MULTILEVEL DETERMINANTS OF CHILDREN'S HEALTH OUTCOMES

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ABSTRACT

Background: Children's health, particularly in the early years, forms the basis of future health and development and plays a significant role in predicting individual life and opportunities. Thus, studies which enhance the understanding of the determinants of children's health status are needed. Previous research on children's health had focused on the family's and infant's characteristics and ignored the potential impact of macro-level influences. The objectives of this thesis were (i) to examine the independent effects of neighbourhood factors on childhood health outcomes, (ii) to explore neighbourhood moderating effects on the associations between some individual risk factors and childhood health outcomes, and (iii) to quantify the contribution of neighbourhood factors to childhood health outcomes.

Method: The study population included 9,888 children born to women residing in Saskatoon during three years, 1992-1994. The data used in this study were extracted from three sources. The information related to birth outcomes and the mother's characteristics was extracted from the birth registration files maintained by Saskatchewan's Vital Statistics Branch. The health services utilization information was generated from Saskatchewan Health's computerized administrative databases. The information related to the neighbourhood characteristics was obtained from Statistics Canada's 1991 Census, from local sources such as the Planning Department of the City, and two specialized neighbourhood surveys. Six domains of neighbourhood were examined in this study: socio-economic disadvantage, social interaction, physical condition, population density, local programs and services, and unhealthy lifestyle norm. This study was divided into two focused topics

corresponding to two children's health outcomes: low birth weight (LBW) and children's hospitalizations (both incidence and length of stay). Multilevel modelling was employed to examine the independent/moderating impacts of neighbourhood characteristics on these children's health outcomes. GIS mapping was used to visualize the associations between neighbourhood characteristics and children's health outcomes.

Findings of focused topic 1: There was a significant variation across Saskatoon neighbourhoods in the distribution of LBW rate. This significant variation was attributed to both the characteristics of individuals living within the neighbourhoods as well as the characteristics of the neighbourhood of residence. Neighbourhood variables were both independent risk factors for LBW and moderators for the association between maternal characteristics and LBW. Specifically, a greater level of socio-economic disadvantage, a lower level of program availability and accessibility within the neighbourhoods were associated with a higher risk of LBW. A significant interaction between neighbourhood social interaction and single parent status was found. The risk of single parent status on LBW was mitigated by a greater level of social interaction within neighbourhoods. With individual level variables held constant, three neighbourhood variables predicted LBW, together contributing to a change in LBW rate of 7.0%.

Findings of focused topic 2: This focused topic employed a longitudinal/multilevel design to examine the effects of socio-economic status at multiple levels on children's hospitalization. The key findings of this focused topic are the following: (i) There was a gradient association between the number of adverse

birth outcomes and childhood hospitalization; (ii) There was a significant interaction between family income and adverse birth outcomes (i.e., the effect of adverse birth outcomes on childhood hospitalization was heightened among those children living in low income families); (iii) Neighbourhood characteristics, specifically neighbourhood socio-economic disadvantage, neighbourhood physical condition, and neighbourhood population density had independent effects on childhood hospitalization over and above the effect of family income; (iv) With individual level variables held constant, three neighbourhood variables (i.e., neighbourhood socio-economic disadvantage, physical condition and population density) together accounted for a variation of 40% in the incidence rate of hospitalization, and two neighbourhood variables (i.e., neighbourhood socio-economic disadvantage and physical condition) together accounted for a change in the length of stay per hospitalization from 2.88 days to 5.18 days across neighbourhoods.

Conclusion: Both individual and neighbourhood characteristics determined childhood health outcomes examined. Neighbourhood factors acted as independent risk factors as well as moderators on the association between individual risk factors and health outcomes. The contribution of neighbourhood factors to children's health outcomes was quite substantial. The findings suggest that future interventions aimed at improving children's health status in Saskatoon may be enhanced by targeting both high risk individuals and high risk neighbourhoods. The geographical variations in children's health outcomes reported in this study are modifiable; they can be altered through public policy and urban planning, and through the efforts of families and children.

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1 INTRODUCTION

This thesis describes research conducted to understand how children's health outcomes, from birth to age six, are critically influenced by a combination of family circumstances and neighbourhood conditions. While it has been known intuitively for many generations that family circumstances and neighbourhood conditions play a critical role in shaping healthy childhood development, there is much to learn about how specific family or neighbourhood characteristics, either alone or in combination, work to affect specific childhood outcomes. This thesis attempts to understand the seemingly intuitive but complex question of how families and neighbourhoods help or hinder children in the earliest years of their lives.

The child poverty rate in Saskatoon is very high. In 1996, 26.1% of Saskatoon children aged 0 to 18 and 31% of children under age five lived in poverty.[1] More importantly, poor families are not randomly distributed in Saskatoon. For instance, it has been shown that in some neighbourhoods in Saskatoon, over 40% of the residents live in low-income households. Meanwhile, in other neighbourhoods, the proportion of low-income households is less than 22%.[2] It has been suspected that children who live in low income neighbourhoods and in low-income families are likely to suffer from

negative impacts far more than children living in only one low-income circumstances, either family or neighbourhood. However, the combined effects of the socio-economic status of individual and the immediate context of individuals (i.e., neighbourhoods they live in) on health have received little attention from health researchers until now. In part, this is because of the difficulty of inferring findings based on group level data to individual disease risk (i.e., ecological fallacy) and also because of a trend to focus on individual risk factors through much of the last century.[3] An increasing interest in the immediate context of individuals combined with advanced statistical techniques for using area level and individual level variables together in regression models has drawn attention to research in area/neighbourhood effects in epidemiology.[4]

The neighbourhood of residence is an excellent proxy for measuring the area level impact on children because (i) people with similar values and lifestyles tend to chose the same geographical locales, (ii) the neighbourhood environment is closer to the everyday pursuits and experiences of people and therefore is very likely to exert direct causal influences, and (iii) neighbourhoods are people's immediate residential environment wherein people often find and use resources to accomplish their daily activities.[5] In Saskatoon, city planners spend years establishing neighbourhood boundaries and assessing the best way to organize urban locales.[6] Neighbourhoods differ in many ways, for example, access to groceries, green space, schools, average income, and percentage of employment. The influence of neighbourhood characteristics on health outcomes has been reported in several studies.[7,8] These studies attributed the influence of neighbourhood characteristics to the material differences between neighbourhoods (in housing, environmental quality, services access…etc.) or

to negative psychological impacts (the prevalence of prevailing attitudes towards health and health related behaviors, stress, lack of social support...etc.). A more sophisticated understanding of neighbourhood influence on children has yet to be articulated.

If children in poor families are more likely to grow up in poor neighbourhoods, then it is necessary to understand what additional impact this experience has on their health at birth and beyond. Interests in going beyond changes to individual risk factors and modifying the broader socio-environmental conditions to improve children's health are shared not only by researchers but also, increasingly, by decision makers and program planners. A better understanding of how each level in society, from children to family and to neighbourhoods, intersects and interacts with other levels to determine children's health may open up additional opportunities and settings for developing interventions and policy. It is hoped that the results of this study will add to the body of literature on neighbourhood influences and children's health status. It is also expected that the results will advance the current understanding of the impact of socio-economic status on children's health outcomes. The study results will also provide important information for policy makers and planners at different levels of governance and jurisdictions.

1.1 Statement of research questions

This study seeks to understand the complex and dynamic interplay of factors shaping present and future health within the settings in which children are raised Studying the characteristics of neighbourhood where children live would likely contribute a better understanding why some children are more likely to get sick than

others. Therefore, this present study employed a multilevel design to explore the independent impact of family socio-economic characteristics and neighbourhood characteristics on children's health outcomes. The study was divided into two focused topics corresponding to two children's health outcomes, low birth weight and children's hospitalization from birth to 6 years (both number of hospitalizations and length of stay). For each outcome, the general study questions addressed were:

> *Question 1: Do neighbourhood factors have significant impacts on children's health outcomes in addition to those due to individual risk factors?*

> *Question 2: Do neighbourhood factors moderate the association between individual risk factors and children's health outcomes?*

Neighbourhood effects are matter of practical concern to policy makers and program planners. Thus, the focused studies also addressed the following question:

> *Question 3: Is there enough evidence that would call for policy interventions targeted at neighbourhoods in addition to those directed at individuals?*

1.2 Rationale for study

The desire to give children the best start in life is shared not only by parents, educators, health and social service providers, and children's health researchers, but also by community activists, policy makers, business people, and religious leaders. However, efforts to enhance children's well-being are hampered by insufficient local information on which to base policies and programs, as well as the lack of a comprehensive understanding of the breadth and complexity of factors that determine children's health.

Studies that seek to identify factors that evaluate the risk of childhood illness and death have traditionally focused on mothers' and infants' characteristics. [9,10] The role of community-level characteristics in determining children's health until recently has been an under-researched area. We need to better understand how various characteristics of the area of residence affect children's health independently and in combination with individual level factors. The rationale for considering the characteristics of the community/neighbourhood where people live has been well recognized in the social sciences. [7,11] First, such an approach is consistent with the broader portrait of children's health and identifies a developmental pathway that fosters healthy adulthood. [12] Second, it has been recognized that many contextual or aggregate variables that are hypothesized to affect childhood health represent properties that vary over geographic and social units but do not have the appropriate corresponding measure at the individual-level. Third, population inequalities in disease are not generally fully accounted for by any known combination of individual genetic and environmental risk factors; therefore, some of the unexplained variations could be attributed to other unmeasured factors, which may operate at an aggregate level. [3,4,13-15] It has been pointed out that "ecological factors may be the most important determinants of the health and disease status of a population". [13] Fourth, there are suggestive evidences that the neighbourhood socio- economic status is associated with health, achievement, and behavioral outcomes even when the individual-level income and education are controlled. [16]

Only a few previous studies have examined the independent effects of neighbourhood on children's health outcomes. However, most of these studies suffered

from many unresolved issues. First, problems such as interviewer bias, proxy response, recall bias and sampling bias plagued many of these studies. Second, these studies rarely included sufficient details on the various contextual dimensions of neighbourhoods and thus failed to assess how these often overlapping dimensions might shape the individual health outcomes. Examining a broader range of neighbourhood factors would allow for testing for more theories and illuminating potential causal pathways involving neighbourhood level variables. Third, these studies often ignored the moderating effects of neighbourhood factors on the association between individual risk factors and individual health outcomes. Examining the moderating effects of neighbourhood factors would help to identify neighbourhood factors that might mitigate the effects of individual risk factors on health outcomes.

The present research attempts to redress these issues by (i) utilizing the Saskatchewan administrative database to minimize the problems of information biases and sampling bias, (ii) by combining the neighbourhood data from Census Canada with the data from the local sources so that information about various neighbourhood domains are available in this study, and (iii) by employing a multilevel modelling technique to examine the independent/moderating effects of various neighbourhood domains.

2 LITERATURE REVIEW

The following is a literature review of the significant issues relevant to the present study. First, the literature on neighbourhood effect will be reviewed. Following that, a discussion on multilevel analysis will be presented. The next section will discuss the literature on the association between socio-economic status and children's health. The final section will provide an overview of administrative data and its use in health research.

2.1 Frequently Used Definitions

This section reviews all the definitions which are frequently used in this study.

– Low birth weight is defined as less than 2500 grams at birth. [17]

– Preterm birth is defined as children born before 37 weeks of gestation.[18]

– Small for gestational age is defined as less or equal to tenth percentile of birth weight for gestational age.[19]

– Neighbourhood refers to a person's immediate residential environment, which is hypothesized to have both material and social characteristics potentially related to health.[20]

– Social capital or collective efficacy is defined as level of trust and attachment characterizing neighbourhood residents and their capacity for mutually beneficial action.[21]

2.2 Neighbourhood Effects

2.2.1 History of Ecological Analysis

During the time from the end of Second World War to the early 1990s, the influence of the local environment on human health did not receive much attention from researchers.[22] There may be several reasons for this absence of attention. The first reason was wariness about the use of ecological data, following persuasive critiques of the ecological fallacy. [23] The ecological fallacy refers to the bias when one infers individual level relationships from relationships observed at the aggregate level. The second reason was methodological developments in statistics, computing and survey methods which significantly enhanced researchers' ability to analyze and use data on individuals.[22] The increased capacity to manipulate large datasets collected whether for the purposes of health research or not, provided the opportunity to analyse individual level predictors of health and their interaction, in complex multivariate analysis. Many researchers were driven by opportunities provided by data and analytical technique available. Although there has been considerable research interest in social stratification and its impact on human health, this has tended to focus on individual rather than on the environment to which individuals are exposed. Recently, there has been some resistance to this tendency to methodological and theoretical individualism, premised on the assumption that social contexts may shape health status as much as traditional individual risk factors.[3,24,25] This resistance has been expressed

in the development of what has been called "the new public health", which attempts to redirect the attention of public health theorists and practitioners back towards structural and environmental influences on health and health behaviors,[26] and it calls to look upstream at the causes of poor health and inequalities in health, rather than downstream at their expression in individuals behaviors or ill-health[27]; or to combine upstream and downstream explanations.[3,24]

2.2.2 Classification of Ecological Variables

There are many types of ecological variables such as environmental variables, structural variables, global variables, etc. The description of the most common types of ecological variables is presented in Table 2-1. However, ecological variables in the epidemiological literature most commonly refer to the aggregate variables. These aggregate variables infer the association between parallel variables of individual level variables with some individual level health outcomes. [28] For instance, measure such as the median income of a group has a parallel at the individual level: individual's income. However, not all aggregate variables have a direct parallel individual level variable. For instance, income inequality (i.e., variation of individual income within a group), which is often measured by the Gini coefficient, does not have a parallel individual level variable.

Table 2-1: A classification of ecological variables

Ecological variable	Description	Examples
Aggregate or contextual variables[24,29]	Aggregate of attributes measured at the individual level. It is often expressed as a measure of central tendency (e.g., mean, median), but may be extended to include measures of variation of individual level variables (e.g., standard deviation)	Mean income Proportion of single parent Proportion of smoking Proportion of Aboriginal
Contagion[24]	Aggregate of the individual level outcome, rather than exposure, that in turn affects the probability of the same outcome in individuals in the same population who are not yet affected	Prevalence of infectious diseases Suicide rate
Environmental[29]	Physical characteristics of a place, with an individual level analogue that usually varies between individuals	Environmental pollutant Latitude and longitude
Structural[28]	Measure the pattern of relationship and interactions among individuals belonging to one group	Social networks
Global or Integral[29]	Measure attributes of groups, organizations or places, and are not reducible to the individual level. They are fixed for all, or nearly all, individual group members	Social capital Legislation or regulation

2.2.3   Theoretical Models of Neighbourhood Effects

A variety of theoretical models of neighbourhood/community level influences on children's outcomes have been proposed. For instance, Jenks and Mayer describe four models about how the social composition of a neighbourhood affects youth behaviour. The "contagion model" stresses the role of peers, especially for children's behavioural outcomes. The "collective socialization model" emphasizes the importance of positive adult role models and monitoring children's activities. The "competition model" focuses on the scarcity of opportunities such as employment and the "relative deprivation model" proposes that residents evaluate their circumstances relative to their neighbours' circumstances.[30] The "net work model" was added by Buck[31] emphasizing to mainstream groups and social networks which enable social inclusion and employment opportunities. Under the competition and the relative deprivation models, children from low income household will do worse in affluent than in poor neighbourhoods while under the contagion, collective socialization and network models, the opposite will be observed.

