or "0" indicating "no" to financial assistance status.

Although the present study is limited to only LBW children, it is recognized that two other distinct and separate birth outcomes are related to this measure: small-for-gestational age (SGA) and preterm children. SGA and preterm are often interrelated and these children, in turn, are also often LBW.

SGA refers to children who fall into the lowest 10th percentile of weight for their gestational age, compared to a standard Canadian population. (121) In this study sample, there were 476 SGA babies, and of these, 106 were LBW.

However, it was decided to limit the focus to LBW and not SGA. For future studies, this may be a relevant sub-population to explore further.

3.3.2 NEIGHBOURHOOD LEVEL VARIABLES

The variables that pertain to neighbourhoods were obtained from the City of Saskatoon and represent neighbourhood level characteristics for 1991. (6, 71) The neighbourhood variables considered were: acres of park space, average cost of a dwelling, proportion of dwellings owned, proportion of dwellings rented, average number of persons per household, average income, proportion of persons with an income of less than \$10,000, proportion of one parent households, employment, total number of aboriginal persons, proportion of population with less than grade 9 education, grade 9 to high school grad, some/completed University and some/completed trade school.

Neighbourhood data were cleaned, some recoding was performed, and neighbourhoods were amalgamated to be consistent with the neighbourhood list provided by Saskatchewan Health. An aggregate level LBW variable by neighbourhood was created, derived as the number of LBW children divided by the total number of births in the neighbourhood multiplied by one hundred.

Neighbourhood of residence proved to be somewhat of a problem upon recoding. First, it was broken down into three categories; "Eastside", "Westside" and "North end". However, due to the small number of children in the North end group (11.5%), this variable was dichotomized into "Eastside" and "Westside". Subsequent analyses proved no significant difference between the different groupings; therefore the most parsimonious option of dichotomizing the variable was used.

Metis, Aboriginal, and Treaty (status) Indian ethnic identifiers were grouped together to produce the summary variable "Aboriginal ancestry". As all variables at the neighbourhood level originated from Statistics Canada, this variable is derived through census questions. In 1991, the question relating to aboriginal ancestry was "Is this person a member of an Indian Band/First Nation?" and "Is this person a treaty Indian or a Registered Indian as defined by the Indian Act of Canada?" and "Of what ethnic origin is this person?". (122) This summary variable then, was the percent of residents with Aboriginal ancestry in the neighbourhood.

3.4 DATA ANALYSIS

3.4.1 UNIVARIATE AND BIVARIATE CONSIDERATIONS

Univariate analysis, also known as "describing" or "exploring" the data is a simple procedure of obtaining means, counts, quartiles and frequencies of the data. Bivariate analysis was performed using each independent variable, and

the dichotomous "low birth weight" dependent variable. The appropriate test-statistic (Pearson's chi-square F-test) was used to assess statistical significance at the conventional p-value set at 0.05.

The data were assessed for the presence of interaction and confounding. Confounding was assessed through adding and deleting terms to the model, and assessing whether or not this change made a significant difference in the coefficients of the remaining variables in the model. Since the objective of this part of the analysis was to identify if any of the variables available and included in the model were potential confounders, each variable's impact on all other variables were assessed, without regard to a primary risk factor. If introducing or deleting a variable resulted in a greater than or equal to ten percent change of the effect estimates in the remaining variables, this variable was considered a confounder.

Interaction was assessed using product terms of the variables considered to be biologically plausible or previously researched. Product terms were added to the model and the likelihood ratio test-statistic was used to compare the change of log-likelihood statistic from the model without the product term. Using a significance level of less than 0.05, two separate interaction terms were considered significant.

3.4.2 LOGISTIC REGRESSION MODELLING

In logistic regression the outcome variable (Y) must be categorical (dichotomous) and the independent variables (X) can be either continuous or categorical. The goal of the logistic regression model is to produce the most parsimonious, best fitting and biologically plausible model.

Graphically, a logistic model consists of an "S" shaped curve, which allows for a threshold of independent variables to produce an effect on the outcome. The beta coefficient when exponentiated in the model is an estimation of the odds ratio, where no association between X and Y is given by an odds ratio of 1.0. (7, 123-125) In the present study, logistic regression was used to model risk of LBW as a function of the independent variables included in the model.

3.4.3 MULTI-LEVEL MODELLING

Increasingly, multi-level models are being used in epidemiological studies. With this dataset, there are two levels of variables, individual and neighbourhood. Conceptually, it is important to remember that individual level data are nested within neighbourhood level data. Therefore, the fundamental assumption of independence between variables is violated. Multi-level models are uniquely designed to analyze several levels of variables, taking into account this nesting within levels. Therefore multi-level modelling was used, as it was felt they are best able to handle both individual and neighbourhood level data at once.

The model first creates a separate linear model for each neighbourhood by each individual variable. These separate models are then regressed on the neighbourhood variables, with one main effects model as the end result. (90)

3.4.4 MAPPING

The best way to display the results of the neighbourhood level data set is to map them. A graphical picture presents results clear and in a manner that is easy to understand. Bivariate maps were produced to aid in detecting the patterns emerging from low birth weight and neighbourhood of residence. There are three ways to group variables using ArcView GIS software; equal groupings, natural cut-points and user defined ranges. Natural cut-points relies on the computer to assign the groups for the researcher, which relinquishes control. User defined ranges are good for when the variable has commonly accepted, and not necessarily equal thresholds. For example, when presenting education attainment, elementary school, high school and university level of attainment may be used as the standard groupings. For the present study, it was decided that equal groupings, specifically quintiles and quartiles, would work best.

3.5 SOFTWARE USED

In order to perform the aforementioned analyses, several computer software programs were used. Primarily, data was explored and analyzed in the Statistical Package for the Social Sciences (SPSS) version 10.05. SPSS was

used for all univariate, bivariate and logistic regression considerations; also all data was recoded and cleaned in this program.

Multi-level modeling of both individual and aggregate level variables was performed using Multi-level modeling for Windows (MlwiN) version 1.10.0008. Upgrades were performed on a regular basis through the MlwiN website.

Several other calculations were performed using a component of EpiInfo 2000, entitled Statcalc. This program was used to derive significance levels for the comparison amongst included and excluded subjects.

Mapping of neighbourhood level data onto City of Saskatoon maps was performed using a geographic information system software (GIS) package entitled ArcView version 3.0.

3.6 ETHICS

For the individual level data, Saskatchewan Health assigned a random study ID for each individual baby. Characteristics identifying individual residents and children were not available. In the case where cell sizes were too small ($n < 5$), Saskatchewan Health amalgamated adjacent neighbourhoods together. Confidentiality is a large concern for Saskatchewan Health when considering research proposals. Only those studies where individual level data cannot be connected to the individual to which it applies will be given data.

(119)

Formal ethics approval was obtained for the larger study, to which the present analysis is a part of. Formal ethics application was made to the Social Science and Behavioural Ethics Committee at the University of Saskatchewan on November 13th, 2001 for the present study. In a written statement this committee deemed ethics approval was not necessary for this project, as it entailed secondary analysis of an already approved dataset. Please see Appendix 1: Ethics Approval for a copy of these statements from the committee.

CHAPTER 4: RESULTS

Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write.

-H.G. Wells

This chapter will highlight the results of all analyses performed on the data. The analysis of excluded cases will begin the chapter. Neighbourhood data and individual level data will be treated separately for both univariate and bivariate analyses. Descriptive and bivariate neighbourhood data will be presented with the aid of maps. Finally, results from multivariate analysis will be presented using logistic regression for individual level data and multi-level modeling for combined individual and neighbourhood level data.

4.1 COMPARISON BETWEEN EXCLUDED AND RETAINED SUBJECTS

The results of the analyses looking at the differences between the excluded cases (n=823) and the included cases (n=5463) are presented below.

The excluded cases had a higher incidence of low birth weight compared to the included cases (11.3% vs. 4.4%), which was statistically significant ($\chi^2=68.0$ $p<0.001$). This is to be expected since multiple birth babies were excluded, and these babies have a higher incidence of LBW compared to singletons.

The proportion of males to females among the excluded subjects was 53.6% compared to the 51.7% for the included children. The difference was not statistically significant ($\chi^2=1.05$ $p=0.306$).

Of the total included sample, 23.6% were dependant on governmental financial assistance; compared to 19.0% of the excluded subjects. This difference was statistically significant ($\chi^2=5.49$, $p=0.019$).

Using the dichotomous categories of mother's age, high and low risk, included and excluded subjects were different. 18.9% of included subjects were in a high-risk age group, while only 14.0% of excluded subjects were. This difference was statistically significant ($\chi^2=10.37$, $p=0.001$).

In terms of parity, 260 (31.6%) women of the excluded subjects were nulliparous, compared to 2345 (42.9%) of the included women. This difference was statistically significant ($\chi^2=29.6$, $p<0.001$).

Whether or not the mother had had a previous stillborn birth was not statistically different between included and excluded subjects. 92 included subjects (1.68%) had a history of previous stillborn delivery, compared to 12 excluded subjects (1.46%). This difference was not statistically significant ($\chi^2=0.13$, $p=0.714$).

Of included subjects, 28.2% were never married, compared to 16.9% of excluded subjects. This difference was statistically significant ($\chi^2=40.8$, $p<0.001$).

Of included subjects, 6.4% had gestational ages of less than 36 weeks, compared to 12.9% of excluded subjects. The proportion of greater than or equal

to 37 weeks old, were the inverse. This difference was statistically significant ($\chi^2=49.21$, $p<0.001$).

Comparing included to excluded subjects on their neighbourhood of residence is difficult. This is due to the inherent nature of the exclusion criteria, where a vast majority of subjects were excluded due to the missing information of neighbourhood of residence. There were 479 subjects who did not have a neighbourhood coded, or did not live within the Saskatoon city boundaries (thus, could not be assigned to a Saskatoon neighbourhood). Therefore, the comparisons of neighbourhood of residence will involve only the 344 excluded subjects who did have a neighbourhood reported, and were excluded for various other reasons.

Using the dichotomous variable of neighbourhood, East or West side, 112 included subjects lived on the Westside, compared to 167 of excluded subjects. This difference was not statistically significant ($\chi^2=0.74$, $p=0.39$).

Although the included and excluded subjects are statistically different for financial assistance rates, mother's age, parity, marital status, and gestational age the actual percentages are not widely different. The difference between the proportions of babies who are LBW is largely due to the presence of multiple births in the excluded category. Babies who were excluded from further analysis were a small proportion of the total sample and therefore babies who were included in the study were representative of the targeted population.

TABLE 4.1: COMPARISON BETWEEN EXCLUDED AND RETAINED STUDY SUBJECTS IN ANALYSIS BY SELECTED DEMOGRAPHIC CHARACTERISTICS

Variable		Included Subjects (n=5,643)	Excluded Subjects (n=823)	Comparison between Groups	
		Frequency (%)	Frequency (%)	Chi-square	Sig.
Mother's Age	Low risk (20-34)	4594 (81.4%)	708 (85.4%)	10.37	0.001
	High risk (<20, 35-40+)	1049 (18.6%)	115 (14.6%)		
Parity	1	2345 (41.6%)	260 (31.6%)	29.64	<0.001
	2+	3298 (58.4%)	563 (68.4%)		
Previous stillborn	0	5551 (98.4%)	811 (98.5%)	0.13	0.714
	1+	92 (1.6%)	12 (1.5%)		
Marital Status	Never married	1543 (27.3%)	139 (16.9%)	40.8	<0.001
	Married/Other	4100 (72.7%)	684 (83.1%)		
Sex	Male	2916 (51.7%)	441 (53.6%)	1.05	0.306
	Female	2727 (48.3%)	382 (46.4%)		
Gestational Age	<36 weeks	349 (6.2%)	106 (12.9%)	49.21	<0.001
	>=37 weeks	5294 (93.8%)	717 (87.1%)		
Financial Assistance	Yes	1289 (22.8%)	158 (19.2%)	5.45	0.019
	No	4354 (77.2%)	665 (80.8%)		

4.2 CHARACTERISTICS OF STUDY SAMPLE

Univariate statistics for the sociodemographic variables included in the analysis are presented in Table 4.2 below.

4.2.1 INDIVIDUAL LEVEL DATA

TABLE 4.2: DEMOGRAPHIC & REPRODUCTIVE CHARACTERISTICS OF THE STUDY SAMPLE (N=5,643)

VARIABLE		FREQUENCY (%)
Mother's Age	< 20	535 (9.5%)
	20 to 24	1215 (21.5%)
	25 to 29	1850 (32.8%)
	30 to 34	1529 (27.1%)
	35 to 39	466 (8.3%)
	>40	48 (0.9%)
Parity	1	2345 (41.6%)
	2	1980 (35.1%)
	3	860 (15.2%)
	4+	458 (8.1%)
Previous stillborn births	0	5551 (98.3%)
	1	74 (1.3%)
	2	11 (0.2%)
	3	3 (0.1%)
	4+	3 (0.1%)
Marital Status	Never married	1543 (27.3%)
	Married	3979 (70.5%)
	Divorced	96 (1.7%)
	Widowed	10 (0.2%)
	Unknown	15 (0.3%)
Birth Weight	Low (<2500g)	249 (4.4%)
	Normal (>2500g)	5394 (95.6%)
Sex	Male	2916 (51.7%)
	Female	2727 (48.3%)
Gestational Age (weeks)	<36	349 (6.2%)
	>=37	5294 (93.8%)
Financial Assistance	Yes	1289 (22.8%)
	No	4354 (77.2%)

Representing just over a third of all mothers is the age group 25 to 29. The second largest group is 30 to 34, followed by 20 to 24. The lowest proportion of mothers in this study are found in 20 years or younger, and 35 years or greater age groups.

The number of children a woman has given birth to, including the study child, is referred to as parity. The majority of women fall in the category of just one baby, with two children representing the second most.

As discussed previously in Chapter 2: Literature Review, previous stillborn deliveries increase the risk of subsequent children being of low birth weight. The proportion of stillborn births amongst the study population was 92 of 5,643 women.

The majority of women in the study population are married. Never married women comprise approximately a third of the women in the study, with divorced, widowed and unknown representing a very small proportion. It is important to control for marital status in subsequent analyses due to its potential to confound the relationship between neighbourhood of residence and low birth weight.

The proportion of babies who are born low birth weight is just over 4% in the study population. When taken as a continuous variable, instead of dichotomized, birth weight is normally distributed.