This section will focus on the model suggested by Ellen *et al.* which seems to be a more appropriate model for examining children's health outcome in the present thesis research as the other available models focused mostly on the behaviour and education outcomes. Ellen *et al.* propose that neighbourhoods can influence health outcomes through four pathways: (1) neighbourhood institutions and resources (2) stresses in the physical environment (3) stresses in the social environment and (4) neighbourhood based network and norms.[32]

Neighbourhood institutions and resources: Neighbourhoods clearly differ in their resources such as parks, libraries, access to healthy food, public transportation, access to health care facilities and so on. Thus, the distribution of those institutionalized resources will have consequence for children's health outcomes. This pathway suggests that collective investment in the quality and quantity of social and material resources would contribute to the outcomes of individual children.

Physical stresses in the neighbourhood environment: the most commonly discussed way in which neighbourhoods influence health is through the proximity of polluting factories and toxic waste sites, which may increase people's chance of contracting cancer and other illness. These threats tend to be more salient in low income areas.

Social stresses in the neighbourhood environment: people's health status can be directly affected by the social conditions in a neighbourhood. For instance, living in a neighbourhood with high rates of crime, a child is more likely to be injured. Furthermore, there have been evidences that exposure to social conditions such as crime, violence, and noise can lead to a higher level of stress. Elevated level of stress in turn may result in many diseases and unhealthy behaviours like smoking.

Neighbourhood based social networks: neighbourhood social networks may shape health outcomes through transmitting norms about accepted behaviour, communicating important information or providing social support. For instance, smoking or eating a high fat diet may be more socially acceptable in some neighbourhoods than in other or feeling of hopelessness and isolation are more widely spread among residents of poorer and less empowered communities.

In conclusion, it is important to note that many authors create writing on this subject typology that best meets the needs of their specific research agenda. There is no model that is better than another. Although authors may name their models, core ideas underlying these models tend to be the same.

2.2.4 Mechanisms and Validity of Ecological Effects

Without a multi-level design, when conducting an ecological study, one would have to be concerned about the ecological fallacy. Multi-level design helps to reduce the potential of ecological fallacy since it enables the researchers to combine more than one level variable in one study. However, it still raises the question whether the effect of an ecological variable is causally valid, independent of explanatory and intervening individual level causes.[28] For example, is it valid to consider ascribing causation to the effect of the ecological exposure "living in a low median income neighbourhood" on the outcome "individual number of hospitalizations"? Or should such observed association be reduced to individual level causal mechanisms like individual income and other risk factors?

There has been some debate that ecological variables do not impact directly on individuals; instead their effect are mediated by intermediate variables at the individual level.[33] For instance, figure 2-1 came from the work of Blakely and Woodward. These authors have suggested that there are three ways that an ecological exposure can have a cross-level effect on an individual outcome: (1) by directly affecting an individual outcome (direct-cross level effect) (2) by modifying the relation between an individual exposure and individual outcome (cross-level effect modification) and (3) by affecting an individual exposure, which in turn affect the outcome (indirect-cross level effect).[28]

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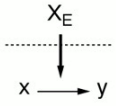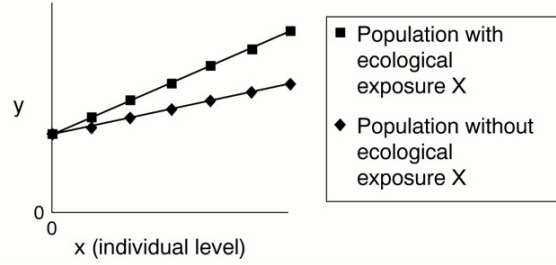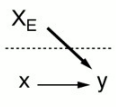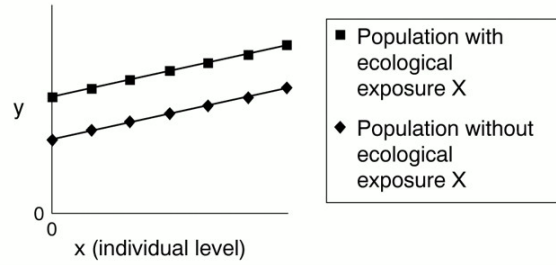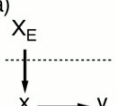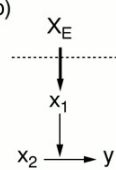
Ecological effect	Example	Possible graphical representation
1 Cross level effect modification X_E ┊ x ⟶ y	*Example:* Income inequality (X_E) modifies the effect of social class (x) on the individual health (y).	y vs x (individual level) graph ■ Population with ecological exposure X ♦ Population without ecological exposure X
2 Direct cross level effect X_E ┊ x ⟶ y	*Example:* Income inequality (X_E) directly affects individual health (y).	y vs x (individual level) graph ■ Population with ecological exposure X ♦ Population without ecological exposure X
3 Indirect cross level effect (a) X_E ┊ x ⟶ y	*Example a:* Community tobacco control policies (X_E) may affect individual smoking (x), which in turn affects individual health (y).	Regression lines for individual level outcome (y) on individual level exposure (x) will not vary by population with varying ecological exposures (X), as any apparent effect of the ecological exposure(s) is explained away by including the relevant individual level exposures (x).
(b) X_E ┊ x_1 x_2 ⟶ y	*Example b:* Workplace organisational structure (X_E) may affect individual worker's decision latitude (x_1), which modifies the association of individual work demand (x_2) on coronary heart disease (y).	

Figure 2-1: Three types of ecological effect

Source: Blakely TA, Woodward AJ. Ecological effects in multi-level studies. J Epidemiol Community Health 2000;54(5):367-74.

In epidemiology, it is accepted that disease causation operates via chains, or webs, of events.[27] The notion of proximal and distal causes can be found elsewhere and disregarding distal causation may overlook important causal mechanisms.[28] For example, case of whooping cough can be attributed easily to the bacteria B pertussis (a

proximal cause) and the loss of herd immunity (a distal or population level cause). Therefore, one shouldn't reject the possibility of the causal association between ecological level risk factors with individual outcome.

Recent researches explicitly represent the ecological context that influences individual through more proximate social and environmental phenomena. For example, figure 2-2 is from the work of Shi *et al.* who used a path analysis strategy to examine the relative impact of the contextual variables of income inequality and the supply of primary care versus specialty in the 50 U.S states. They found that both income inequality and the supply of primary care physicians directly influenced most of the population health and they presented potential pathways from ecological context to individual health in figure 2-2.[34]

One might question that "neither direct cross level effect nor cross level effect modification of ecological exposures on individual outcome are complete causal chains but require reduction to indirect cross level effects". [28] However, it has been argued that such reductionism would require the information on all possible variables and it is often redundant and may even be counterproductive for the identification of intervention points for public health policy and action.[25,35]
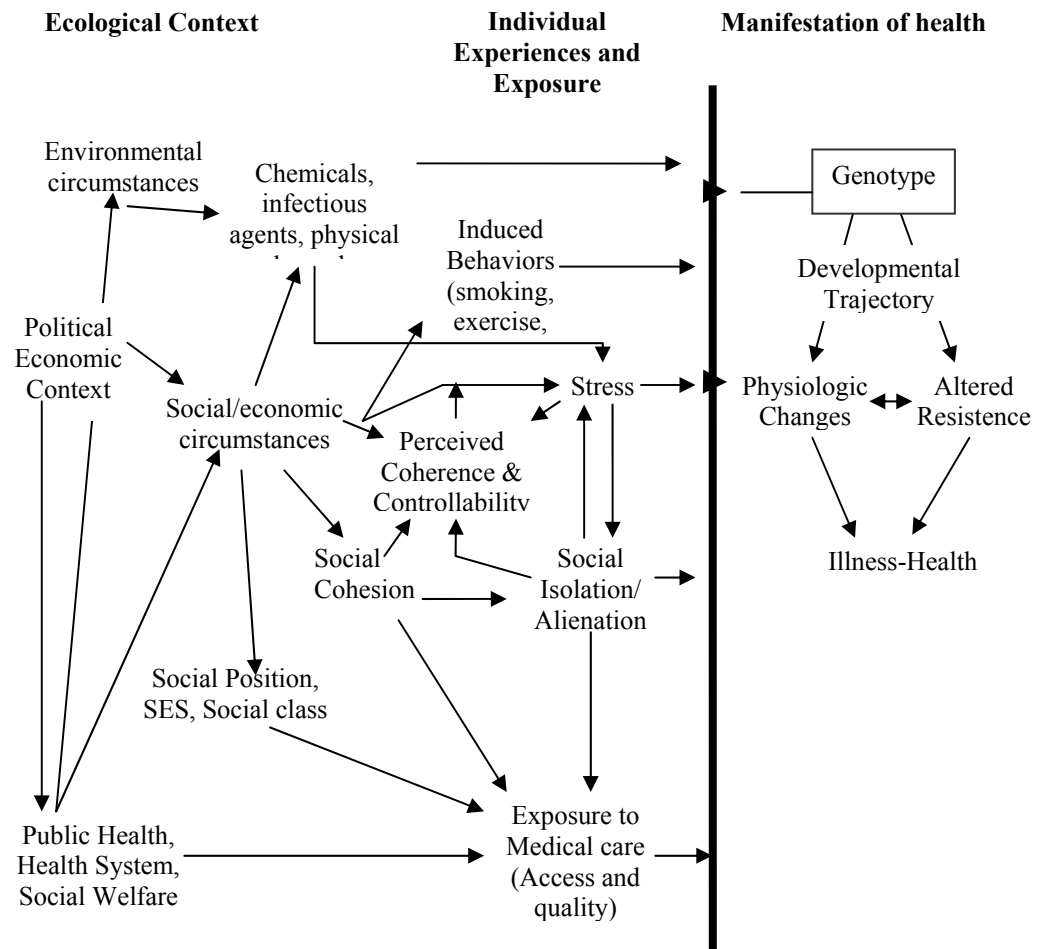
Figure 2-2: Prevention of death, disease, and disability

Source: Shi, L.B. Starfield, B. Kenedy & I. Kawachi. 1999. Income, Inequality, primary care, and health indicators. J Fam Pract. 4: 275-84.

2.2.5 Association between Neighbourhood Effects and Health Outcomes

Neighbourhoods are not random designations of space. Sociologists and social geographers have long recognized the importance of neighbourhood environments as the structural conditions that shape individual lives and opportunities[36]. In public health, it has been argued that the physical and social environment of neighbourhoods may have impact on the distribution of health outcomes.[23,37] To examine the

association of neighbourhood or area characteristics on health outcome, the investigators can choose among three empirical strategies. These are ecological studies, contextual or multilevel studies, and comparisons of small numbers of well defined neighbourhoods.[20]

Ecological studies are often used to examine the association between morbidity and mortality rates across area and the area characteristics. Various sizes of areas have been investigated in ecological studies. Frequent area characteristics examined in ecological studies are the socio-economic characteristics and indices of deprivation.[20,38] Most studies reported significant relationships between these area characteristics with mortality or morbidity rates.[39-41] While ecological studies may be useful in documenting and monitoring inequalities in health, they cannot answer the question whether area characteristics impact health outcomes over and above individual characteristics. Ecological studies also cannot evaluate the cross level interaction and cross level confounders between individual and area characteristics.[20]

Comparisons of small numbers of well defined and purposely selected contrasting neighbourhoods is a method which directly collects detailed information on neighbourhood characteristics and heath outcomes through a combination of quantitative and qualitative strategies. This method has the advantage in that they employ the locally definitions of neighbourhoods. The direct collection of data is also an advantage as it enables the investigators to understand the processes through which the neighbourhood environment can affect health. The major limitation of this method is that the number of neighbourhoods that can be investigated in one study is small and thereby reduces the generalizability of the study results.[20] Several studies employing

this method had reported associations between neighbourhood's resources and services and health behaviors.[37,42,43]

Contextual or multilevel analysis is a relative new method in epidemiology, which allow the investigators to examine the impact of neighbourhood characteristics after controlling for individual-level confounders.[22,44,45] Until now, contextual studies have concentrated on the association between the socio-economic environment and health outcomes. The socio-economic characteristics which have been examined included aggregate income (median income or average household income), education, unemployment rate, race, percentage of single parent, and some index of deprivation.[46] Most contextual studies report independent effects of neighbourhood socio-economic characteristics on individual health outcomes after controlling for individual level socio-economic status. [47-50]

2.2.6 Issues in Neighbourhood Studies

There has not been a complete definition of the geographic area whose characteristics may be relevant to all specific health outcomes being studied. In health research, the term "neighbourhood" or "community" often refers to a person's immediate residential environment, which is hypothesized to have both material and social characteristics potentially related to health.[20] Depending on the research questions, there may be many different criteria used to define a neighbourhood. Criteria can be historical, based on people's characteristics, based on administrative boundaries, or based on people's perceptions. More important, boundaries based on these different criteria will not necessarily overlap.[51] For instance, neighbourhoods defined on the basis of people's perceptions may be applicable when the

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neighbourhood characteristics of interest relate to social interactions or social cohesion while administratively defined neighbourhoods may be relevant when the hypothesized processes involve policies. On the other hand, geographically defined neighbourhoods may be relevant when features of the chemical or physical environment (e.g., toxic exposures) are hypothesized to be important.

The size of the relevant geographic area also depends on the processes through which the area effect is hypothesized to operate and the outcome being studied. Areas ranging from small to large with varying geographic definitions may be important for different health outcomes or for different mediating mechanisms.[51] For example, counties may be important geographic contexts for outcomes potentially related to county policies or economic structures. For some purposes, the relevant area may be the block on which a person resides; for others, it may be the blocks around the residence; and for still others, it may be the geographic area in which services such as stores or other institutions are located. Therefore, the size and definition of the area, the relevant processes, and the outcome being studied are linked.[20] The development and testing of hypotheses regarding the precise geographic area that is relevant for a specific health outcome will help strengthen inferences regarding area effects.

Although the definition and the size of relevant geographical area may vary depending on the research questions, in order to conduct large quantitative studies, researchers often have to rely on existing administrative definitions.[20] The choice of political boundaries permits straightforward linkage with routinely collected area level data, an appropriate choice in the early stage of the investigation of etiological hypotheses; however, these units may be inappropriate if they do not correspond to the

actual geographical distribution of the causal factors linking the social environment to health. Pickett and Pearl recommended that studies using multilevel analyses of neighbourhood level effects should use geographical boundaries that are "ecologically meaningful".[46] However, defining what constitutes of an "ecologically meaningful" neighbourhood boundary is by no mean an easy task. As put by Willms, "to make any progress, a researcher must specify the units of analysis, and in some way define 'community'. But any definition of community is easily challenged."[52]

After dealing with the challenges in defining the boundaries and the size of relevant geographical area, we have to consider the challenge of specifying the relevant neighbourhood or area characteristics. Macintyre *et al.* have suggested an organizing framework for area-level characteristics that includes the following five types of features of local.[22]

- Physical features of the environment: These features are shared by all residents in a locality, for instance the quality of air and water, latitude, climate and so on. These features are likely to be shared by neighbourhoods across a wide area.

- Environments at home, work and play: Neighbourhoods vary in their availability of green areas, decent houses, safe play areas for children, non-hazardous working environment. However, people living in the same area may not be affected in the same way as by the physical features of the environment. For example, children may be more affected than elderly people, employed may be more affected than unemployed.

- Availability of public or private services: Public or private services include number of schools, number of daycare facilities, transportation, policing, and health care networks. Similarly, how these affect people may vary by personal circumstances. For example the number of daycare facilities in a neighbourhood matter only to families with small children.