Male children are slightly more prevalent than female children (51.7%).

Gestational age is defined as the length of time in weeks from the date of the mother's last menstrual period. The mean gestational age of this study sample was 39.2 weeks (SD=1.90). Preterm children comprise a small proportion of the study population at just over 6%.

The proportion of study children with families who rely on government financial assistance represents just under a quarter of the study population, at 22.8%.

Brevoort Park had the smallest number of births in the study period with 71 (1.3%) children. The combined neighbourhood with the most births was Sutherland, Forest Grove and University Heights Suburban Centre with 368 (6.5%) births. It is important to note that these numbers account for ALL births within the City of Saskatoon from April 1st 1992 to March 31st 1994; therefore problems of sampling bias are not present.

4.2.2 NEIGHBOURHOOD LEVEL DATA

For the present study, wherever neighbourhoods were not used separately, the convention of division by the South Saskatchewan river into East and West side of the city was used. This is a convention used by city residents, and analysts at the city of Saskatoon.

Neighbourhood characteristics are best described and understood with the aid of maps. To that end, the following maps are presented.

FIGURE 4.1: PERCENTAGE OF ABORIGINAL RESIDENTS BY SASKATOON NEIGHBOURHOOD

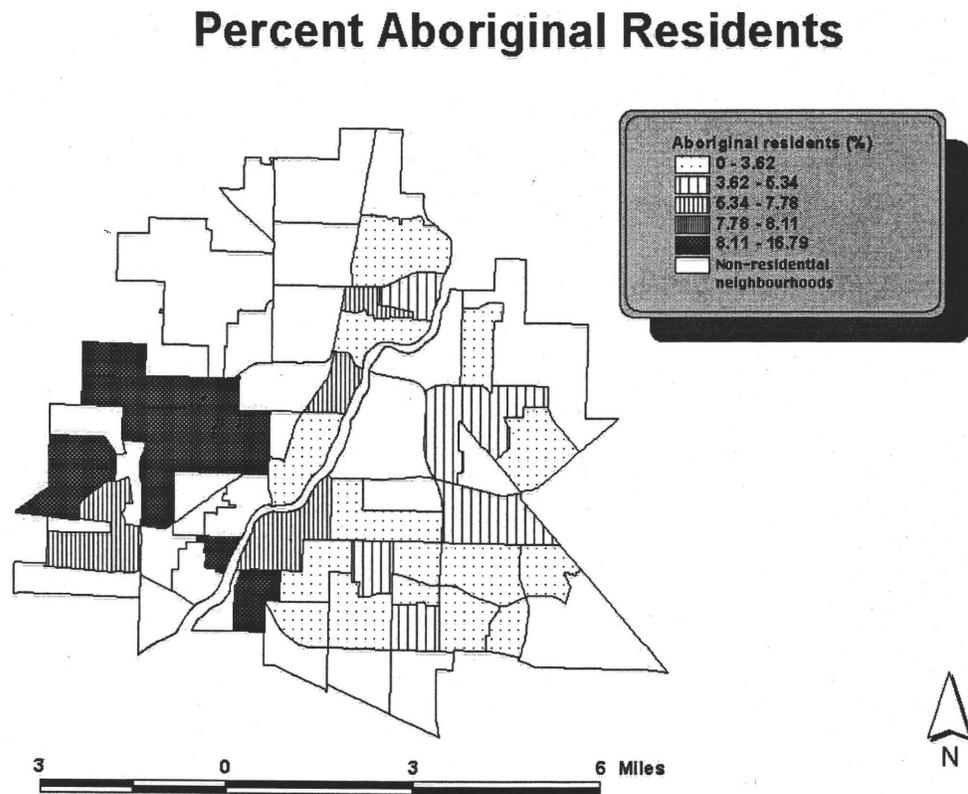
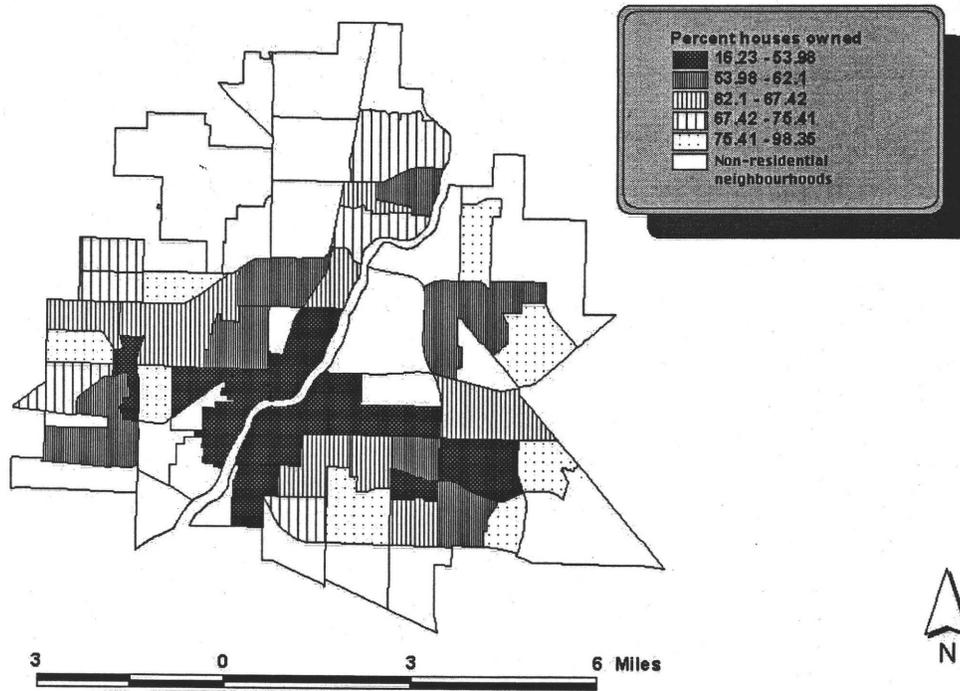


Figure 4.1 shows the distribution of residents of Aboriginal ancestry by Saskatoon neighbourhoods. In this map, as in all maps presented in the thesis, the variable being mapped represents groups of equal size (specifically quintiles or quartiles).

The darkest shaded areas show neighbourhoods with the highest percentage of Aboriginal residents; with the exception of Exhibition, all of these neighbourhoods exist on the Westside of the river.

FIGURE 4.2: PERCENTAGE OF HOUSES OWNED BY SASKATOON NEIGHBOURHOOD

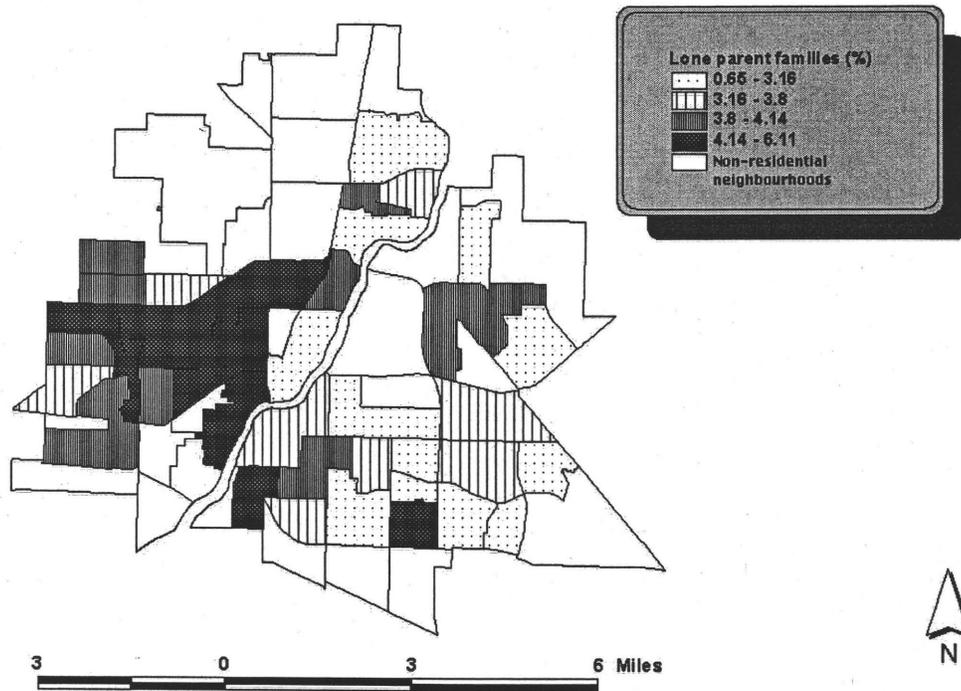
Percentage houses owned



From this map, it is clear that the percentage of houses owned per neighbourhood is fairly evenly dispersed throughout the city, with neighbourhoods with lower levels of houses owned representing most commercial areas.

FIGURE 4.3: PERCENTAGE OF LONE PARENT FAMILIES BY SASKATOON NEIGHBOURHOOD

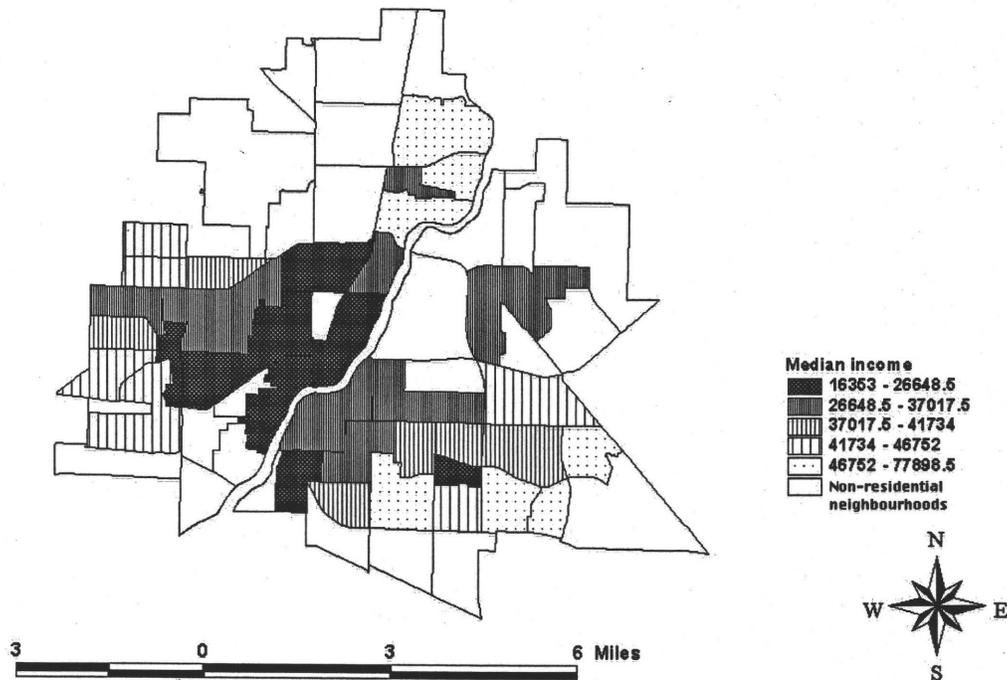
Percent Lone Parent Families



The darkest shaded areas represent the highest percentage of lone parent families. These neighbourhoods are: Confederation Park, Massey Place, Confederation Suburban Centre, Mount Royal, Meadowgreen, Pleasant Hill, Riversdale, King George, Holiday Park, Westmount, Hudson Bay Park, Mayfair, Kelsey/Woodlawn, Exhibition and Eastview. The neighbourhoods with the highest proportion of lone parent families tend to cluster around the west side of the South Saskatchewan river.

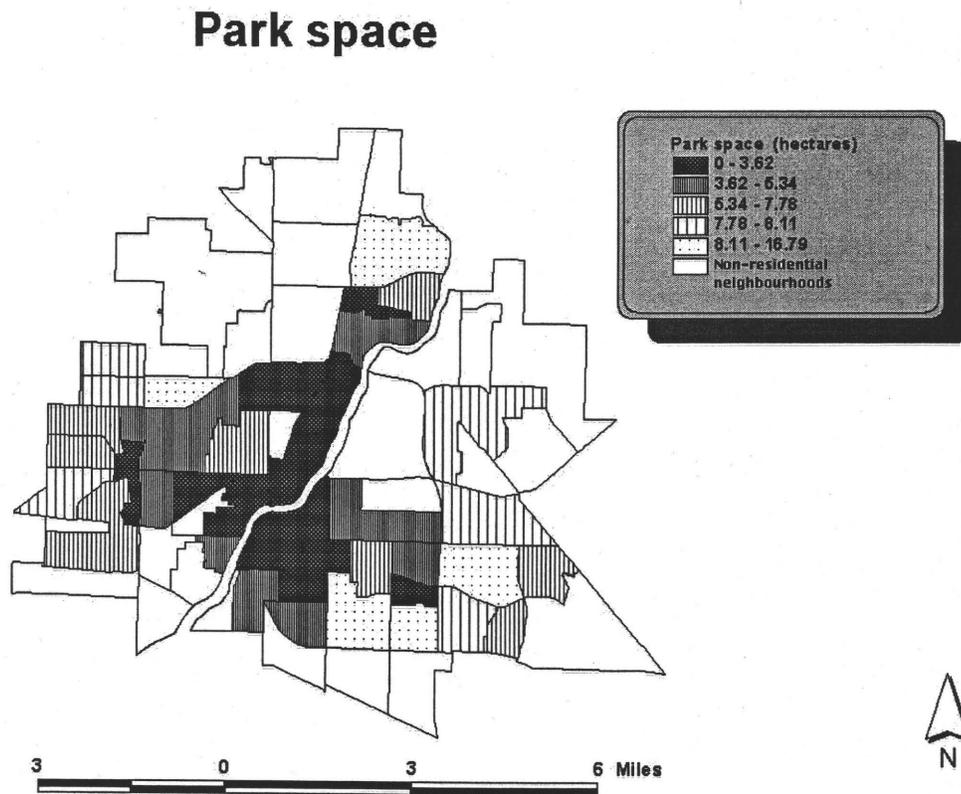
FIGURE 4.4: MEDIAN INCOME OF RESIDENTS BY SASKATOON NEIGHBOURHOOD

Median income



Neighbourhoods with the lowest median income category, \$16,000-\$27,000 per year, exists largely on the Westside of the river. Neighbourhoods with the highest median income tend to be in the southeast and north end of the city. These are: Briarwood, Lakeridge, Lakeview, Nutana Park, River Heights, Lawson Heights and Silverwood Heights.

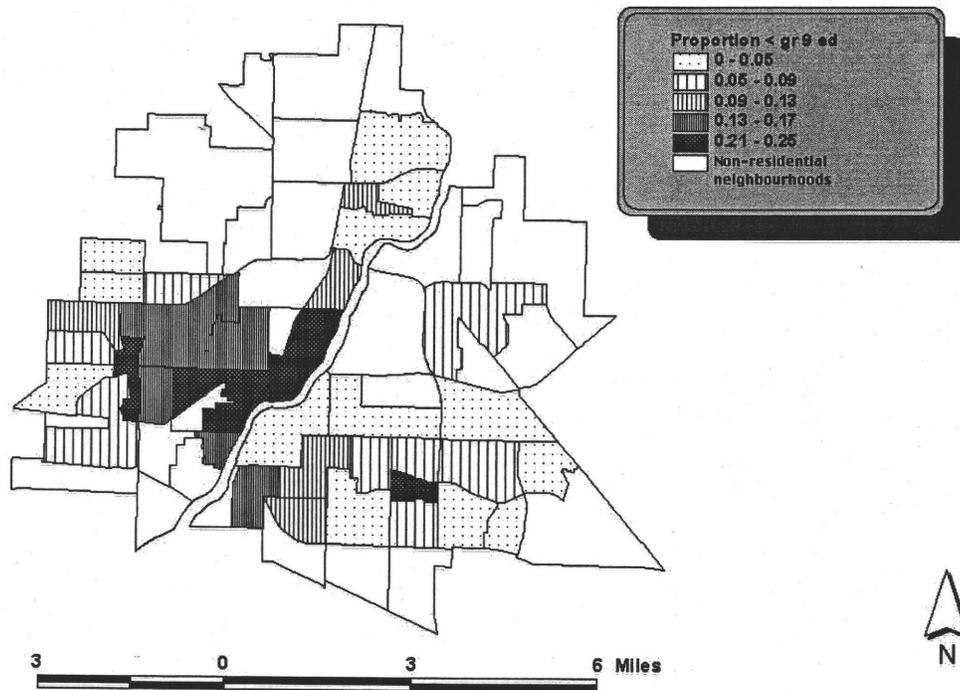
FIGURE 4.5: PARK SPACE IN HECTARES BY SASKATOON NEIGHBOURHOOD



It appears that park space in Saskatoon is evenly distributed amongst neighbourhoods particularly in areas that were developed relatively recently. The older neighbourhoods, on the whole, tend to have less park space.

FIGURE 4.6: PROPORTION OF RESIDENTS WITH LESS THAN GRADE 9 EDUCATION BY SASKATOON NEIGHBOURHOOD

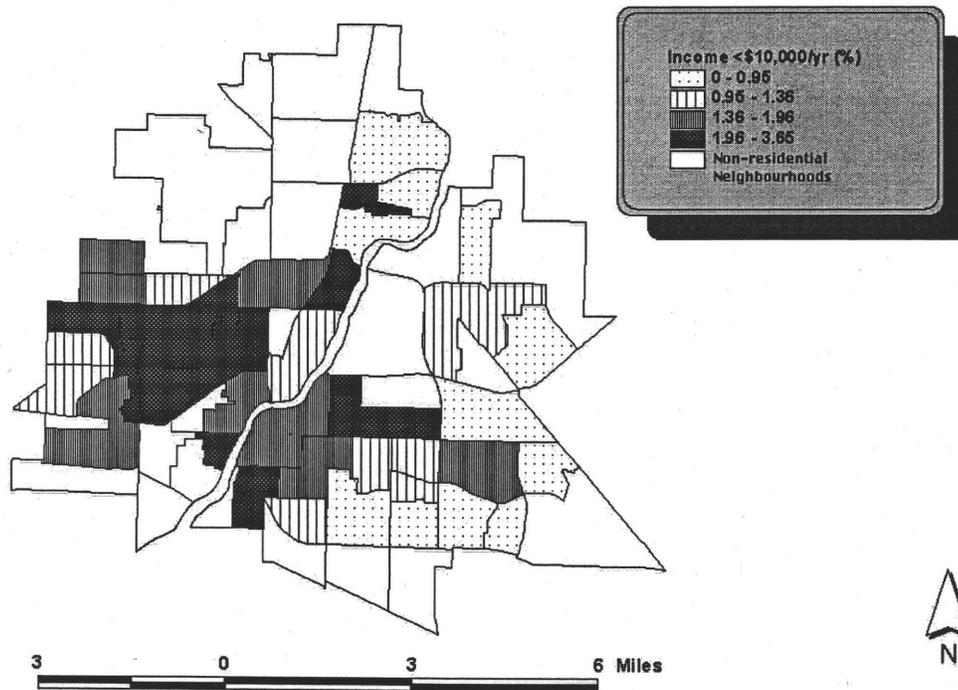
Proportion residents with < grade 9 education



The darkest shaded areas represent neighbourhoods with the lowest education levels. These are: Confederation Suburban Centre, Pleasant Hill, Riversdale, King George, Central Business District, City Park and Nutana suburban center. It is noted that age-adjustment for this variable would have produced more accurate mapping and results; however, as it is a neighborhood level aggregated variable individual age adjustment was not attempted.

FIGURE 4.7: PERCENTAGE OF RESIDENTS WITH INCOMES OF LESS THAN \$10,000 PER YEAR BY SASKATOON NEIGHBOURHOOD

Residents earning < \$10,000/yr



From this map, the high percentage of residents (adults only) earning less than \$10,000 per year exists on both sides of the river. However, those neighbourhoods in the eastern periphery and in the north end have a lower percentage of households with low income.

4.3 BIVARIATE ANALYSIS

When one considers two variables at the same time, this is referred to as bivariate analysis. In the present study the dependant variable is low birth weight; therefore was included in all bivariate considerations.

4.3.1 INDIVIDUAL LEVEL DATA

TABLE 4.3 ASSOCIATIONS BETWEEN MATERNAL AND CHILD CHARACTERISTICS AND LOW BIRTH WEIGHT

n=5463

VARIABLE		LBW (%)	NORMAL WEIGHT (%)	χ^2	SIG.
Mother's Age	Low risk (20-34)	194 (78%)	4400 (78%)	2.11	0.147
	High risk (<20, 35-40+)	55 (22%)	994 (22%)		
Parity	1	129 (52%)	2216 (41%)	11.27	0.001
	2+	120 (48%)	3178 (59%)		
Previous stillborn	0	236 (95%)	5315 (97%)	20.94	<0.001
	1+	13 (5%)	79 (3%)		
Marital Status	Never married	84 (34%)	1459 (27%)	5.36	0.021
	Married/Other	165 (66%)	3935 (73%)		
Sex	Male	111 (45%)	2805 (51%)	5.25	0.022
	Female	138 (55%)	2589 (49%)		
Gestational Age	<36	173 (70%)	176 (3%)	1798.6	<0.001
	>=37	76 (30%)	5218 (97%)		
Financial Assistance	Yes	82 (33%)	1207 (22%)	15.01	<0.001
	No	167 (67%)	4187 (78%)		
Neighbourhood	Eastside	137 (55%)	3161 (58%)	1.26	0.262
	Westside	112 (45%)	2233 (42%)		

With age categorized into "low risk" and "high risk" age groupings it failed to show a significant association with low birth weight ($\chi^2= 2.11$ p=0.147). The high-risk age group, less than 20 and greater than 35 years of age, had a low birth weight proportion of 5.24%. The low risk age group, 20-35 years of age, had a low birth weight proportion of was 4.22%.

Although in this way of categorizing age there was no statistically significant difference between the age groups, age was retained in future models because of its biological significance and significance in the literature.

Women who were primiparous had an increased proportion of low birth weight children. This proportion was 5.50% for primiparous women compared to 3.64% for multiparous women. This difference was statistically significant ($\chi^2=11.27$, $p=0.001$).

Women who had a previous still born birth had an increased proportion of low birth weight. This proportion was 4.25% for women with no previous stillborn birth compared to 14.13% for women with a previous stillborn birth in their obstetrical history. This difference was statistically significant ($\chi^2=20.94$, $p<0.001$).

Women who were never married had an increased proportion of low birth weight. This proportion was 5.44% for single women compared to 4.02% for married (and other, including divorced, widowed and unknown) women. This difference was statistically significant ($\chi^2=5.36$, $p=0.021$).

Female babies had an increased proportion of low birth weight. This proportion was 5.06% for females compared to 3.81% for males. This difference was statistically significant ($\chi^2=5.25$, $p=0.022$).

Babies who were born at less than or equal to 36 weeks of gestational age had an increased proportion of low birth weight. This proportion was 1.44% for babies born at 37 weeks or greater compared to 49.57% for babies born at less

than or equal to 36 weeks. This difference was statistically significant ($\chi^2=1798.56$, $p<0.001$).

Women who were on financial assistance had an increased proportion of low birth weight. This proportion was 3.84% for women not on financial assistance compared to 6.36% for women who did utilize this service. This difference was statistically significant ($\chi^2=15.01$, $p<0.001$).

Women who live on the Westside of Saskatoon had a slightly increased proportion of low birth weight. This proportion was 4.15% for women who lived on the Eastside compared to 4.78% for women who lived on the Westside. This difference was not statistically significant ($\chi^2=1.26$, $p=0.262$).

4.3.2 NEIGHBOURHOOD LEVEL DATA

In order to present a clear picture of bivariate associations between LBW and neighbourhood characteristics, LBW was used as an aggregate variable. One-way analysis of variance (ANOVA) was performed to test this association. Table 4.3 shows results of bivariate associations between neighbourhood level variables and LBW.

The amount of park space (in hectares) was statistically significant with LBW at the neighbourhood level ($F=3.060$, $p=0.015$).

The variable "houses owned" was statistically significant with LBW at the neighbourhood level ($F=2.637$, $p=0.030$).

The median yearly income in the neighbourhood was statistically significant with LBW at the neighbourhood level ($F=2.952$, $p=0.018$).

The variable measuring "residents with an income less than \$10,000 per year" was statistically significant with LBW at the neighbourhood level ($F=4.094$, $p=0.004$).

Lone parent households was statistically significant with LBW at the neighbourhood level ($F=5.087$, $p=0.001$).

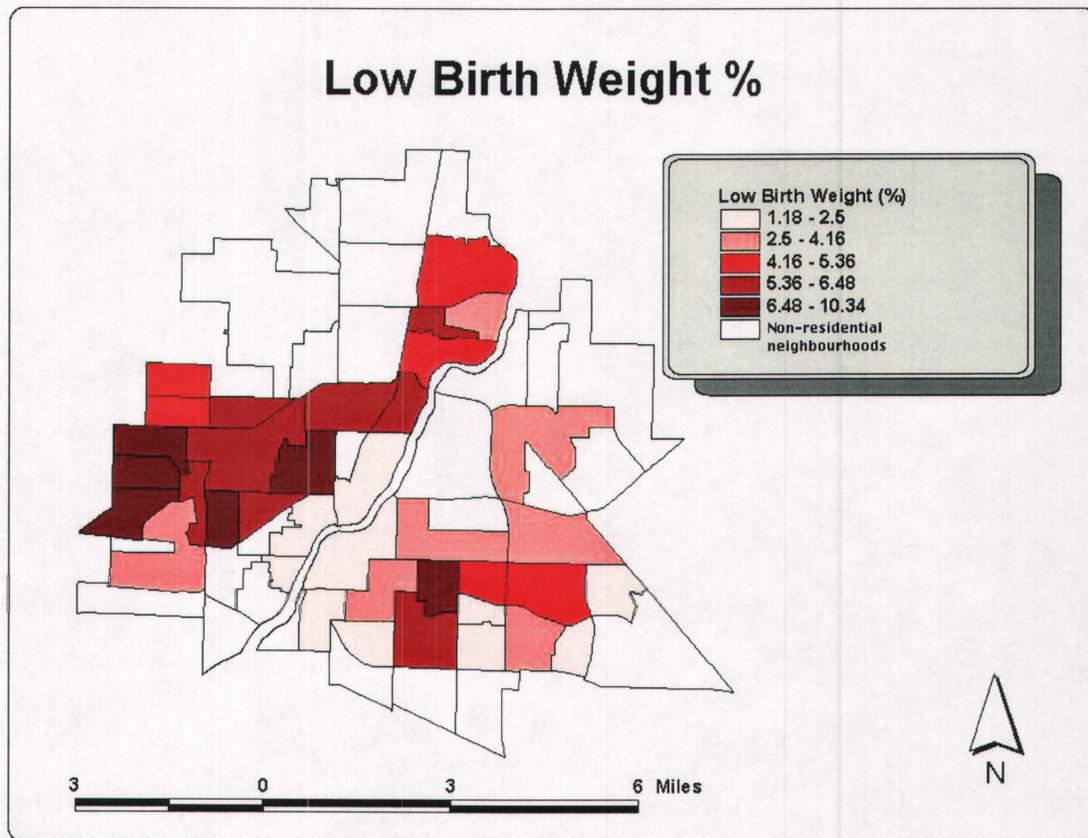
The neighbourhood variable "Aboriginal persons" was statistically significant with LBW at the neighbourhood level ($F=3.864$, $p=0.005$).

TABLE 4.4: BIVARIATE ASSOCIATIONS BETWEEN NEIGHBOURHOOD CHARACTERISTICS AND LOW BIRTH WEIGHT

Variable	df	F-statistic	p-value
Average Cost of Dwelling	31	2.009	0.086
Education <grade9	31	2.263	0.056
Grade 9-12	31	1.136	0.397
Compl/some University	31	0.955	0.529
Compl/some Trade School	31	0.625	0.810
Number of houses owned	31	2.637	0.03
Number of houses rented	31	0.756	0.698
Avg # of persons/household	31	1.829	0.118
Median income	31	2.95	0.018
Residents with income <\$10k/yr	31	4.09	0.004
Park Space (hectares)	31	3.06	0.015
Lone parents	31	5.087	0.001
Residents employed	31	1.7	0.148
Aboriginal ancestry	31	3.86	0.005

Again, these patterns are best visualized through the use of maps of the neighbourhoods. Please refer to the following maps of LBW and each statistically significant neighbourhood characteristic.