- Socio-cultural features of a neighbourhood: These include the political, economic, ethnic and religious history of a community: norms and values, the degree of community integration, levels of crime, and networks of community support and so on.

- The reputation of an area: How areas are perceived by their residents, by services or amenity planners and providers may influence the infrastructure of the area, the self-esteem and morale of the residents.

The first three of these categories can be considered as material or infrastructural resources while the last two categories relate to collective social functioning and practices.[22] However, it should be noted that it is difficult to tease these dimensions apart since many of them may be interrelated and may also influence each other.[37] For example, the characteristics of the physical environment of one neighbourhood may impact the types of social interaction and vice versa. Thus, making inferences about the impact of a specific neighbourhood characteristic on the outcome is not a straightforward question.

It is not always possible or necessary to examine all types of neighbourhood or relevant geographical area characteristics. Sometimes the data we need are not

available and the relevant neighbourhood attributes may differ from one outcome to another. For example, mechanism involving resources and the physical environment may be more relevant for the study of physical activity outcome while the availability of health care network may be more relevant for the study of health services utilization. Until now, most existing research concentrated on examining the impact of neighbourhood socio-economic characteristics on health outcomes.[53]

Measuring area/neighbourhood characteristics also play an important role in the study of neighbourhood effects. We need to develop a valid and reliable measures of relevant area characteristics that can be obtained in a systematic fashion across many areas.[54] Options for the collection of this type of information include survey of residents, direct observation, ranking of neighbourhoods on pre-specified criteria, and linking databases with geographically linkable information.[55]

2.3 Multilevel Analysis

Multilevel analysis is an analytical approach that is appropriate for data with nested sources of variability--that is, involving units at a lower level or micro units nested within units at a higher level or macro units.[56-59] In multilevel analysis, groups or contexts are not treated as unrelated but are conceived as coming from a larger population of groups about which inferences are wished to be made. Multilevel analysis allows the simultaneous examination of the effects of group level and individual level variables on individual level outcomes. [60] Multilevel analysis also allows the examination of both between group and within group variability and how group level and individual level variables are related to variability at both levels. Thus,

multilevel models can be used to draw inferences regarding the causes of inter-individual variation (i.e., the relation of group and individual level variables to individual level outcomes) and inferences regarding inter-group variation (i.e., whether it exists in the data, and to what extent it is accounted for by group and individual level characteristics). [60]

In its present form, multilevel analysis is a combination of contextual analysis and random effects models. Contextual analysis is a development in the social sciences which has focused on the effects of the social context on individual behavior.[61] In contextual analysis, group level predictors (often constructed by aggregating the characteristics of individuals within groups) are included together with individual level variables in standard regressions with individuals as the units of analysis. This approach permits the simultaneous examination of how individual level and group level variables are related to individual level outcomes. It thus allows for macro processes that are presumed to have an impact on individuals over and above the effects of individual level variables.[11]

The terms "contextual analysis" and "multilevel analysis" have sometimes been used synonymously, [57,62] and both approaches are similar in allowing the investigation of how group level (or macro) and individual level (or micro) variables (as well as their interactions) are related to individual level outcomes. However, multilevel analysis are more general than the original contextual models for following reasons (1) they allow for (and account for) the possibility of residual correlations between individuals within groups, and (2) they allow for the examination of between-group variability and the factors associated with it. In contrast, contextual models often

do not account for residual correlation (although they can be modified to do so) and do not allow the examination of inter-group variability or of the factors associated with it.[63]

Random effects models are statistical models in which regression coefficients (intercepts or covariate effects) are allowed to vary randomly across higher level units (technically, are assumed to be realizations of values from a certain probability distribution).[58,64] For example, in the case involving individuals nested within neighbourhoods, a model treating neighbourhood differences as fixed would include all neighbourhoods represented in the sample as a set of dummy variables in a regression equation with individuals as the units of analysis. In contrast, a random effects model would allow neighbourhood intercept to vary randomly across neighbourhoods following a probability distribution (random intercept). Similarly, the effect of personal income, for example, on individual health may be allowed to vary randomly across neighbourhoods (random slope). The use of random effects or random coefficients is especially appropriate when the higher level units (or groups) can be thought of as random samples from a larger population of units (or groups) about which inferences wish to be made.[63]

Multilevel analysis has a broad range of applications in many situations involving nested sources of random variability (e.g., persons nested within neighbourhoods), meta analysis (e.g., observations nested within sites), longitudinal data analysis (repeated measurements over time nested within persons), multivariate responses (multiple outcomes nested within individuals), the analysis of repeated cross sectional surveys (multiple observations nested within time periods), the examination

of geographical variations in rates (rates for smaller areas nested within regions or larger areas), and the examination of interviewer effects (respondents nested within interviewers).[63] Multilevel analysis can also be used in situations involving multiple nested contexts (for example, multiple measures over time on individuals nested within neighbourhoods) [58,65] as well as overlapping or cross classified contexts (for example, children nested within neighbourhoods and schools). [66]

In multilevel studies, it is essential to distinguish contextual effects from compositional effects. Several recent studies had warned against the confusion between compositional effects and contextual effect.[37,67,68] Compositional effects operate because of the distribution of varying types of people whose individual characteristics influence their health. That is, similar types of people will have similar health experiences regardless where they live. Contextual effects refer to the effects of higher level variables (usually at the group level) on outcomes defined at a lower level (usually at the individual level) after controlling for relevant individual level (lower level) confounders. Contextual effects operate where the health experience of a particular type of individual depends not only on his or her own characteristics but also on the area where he or she lives, so that similar types of people have different health status from one part of the country to another. [37,67,68] For example, in Saskatoon, the neighbourhoods located on the West side of the river generally have higher rate of low birth weight and West side neighbourhoods are also known to have higher prevalence of single parents, low income families, and people with low education levels. So if the higher rates of low birth weight in West side neighbourhoods are totally due to the differences in the characteristics of residence in those neighbourhoods then it describes

compositional effects. However, if all the differences in the characteristics of residents in West side neighbourhoods are taken into account but neighbourhoods still have an impact on LBW rate, then it describes contextual effects.

Cross-level inference refers to the drawing of inferences regarding factors associated with variability in the outcome at one level based on data collected at another level (for example, drawing inferences regarding relations between individual level variables based on group level associations, or vice versa).[63]

2.4 Socio-economic Status

2.4.1 Definition

Socio-economic status (SES) may be defined using many indicators such as educational attainment, employment, income, and dwelling characteristics.[69] However, SES has been widely defined on the basis of education, occupation and family income,[18] and these factors are highly inter-correlated.[17] Recently, there is a recognition of the need to include the aggregate level variables when defining SES.[70] SES is an important variable in social research because it affects a person's chances for education, income, occupation, marriage, health, friends and even life expectancy. [71]

2.4.2 SES and Children's Health Status

Compared to the data on adults regarding the relation between SES and health, the data on children is less complete and less consistent. However, evidence indicates a substantial relation that begins before birth.[16] Children from low-SES families are more likely to suffer from growth retardation and inadequate neurobehavioral development in utero.[17] They are more likely to be born prematurely, low birth weight,

with asphyxia, birth defect, disability, fetal alcohol syndrome, or AIDS. [16-18,72] Early

health problems often emanate from poor prenatal care, maternal substance abuse,

poor nutrition during pregnancy, maternal lifestyles that increase the likelihood of

infections (smoking, drug use), and living in a neighbourhood that contains hazards

affecting fetal development.[16]

After birth, low-SES infants are more likely to suffer injuries and mortality.[73]

During childhood, SES is associated with many diseases, for instance, low SES is

associated with an increased likelihood of dental caries, higher blood lead levels, iron

deficiency, stunting, sensory impairment[16] and respiratory illnesses. [74] These outcomes

likely reflect an array of conditions associated with low SES, including inadequate

nutrition, exposure to tobacco smoke, failure to get recommended immunizations, and

inadequate access to health care.[16] When low-SES children experience health

problems, the consequences are often more severe. For instance, low-SES children

born preterm are far more likely to suffer health and developmental consequences than

their more affluent counterparts.[75] Children from low-income families are two to three

times as likely to suffer complications from appendicitis and bacterial meningitis and

to die from injuries and infections at every age.[16]

More importantly, it has been observed that biologic impacts during childhood

create vulnerabilities that result in adverse health outcomes in adulthood. For example,

Power *et al.* found that SES measured in mid childhood and adolescence was related to

health status at age 23, even after controlling for SES at age 23.[76] Hertzman suggests

that there is evidence for "latent" effects of early biologic damage, termed "biological

embedding" (e.g., a higher propensity for adult cardiovascular disease for low birth weight children). Specifically, he writes that "systemic differences in the quality of early environments, in terms of stimulation and emotional and physical support, will affect the sculpting and neurochemistry of the central nervous system in ways that will adversely affect cognitive, social, and behavioral development".[77]

On the other hand, SES is not implicated in all illnesses, and the SES/health gradient appears less steep in more egalitarian nations.[78] Moreover, the relations between particular SES indicators and health factors may be quite complex. For example, the impact of low income appears to depend on how long poverty lasts and the child's age when the family is poor. [16]

2.4.3 Pathways through which SES may Influence Health

2.4.3.1 Access to medical care

One explanation for the SES-health gradient is that individuals lower in the SES hierarchy have less access to medical care. This explanation supports the belief that universal health insurance could reduce SES differences in health. However, three sets of findings suggest that while universal health insurance may be a necessary condition, it is not sufficient to reduce substantially social inequalities in health. First, countries that have universal health insurances show the same SES-health gradient as those found in many other countries without universal health insurances. In a study in the UK, it was reported that the forming of the National Health Services did not bring a reduction of SES impacts in health but instead widened SES differences.[79]

Second, SES differences were reported between levels at the upper range of the SES hierarchy. At upper levels, individual are likely to have health insurances, thus lack of coverage is not appropriate explanation for the health effects of SES differences.[80]

Third, SES differences appear in many types of morbidities, both those that are amenable to treatment and those that are not.[80] In terms of overall mortality, adequacy of care is estimated to account for about 10% of the outcome, while human biological factors and environmental factors each account for 20% and other individual factors account for 50%.[81]

Still, it should be noted that provision of insurance does not always ensure equal or adequate access. In those areas that are underserved, individuals with fewer socio-economic resources will find it more difficult to gain access.[82] Even among individuals in the same area who technically have equal access, true access may differ for those at different SES levels. Individuals with more education and income, who may be more skilled in dealing with bureaucracies and social systems, may be more efficient in determining who provides the best care and also in obtaining care when needed.[80]

2.4.3.2 Behaviors and Risk Factors

Health behaviors may represent another pathway by which SES may impact health even though they do not account for all of the association. Behaviors such as smoking, diet, and lack of exercise are associated with health status.[83] Both the behaviors and the risk factors show a linear relationship with SES. For instance,

smoking rates increase significantly as one went down the SES hierarchy. A significant inverse linear association has also been found between employment grade with exercise and diet (the lower the employment grade, the higher the percentage reporting getting no exercise and lower the percentage of individuals consuming skimmed milk, whole meal bread, and fresh fruits and vegetables).[84-86]

Early effects of those behaviors are reflected in risk factors such as cholesterol level, obesity, and blood pressure; longer-term effects can be seen in disease and premature mortality. The association between higher risk factors and lower SES was also reported in many studies. For example, Mathews *et al.* found that educational level was significantly associated with cholesterol levels[85]; Kraus *et al.* found a linear gradient between prevalence of hypertension and six level of SES based on education and occupation.[87]

It should be also noted that the pattern of health risk behaviors in which those with a higher SES are less likely to smoke and eat high-fat diets and are more likely to exercise has not always been true. Earlier in the 20th century, many of these behaviors (eg, smoking, eating red meat) were not classified as health-risking behaviors but as luxuries. During this time, rates of coronary heart disease were greater in higher-SES groups.[80] However, as health promotion has become more popular, upper-SES groups have been the quickest to acquire and act on information regarding health risks. Despite this seeming advantage, a few life-style differences place higher-SES individuals at relatively greater risk for specific diseases. For instance, rates of breast cancer are greater among higher-SES women, which may reflect differences in

childbearing patterns.[80] However, once breast cancer is diagnosed, survival is positively associated with SES even when stage at diagnosis is taken into account.[88]

2.4.3.3 Other Pathways

Other potential pathways by which SES may influence health are through differential exposure to physical and social contexts that are damaging to one's health. The lower an individual is in the SES hierarchy, the more likely he or she is to experience adverse environmental conditions, such as exposure to pathogens and carcinogens at home and at work, and to social conditions, such as crime.[89] This pathway will be discussed more specifically in the section 2.5, the effects of neighbourhood characteristics on health.

Placement in the SES hierarchy is also associated with the differential ability of individuals to control their environment. A clear effect is one's ability to avoid risks of disease and injury. For example, safety features in cars (most recently air bags) have been more available in higher-priced cars.[80] As Dutton and Levine note, individuals lower in the social hierarchy experience "more disruption and daily struggle as well as more simple physical hardships." [90] There are many ways in which higher-SES individuals can control their environment, and the experience of control itself has been linked to better health outcomes.[91]

2.5 Utility, Validity and Reliability of Administrative Health Databases

The development of a complex health care system in several countries has contributed to the creation of large health databases for administrative purposes.

Although health databases were not originally intended for research use, the potential of those databases for research in health care is increasingly being recognized.[92,93]

Health administrative databases constitute powerful and relatively cost efficient tools for health services research. They offer considerable advantages over other sources of data, including 1) high capacity for generalizability because data are truly population-based or universal, 2) the absence of recall bias, which has been associated with the use of survey data to collect primary data, 3) the ability to readily choose representative samples of people for study or comparison groups, 4) the creation of health utilizations histories before an event of interest, and 5) higher accuracy in determining timing and number of events.[94] Potential uses of health administrative databases in cohort studies are threefold: identification of a cohort, active follow-up including obtaining current addresses, and passive follow-up through record linkage.[95] The size of a study is constrained only by the size of the databases and the availability of computer resources.[94]

Several studies noted that due to the difficulty in linking data from different sources, vital and demographic statistics are two types less frequently used in some countries, although they include a lot of useful information.[92] To be able to link databases, researchers need to find key variables that can connect records from one database to the other.[96] In Saskatchewan, health administrative databases record linkage is performed easily due to the availability of unique identifiers in all databases. More important, since Saskatchewan Health covers all Saskatchewan residents, the Saskatchewan Health databases do not have the major limitation often cited in literature regarding routinely collected databases. That is the problem of non-

universality, which happen in many American studies using Medicare data for research purposes.[97]

When working with large administrative datasets, it is essential to ensure the accuracy of information. Several studies have examined the accuracy of hospital separation abstracts and physician services claims in Saskatchewan, as well as in other parts of Canada. The accuracy of administrative data has generally been found to be very high.[98] The reliability and validity of information in administrative databases, including diagnosis codes and patient demographic information, as compared with other sources, such as medical charts and health surveys, has also been proven to be high. For example, Rawson and Malcolm's study of the validity of the recording of ischaemic heart disease and chronic obstructive pulmonary disease in the Saskatchewan health care data files found the diagnosis agreement between the hospital data files and medical charts was greater than 94%, and the contextual information related to the hospitalizations was clinically and epidemiologically realistic.[99] In Edouard *et al.*'s study of the reliability of the recording of hysterectomies in Saskatchewan health care databases, a comparison was made between routinely collected data covering hospital discharge records and practitioner claims for reimbursement of service and clinical charts. In this study it was found that "Saskatchewan health care utilization data files provide a source of valid data for research and evaluation studies".[100] In Muhajarine *et al.*'s study, it was noted that the overall agreement between survey and claims data for identification of hypertension was moderate to high (from 82% to 85%).[101]

It is important to note that the Saskatchewan Health database is not intended for research – it is a database maintained for administrative and insurance purposes. Therefore, many interesting variables are not available. For this study, many individual level factors that may be important confounders are not included such as maternal smoking status, nutritional status, education level…etc

3 METHODOLOGY

This chapter will describe all data sources and methods used in this study. First, there will be a discussion of the study population, including exclusion criteria. A description of data sources will follow. Next, there will be a description of neighbourhood and individual variables examined in this study. After that, the general analytical method used in this study will be presented. A discussion of software used in the analysis and ethnics approval for this study will also be given in this chapter.