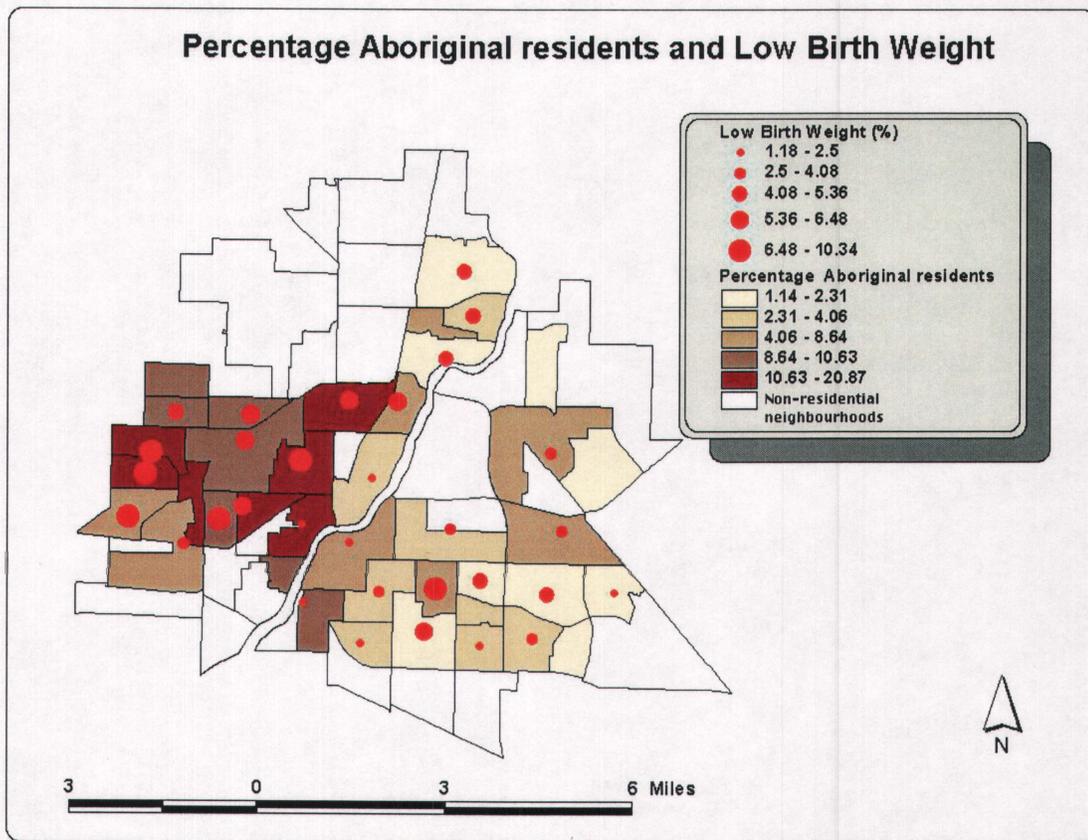
FIGURE 4.8: LOW BIRTH WEIGHT BY SASKATOON NEIGHBOURHOODS



The neighbourhoods with the highest percentage of LBW are: Parkridge, Pacific Heights, Confederation Park, Meadowgreen, Westmount, Caswell Hill, and Holliston. From this map it is clear that there are areas with a larger proportion of LBW babies compared to others. These areas tend to cluster on the west side of the river, particularly in the far west end.

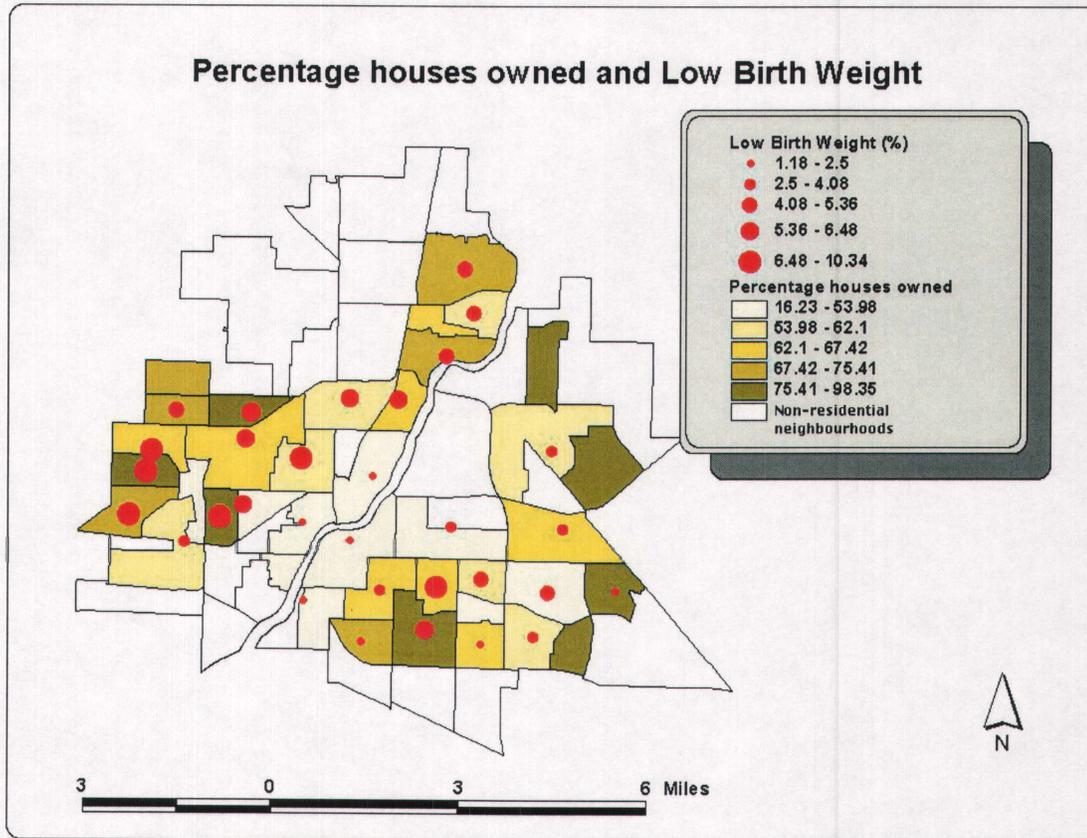
The next series of maps presented (Figures 4.9 to 4.15) show two variables mapped together: proportion of low birth weight and each of the significant neighbourhood level variables.

FIGURE 4.9: PERCENTAGE OF ABORIGINAL RESIDENTS OVER-LAYED WITH PERCENTAGE OF LBW CHILDREN BY SASKATOON NEIGHBOURHOOD



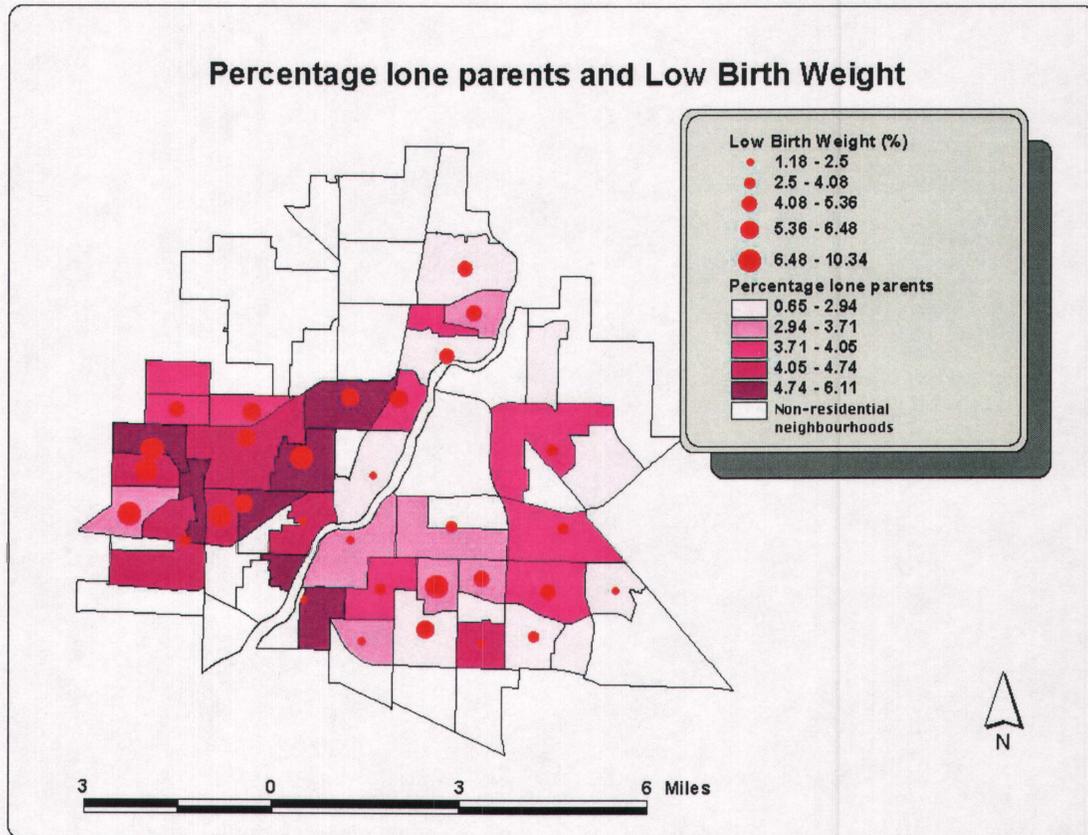
The largest red dots indicate areas with the highest percentage of LBW. It is interesting to note that these areas mainly correspond to the darker shaded areas, representing higher percentages of Aboriginal residents.

FIGURE 4.10: HOUSES OWNED OVER LAYED WITH PERCENTAGE OF LBW CHILDREN BY SASKATOON NEIGHBOURHOOD



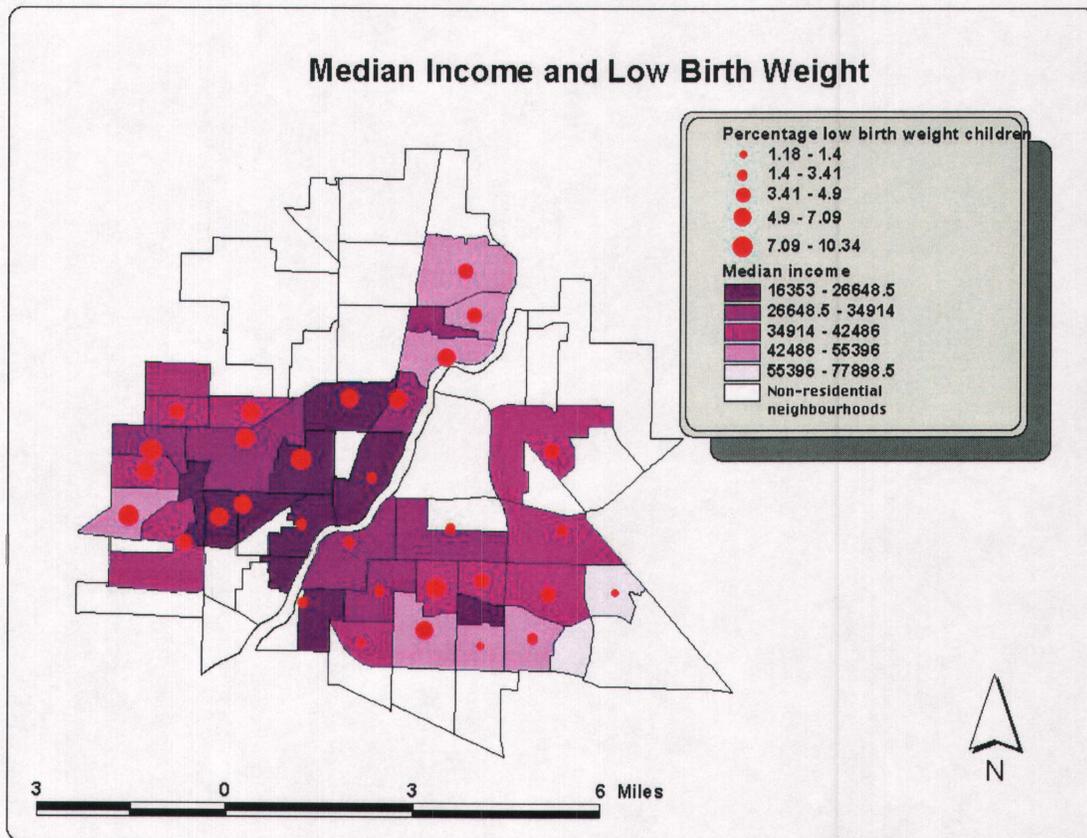
The darkest shaded areas represent neighbourhoods with the highest percentage of people owning their houses. While there is variation, neighbourhoods with higher percentages of LBW seem to correlate with neighbourhoods with lower a proportion of people owning their houses.

FIGURE 4.11: PERCENTAGE OF LONE PARENT FAMILIES OVER LAYED WITH PERCENTAGE OF LBW CHILDREN BY SASKATOON NEIGHBOURHOOD



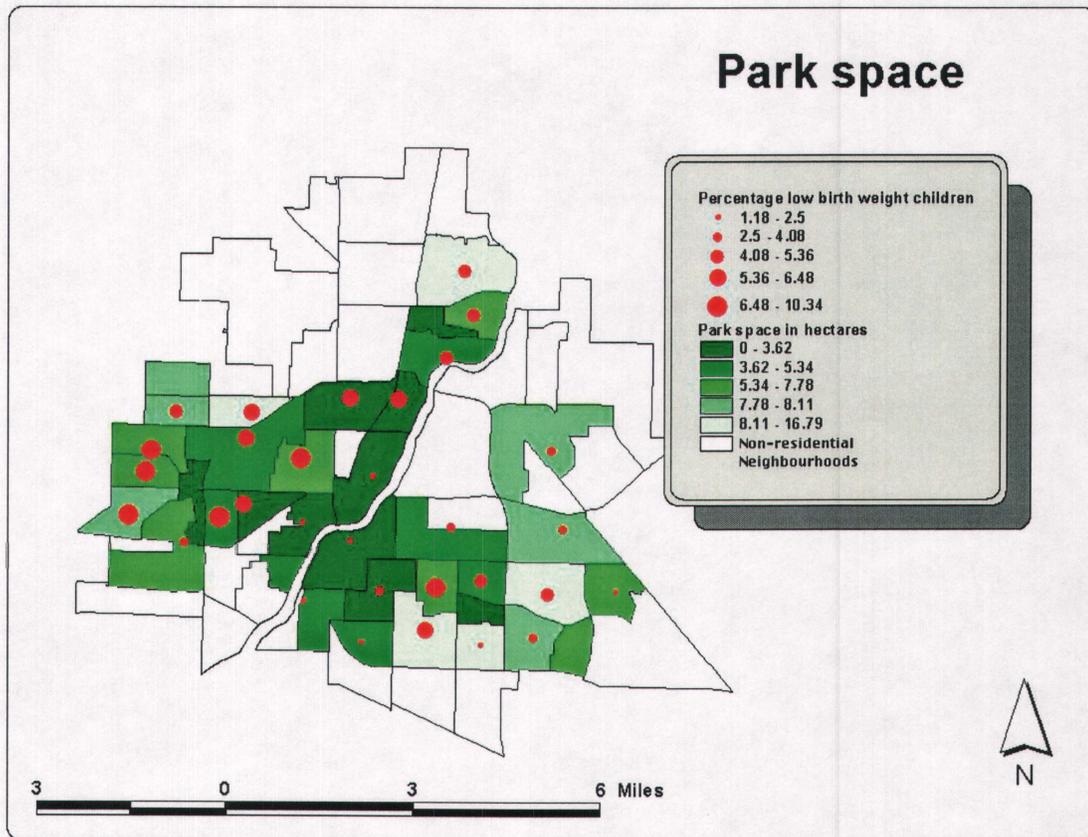
The darkest areas of the map represent larger percentages of lone parent families in the neighbourhood. The dominant pattern from this map is the majority of the darkest shaded areas existing on the Westside of the river, which correlate with higher percentages of LBW.

FIGURE 4.12: MEDIAN INCOME OVER LAYED WITH PERCENTAGE OF LBW CHILDREN BY SASKATOON NEIGHBOURHOOD



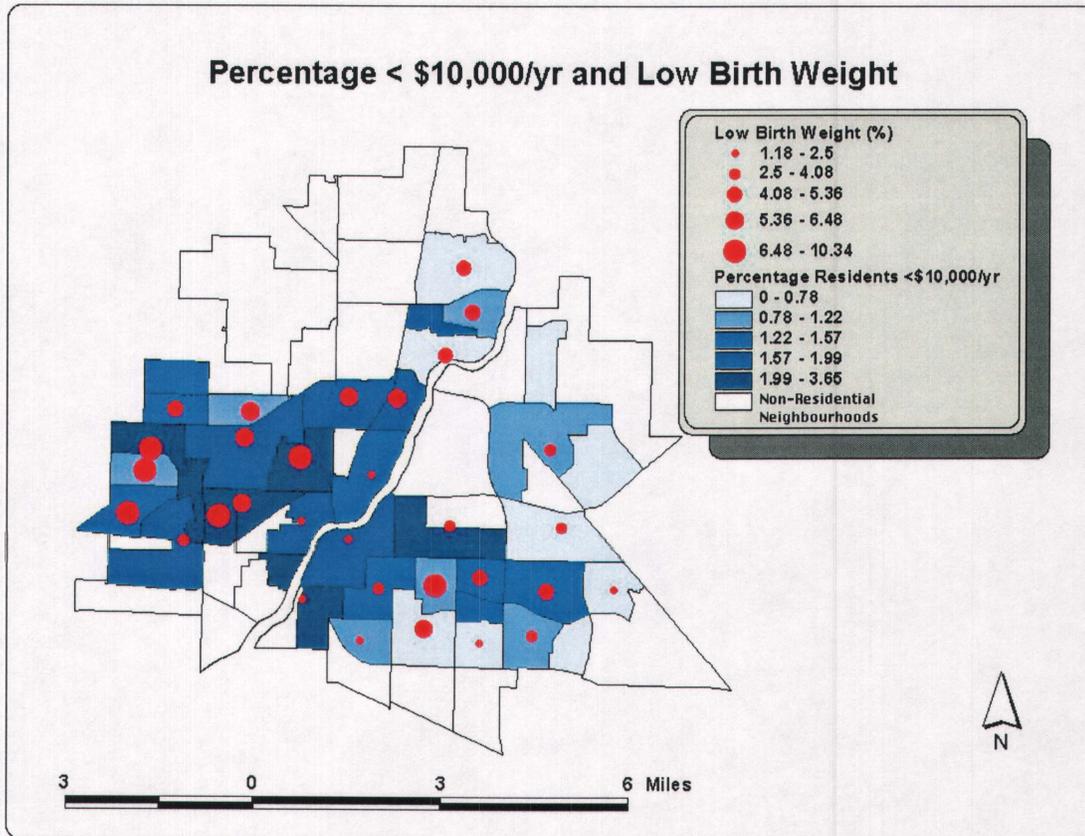
Lighter shaded neighbourhoods represent the highest median income. This map shows an inverse relationship between LBW and median income. Neighbourhoods with average median income tend to have average proportions of LBW, neighbourhoods with high median income tend to have smaller proportions of LBW and neighbourhoods with low median income tend to have high proportions of LBW.

FIGURE 4.13: PARK SPACE IN HECTARES OVER LAYED WITH PERCENTAGE OF LBW CHILDREN BY SASKATOON NEIGHBOURHOOD



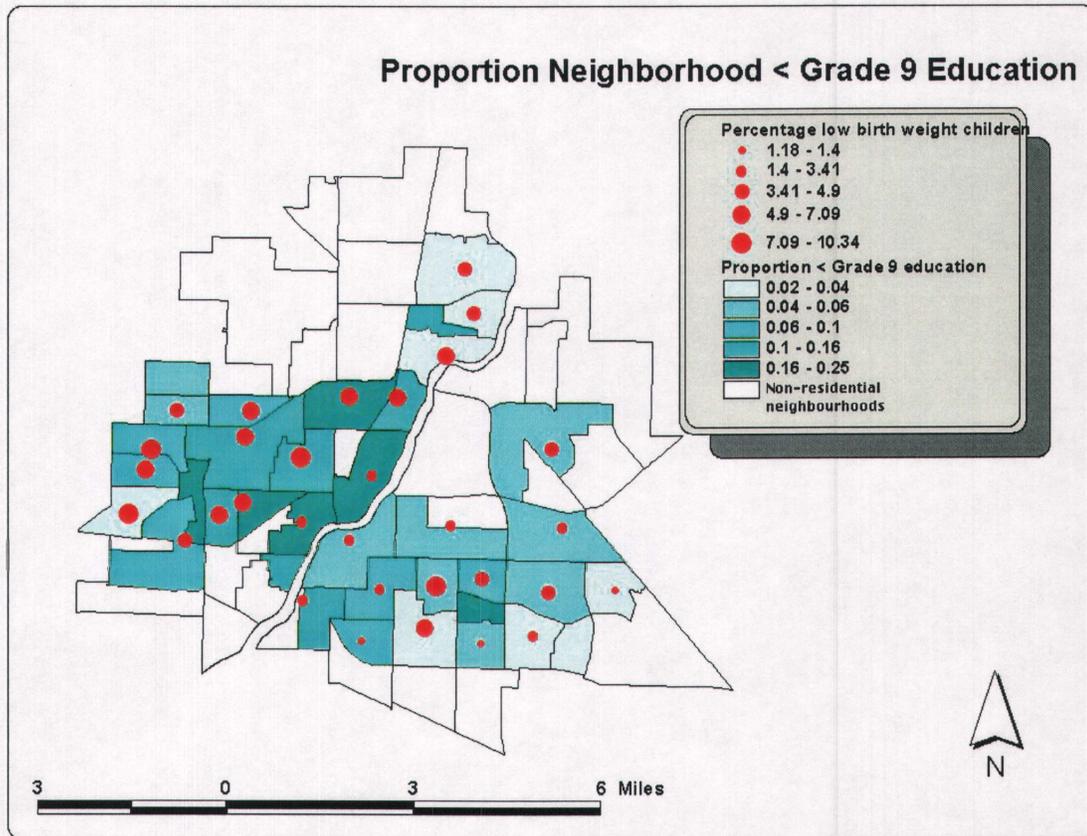
The darkest shaded areas represent neighborhoods with the least amount of park space. It is interesting to note that many of the areas with the least amount of park space also have the lowest proportion of LBW.

FIGURE 4.14: PERCENTAGE OF RESIDENTS EARNING LESS THAN \$10,000/YR OVERLAYS WITH PERCENTAGE OF LBW CHILDREN BY SASKATOON NEIGHBOURHOOD



The neighbourhoods with the largest percentage of residents with annual incomes less than \$10,000 per year, and the highest proportions of LBW are: Confederation Park, Meadowgreen, Pleasant Hill, and Westmount. Other neighbourhoods either have high proportions of LBW or high proportion of families with incomes of less than \$10,000 per year, not both.

FIGURE 4.15: PROPORTION OF RESIDENTS WITH LESS THAN GRADE 9 EDUCATION OVER LAYED WITH PERCENTAGE OF LBW CHILDREN BY SASKATOON NEIGHBOURHOOD



The majority of Saskatoon neighbourhoods have a proportion of residents with less than grade 9 education of 6-10%. Generally, there is no evidence for a close correlation between those who have less than grade 9 education, and low birth weight, by neighbourhoods.

From the bivariate analysis of neighbourhood characteristics and LBW, seven neighbourhood level variables are significant. Each of these seven variables were mapped, to display graphically the relationship between them and LBW. From these patterns it is clear that crude associations between LBW and the neighbourhood level variables exist.

4.4 MULTIVARIATE ANALYSIS

Multivariate analysis, models taking into account many variables, specifically, both individual and neighbourhood level variables, were performed. A discussion of interaction and confounding is presented as they relate to the study variables, followed by a description of the analyses performed as they relate to the study objectives.

4.4.1 INTERACTION

In order to have the most parsimonious and best fitting model, one must assess for interaction amongst separate variables. Interaction, or effect modification, between variables is defined when the association between an independent and dependant variable differs (or is modified) by the levels of another variable. (124, 125)

In the present study, interaction was assessed using logistic regression analysis with low birth weight as the dependant variable and product terms that were considered effect modifiable, either biologically or through examination of the literature.

Interaction terms that were statistically significant were gestational age (less than or equal to 37 weeks (preterm), or greater than 37 weeks (term)) by previous stillborn births and gestational age by parity. These interactions are presented graphically in Figures 16 and 17. When considering the biology of low birth weight, one would expect to see the strong influence of stillborn births and gestational age. Simply put, one cannot discuss the significance of the relationship between low birth weight with parity and stillborn births without taking gestational age into consideration.

As shown in Figure 16, the proportion of LBW babies is slightly higher among babies born preterm, compared to term, irrespective of the mothers history of previous stillborn births. However, among babies born preterm there appears to be a substantial increase in the proportion of LBW babies if the mother had had a previous stillborn birth, compared to mothers who had not. For babies born term, such an increase in the proportion of LBW if the mother had had previous stillborn births, was not seen. In other words, the probability of LBW babies appear to be increased for preterm babies born to mothers with a previous stillborn birth than it does for term babies born to mothers with a previous stillborn birth.

As shown in Figure 17, the proportion of LBW babies is significantly higher among babies born preterm, compared to term, irrespective of mothers parity. However, among babies born preterm there appears to be a substantial decrease in the proportion of LBW babies if the mother was multiparous

compared to primiparous. For babies born term a decline of the proportion of LBW babies was seen if the mothers were multiparous, but not as sharply. In other words, the probability of LBW babies appear to be lowered more sharply for preterm babies born to multiparous mothers than it does for term babies born to multiparous mothers. Clearly, the gestational age of the child must be considered when examining the relationship between previous stillborn births and parity for low birth weight risk.

Figure 16: Interaction of Gestational Age and History of Stillborn Births with LBW