3.1 Study Population

The study population was all children born to women residing in Saskatoon, Saskatchewan during three years, 1992-1994. The exclusion criteria were: (1) Children who were born as twins or multiple births, (2) Children who lived in areas in the city that were predominately non-residential, (3) Children who did not have information about their neighbourhood or residence (4) Children who lived in rural municipalities.

In the present study, forty Saskatoon neighbourhoods were defined for inclusion instead of the fifty six neighbourhoods in Saskatoon. Saskatchewan Health, from input from Dr Muhajarine, divided and amalgamated Saskatoon slightly differently from the

neighbourhood division of the City of Saskatoon because of the size of the study

population in certain neighbourhoods. Those neighbourhoods with few children born

during the study years were grouped together with other neighbourhoods to protect the

confidentiality of the health information of the residents. Neighbourhoods were

grouped together based on two criteria: contiguity (i.e., adjacent neighbourhoods were

grouped) and comparableness (i.e., neighbourhoods must be similar in terms of

physical condition, socio-economic status, programs and services, social interaction,

unhealthy life style norm and population density).

3.2 Data Sources

This study used data from a larger study supported by Saskatchewan Health

Research Foundation (SHRF) and Canadian Population Health Initiative (CPHI) grant

awarded to Dr Nazeem Muhajarine in 2001.[102] The study employed a retrospective

birth cohort design. For this study, a sample of 9,888 children born to women residing

in Saskatoon during three years, 1992-1994, was used. These births were identified

through the birth registry maintained by the vital statistics branch of the provincial

government. Birth registry records for the birth cohort were then linked to health care

utilization files maintained by the provincial health ministry to create continuous

histories of health care utilization for each child from birth to 6 years of age.

Saskatchewan Health administers Canada's universal health insurance program in the

province of Saskatchewan and maintains all records pertaining to this program. All

children born in the province and have needs for medically necessary services are

provided these services at no financial cost to the parent or family.

The data used in this study were generated from three sources. The information related to birth outcomes and mothers' characteristics was extracted from the birth registration files maintained by Saskatchewan's Vital Statistics Branch. The health services utilization information was extracted from Saskatchewan Health's computerized administrative databases. Data were provided in a non-identifiable format, such that no individual child could be identified. For each child in the cohort, the neighbourhood of residence at birth was indicated. The information related to the neighbourhood characteristics was obtained from Statistics Canada's 1991 Census, from local sources such as the planning department of the City, and two specialized local neighbourhood surveys. (See appendix II for more information on data management in this study.)

3.3 Ethics Approval and Confidentiality

The study received exemption from a full and standard review of research ethics approval by the University of Saskatchewan Committee on Ethics in Human Experimentation due to its low-risk nature for ethical violations. First, this study utilizes secondary data that are de-identified and is not traceable to any individual. The study had no contact whatsoever with human subjects. Second, the larger study (Dr. Nazeem Muhajarine, Principal Investigator), on which this thesis is based on, underwent ethics review of its own by the University committee as well as Saskatchewan Health's internal review committee.

3.4 Definitions of Individual and Neighbourhood Characteristics

3.4.1 Individual Characteristics

In this study, information on 11 individual characteristics was available. The definitions of these individual characteristics are presented in Table 3.1.

Table 3-1: Description of individual variables

Individual variables	Definition
Time varying variables	
Children's age	This variable was a count variable which ranged from 0 to 6
Longitudinal income*	This variable was a time-varying covariate. Operationally, it took the value of '1' if the child's family had received income benefit during a follow up year or '0' if the family had not received any support. Therefore, for each child this variable takes a value of either '1' or '0' for each year of follow up, to a maximum of 6 years. This variable was used to test the association between the incidence rate of hospitalization during the follow up years with the changeable family income status during the same years.
Baseline variables	
Mother's age	This variable was a categorical variable with three values, '0' for mother's age at delivery from 20 to 40 years old, '1' for mother's age at delivery less than 20, and '2' for mother's age at delivery greater than 40 years.
Father's age	This variable was a categorical variable with three values, '0' for father's age at delivery from 20 to 40 years old, '1' for father's age at delivery less than 20, and '2' for father's age at delivery greater than 40 years
Sex of the child	This variable was a dichotomous variable, with female children as the reference group since the literature has shown that male children have higher risks of some diseases compared to female children.
Aboriginal status	This variable was a dichotomous variable with two values, '0' for non-Aboriginal and '1' for children of Aboriginal ancestry (i.e., registered Indian status)

Individual variables	Definition
Single parent	This variable was a categorical variable with three values, '0' for children who had married/common law parents, '1' for children who lived with single parent, and '2' for children whom information about the marital status of parents was missing
Family income assistance at birth*	This variable was a dichotomous variable, which took the value '1' if the family received income benefits at anytime during the year of birth of the child, or '0' if the family did not receive any income benefits during the birth year. This variable was used in analysis that examined the association between family income status and adverse birth outcomes.
Income status*	This variable was a dichotomous variable, which would take value '1' if the child's family had ever received income assistance from the government during 6 years after birth and take value '0' if the family had never received that support. This variable was used to test the association between family income status and the average length of stay per hospitalization during 6 years after birth.
Adverse birth outcome	This variable was a categorical variable with three values, '0' for children born normal, '1' for children born with only one adverse birth outcome, and '2' for children born with at least two adverse birth outcomes
Parity	This variable was a dichotomous variable which would take the value '1' if the mother had one live birth and '0' if the mother had two or more live births.
Stillbirth	This variable was a dichotomous variable which would take the value '1' if the mother had a history of one or more stillbirths in the past and '0' if the mother did not have any history of previous stillbirth.

*Receiving income assistance from the government was used as a proxy for the income status of the family since the information about the actual family income was not available. It was assumed that if the family of the child received income assistance from the government for a certain year, it meant that the family had low income during that year.

3.4.2 City of Saskatoon

Saskatoon, "the City of Bridges", lies alongside the South Saskatchewan River-
- a clean, freshwater river system that rises in the Rocky Mountains and discharges
into the Hudson Bay. Established in the late 1800s as a temperance colony, Saskatoon
is now a vibrant, diverse and modern city with an economy based in agricultural
services, education, mining administration and an expanding high-tech industry.
Saskatoon provides most of the amenities that you would expect in a large city -- large
shopping centers, restaurants to suit most tastes and budgets, many parks, well-
equipped sports facilities, a zoo, many movie theatres, symphony orchestra, a museum
of natural sciences, and a conservatory and art gallery.

Saskatoon has a population of about 226,000 and has experienced steady
population growth.[6] People move to Saskatoon for work, to go to school, and to retire.
About ten percent of the city's population either attends or work at the University of
Saskatchewan, the largest university in the province of Saskatchewan. There are 56
neighbourhoods in Saskatoon. Neighbourhood boundaries established by city planners
are well defined, long standing and readily recognized by those who dwell within
them. The neighbourhood boundaries may not necessarily overlap with census tract
boundaries as there are only 44 census tracts in Saskatoon. According to the City of
Saskatoon Neighbourhood Profile 1996, the average household size for the city of
Saskatoon was 2.4 persons (ranged from 2 to 3.6 persons among Saskatoon
neighbourhoods). The average family income for Saskatoon in 1996 was $48,927
(range from 19,242 to 100,000 among Saskatoon neighbourhoods). Approximately

34.9% of children in Saskatoon were living in low income families (ranged from 0% to 75.93%), 18.1% were Aboriginal (ranged from 0% to 44.63%), and 30.6% were headed by a single parent (ranged from 0% to 37.6%). Families of low socioeconomic status tend to be concentrated in certain areas of the city, particularly central-west of the South Saskatchewan River.[6]

3.4.3 Neighbourhood Characteristics

The data on neighbourhood characteristics came from the Statistics Canada's 1991 Census (i.e., economic, political, and demographic information) and from the local surveys (i.e. crime incidence, smoking prevalence, physical condition, programs and services). In this study, the characteristics of the neighbourhoods were classified into 6 domains: (1) Socio-economic disadvantage, (2) Physical condition, (3) Social interaction, (4) Population density, (5) Unhealthy lifestyle norms, and (6) Availability/accessibility of programs and services for children from 0 to 6 years of age and their parents.

The classification of neighbourhood characteristics was done in two steps. In the first step, I identified the five underlying dimensions by using principal component analysis. In the second step, I checked to see whether the neighbourhood dimensions identified using factor analyses were consistent with the existent literature on neighbourhood effects. One may argue that instead of using principal component analysis to get multivariate indices of underlying dimensions of neighbourhood characteristics, you should use the measures of single neighbourhood characteristics because of the greater ease of interpreting the results and the presumed greater ease of

identifying policy-applicable results. However, it is important to emphasize that those neighbourhood characteristics may *only* be distal markers or indicators of processes that would need to be targeted through policy interventions. More important, due to the high inter-correlations among those neighbourhood characteristics, the interpretation of analyses employing single neighbourhood variables may be misleading.[103]

Principal component analysis involves a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called *principal components*. The basic idea in principle component analysis is to find the components $s_1, s_2, ..., s_n$ so that they explain the maximum amount of variance possible by *n* linearly transformed components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible.[104] Principle component analysis was applied to study the inter-correlations among fourteen neighbourhood characteristics (descriptions of these neighbourhood characteristics are presented in Table 3.2), and then examined for theoretical interpretability. Principle component analysis with varimax rotation method indicated that four factor solution resulted in the lowest number of double loaded variables and the most interpretable factors in light of the existent literature on relevant neighbourhood compositional factors. These four factors were named as "neighbourhood socio-economic disadvantage", "neighbourhood social interaction", "neighbourhood population density, and "neighbourhood unhealthy norm". Principal component analysis was done using SPSS (Statistical Package for the Social Sciences) version 11.5 for Window.

Table 3-2: Description of neighbourhood characteristics

	Neighbourhood characteristics	Definitions
1	*Average cars per person in neighbourhood*	The number of cars per resident is calculated by dividing the number of registered vehicles in a neighbourhood by the neighbourhood's population.
2	*Average household size*	This variable measures the average number of people per family
3	*Crime per capita*	This variable takes into account the number of reported property crimes per 1,000 residents per year in each neighbourhood.
4	*Ethnic diversity*	This measure is based on Statistics Canada's Single and Multiple Ethnic Origin Response table. The index is calculated on the neighbourhood level and compares the population of a given ethnic group in a neighbourhood to the population of the same ethnic group within the city as a whole. The sum of the indexes of concentration of all ethnic groups present in a neighbourhood shows the intensity of the ethnic presence in that neighbourhood. The higher the sum of indexes the more diversified the population.
5	*Percentage of aboriginal residents*	The proportion of population that are of aboriginal ancestry in a neighbourhood
6	*Percentage of LICO*	The proportion of families who fall below the low-income cut-off (LICO) established by Statistics Canada. LICO adjusts for number of persons in the family and the size of city/region of residence. (Low-income cut-off: the proportion of income spent on essentials is greater than 54.7%.)
7	*Percentage of lone parent*	The proportion of families with children headed by lone-parents in a neighbourhood.
8	*Percentage of movers during the last year*	The proportion of the population that has made a residential move in the past year in a neighbourhood.
9	*Percentage of population age >15 without*	The proportion of the population aged 15 years and over in a neighbourhood who did not complete grade 9.

	Neighbourhood characteristics	Definitions
	grade 9	
	Neighbourhood characteristics	**Definitions**
10	*Percentage of unemployment*	The proportion of the labour force (15-65 years) who were unemployed at the Canada Census year.
11	*Percentage of voter participation (municipal)*	Voter participation in the 1997 Civic Election in each neighbourhood.
12	*Percentage of voter participation (federal)*	Voter participation in the 1997 Federal Election in each neighbourhood.
13	*Percentage who owned their houses*	The proportion of private, residential dwellings that are privately owned by one of the residents.
14	*Percentage of smokers*	The percentage of people who are declared as "current smokers" in a neighbourhood.

Neighbourhood socio-economic disadvantage: variable "neighbourhood socio-economic disadvantage" indicated the level of socio-economic disadvantage in Saskatoon neighbourhoods, the higher the score of this variable, the lower the socio-economic status of neighbourhood. Using principal component analysis, this variable was constructed from seven neighbourhood characteristics (i.e., percentage of Aboriginal, percentage of low income families, percentage of population with an education level less than grade 9, percentage of single parent, percentage of employment, percentage of owned houses, and average car per person). Of these, seven neighbourhood characteristics, four had positive correlation (i.e., percentage of Aboriginal, percentage of low income families, percentage of population with an education level less than grade 9, and percentage of single parent) and three had

negative correlation (i.e., percentage of owner houses, average care per person, and percentage of employment) with neighbourhood socio-economic disadvantage (see appendix VI for the principal component analytical results). Cronbach alpha for the seven items used to construct this variable was 0.95. Cronbach alpha measures the internal consistency, based on the average inter-item correlation. It ranges from 0 to 1, with 1 indicates the highest level of internal consistency.

Social interaction of neighbourhood: variable "neighbourhood social interaction" measured the level of social interaction in Saskatoon neighbourhoods, the higher the score of this variable, the lower the level of social interaction in that neighbourhood. Two concepts borrowed from sociology, the level of collective efficacy (i.e., level of trust and attachment characterizing neighbourhood residents and their capacity for mutually beneficial action, which is positively correlated with the level of social interaction within a neighbourhood) and the degree of social disorder (i.e., indicators of crime, gang activity, prostitution, which may encourages residents to secure themselves and their children within their home which is negatively correlated with the level of social interaction within a neighbourhood) were employed to construct this variable. [21,55,105] Using principal component analysis, this variable was extracted from five neighbourhoods characteristics. Of these, four were used to measure the level of collective efficacy within a neighbourhood (i.e., percentage of voter participation for Saskatoon, percentage of voter participation for federal, percentage of mover, and ethnic diversity) and one was used to measure the degree of social disorder (crime per capital). The percentage of voter participation in local municipal elections and percentage of voter participation in federal elections could be

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considered as a proxy indicator for the frequency of contact among individual within a neighbourhood, their willingness to participate in volunteer activity, as well as their social engagement. Thus, these percentages of voter would be positively correlated with the level of collective efficacy within a neighbourhood. On the contrary, the percentage of families who moved in the last year in a neighbourhood and ethnic diversity would be negatively correlated with the level of collective efficacy. The percentage of movers affects the length of time each individual knows others in their neighbourhood, the degree to which they are defined on the basis of traditional neighbourhood structures. Ethnic diversity negatively reflects the extent to which individuals are similar to each other in a network (for instance, Sampson argued that high ethnic heterogeneity and high residential instability lead to a weakening of adult friendship networks and value consensus in the neighbourhood[106]). Cronbach alpha for the five items used to construct this variable was 0.82. Please see appendix VII for the principal component analytical results for this variable.

Population density of neighbourhood: population density of Saskatoon neighbourhood was measured by the average number of person per household in each neighbourhood. A high average number of person per house in one neighbourhood refers to a denser population.

Unhealthy lifestyle norms: the popularity of unhealthy lifestyle norms within one neighbourhood was evaluated by the percentage of people who are currently smoking within that neighbourhood. High number of smokers within a neighbourhood would mean that unhealthy lifestyle norms are very popular within that neighbourhood.

Physical condition of neighbourhood: neighbourhood physical condition measured the overall physical condition of Saskatoon neighbourhood. This variable was derived from principal component analysis of data collected via observations of neighbourhoods in Saskatoon (i.e., the survey and the analysis were done by "Understanding the Early Years" study). This variable measured nine aspects of neighbourhoods: condition of neighbourhood, percentage of housing in need of major repair, street width, road condition, appearance, noise, stoplight, quality of outdoor environment, and crosswalk. A high the score on this variable showed a poor neighbourhood physical condition (see appendix IV for the instrument used to evaluate neighbourhood physical condition and appendix V for the principal component analytical results). Cronbach alpha for the nine items used to construct this variable was 0.73.

Availability/accessibility of programs and services for children from 0 to 6 years of age and their parents (neighbourhood programs and services): the availability and accessibility of programs and services for children aged 0 to 6 and their families in Saskatoon neighbourhoods was measured by the Program Access Score. In this section, I would just provide an overview of how the "Program Access Score" was calculated, please refer to Appendix III for more information. Briefly, based on a survey of programs and services conducted by the "Understand the Early Years" study, each program was designated to one of 52 neighbourhoods by postal code of program location. To calculate the score for each neighbourhood, each program was given a base score of 1 and then points were removed for barriers to access. Barriers were any program criteria that limited full accessibility to all

individuals that might be based on family income, transportation, handicap or program demand. Base scores were penalized by .2 for each barrier, including 1) if there was a waiting list, 2) user fee 3) no wheelchair access and 4) the program site was not accessible by public transportation. If the program offered transportation to the site a bonus of .2 was added. The lowest possible score for a program was .2, the highest 1.2. There were 351 programs surveyed. The programs were then assigned to 17 types (see Appendix III) and then organized into 12 categories.

It was hypothesized that each neighbourhood domain would have independent impact on children's health outcomes from birth to 6 years of age:

− The following neighbourhood factors were hypothesized to have beneficial impacts on children's health outcomes: high level of social interaction, good physical condition, high availability/accessibility of program and services for children 0-6 years of age and their parent.

− The following neighbourhood factors were hypothesized to have negative impact on children's health outcomes: high level of socio-economic disadvantage, dense population, popularity of unhealthy lifestyle norms

− Furthermore, there may be interactions among these six domains. Figure 3-1 presents the hypotheses regarding the effects of 6 neighbourhood domains.
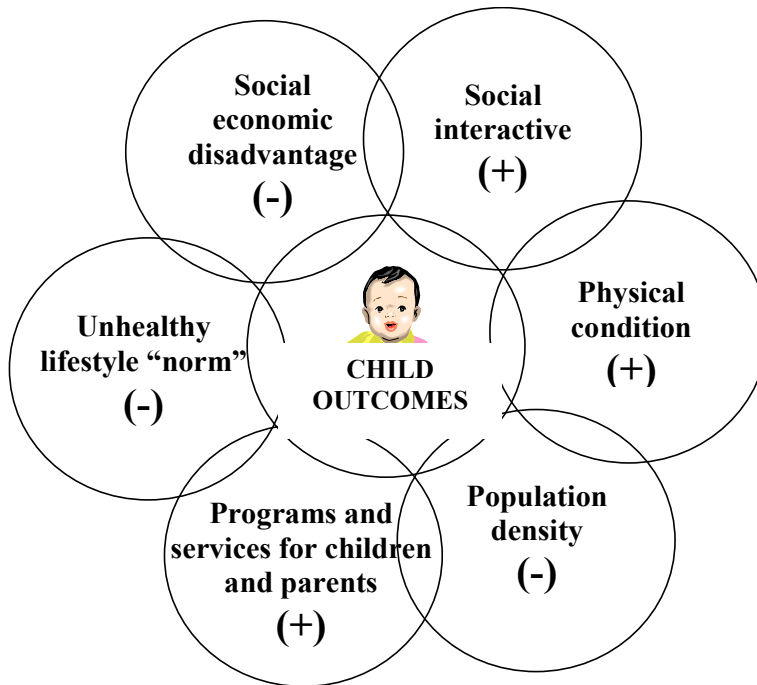
Figure 3-1: Neighbourhood domains and their hypothesized relationship to child health outcomes

3.5 Analytic Plan

3.5.1 Characteristics of the Study Population and Neighbourhoods

Graphical and tabular techniques were used to describe the main characteristics of this study population at both levels, individual and neighbourhood. A description of the population at the individual level such as the proportion of single parent, the distribution of family income status, the distribution mother's age, the number of stillbirth babies, and the number of live born babies was provided. The spatial distributions of all neighbourhood characteristics were also presented in this section using mapping techniques.

3.5.2 Multilevel Modeling

3.5.2.1 Introduction of a Multilevel Model

Most statistical techniques assume that observations in the dataset are independent from each other. However, when groups of observations share some features in common, they are no longer independent. When the data have information at different levels such as individual, neighbourhood, and region, the data are called hierarchical data. With hierarchical data, multilevel modeling is required to (1) Remove the effect of clustering in order to obtain valid point estimates for the parameters and standard errors for the point estimates (2) Study the effect of variables that act at different levels of the hierarchy and how the variance of the outcome is distributed across the levels of the hierarchy. From that, it can be determined at which level of the hierarchy, the greatest variation resides. It is speculated that this information would be of use for health policy makers since interventions targeted at that level will have the greatest chance of success and have the greatest effect on the whole community (3) Disentangle the contextual effects from the compositional effects.

This section will provide some background in multilevel modelling such as what are two-level and three-level models, equations and notations. The following summarizes the work of two well-known pioneers of multilevel analysis, Harvey Goldstein[65] and Stephen Raudenbush[107].

A two-level model

A two-level model consists of two sub-models at level 1 and level 2. For example, if the research data has two levels, neighbourhood and children, in which children are nested within neighbourhoods, the level 1 model represents the relationships among the children level variables and the level 2 model examines the influence of the neighbourhood level factors.

A two-level model for a linear outcome

In the level 1 model, the outcome Y_{ij} for case i nested within neighbourhood j can be expressed as follow:

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{1ij} + \beta_{1j} X_{1ij} + \ldots\ldots + \beta_{Qj} X_{Qij} + e_{ij}$$

$$= \beta_{0j} + \sum_{q=1}^{Q} \beta_{qj} X_{qij} + e_{ij} \quad (3.1)$$

Where

β_{0j}*: level 1 intercept*

β_{qj}*: level 1 coefficients*

X_{qij}*: level 1 predictor q for case i within unit j*

e_{ij}*: the level 1 random effect and σ^2 is the variance of e_{ij}, that is the level 1 variance*

The random term e_{ij} is assumed to follow a normal distribution with mean 0 and variance σ^2 ; $e_{ij} \sim N (0, \sigma^2)$

Q: the number of level 1 predictors

In level 2 model, each of the level 1 coefficients, β_{qj}, defined in the level 1 model

becomes an outcome:

$$\boldsymbol{\beta_{qj}} \quad = \quad \gamma_{q0} + \quad \gamma_{q1}\mathbf{W_{1j}} + \quad \gamma_{q2}\mathbf{W_{2j}} + \quad \text{........} + \gamma_{qSq}\mathbf{W_{Sqj}} + \mathbf{u_{qj}}$$

$$= \quad \gamma_{q0} + \sum_{s=1}^{S_q} \gamma_{qS}\mathbf{W_{sj}} + \mathbf{u_{qj}} \qquad (3.2)$$

Where

γ_{qs} *(q=0, 1,...........S_q): level-2 coefficients*

Wsj: level-2 predictors

u_{qj}*: is level 2 random effect.*

Again, all the level 2 random effects (u_{qj}) are assumed to follow a normal

distribution with mean of 0 and variance of τ_{qq}. Furthermore, for any pair of

random effects q and q' Cov(u_{qj}, $u_{q'j}$)= $\tau_{qq'}$.

There are many names for the model described in the equation (3.1) and (3.2).

The first name is a "hierarchical" [107] model because it specifies a model for Y_{ij} given

first level parameter (β_{qj}), while these parameters, in turn, depend on second level

parameters (γ_{qS} and τ_s). Thus it is the hierarchical dependence among the parameters

that is decisive in making the model "hierarchical", not necessarily the hierarchical

structure of the data, although the two often go together. The second name for this

model is a "multilevel" model [65] because it describes data that vary at two levels:

within neighbourhoods and between neighbourhoods. The third possible name for this

model is a "random coefficients"[108] model because the level 1 model defines

coefficients β_{qj} that vary randomly over neighbourhoods at level 2. The fourth name for this model is a "mixed"[109] model because it incorporates both fixed and random effects. To see this, substitute the equation 1 into equation 2, yielding the combined model:

$$\mathbf{Y_{ij}} \quad = \quad \mathbf{\gamma_{q0}} + \quad \mathbf{\gamma_{qs} \, X_{qij}} + \quad \mathbf{\varepsilon_{ij}}$$

Where : $\qquad \mathbf{\varepsilon_{ij} = u_{q0} + \; u_{qj} \, X_{qij} + e_{ij}}$

Thus, this model has fixed effects (γ_{qs}) and random effects (u_{q0}, u_{qj}) as well as the elemental residual e_{ij}.

Finally, this model can be called a "random effect"[110] model because individual differences are characterized by random effects (u_{q0}, u_{qj}).

A two-level model for a dichotomous outcome

The model for a dichotomous outcome uses a binomial sampling model and a logit link. In level 1 model, the outcome Y_{ij} for case i nested within neighbourhood j can be expressed as follow:

Probability $(Y_{ij}{=}1|B) = \Phi_{ij}$

Level 1 variance = $[\Phi_{ij} \, (1{-} \, \Phi_{ij})]*$

Predicted log odds $\eta_{ij} = \log[\Phi_{ij} \, /(1{-} \, \Phi_{ij})]$

$$\mathbf{\eta_{ij} = \beta_{0j} + \sum_{q=1}^{Q} \beta_{qj} \, X_{qij}} \qquad (3.3)$$

Where

Φ_{ij} : the probability that the ith individual in the jth neighbourhood take value "1"

("1" indicates the presence/occurrence of an event)

β_{0j}: level 1 intercept

β_{qj}: level 1 coefficients

X_{qij}: level 1 predictor q for ith individual within jth neighbourhood.

* In some occasions, the actual level 1 variance may be larger than assumed (over-dispersion) or smaller than that assumed (under-dispersion). In these cases, HLM software can allow the model to estimate a scalar variance component, so that the level 1 variance will be σ^2.

The predicted log-odds can be converted to an odds ratio by computing

$$OR= \exp(\eta_{ij})$$

The predicted log-odds can be converted to a predicted probability by computing

$$\Phi_{ij}=1/[1+\exp(-\eta_{ij})]$$

Level 2 model for two-level model for dichotomous outcome is the same as the level 2 model for linear outcome. Each of the level 1 coefficients, β_{qj}, defined in the level 1 model becomes an outcome in the level 2 model

$$\beta_{qj} \quad = \quad \gamma_{q0} + \gamma_{q1}W_{1j} + \gamma_{q2}W_{2j} + \ldots\ldots + \gamma_{qSq}W_{Sqj} + u_{qj}$$

$$= \quad \gamma_{q0} + \sum_{s=1}^{S_q} \gamma_{qS}W_{sj} + u_{qj} \qquad (3.4)$$

Where

γ_{qs} (q=0, 1,………...S_q) are level-2 coefficients

Wsj are level-2 predictors and u_{qj} is level 2 random effect.

All the level 2 random effects (u_{qj}) are assumed to follow a normal distribution
with mean of 0 and variance of τ_{qq}. Furthermore, for any pair of random effects q and
q' Cov(u_{qj}, $u_{q'j}$)= $\tau_{qq'}$. A comparison of the variance component (τ_{qq}) of the intercept
(β_0) with it's standard error gives an indication of whether there are variations
among Saskatoon neighbourhoods in term of the health outcome.

A three-level model for count outcomes

A three-level model consists of three sub-models at level 1, level 2 and level 3.
For example, if the research data has three levels, neighbourhood, children, and
repeated measurement, in which repeated measurements are nested within children and
children are nested within neighbourhoods, the level 1 model would represent the
relationships among the repeated measurement variables, the level 2 model would
represent the relationships among the children level variables, and the level 3 model
would examine the influence of the neighbourhood level factors. A three-level model
for a count outcome would have the following form:

Let Y_{ijk} be the number of events that happens during an "exposed" time having length
n_{ijk} (For instance, Y_{ijk} could be the number of hospitalizations in measured at time i for
a person j who live in neighbourhood k).

Then we have $\mathbf{Y_{ijk}/\lambda_{ijk} \sim P\ (n_{ijk}, \lambda_{ijk})}$, which mean that $\mathbf{Y_{ijk}}$ follows a Poisson
distribution with exposure $\mathbf{n_{ijk}}$ and rate $\mathbf{\lambda_{ijk}}$

Under the Poisson distribution, the expected value and variance of Y_{ijk} are

$$\mathbf{E(Y_{ijk}/\lambda_{ijk})= n_{ijk}\ \lambda_{ijk}\quad Var(Y_{ijk}/\lambda_{ijk})= (n_{ijk}\ \lambda_{ijk})}$$

When the level 1 model is Poisson, the log link function is used

$$\boldsymbol{\eta_{ijk}= log(\lambda_{ijk})}$$

$$\boldsymbol{\eta_{ijk} = \pi_{0jk} +\sum_{q=1}^{Q} \pi_{qjk}\ a_{qijk}}\quad \mathbf{(3.5)}$$

Where

λ_{ijk} *: the event rate*

η_{ijk}*: the log of the event rate*

π_{qij}*: level 1 coefficients*

a_{qijk} *: level 1 predictor q for repeated measurement i for individual j within neighbourhood k*

In Level 2 model, each of the regression coefficients in the level 1 model (repeated level) including the intercept can be viewed as either fixed, non-randomly varying, or random

$$\boldsymbol{\pi_{pjk} = \beta_{p0k} +\sum_{q=1}^{Q_p} \beta_{pqs}\ X_{qjk} +r_{pjk}}\quad \mathbf{(3.6)}$$

Where

β_{pqk} *: level 2 coefficient*

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X_{qjk} : *level 2 variable*

r_{pjk} : *level 2 random effect*

In Level 3 model, each of the level 2 coefficients, β_{qjk}, defined in the level 1 model, in turn becomes an outcome:

$$\beta_{pqk} = \gamma_{pq0} + \sum_{s=1}^{S_{pq}} \gamma_{pqs} W_{sk} + u_{pqk} \qquad (3.7)$$

Where

γ_{pqs} : *level 3 coefficient*

W_{sk} : *level 3 variable*

u_{pqk} : *level 3 random effect*

Both u_{pqk} and r_{pjk} are assumed to follow a normal distribution with mean 0 and variance σ^2_v and σ^2_u, respectively. The variance σ^2_u and σ^2_r are used as measurement for the variation among neighbourhoods and among individuals, respectively. A comparison of σ^2_u with it's standard error gives an indication of whether there are variations among Saskatoon neighbourhoods in term of the health outcome.