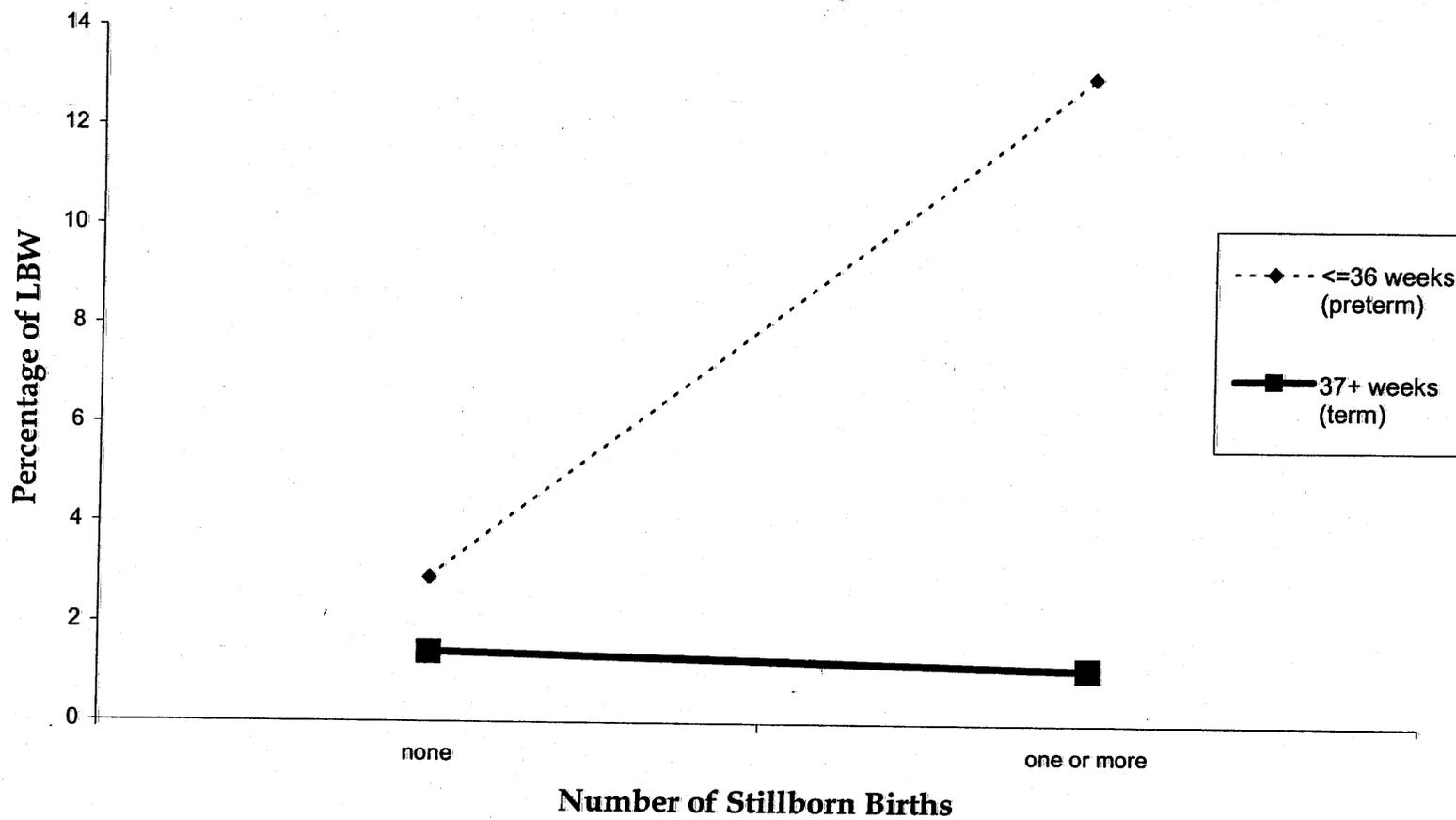
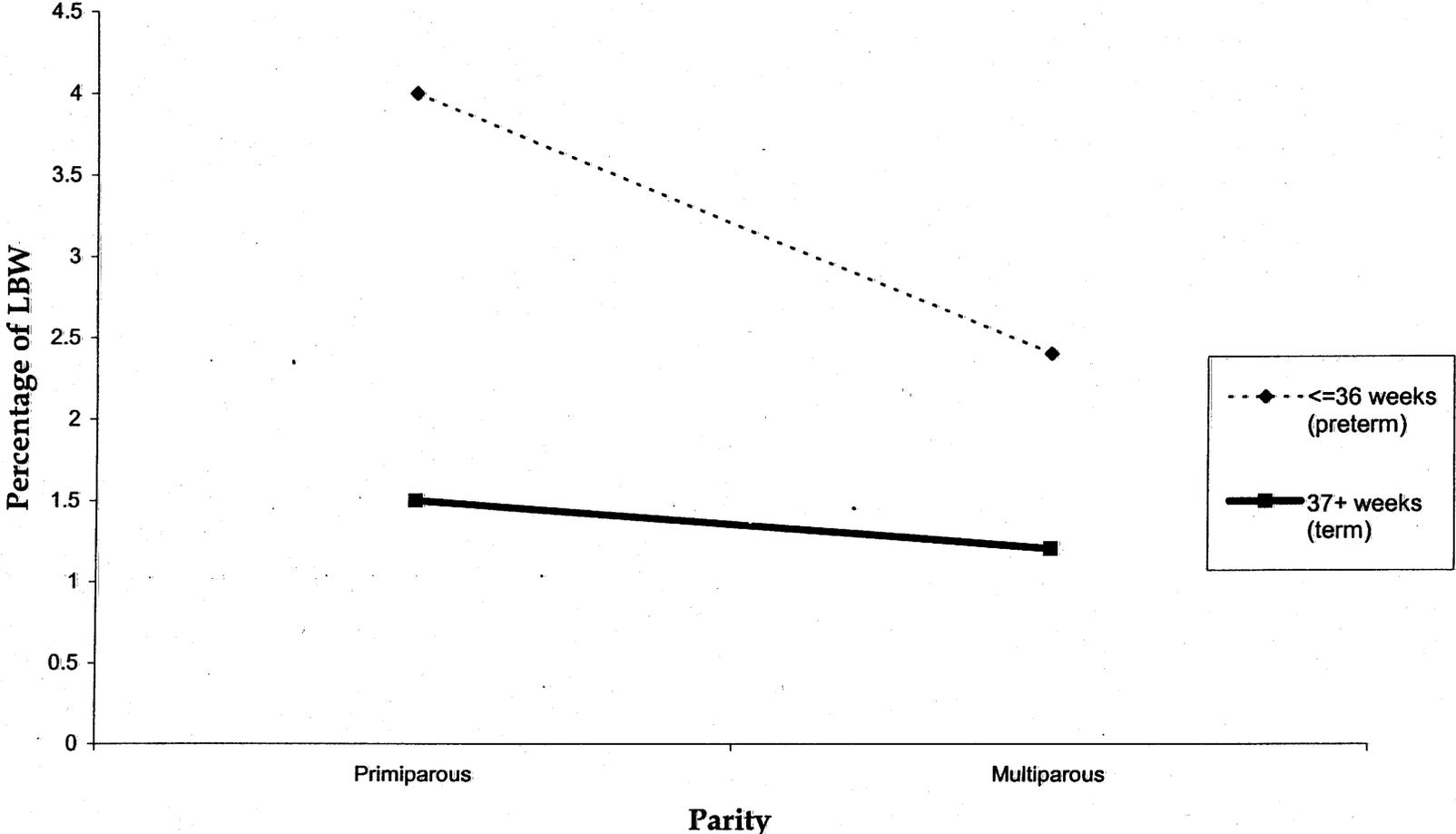


Figure 17: Interaction of Gestational Age and Parity with LBW



4.4.2 CONFOUNDING

Confounding in the context of this study; refers to the potential of a variable to distort the effect of another variable on low birth weight. This distortion is seen because the variable itself is a risk factor for low birth weight and is also associated with the other variable. For example, one might say that marital status is a confounder in the relationship between previous stillborn births and low birth weight, as single mothers may be under more stress than mothers with partners and therefore have an increased likelihood of having low birth weight babies; as well as being predisposed to having stillborn births in the past.

To assess for confounding one does not perform a statistical test but rather looks at the change related to the regression coefficients of the variables, given the potential confounder in the model compared to the model without. Some confounders may be considered biologically significant, given their inherent influence on health events (such as age, sex), while others have been identified in previous studies.

In the present study marital status, neighbourhood of residence and mother's age were assessed as potential confounders. Given a threshold of a 10% change in the beta values, none of these potential confounders were considered to be confounding the relationship with low birth weight. Mother's age, however, was retained in the main effects model because of its biological significance to the relationship of low birth weight.

4.4.3 RESEARCH OBJECTIVE 1: WHICH INDIVIDUAL LEVEL VARIABLES TOGETHER CONTRIBUTE TO A RISK OF LBW?

Logistic regression was used in order to determine which variables contributed significantly to the risk of low birth weight. All variables were initially included in the model and the researcher, not the computer program, decided which variables were non-significant, either biologically or statistically. Marital status of the mother and neighbourhood of residence did not significantly add to the model of low birth weight, marital status of the mother and neighbourhood of residence.

The final model for low birth weight included the following individual level variables: sex of child, financial assistance, mother's age (not statistically significant but retained for biological significance), gestational age of child, and the interaction terms of gestational age and parity and gestational age and previous stillborn births. Also, due to the hierarchical principle, both stillborn births and parity were included in the final main effects model (See Table 4.4). This principle states that all variables of product terms must be retained in the model, even if they are non-significant. (123, 124)

TABLE 4.5: INDIVIDUAL LEVEL PREDICTORS OF LBW

Variable	Odds Ratio	95% CI	p-value
Sex (female vs. male)	1.75	1.27-2.41	.001
Financial Assistance (yes vs. no)	1.50	1.05-2.14	.025
Mother's Age (high risk vs. low risk)	.96	0.64-1.44	.846
Gestational Age (<=36 weeks vs. 37+ weeks)	85.82	54.02-136.35	< .001
Parity (primiparous vs. multiparous)	.79	0.50-1.25	.321
Previous Stillborn Births (yes vs. no)	.95	0.13-6.99	.963
Gestational Age by Parity*			.103
Gestational Age by Stillborn*			.051
Omnibus Test of Coefficients (model) = 802.0, p<0.001			
Hosmer and Lemeshow's Goodness of Fit = 9.485, df=7, p=0.220			

* please see Figures 16 and 17

In this final model, one can interpret each variable as it contributes to the overall significance of the model. In terms of sex, female children have an elevated risk of low birth weight births compared to males. Females are 1.7 times more likely to be low birth weight than males. (OR=1.75, p=.001) This is in keeping with the literature surrounding low birth weight and sex.

A very interesting relationship is the financial assistance variable to LBW. Those families who receive financial assistance from the government are 1.5 times more likely to have a low birth weight baby (OR=1.50, p=.025). Financial assistance can be thought of as a proxy for family socioeconomic status.

Not surprisingly, gestational age of the child also predicts low birth weight. Children who are less than or equal to 36 weeks gestational age are

about 86 times more likely to be low birth weight (OR = 85.82, $p < 0.001$).

Biologically, one would expect this, as less time in the womb would result in less growth and development, leading to lower birth weights.

Mother's age, which was categorized to be either high risk, (<20 and greater than 35) or low risk, (all other age groups) was not statistically significant in the model. However, it was retained because of its previously reported biological significance.

In previous analyses, it was discovered that both parity and stillborn births had an interaction effect with gestational age. Therefore, these two variables are best understood in their interactions, and are displayed graphically and explained above. However, both parity and stillborn births are retained separately in the model.

Hosmer and Lemeshow's goodness of fit statistic, measures how well the model fits the data. (123, 125) Taking the squared differences between the observed and predicted probabilities derives this statistic. In the present model, Hosmer and Lemeshow's goodness of fit statistic was 9.485, with 7 degrees of freedom and a p-value of 0.22. The goodness-of-fit statistic indicates that the model has reasonable fit to the data.

Multicollinearity is a problem that can occur within a dataset. It refers to the possible associations between predictor variables that can lead to biased estimates and inflated standard errors. In linear regression, SPSS will give collinearity diagnostics with the test results. However, as multicollinearity is

less of an issue in logistic regression, simple scatterplots has been used to assess for multicollinearity. In the present study, each variable was graphed by low birth weight and then plotted together. The graphs all showed a random pattern of data points. The results indicate that multicollinearity is not present, and the assumption of multivariate equality of variance was met.

4.4.4 RESEARCH OBJECTIVE 2: DO NEIGHBOURHOOD FACTORS CONTRIBUTE INDEPENDANTLY TO RISK OF LBW?

As mentioned above, simple regression models are not complex enough to handle both neighbourhood and individual level data together. However, it is often very interesting to be able to produce a model with both individual and neighbourhood level considerations. To that end, multi-level modelling was preformed on the dataset.

The following will be a description of the multi-level modelling results for both the continuous outcome of birth weight, as well as for the dichotomous outcome of LBW (versus normal weight).

4.4.4.1 MULTI LEVEL MODELLING WITH A CONTINUOUS MEASURE OF BIRTH WEIGHT

When using birth weight as a continuous measure a normal, as opposed to binomial distribution, model can be used. This is the simplest method, and therefore, the beginning of the process.

Multi-level modelling using a normal distribution attempts to fit a variance component model to assess the amount the continuous measure

changes when individual and neighbourhood level predictors are added to the model; these models also assess between neighbourhood variations. (91).

The null model provides the baseline log likelihood value to which subsequent models are compared. The null model of birth weight amongst individuals and neighbourhoods is as follows:

$$\text{bwt}_{ij} \sim N(XB, \Omega)$$

$$\text{bwt}_{ij} = \beta_{0ij} \text{cons}$$

$$\beta_{0ij} = 3424.083(8.865) + \mu_{0j} + e_{0ij}$$

$$\left[\mu_{0j} \right] \sim N(0, \Omega_u) : \Omega_u = \left[703.701(603.523) \right]$$

$$\left[e_{0ij} \right] \sim N(0, \Omega_e) : \Omega_e = \left[304274.100(5743.319) \right]$$

$$-2 * \log \text{likelihood}(IGLS) = 87271.600(5643 \text{ of } 5643 \text{ cases in use})$$

Where;

bwt = birth weight

cons = constant (1)

subscript i = individual level

subscript j = neighbourhood level

μ_{0j} = neighbourhood level residuals

e_{0ij} = individual level residuals

Ω = variance and covariances of the random terms over both individual and neighbourhood.

The values in each equation that are not surrounded by brackets are variances; those in brackets are the standard error of the variance. The -2 log likelihood value is important at this stage in order to have a baseline value to compare increasingly complex models to. Next, each individual level variable that was statistically significant from the logistic regression models were added

one at a time to the model. Afterward, each neighbourhood characteristic was added separately to the model already containing the individual level variables and significant improvement over the $-2 \log$ likelihood value was assessed. The quantifiable difference in birth weight associated with each variable was assessed in the final multi-level model, while the $-2 \log$ likelihood change was assessed as each variable was separately added to the model. The estimation method used was iterative generalized least squared (IGLS), which is the most appropriate method for variables with multivariate normal distributions and gives the value for the maximum likelihood estimates. (90)

The first individual level variable that was added to the model was sex of the child. It was determined that sex significantly added to the prediction of the model, due to the improvement in the $-2 \log$ likelihood value over the null of 69 units ($\chi^2 = 6.64, p < 0.01$). The variance decreased at both the individual and neighbourhood level. Female children weighed 128 grams less than males.

The addition of the financial assistance variable showed a better fitting model over the model with just sex alone; the log likelihood value improved by 32.5 units ($\chi^2 = 6.64, p < 0.01$). Interestingly though, neighbourhood effects have dropped out of the model (variance = 0.0, standard error = 0.0). This model predicts that those individuals who rely on financial assistance have babies on average weighing 69 grams less than those who do not rely on financial assistance.

The addition of gestational age showed a better fitting model over the model with sex and financial assistance alone. This improvement was quite large, with a log likelihood value change of 2491 units ($\chi^2 = 6.64$, $p < 0.01$). This model predicts a gain of 171 grams for every week of pregnancy the mother is closer to term. It should be noted that at this stage of the analysis, the variable gestational age was used in weeks, not as a dichotomous measure.

The addition of parity showed a better fitting model over the model with sex, financial assistance and gestational age alone. The log likelihood value decreased by 78 units, which was statistically significant ($\chi^2 = 6.64$, $p < 0.01$). This model predicts that multiparous women on average have babies 106 grams larger than primiparous women.

The addition of previous stillborn births to the model showed a statistically significant difference. The log likelihood value changed by 1.4 units. This model predicts that mother's with a previous history of stillborn births, will on average, have children weighing 1300 grams less than mother's who have not had a previous stillborn birth. It should be noted, however, that this estimate had a very wide confidence interval and may be an unstable estimate.

The interaction term of gestational age by stillborn births was statistically significant ($\chi^2 = 3.84$, $p = 0.05$). The log likelihood value improved by 5 points. This interaction is best understood by referring back to the graph on page 78. The significant individual level interaction of gestational age with parity from previous analyses was not statistically significant using this technique. Also

mother's age was not statistically significant in these models (retained in this and previous models for its biological significance).

Neighbourhood level variables were all added one at a time to determine if they produced a better fitting model than the one with the individual level variables alone. It was discovered that *not one* neighbourhood level variable was statistically significant, once the significant individual level predictors had been controlled for. These results can be seen in the following table.

TABLE 4.6: SUMMARY OF MULTI-LEVEL MODEL USING BIRTH WEIGHT AS A CONTINUOUS VARIABLE

	Variable ^a	Estimate (s.e.) _b	95% CI	-2 log likelihood change ^c
Individual level variables	Constant	3424.08 (8.87)	3406.7-3441.47	87271.60
	Sex (1=male, 2=female)	-128.26 (11.61)	-151.0-(-105)	69
	Financial Assistance (0=no, 1=yes)	-69.38 (14.08)	-96.98-(-41.8)	32.5
	Gestational age (weeks)	170.8 (3.14)	164.65-176.95	2490.9
	Parity (1=primiparous, 2= multiparous)	106.02 (11.85)	82.79-129.25	78.1
	Previous stillborn births (0=none, 1= stillborn birth)	-1291.93 (560.81)	-2391-(-192)	1.4
	Gestage*parity	-5.78 (6.12)	-17.78-6.22	0.9
	Gestage*stillborn births	32.35 (14.62)	3.69-61.01	5.0
	Mother's age (0=low risk, 1=high risk)	13.95 (15.18)	-15.8-43.7	-6.5
Neighbourhood level variables	< grade 9 education	-19.50 (97.50)	-210.7-171.66	0.2
	Houses owned	0.01 (0.01)	-0.01-0.03	0.8
	Median income	0	0	0
	Income < \$10,000/yr	-0.13 (0.16)	-0.44-0.18	0.7
	Park space (hectares)	-1.43 (2.13)	-5.60-2.74	0.5
	Lone parents	0	0	0
	Aboriginal ancestry	0.005 (0.028)	-0.05-0.06	0

^a STATISTICALLY SIGNIFICANT VARIABLES AND THEIR ESTIMATES ARE **BOLDED**

^b **BOLDED** ESTIMATES ARE FROM THE FINAL MODEL EXCLUDING NON-SIGNIFICANT VARIABLES (EXCEPT MOTHER'S AGE, RETAINED FOR BIOLOGICAL SIGNIFICANCE)

^c = CHANGE IN THE -2 LOG LIKELIHOOD VALUE AS EACH VARIABLE IS SEQUENTIALLY ADDED TO THE MODEL

4.4.4.2 MULTI LEVEL MODELLING WITH A DICHOTOMOUS MEASURE OF BIRTH WEIGHT

When using birth weight as a dichotomous measure, a binomial distribution of the model must be used, as there is a basic binary response; low or normal birth weight. A binomial model fits variance components in the model to assess the average probability of being low birth weight, along with the between neighbourhood variation.

First, one should test whether or not the binomial assumption holds or whether the data exhibits "extra binomial" variation. The values that were produced from this test showed little change from the null, with only the level 1 variance multiplier decreasing slightly from 1.0 to 0.992. Therefore there is no evidence that the response variable is not binomially distributed.

The null binomial model is as follows:

$$\left. \begin{aligned} \text{bwcat}_{ij} &\sim \text{Binomial}(\text{denom}_{ij}, \pi_{ij}) \\ \text{bwcat}_{ij} &= \pi_{ij} + e_{0ij} \text{bcons}^* \end{aligned} \right\}$$

$$\text{logit}(\pi_{ij}) = \beta_{1j} \text{cons}$$

$$\beta_{1j} = -3.070(0.084) + u_{1j}$$

$$[u_{1j}] \sim N(0, \Omega_u) : \Omega_u = [0.085(0.055)]$$

$$\text{bcons}^* = \text{bcons} [\pi_{ij}(1 - \pi_{ij}) / \text{denom}_{ij}]^{0.5}$$

$$[e_{0ij}] \sim (0, \Omega_e) : \Omega_e = [0.992(0.019)]$$

Where:

bwcat: categorical variable of birth weight (low vs. normal)

bcons = constant

subscript i = individual level

subscript j = neighbourhood level

u_{0j} = neighbourhood level residuals

e_{0ij} = individual level residuals

Ω = variance and covariances of the random terms over both individual and neighbourhood levels.

From this null model one can see that neighbourhood is already a non-significant effect ($0.085 < 1.96 * 0.055$). Upon further additions of variables into the model, the same findings as the previous model were found. However, we are unable to quantify the change in birth weight with the different variables, as we were able to do previously. This is due to the nature of the binomial distribution, without a continuous measure of birth weight one cannot say what the quantifiable change in grams is. However, we are able to compute a "binomial estimation" which is given by the equation:

$$[1 + \exp(\text{variance})]^{-1}$$

Adding in the variance from the null equation we arrive at a binomial estimation of:

$$[1 + 2.718(3.070)]^{-1} = 0.107$$

This gives us an estimate of the median proportion of low birth weight in the data, 0.107.

Variables chosen for this model were all individual and neighbourhood level variables that were significant from the bivariate tests. Variables were added to the model one at a time and determined to be statistically significant by calculating the 95% confidence interval using the standard error of the estimate at each step. The first order MQL method was used according to Goldstein. (90)

Please see the following table with summary statistics from the binomial multi level model. Note the similarities to the previous model.

TABLE 4.7: SUMMARY OF MULTI-LEVEL MODEL USING BIRTH WEIGHT AS A DICHOTOMOUS VARIABLE

	Parameter ^a	Estimate (s.e.) ^b	Binomial Estimate	Odds Ratio	95% C.I.
Individual Level Variables	Constant	-3.07 (0.08)	0.11	0.05	-2.9-(-3.2)
	Sex (1=male, 2=female)	0.62 (0.18)	0.37	1.86	1.31-2.65
	Financial Assistance (0=no, 1=yes)	0.46 (0.19)	0.44	1.58	1.09-1.45
	Gestational age (weeks)	-1.08 (0.05)	0.25	0.34	0.31-0.37
	Parity (1=primiparous, 2= multiparous)	-0.39 (0.17)	0.49	0.68	0.49-1.34
	Previous stillborn births (0=none, 1= stillborn birth)	0.79 (0.48)	0.32	2.20	0.86-5.65
	Gestage*parity	0	0	0	0
	Gestage*still	0	0	0	0
	Mother's age (0=low risk, 1=high risk)	-0.24 (0.22)	0.63	0.79	0.51-1.21
Neighbourhood Level Variables	< grade 9	0.90 (1.88)	0.29	2.46	0.06-97.98
	Houses owned	0	0	0	0
	Median income	0	0	0	0
	Income< 1,000/yr	0.001 (0.002)	0	0	0
	Park space (hectares)	0.03 (0.03)	0	0	0
	Lone parents	0	0	0	0
	Aboriginal ancestry	0	0	0	0

^a SIGNIFICANT VARIABLES AND THEIR ESTIMATES ARE **BOLDED**

^b **BOLDED** ESTIMATES ARE FROM THE FINAL MODEL EXCLUDING NON-SIGNIFICANT VARIABLES (EXCEPT MOTHER'S AGE, RETAINED FOR BIOLOGICAL SIGNIFICANCE)

From the multi level modeling procedure on this data set, the results show that once individual level predictors are in the model and controlled for, neighbourhood level predictors are no longer statistically significant.

The regression diagnostics used for multilevel modelling were: testing for extra binomial variation and testing for multicollinearity. Extra binomial variation was discussed above. Multicollinearity was assessed by graphing each variable with birth weight, and comparing the resulting graph to the standard graphs in Goldstein, which illustrates the presence of multicollinearity. (90) This

dataset did not exhibit multicollinearity. Also, the eigenvalues in each model were not above 30, which indicates that multi-collinearity between the variables is not present. (91)

The results of the multilevel models both refine the results of the previous logistic models. With the exception of previous stillborn births, parity and the interaction terms of gestational age by parity and stillborn births, the same individual characteristics were significant.

A major bonus of the normally distributed, as opposed to the binomial, multi-level model is the ability to quantify the change in birth weight given the different predictors. It is interesting to see the actual quantity of risk change and reduction given different variables in the model.

The most important piece of information to gain from the multi-level modelling comes from the reason it was used in the first place; the ability to put both micro and macro level variables in the same equation allowing one to control for the known individual level risk factors and subsequently add neighbourhood level variables. All neighbourhood level characteristics previously statistically significant were no longer significant. And, once all individual level variables were controlled for, the data did not exhibit neighbourhood level effects.

Factors relating to neighbourhood of residence, when significant individual level predictors are accounted for, are not associated with low birth weight in this cohort of children.

CHAPTER 5: DISCUSSION

This chapter will address the previous results and relevant issues surrounding my thesis research. A highlight of the major results will be followed by a discussion of the limitations and strengths of the study. A discussion of the relevance and implications of this study will conclude the chapter.

5.1 INTERPRETATION OF THE RESULTS

5.1.1 NEIGHBOURHOOD PATTERNS OF LBW

From the use of mapping techniques and frequencies, it is clear that the distribution of LBW and other variables are not uniform across Saskatoon neighbourhoods. Certain Saskatoon neighbourhoods have a higher incidence of the adverse birth outcome, LBW. These neighbourhoods exist mainly on the Westside of the City, except for one. They are: Parkridge, Pacific Heights, Confederation Park, Westmount, Caswell Hill, Meadowgreen, and Holliston (Eastside). In these neighbourhoods 6.48-10.34% of births were low weight.

In spite of the lack of statistical significance of the neighbourhood factors when analyzed in combination with individual level factors and the incidence of LBW, it is obvious that there are differences amongst neighbourhoods in Saskatoon. The mapping of the variables provides an excellent opportunity to visualize these differences and patterns in the city.

The Westside of Saskatoon has consistently more adverse neighbourhood characteristics. There is less park space, more lone parent families, residents with lower levels of education, lower incomes, and more rental property. However, there are pockets of neighbourhoods on the Eastside that consistently share in the same patterns as those Westside neighbourhoods: Exhibition and Holliston. Also, the Westside of the river technically takes into account the neighbourhoods in the North End of the city; but these neighbourhoods do not seem to share the same patterns as the Westside.

It is recognized that neighbourhoods in Saskatoon are heterogeneous, and therefore speaking about strict divisions of East and Westside of the city are do not capture the detailed characteristics of these neighbourhoods. However, from the maps presented previously, the distribution of socio-economic status in Saskatoon is shown. The maps clearly show some residential segregation according to SES, with concentrations of and low SES families on the southwest side of the city, and high SES families on the eastern side of the city, and along the northwestern bank of the South Saskatchewan River.

The areas of low SES families are in general contiguous, as are the areas of high SES. Also, there are a few enclaves of low SES families in the east side of the city, which are surrounded by high SES areas.

5.1.2 SIGNIFICANT INDIVIDUAL LEVEL FACTORS RELATED TO LBW

The individual level factors that were associated with LBW for this study population were: parity, history of previous stillborn births, marital status of the mother, sex of the child, gestational age of the child family reliance on government financial assistance, and interactions of parity and stillborn births with gestational age. With the exception of family reliance on Government assistance and the interactions present, all individual level factors associated with LBW to the best of my knowledge had been documented elsewhere.

Families' who rely on government assistance plans, are more likely to have a low birth weight child, compared to families who do not rely on financial assistance. I would argue that the financial assistance variable is a proxy measure for family income. Perhaps this measure is illustrating the relationship between socio-economic status of the family and adverse birth outcomes. Perhaps families who rely on government assistance are less likely to have adequate nutrition and members are more likely to engage in risk behaviour related to LBW, such as maternal smoking.

Financial assistance reliance is the only individual level variable in the study that is modifiable. All other variables that are related to LBW, sex,

gestational age, parity (to a certain extent) and previous stillborn births are not considered to be “modifiable” characteristics. Efforts in preventing LBW may well be served by targeting the population that relies on government financial assistance.

The interactions between parity and previous stillborn births with gestational age of the child are very interesting and require exploration here.

If a mother has had more than one child, the risk of subsequent children being of low birth weight is lower. This lowered risk is seen more sharply for babies born preterm compared to term children. The reasons behind this remain speculative, and could include the overall benefit of being a multiparous mother, which itself tends to decrease the risk of LBW.

The second significant interaction concerns gestational age and history of stillborn births. If the mother has a history of previous stillborn births, the risk of having a child of low birth weight is much higher for preterm children than term children. This relationship makes intuitive sense, as one would expect that preterm children would have an increased risk of LBW; having a history of stillborn births compounds the risk.

Gestational age of the child is a very significant factor to consider when discussing the risk of LBW and parity or previous stillborn births. Clearly, where parity is high or previous stillborn births has not occurred, the risk for having a LBW child is lower.

Another interesting anomaly is the lack of statistical significance of mother's age. The reasons for this are speculative; perhaps this variable is dependant on information not available in this study, such as maternal smoking. Perhaps the variables that were significant, sex, gestational age, parity, etc., are stronger predictors of LBW. Also, the literature on the subject varies, some studies find a significant relationship between mother's age and LBW, and some do not. However, by retaining the variable in all models due to its inherent biological significance, I believe the issue is adequately addressed.

5.1.3 ASSOCIATION BETWEEN NEIGHBOURHOOD LEVEL FACTORS AND LBW

At the outset of this study, the main objective of the research was to determine if factors related to neighbourhood of residence increase the risk of low birth weight children. The answer to this question is no. When multi-level models are employed, only individual level variables account for the risk of low birth weight children in Saskatoon.

When considering neighbourhood level factors alone, those that were associated with LBW for this study population were: proportion of neighbourhood with education levels less than grade 9, number of houses owned in the neighbourhood, median income, number of residents with incomes less than \$10,000/year, park space, number of lone parent families, and the number of Aboriginal residents in the neighbourhood.

Neighbourhood level variables, when individual level variables are not accounted for, are significantly related to LBW. Although individual level factors may contribute more to the prediction of LBW, and dilute the contribution of neighbourhood level factors, it is still interesting to note that these factors on their own contribute to overall risk. Perhaps, neighbourhoods with lower income, less park space, increased lone parent families and lower education, might be appropriate to target areas for programs and measures to prevent LBW.