The predicted log of the event rate (η_{ijk}) can be converted to an event rate by computing

λ_{ijk} = event rate = $\exp(\eta_{ijk})$

How the coefficients defined in the lower level are modeled at the higher level

There are four general forms that the coefficients defined in the lower level are modeled at the higher level. For instance, the four forms that a level 1 coefficient is modeled at level 2 are:

The first case is that level 1 coefficient is modeled as fixed effect:

$$\beta_{qj} \quad = \quad \gamma_{q0}$$

In the second case, it is examined as a non-randomly varying level 1-coefficient:

$$\beta_{qj} \quad = \quad \gamma_{q0} + \quad \sum_{s=1}^{S_q} \gamma_{qs} W_{sj}$$

In third case, it is modeled as a random varying level-1 coefficient:

$$\beta_{qj} \quad = \quad \gamma_{q0} \quad + \quad u_{qj}$$

The last case is a combination of the second case and the third case, in which level 1 coefficient is considered to have both non-random and random sources of variation:

$$\beta_{qj} \quad = \quad \gamma_{q0} + \sum_{s=1}^{S_q} \gamma_{qs} W_{sj} + u_{qj}$$

3.5.2.2   Parameter Estimation and Goodness of Fit Test

Parameter estimation and goodness of fit test for linear outcome

For a 2 level linear model, the HLM software provides three kinds of parameter estimation: empirical Bayes estimates of randomly varying level 1-coefficient; generalized least squares estimates of the level 2-coefficient, and maximum likelihood

estimates of the variance and covariance components.[111] The likelihood ratio test can

be used to compare alternative models for the data and carry out significant test (i.e.,

goodness of fit test).[112]

Parameter estimation and goodness of fit test for non-linear outcomes

The HLM software used "penalized quasi-likelihood" or PQL approach to

estimate parameters for non-linear outcomes (for instance, dichotomous or count

outcome). With PQL, HLM produces approximate empirical Bayes estimates of the

randomly-varying level 1 coefficients, generalized least squares estimators of the level

2 (and level 3) coefficients, and approximate restricted maximum likelihood estimators

of the variance and covariance parameters. [111]Although the -2log likelihood value is

reported in the standard output for each model, the likelihood value and likelihood

ratio test are not recommended for use in the case of non-linear outcomes.[111] Some

authors have suggested using the variance to compare alternative models.[112] However,

so far, no official goodness of fit test is available for the non-linear outcomes.

3.5.2.3 Location of Independent Variables

For the individual independent variables, there are three forms, in which they

can be used to enhance their interpretability: the natural value, centering around the

grand mean, and centering around the group mean. For the neighbourhood variables,

there are two possibilities, centering around the grand mean, and the natural value. In

multilevel modeling, it is often recommended that independent variables should be

centered around their means so that the intercept of the model would be more

meaningful.[50,65,66,107,113] If all the independent variables are centered around the grand

mean, the intercept will be the expected outcome for a subject whose value on

independent variables are equal to the grand mean. In this case, the random term of the intercept at the group level is the variance among the group level in the adjusted mean. Centering around the grand mean is used more often that centering around the group mean. If the independent variables are centered around their corresponding highest level unit means, the intercept will become the unadjusted mean for each group and the variance of the intercept is now just the variance among the level-2 unit means.[107]

3.5.2.4 Multilevel Modeling Strategy

In building multilevel models, the general goals of multivariate analysis were observed: the most biologically reasonable, the best fit and the most parsimonious model.[114] The principle "the most parsimonious" directs the researcher to choose among several alternative models when all else was equal, a model that includes the fewest number of variables and is the simplest. The three stage strategy was employed to achieve a predictive model that satisfies these goals. This process allowed a simultaneous consideration of ith individuals nested within jth neighbourhoods.[65,115,116]:

− The first model, usually called the "empty" or "null model, was fitted with no explanatory variables. The empty model was used to determine whether the overall difference between neighbourhoods and individuals in terms of children's health outcome (i.e., low birth weight and hospitalization) was significant.

− The second model, called the "individual" model, included various individual characteristics to allow assessment of the association between study outcomes and these individual characteristics. The individual model was used to test whether the variation across geographical areas could be explained by the characteristics of the

people who live within that geographical area or not. Individual variables were entered one at a time as random effects; if a significant variance component was reported, the variable was kept as a random effect, otherwise the variable was constrained to be fixed across neighbourhoods. All the variables which showed significant associations with the outcomes would remain in the model, the variables which did not indicate significant associations with the outcomes but were biological important (for instance, mother's age) would also be retained in the model.

- After that, a third model called the "final" model was generated, which included explanatory variables at both levels. This model was used to test for the contextual effect of neighbourhood (i.e., independent effects of neighbourhood variables above and over individual variables). In this model, only the neighbourhood and the individual characteristics which showed significant associations with the study outcomes would stay in the final model.

3.6 Software

In order to perform the aforementioned analyses, several computer software programs were used. Primarily, data was explored and analysed in the Statistical Package for the Social Sciences (SPSS) version 11.5. SPSS was used for data manipulation, univariate, bivariate analyses, and principal component analysis. Multilevel modelling was performed using Hierarchical Linear and Nonlinear Modeling (HLM) version 5.05. Mapping of neighbourhood level data onto City of Saskatoon maps were performed using a geographical information software package entitle ArcGIS version 8.0.

4 CHARACTERISTICS OF THE STUDY POPULATION AND NEIGHBOURHOOD

This chapter reviews the selection of the study sample as well as the descriptive analyses of individual and neighbourhood variables. Neighbourhood data and individual data were treated separately. Descriptive neighbourhood data are presented with the aid of maps.

4.1 Selection of the Study Sample

Of the 9,888 children born in Saskatoon during the period of 1992 to 1994 and covered under Saskatchewan health insurance, 1384 children (14%) were excluded from the study. Figure 4-1 presents the reasons for the exclusions.

First, 248 (3%) children were excluded from the study because they were born of multiple births, which included twins. In studies of adverse birth outcomes, this exclusion criterion is common since children of multiple births are almost always born under adverse circumstances.[17] The sharing of placenta and uterus often result in a smaller birth size and prematurity. Thus, multiple births were excluded in order to control for this inherent bias.

Second, 882 (9%) children living in rural municipalities were excluded in order to limit the study to the city of Saskatoon and allow the analysis at neighbourhood levels. Furthermore, the children living in rural municipalities may be different from children living in Saskatoon in term of accessibility to health care services. Thus, they needed to be excluded in order to avoid the potential of this confounder.
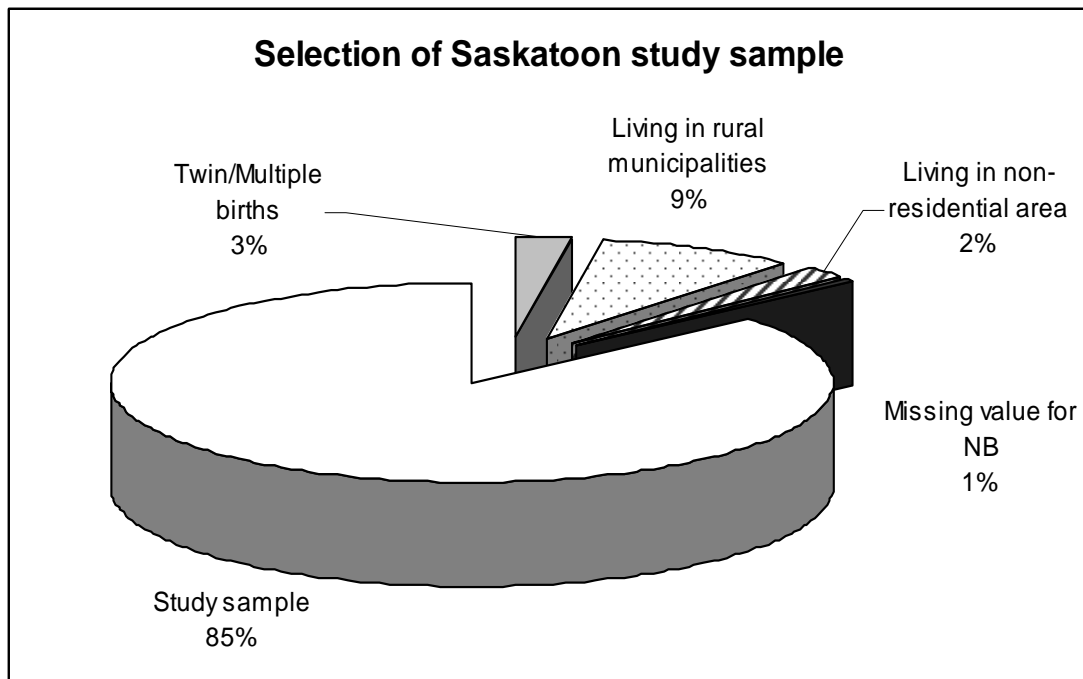
Figure 4-1: Selection of the study sample

Third, 62 (1%) children, for whom there were missing values for neighbourhood, were not included in the analysis because without a neighbourhood of residence reported, it was not possible to link the neighbourhood level data to the individual level data in order to perform the multilevel analysis.

Finally, 192 (2%) children were excluded because they lived in areas in the city that were prominently non-residential. These areas included 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, and University Land.

In all 15% of the birth cohort, or 1384 children, were not retained in the study sample for further analysis, and this group of children was not significantly different from the study sample (i.e., 8504 children) in mother's age, parity, sex of the child, and family income status (all comparisons, $p > 0.05$).

4.2 Individual Level Data

Figure 4-2 indicates family income status by children's age. On average, during 6 years after birth, 20% of children in this study population were considered to live in low income families (i.e., their families received income assistance from the government, which was used a proxy for low income status). Specifically, during birth year (age 0), 14% of children lived in low income families. In subsequent years, the proportion of children in low income families were 20%, 19%, 20%, 24% and 26% when children were 2, 3, 4, 5, and 6 years of age, respectively.

Table 4-1 presents the descriptive results for all individual variables included in the analysis. It can be seen that male children slightly outnumbered female children in this study sample (51.9% vs. 48.1%).

The number of children a woman had given birth to, including the study child, was referred to as parity. The proportion of children who had mothers with more than one child was greater than the proportion of children who had mothers with only one child (58.4% vs. 41.6%). Previous stillbirth deliveries increase the risk of adverse birth

outcomes. The proportion of children who had mothers with at least one prior stillbirth was 2%.
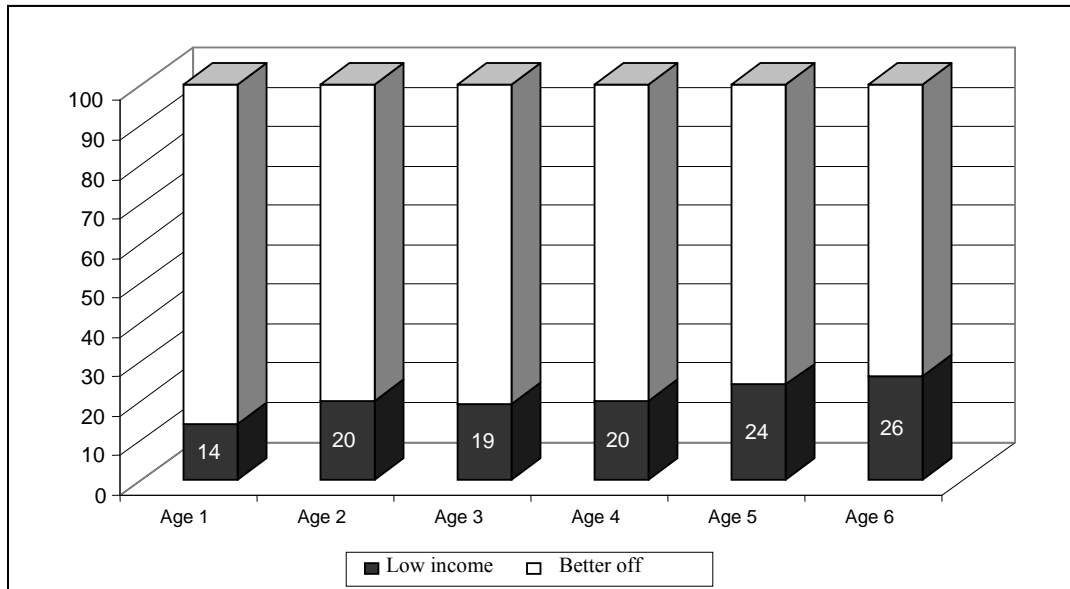
Figure 4-2: Distribution of family income by age

The majority of women in the study population (68.6%) were married. Single parent accounted for 29.2% while families, who information of marital status was missing, accounted for 2.3% of the population.

Of 8504 children in the study, 89.3% had mothers, who were from 20 to 40 years old at delivery time, 9.8% had mothers, who were less than 20 years of age and 0.9% had mothers, who were older than 40 years. This variable was categorized in this way because of the "U-shaped" relationship between mother's age and adverse birth outcome found in the literature. Similarly, children whom father's age were less than 20, from 20 to 40, and greater than 40 accounted for 3%, 81.7%, and 4.9% of the study population, respectively.

Table 4-1: Summary of population characteristics

	Category	Frequency	Percent
Parity	1	3541	41.6
	>=2	4963	58.4
Birth Weight	Non Low Birth Weight	8105	95.3
	Low Birth Weight Child	399	4.7
Marital status	Married/Common Law	5831	68.6
	Single Parent	2480	29.2
	Unknown	193	2.2
Family Income at Birth	Low Income	1192	14.0
	Not Low Income	7312	86.0
Mother's age	20-40 years of age	7597	89.3
	Less than 20 years of age	835	9.8
	Older than 40 years of age	72	0.9
Father's age	20-40 years of age	6951	81.7
	Less than 20 years of age	251	3.0
	Older than 40 years of age	413	4.9
	Unknown	889	10.4
Adverse birth outcome	Born without adverse birth outcome	7396	87.0
	Born with one adverse birth outcome	718	8.4
	Born with at least two adverse birth outcomes	390	4.6
Sex	Male	4412	51.9
	Female	4092	48.1
Stillbirth	No prior stillbirth	8337	98.0
	At least one prior stillbirth	167	2.0

In the study sample, 4.7% of children were born low birth weight, 6.5% were born preterm and 7.1% were born small for gestational age babies. The adverse birth outcome rates in this study sample were expected to be lower than the rates of Saskatoon or Saskatchewan because of the exclusion of multiple births. Since the literature suggested that the combination of adverse birth outcomes (i.e. preterm birth with low birth weight, preterm birth with small for gestational age, or low birth weight with small for gestational age) would increase the health risk for children, it was necessary to explore how adverse birth outcomes were combined in this study population.[17,117] Figure 4-3 presents the distribution of the adverse birth outcomes in the study population. In summary, children born with no adverse birth outcomes (i.e., no LBW, preterm or small for gestational age) accounted for 87% of the study population.
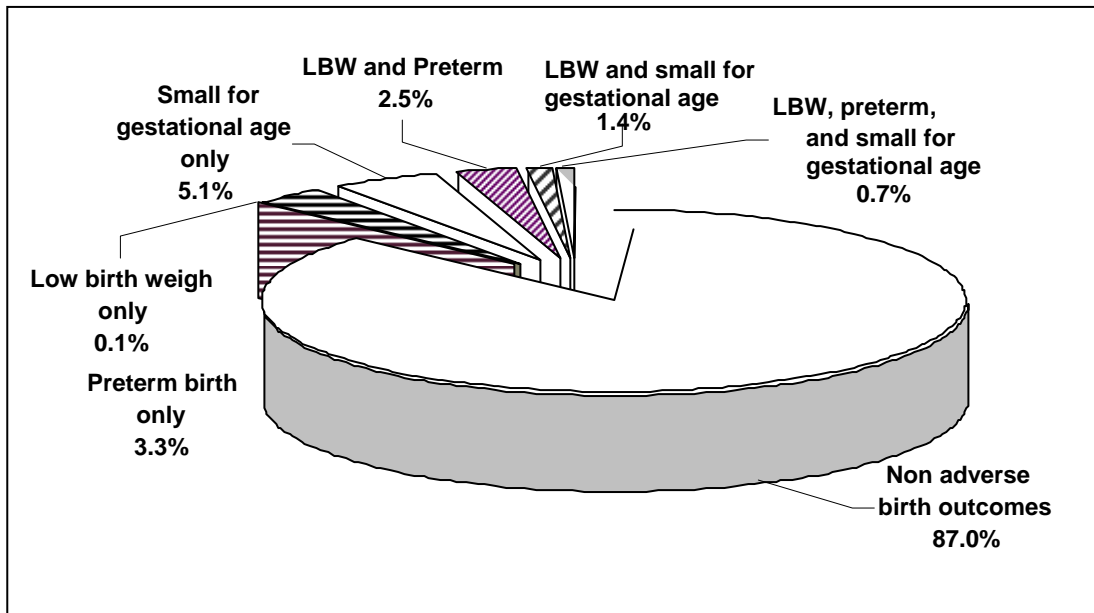
Figure 4-3: Distribution of adverse birth outcomes in the study population

4.3 Characteristics of Neighbourhood of Residence

At the neighbourhood level, there were 6 variables reflecting 6 different domains of Saskatoon neighbourhoods (i.e., social interaction, physical condition, population density, socio-economic disadvantage, unhealthy lifestyle norms, and programs and services for children 0-6 years of age and their families). All of them were continuous variables.

Table 4-2: Descriptive analytical results for neighbourhood variables

	Minimum value	Maximum value	Percentile		
			10th	50th	90th
Social interaction (-)	-1.63	3.12	-1.09	-0.19	1.11
Physical condition (-)	8.00	16.25	9.02	10.33	12.4
Population density (-)	1.5	3.5	2.1	2.53	3.29
Socio-economic disadvantage (-)	-1.79	3.07	-1.01	-0.27	1.09
Unhealthy lifestyle "norm" (-)	1.96	41.94	6.33	17.71	35.48
Programs and services (+)	0.7	26.5	1.24	4.05	9.99

Note: (-) the higher the score, the more disadvantage and (+) the higher the score the better

Table 4-2 presents the summary descriptive analysis for these variables. The range of variable "social interaction" was 4.75 (i.e., the higher the score the lower the level of social interaction within a neighbourhood). The range of variable "physical condition" was 8.25 (i.e., the lower the score, the better the neighbourhood physical condition). The range of variable "population density" was 2.00 (i.e., the higher the

score, the denser the population). The range of variable "socio-economic disadvantage" was 4.86 (i.e., the higher the score, the more disadvantage of neighbourhood socio-economic). The range of variable "unhealthy lifestyle norm" was 39.97 (i.e., the higher the score, the more likely to find unhealthy lifestyle norm within a neighbourhood). The range of variable "programs and services" was 25.8 (the higher the score, the better availability and accessibility of programs and services within a neighbourhood)

Table 4-3: Inter-correlations among neighbourhood-level variables

	Social interactive	Physical condition	Population density	SE disadvantage	Unhealthy lifestyle	Programs and services
Social interactive	1	-	-	-	-	-
Physical condition	.613	1	-	-	-	-
Population density	-.306	-.545	1	-	-	-
Social economic disadvantage	.737	.687	-.375	1	-	-
Unhealthy lifestyle	.492	.286	.034	.601	1	-
Programs and services	.372	.268	-.278	.212	-.038	1

Table 4-3 presents the inter-correlations among neighbourhood level variables. The highest correlation was the correlation between neighbourhood social economic disadvantage and neighbourhood social interaction (Pearson correlation=0.737) and

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the lowest correlation was the correlation between neighbourhood programs and services and neighbourhood unhealthy lifestyle norm (Pearson correlation=-0.038).

Distribution of neighbourhood characteristics is best described and understood with the aid of maps. To this end, the following maps are presented.
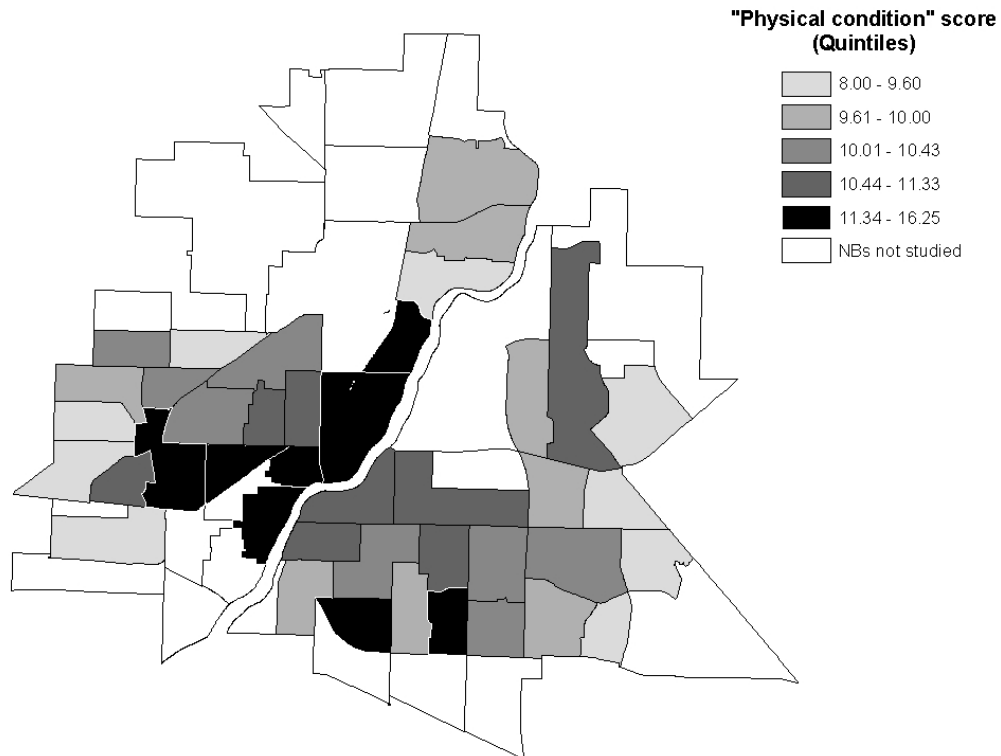
Figure 4-4: Spatial distribution of the physical condition in Saskatoon neighbourhoods

Figure 4-4 presents the distribution of neighbourhood physical condition in Saskatoon (by quintiles). The darkest shaded areas show neighbourhoods with the worst physical condition; with the exception of Avalon and Nutana Park, all of these neighbourhoods exist on the Westside of the river.
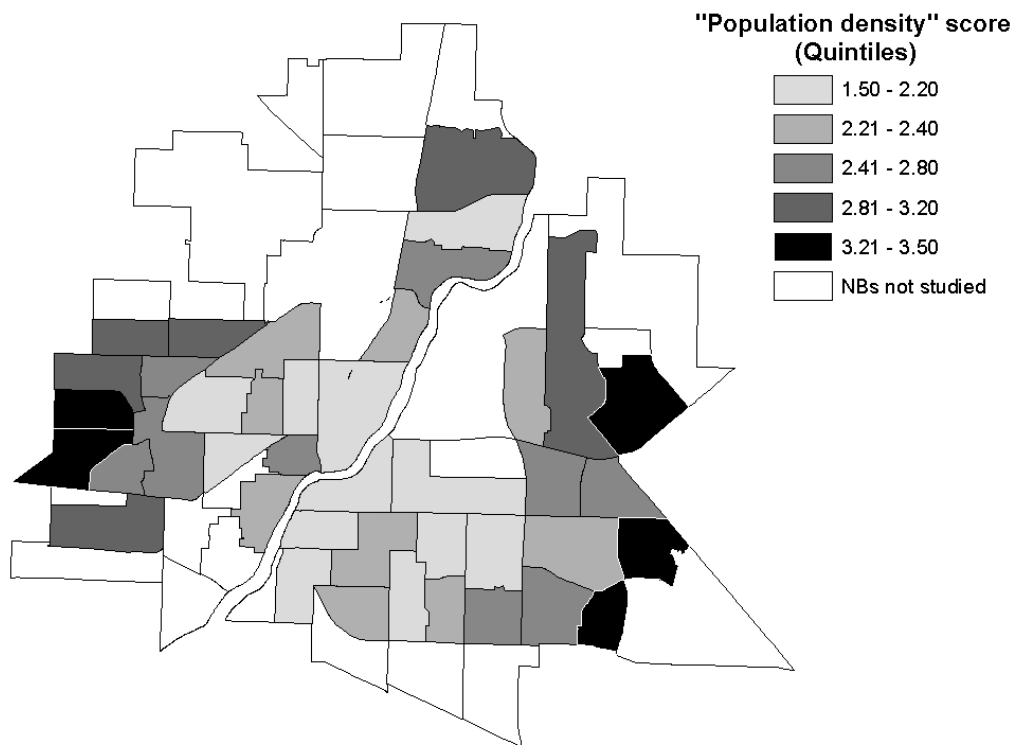
Figure 4-5: Spatial distribution of population density in Saskatoon neighbourhoods

Figure 4-5 indicates the distribution of population density in quintiles across Saskatoon neighbourhoods. From this map, it is clear that the population density was fairly evenly dispensed throughout the city. It is also interesting to note that those neighbourhoods with better physical condition and higher socio-economic status tend to have denser population.
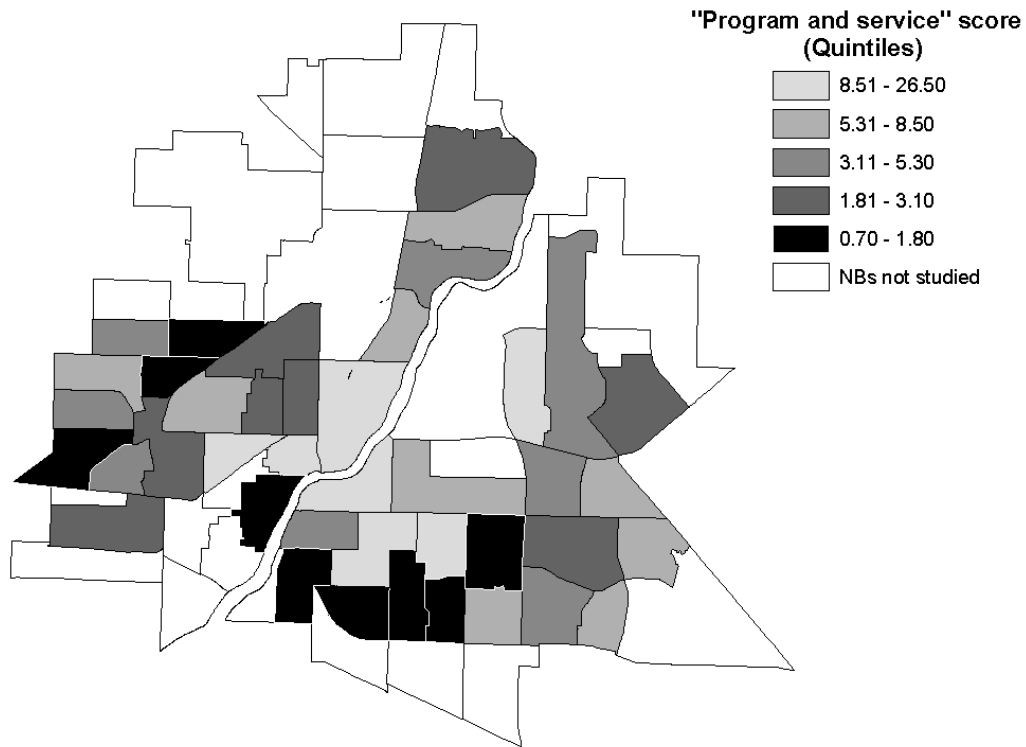
Figure 4-6: Spatial distribution of programs and services for children and their families in Saskatoon neighbourhoods

The higher the score of variable "programs and services" one neighbourhood has the more available and accessible programs and services for children and their families in that neighbourhood are. Thus, the darkest polygons in Figure 4-6 represent those neighbourhoods in which programs and services are the least available and accessible. Those neighbourhoods are: Nutana S.C and Brevoort Park, Nutana Park, Avalon, Adelaide/ Churchill, Exhibition, Holiday Park and King George, Parkridge, Massey Place, and Westview. The brightest polygons are those neighbourhoods in which programs and services are the most available and accessible. Those neighbourhoods

are: City Park, Riverdale, Nutana, Queen Elizabeth and Haultain, Pleasant Hill, and

Sutherland.
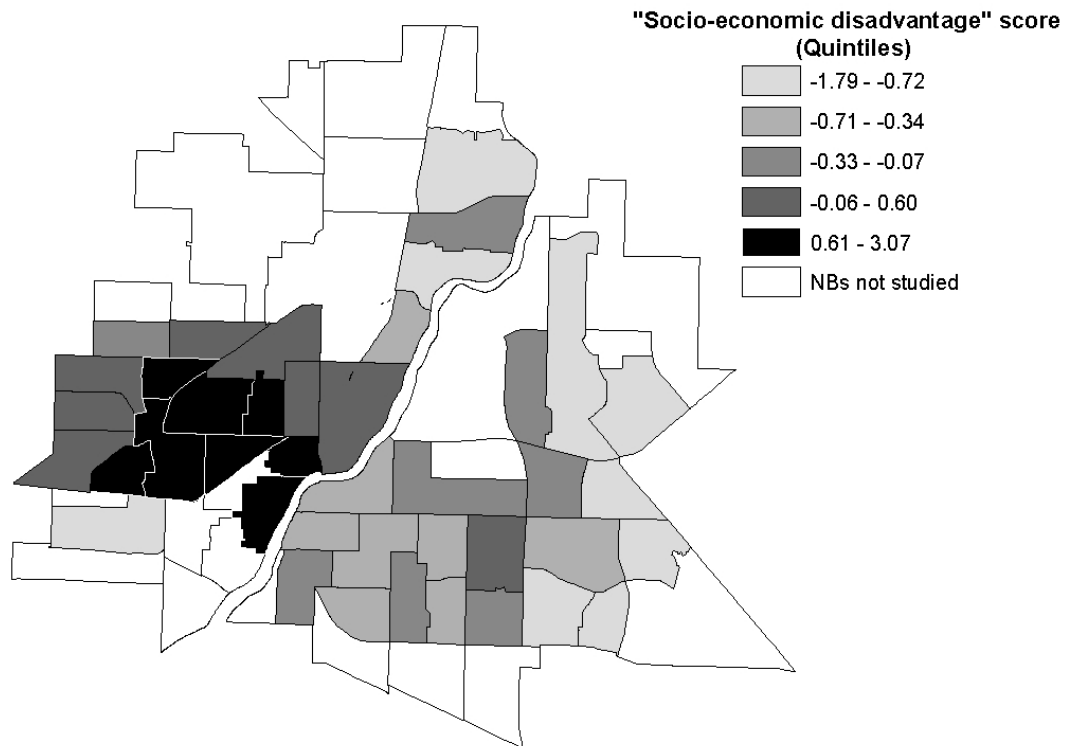
**Figure 4-7: Spatial distribution of socio-economic disadvantage in Saskatoon
neighbourhoods**

Figure 4-7 shows the level of socio-economic disadvantage in Saskatoon

neighbourhoods. It can be observed that the most socio-economically disadvantaged

neighbourhoods are located on the West side of the river (these socio-economically

disadvantaged neighbourhoods are represented by the darkest polygons in the map).