In his study of neighbourhood level and individual level factors and the incidence of LBW, Roberts found that communities with lower socioeconomic status, crowded housing and high percentages of young and African-American residents were positively associated with low birth weight. (69) He, and others (49, 57), asks for an increase of macro level studies to help our understanding of the problem. Given the results of this thesis research, I would be careful of studies that call for an increase in combined micro and macro level studies and LBW.

Aggregate neighbourhood level variables and LBW are significantly related. Individual level variables and LBW are significantly related. And, certain neighbourhoods with worse social conditions have a higher incidence of LBW. Interestingly, it is only through the use of multi-level modelling, with the presence of each individual level factor, that each of the neighbourhood characteristics lacks statistical significance.

While this may be an apparently negative finding, I would argue that it is important nonetheless. Since the 1970's epidemiologists have studied the risk factors of LBW. Since then, many authors have argued for a broader perspective of research into the problem, to focus less on individual level factors and look at other possible explanations for the incidence of LBW. From the results of this study, however, one should be more cautious in stating what the link is between LBW and aggregate measures.

5.1.4 LINKAGE BETWEEN STUDY FINDINGS AND LITERATURE SURROUNDING LBW

In terms of the epidemiology of LBW, the present study did not deviate from the literature surrounding LBW and individual risk factors. Female babies had an increase risk of LBW, higher parity lowered the risk, younger gestational age increased the risk, history of previous stillborn births increased the risk and unmarried women had a greater risk. Mother's age did not have a relationship consistent with the literature (although the literature itself did not always show consistent relationships), but was retained in subsequent models due to its biological significance. Also, the interactions present in this study are supported by the literature. (2, 21, 39, 55, 68, 127)

In terms of the link between neighbourhood of residence and health of the residents, this study helps to shed some light on the subject. Ross and Dunn espouse an interesting theory on the subject, theorizing that neighbourhoods act as "sorting mechanisms" for different levels of risk for health conditions. They

state that several reasons, including housing prices or property taxation, can determine which neighbourhood a person chooses to reside in. (82, 58, 83, 84)

This study shows that there is a real link between low birth weight and neighbourhood of residence, as different neighbourhoods have different levels of LBW. However, I would caution that this relationship can be explained, in the present analysis, by individual level variables.

5.2 STUDY LIMITATIONS

This study has several limitations; results must be read with these limitations in mind.

The use of administrative data makes it impossible to control for important potentially confounding individual level variables, such as maternal smoking, prenatal care or nutrition in the analysis. However, as the main results of the study have demonstrated, once the individual level variables that are available are accounted for in the model neighbourhood level variables are no longer significant. Due to the lack of potential individual level confounders, the lack of significance of the neighbourhood level variables is most likely an underestimation of the true effect.

Administrative data lacks information that survey data can attain. By using simple quantitative measures, this study may have missed how the area of residence affects pregnancy, nutrition and childbirth. Qualitative responses can provide unique, individual perspectives, and add depth to analysis.

The City of Saskatoon neighbourhood level data was also lacking some potentially interesting and important variables. Access to grocery stores, cigarette sales, or crime proportions might have added important sources of variation into statistical models. These variables are not available in the data source used. However, this missing information might again cause an underestimation of the effect, as they are aggregate measures of individual level characteristics, which explain the variation in LBW proportions in Saskatoon alone. However, they may have created a neighbourhood effect on LBW.

The exclusion criteria of the study may have had adverse effects on the results. Where the neighbourhood of residence was missing or unknown, this may have caused the most potential problems. It is impossible to know in which direction this would affect the results. The other exclusion criteria should not have had an effect (rural residents who do not live in an urban neighbourhood, and multiple births).

This study did not take into account the potential for between-level interactions. For example, marital status (individual level) could interact with proportion of lone parent families (neighbourhood level). This decision was deliberate, as cross-level interactions are beyond the scope of this thesis. Subsequent studies may be well served to address this issue.

There exists a potential for misclassification bias in this study, as potentially heterogeneous neighbourhoods are assumed to be homogeneous. It is impossible to know exactly in which direction this bias could affect the

results. The use of individual data in combination with the aggregate level data should minimize this risk, as the individual data is heterogeneous and may offset the assumption of homogenous neighbourhoods when used in combination with neighbourhood level data.

A similar limitation to the study is the amalgamation of the neighbourhoods. As mentioned in Chapter 3: Methodology, Saskatchewan Health amalgamated adjacent neighbourhoods to protect the confidentiality of the residents when cell sizes were less than 5. This limitation could not be avoided, but should nonetheless be kept in mind when interpreting the results. The lack of neighbourhood level effect may change if smaller units of measure were used, such as enumeration areas (EAs) instead of neighbourhoods. EAs are smaller and compared to neighbourhoods may potentially be comprised of more homogeneous groups. However, EAs were not used because as geographical units they do not hold much meaning to residents. In Saskatoon, it is possible that homogeneity occurs only in areas smaller than neighbourhoods, or perhaps Saskatoon is not as polarized as some cities. For example, in the study by Roberts looking at Chicago neighbourhoods – groups of neighbourhoods were much more polarized in relation to ethnicity and socio-economic status. (69)

A major consideration when interpreting the results of this study is the potential for ecological fallacy. Ecological fallacy is the bias that “may occur because an association observed between variables on an aggregate level does

not necessarily represent the association that exists at an individual level". (125)

In other words, it is the misinterpretation that can occur by using aggregate level variables to explain individual level behaviour. This bias is reduced in this study by the use of both individual and neighbourhood level variables in the analysis.

5.3 STUDY STRENGTHS

Firstly, the outcome measure of LBW has its advantages. The World Health Organization has defined it, it is a simple quantitative measure and leaves little room for error in measurement.

While the use of administrative data has limitations, it also has its strengths. Certain types of biases are not present in this study, such as recall bias, proxy respondent bias and selection bias, which generally plague studies that rely on survey information. Also, the data is quantitative in nature, includes all children born in Saskatoon during the study period, and comes from a central source.

Cause and effect are more easily identified in studies dealing with adverse birth outcomes. Birth occurs at a specific point in time, and therefore the sequence of the events is easily understood. It is less likely that the adverse birth outcome is the cause of the individual level risk factor, as the adverse birth outcome occurs after the influence of the individual factor.

This study has the added strength of combining both individual and neighbourhood level variables, which adds validity to the results.

The use of relatively new techniques in epidemiological research allow for a wonderfully unique perspective on the data. The use of multi-level modeling and GIS software to map information are definite study strengths.

5.4 PRACTICAL IMPLICATIONS

While it may be true that neighbourhood level measures are related to LBW separately, when the individual level factors are taken into account they no longer have any bearing on the effect. This is encouraging; in that it is not necessarily the place where the family or mother lives that causes adverse birth outcomes, but the individual behaviour.

This study has several practical implications. Policy aimed at preventing low birth weight in Saskatoon would be well served to understand that, from the results of this study, individual level factors are much more important than aggregate level factors in relation to the incidence of LBW.

One very interesting finding of this research is the relationship between LBW and family reliance on government assistance. This may be an indication of family income relating to LBW, and educational efforts surrounding cheap adequate nutrition, smoking cessation, and perhaps even birth control - would be well served to be aimed at this population.

Prevention of LBW should be aimed at decreasing preterm births, education to mothers regarding known individual risk factors of LBW not examined here, and physician's awareness of family income when providing prenatal care. Perhaps this research can be regarded as hopeful - no matter where one lives a healthy baby can be born.

APPENDIX 1: ETHICS APPROVAL



Research Services

Dr. Valerie Thompson, Chair
University Advisory Committee on Ethics in
Behavioural Science Research
c/o Rm 210 Kirk Hall, 117 Science Place
SASKATOON, SK S7N 5C8 CANADA
Phone: 966-4053 Fax: 966-8597

MEMORANDUM

To: N. Muhajarine (M. Jackson)
Department of Community Health & Epidemiology

From: Valerie Thompson, Chair
University Advisory Committee on Ethics in Behavioural Science Research

Date: November 13, 2001

Re: BSC #2001-194: Low Birth Weight and Neighbourhood of Residence: A Multi-Level Analysis

The project entitled "Low Birth Weight and Neighbourhood of Residence: A Multi-Level Analysis" is exempt from the Research Ethics Board review process because:

1. There is no personally identifying information in the database you propose to use;
2. You are not gathering any new data from participants.

You do not require approval to conduct a secondary analysis of data that cannot be linked to individuals, and for which there is no possibility that individuals can be identified in any published reports.

Sincerely,

Valerie Thompson, Chair
University Advisory Committee on
Ethics in Behavioural Science Research

/bk

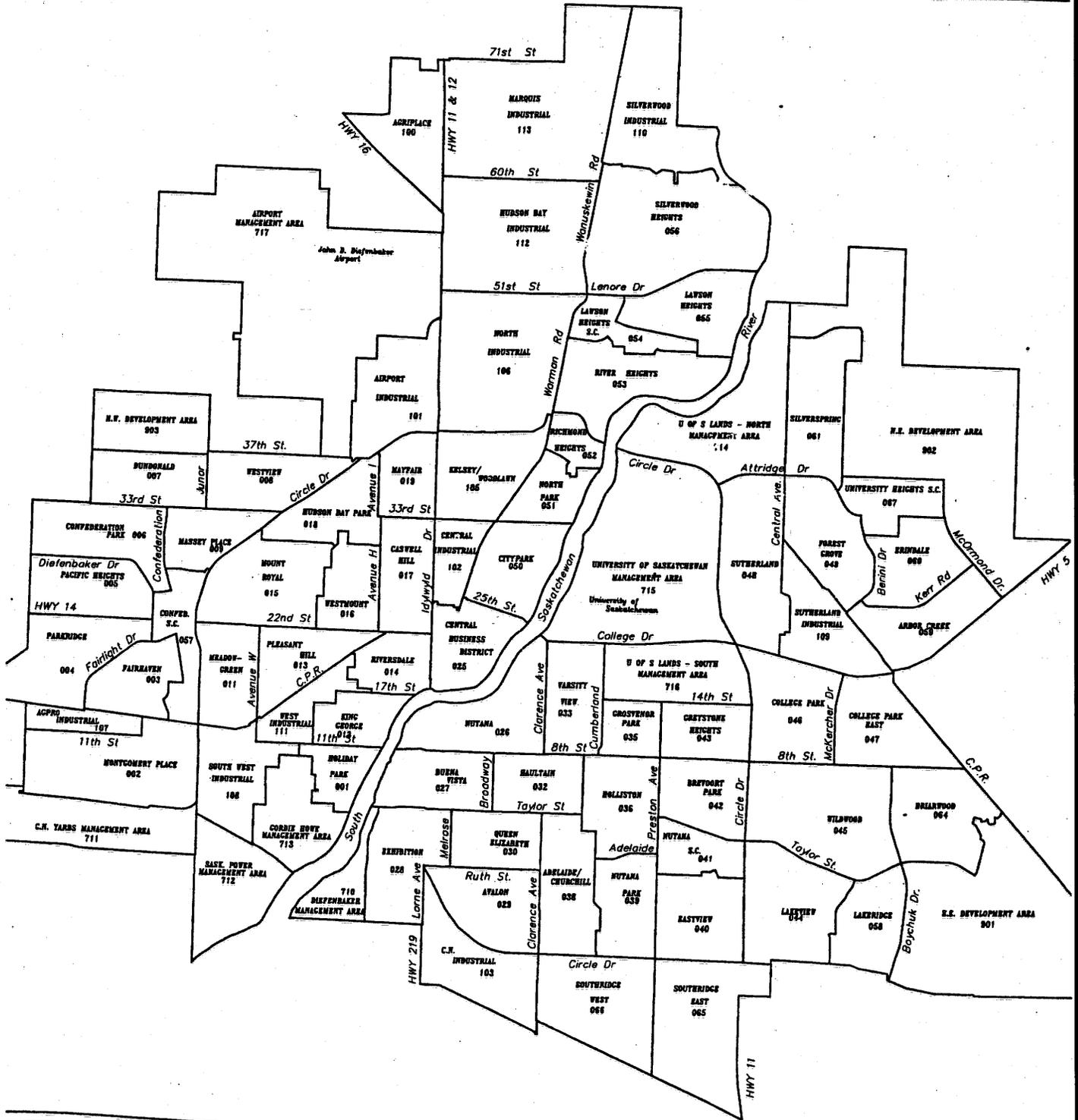
cc: Dr. B. Tan, Head
Department of Community Health and Epidemiology

APPENDIX 2: STUDY CHARACTERISTICS

Births April 1st 1992 - March 31st 1994 by Saskatoon Neighbourhood of Residence at Study Entry
n=5,643

VARIABLE	FREQUENCY (%)
Brevoort Park	71 (1.3%)
Holliston	84 (1.5%)
Eastview	84 (1.5%)
Avalon	85 (1.5%)
North Park, Richmond Heights & Lawson Heights Suburban Centre	102 (1.8%)
Westview	108 (1.9%)
River Heights	112 (2.0%)
Holiday Park & Exhibition	120 (2.1%)
King George & Riversdale	125 (2.2%)
Mayfair & Kelsey/Woodlawn	132 (2.3%)
Central Business District, Nutana Suburban Centre & City Park	134 (2.4%)
Meadowgreen	141 (2.5%)
Wildwood	143 (2.5%)
Lakeridge & Briarwood	143 (2.5%)
Lawson Heights	144 (2.6%)
Pacific Heights	145 (2.6%)
Parkridge	150 (2.7%)
Adelaide/Churchill & Nutana Park	156 (2.8%)
Dundonald	188 (3.3%)
Arbor Creek, Erindale & Silverspring	200 (3.5%)
Westmount & Caswell Hill	199 (3.5%)
Varsity View, Grosvenor Park & Greystone Heights	202 (3.6%)
Lakeview	209 (3.7%)
Queen Elizabeth & Haultain	209 (3.7%)
Nutana & Buena Vista	230 (4.1%)
Pleasant Hill & Confederation Suburban Centre	238 (4.2%)
Montgomery Place & Fairhaven	263 (4.7%)
Confederation Park	282 (5.0%)
Massey Place, Mount Royal & Hudson Bay Park	288 (5.1%)
Silverwood Heights	295 (5.2%)
College Park & College Park East	293 (5.2%)
Sutherland, Forest Grove & University	368 (6.5%)

APPENDIX 3: MAP OF THE CITY OF SASKATOON



Saskatoon Planning and Building Department

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