The level of disadvantage socio-economic status of the neighbourhood is positively

correlated with by percentage of single parents, LICO families, Aboriginal status, and

population with an education level under grade 9 and negatively correlated with the

average number of cars per person, percentage of employment, and percentage of owned houses. It is interesting to observe that neighbourhood that are the most socio-economically disadvantaged are also those with the lowest level of social interaction.
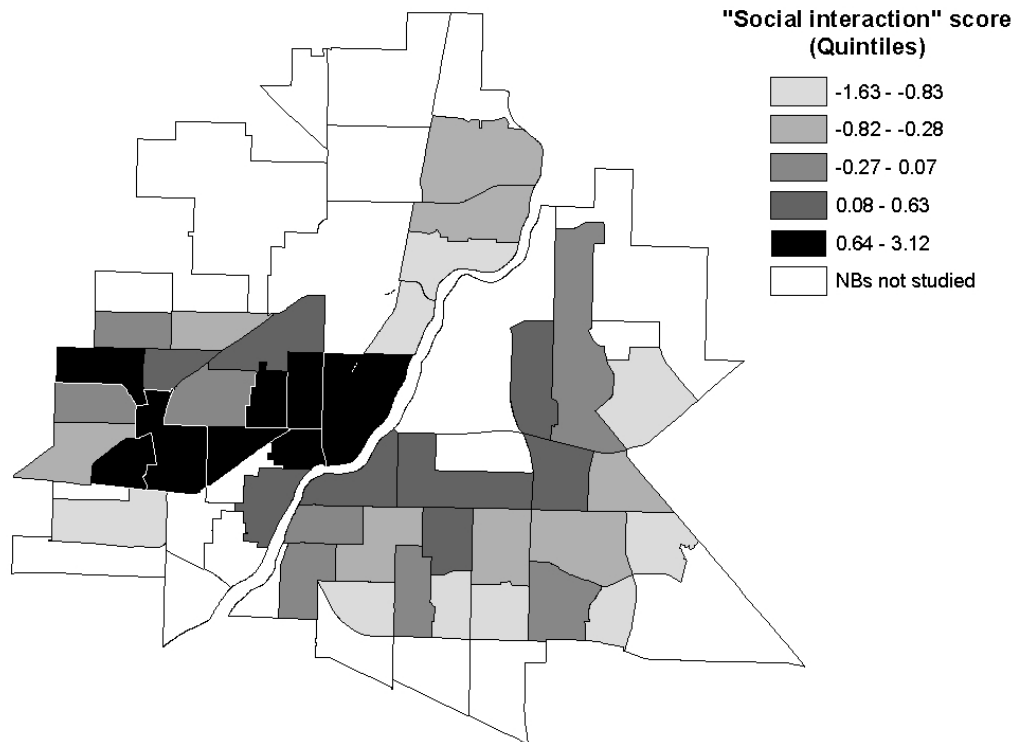
Figure 4-8: Distribution of level of social interaction in Saskatoon neighbourhoods

The level of social interaction within a neighbourhood is expressed in Figure 4-8. Again, the darkest polygons are used to indicate the neighbourhoods with the lowest level of social interaction. As for neighbourhood socio-economic disadvantage, those neighbourhoods with the lowest level of social interaction are located on the West side of the river.
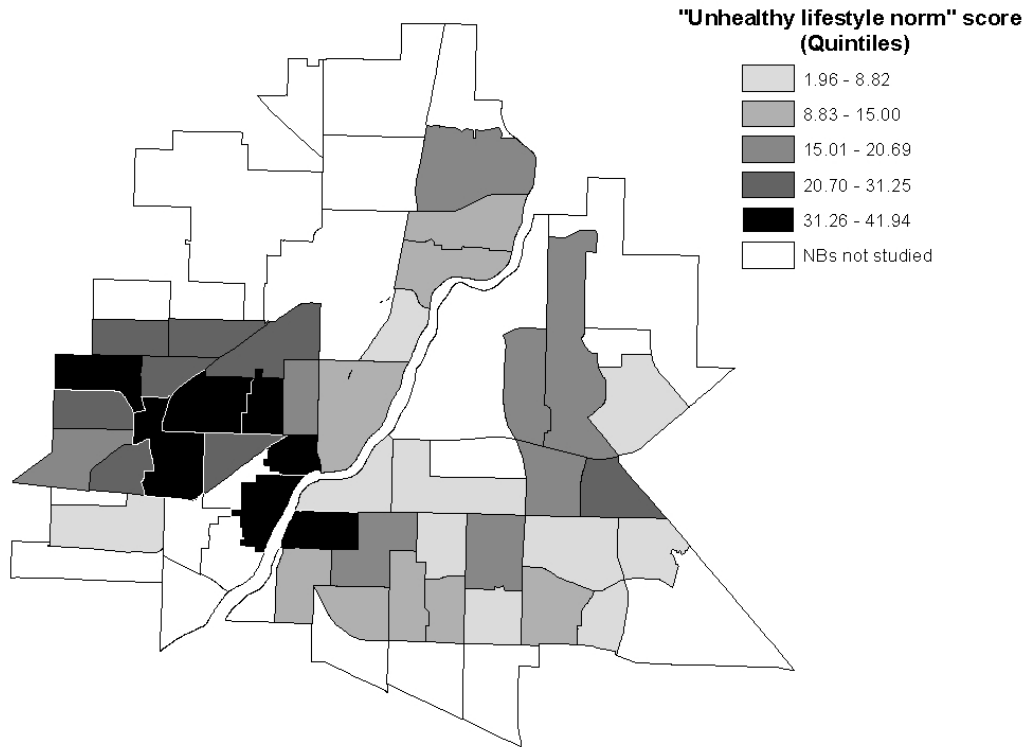
Figure 4-9: Distribution of unhealthy lifestyle norm in Saskatoon neighbourhoods

Another domain of Saskatoon neighbourhood, unhealthy lifestyle norm is presented in Figure 4-9. The prevalence of unhealthy lifestyle norm in Saskatoon neighbourhoods is measured by the percentage of smokers per neighbourhood. With the exception of Buena Vista, all of the neighbourhoods, in which unhealthy lifestyle norm are the most popular (i.e., with the highest percentage of smokers), exist on the West side of the river. These neighbourhoods are shown by the darkest polygons in the map.

FOCUSED TOPIC 1

5 LOW BIRTH WEIGHT IN SASKATOON: ARE THERE CONTEXTUAL EFFECTS OF NEIGHBOURHOOD OF RESIDENCE?

This chapter will present the results of the first focused topic, which examines the contextual effects of neighbourhood on the prevalence of low birth weight (LBW) in Saskatoon. First, the research objectives and rationale will be discussed. Second, the literature on the risk factors of low birth weight (at both individual and neighbourhood level) will be reviewed. Following that, an overview of analytical methods used in this project will be provided in the third section. Fourth, the analytical results will be presented separately for each research objective. Finally, the last section will summarize and discuss the research findings as well as all the strengths/limitations of this focused topic.

5.1 Introduction

Low Birth Weight (LBW) is a common and preventable public health concern. During the neonatal and infant period, LBW has been significantly associated with a

higher risk of handicap, mortality and morbidity.[17,18,118-120] Studies have shown that LBW has long term consequences as well. Recent evidence suggests that poor growth in utero leads to a variety of chronic disorders such as cardiovascular diseases, non-insulin dependent diabetes and hypertension many decades later in adulthood.[121] Therefore LBW is not only an important outcome in children but also a sentinel indicator of adult health.

Among industrialized nations in 1995, Canada's low birth weight prevalence (5.6 %) falls close to the middle of the pack. Japan had the highest rate (7.5%) and Finland, the lowest (4.9%).[122] The prevalence of LBW in the US (7.3%) is higher than that in Canada.[122] The rate of low birth weight in Canada has not changed appreciably over the past two decades: 6% of live births in 1980 compared to 5.5% in 1990 and 5.8% in 1996. [122] The prevalence of low birth weight in Saskatoon is 5.9% in 1996, which is higher compared to the Saskatchewan rate (5.4%) and the national rate.[123]

Many risks factors associated with LBW have been reported. However, the risks for LBW have been "individualized", emphasizing those characteristics of individuals that increase the likelihood of LBW rather than environmental and social factors affecting population rates.[124] It has been pointed out that individual risk factors explain only a small proportion of the overall variation in birth weight[17] and that the focus on individual level factors has the inherent limitation of ignoring important macro-level influences. [124] It is likely that the social phenomena that affect people at the level of entire communities would account for the unexplained variation on LBW risk. Therefore, it is necessary to examine how neighbourhood/area factors, such as the

level of social interaction, the poverty rate, and the condition of the physical environment could contribute to the risk of LBW.

A few studies have examined area-level factors together with individual-level factors in relation to LBW.[46,50,125,126] These studies have reported independent effects of area/neighbourhood on LBW, and most of these studies have been done in either the US or the UK. Since characteristics of area/neighbourhood factors are very much locally-based and may not be generalized to wider settings, studies need to be conducted that examine the contextual effects of area/neighbourhoods in Canadian settings.

Also, most previous studies have focused on the socio-economic domain of the neighbourhood to the exclusion of other relevant dimensions of neighbourhood (i.e., physical condition, programs and services available, or social interaction). Clearly, studies need to take into account not only the socio-economic domain of neighbourhoods but also other relevant neighbourhood level characteristics to portray a fuller picture of neighbourhood factors that may be associated with outcomes such as LBW.

The goal of this analysis then was to examine both neighbourhood level and individual level characteristics that would impact low birth weight in a specific setting, Saskatoon. Specifically, the following research objectives were examined in this study:

Objective 1: To describe the variation in the distribution of LBW rate across Saskatoon neighbourhoods. This objective was addressed by testing the following hypothesis.

Hypothesis 1: LBW rate will vary significantly across Saskatoon neighbourhoods with higher rates generally corresponding with low socio-economic status neighbourhoods.

Objective 2: To examine the independent effects of neighbourhood factors on LBW as well as their moderating effects on the association between individual risk factors and LBW. This objective was addressed by testing the following hypotheses.

Hypothesis 2a (i.e., the independent effects of neighbourhood factors): *Neighbourhood factors, such as its physical condition, socio-economic milieu, programs and services available, social interactions, population density, and unhealthy lifestyle norm, will be related to LBW, in addition to the effects of individual risk factors on LBW.*

Hypothesis 2b (i.e., the moderating effects of neighbourhood factors): The *magnitude of the effects of individual risk factors on LBW will depend on the context of neighbourhood such as collective social interactions and socio-economic disadvantage.*

Objective 3: To estimate the overall contribution of neighbourhood effects to LBW compared to the contribution by individual effects. This objective was addressed by testing the following hypothesis.

Hypothesis 3: The overall effects of neighbourhood factors will be stronger compared to the effects of other modifiable individual risk factors, suggesting that neighbourhoods should be considered as an important target for health

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policy and health promotion programs which aim at reducing LBW in

Saskatoon.

The three specific research objectives addressed in this focused topic are linked to the overall research questions, which were stated in Chapter 1, "Introduction". Specifically, objective 2 will address the overall research question 1 (i.e., by testing hypothesis 1) and research question 2 (i.e., by testing hypothesis 2) and objective 3 will address the overall research question 3.

This study aims to identify and quantify the contextual effects of neighbourhood on birth outcomes. It will be interesting to discover what specific aspects of Saskatoon neighbourhoods contribute to differences in the distribution of low birth weight and to predict how the LBW rate in Saskatoon will change if we improve the quality of Saskatoon neighbourhoods. The multilevel design of this study will contribute new knowledge to current literature of LBW by including macro level factors in the explanatory models. By understanding how contextual factors influence low birth weight, we may be able to design more effective intervention strategies to reduce the social inequalities in maternal health.[4,50]

5.2 Literature Review:

5.2.1 Definition

Low birth weight (LBW) is generally described as less than 2500 grams (or 5 pounds 8 oz).[17] This is a universally accepted threshold for LBW, below it neonatal morbidity has been observed to rise sharply.[17]

5.2.2 Long Term and Short Term Consequence

Low birth weight babies are at a much greater risk of death, disease, and disability. In 1990, over 15% of the deaths occurring in the first month of life were infants who were born too soon or too small.[17] Even though the mortality rate of LBW and very LBW (under 1000 gram) has been decreasing significantly due to better perinatal care,[127] the proportion of surviving infants with severe sequelae, such as cerebral palsy, learning disabilities, visual problems and respiratory problems, has not. Very LBW infants are more susceptible to all of the possible complications of premature birth, both in the immediate neonatal period and after discharge from the nursery.[17,119,127]

More significant, LBW can produce results beyond those experienced during the neonatal and infant period. In the late part of the 1980s and early into the 1990s, researchers began to examine the longitudinal effects, which LBW could have on later life.[128] For instance, McCormick *et al.* followed up 1868 children of very low birth weight and normal weight to examine the health and development status of the cohort from age 8 to 10 years. In this study, it was concluded that lower birth weight was associated with increased morbidity for all measures, except the depression/anxiety

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score.[129] In another study, a cohort of 242 very low birth weight survivors (<1500grams) was compared to 233 of controls of normal weight at age 18-20. The authors concluded that "educational disadvantage associated with very low birth weight persists into early adulthood" since they found that fewer very low birth weight (VLBW) had graduated high school, VLBW men were less likely to attend post-secondary education, and VLBW adults had a lower mean IQ and lower academic achievement scores compared to normal weight.[130] In Chaudhari *et al.*'s six year follow up study, it was concluded that controlling for socio-economic status, mother's education and housing condition, the mean IQ of low birth infants were within normal limits (94.3) but were significantly lower than the controls. When looking at preterm and its relationship to the outcome and low birth weight, the authors also concluded that preterm low birth weight children had the lowest mean IQ score across the groups.[131]

5.2.3   Epidemiology of LBW

5.2.3.1   Individual Risk Factors

The factors that contribute to low birth weight are complex. For developed countries, the following variables were reported to be risk factors for LBW: infant sex (female babies are more likely to be born of LBW), racial/ethnic origin, maternal height, pre-pregnancy weight, maternal birth weight, mother's age, parity, history of prior LBW, gestational weight gain and caloric intake, general morbidity and episodic illness, malaria, cigarette smoking, alcohol consumption, tobacco chewing, drug use, and socio-economic status.[17]

Mother's age: It has been demonstrated that the risk of adverse birth outcome (including LBW) has a "U" shaped relationship with age of the mother, that is, risk is higher among adolescents and women over the age of 35 years and lower in the middle reproductive age-range.[126,132-137] However, it is not clear whether chronological age is an independent predictor of adverse birth outcomes or whether the increased risk results from characteristics related to the extremes of mother's age. Pregnant adolescents are more likely to receive inadequate prenatal care, to be non-Caucasian, to be unmarried, to have lower education levels and lower income than their adult counterparts.[134,137-139] Most studies attribute the increased risk in adolescent pregnancies to socio-economic characteristics rather than to physiologic factors.[17,126,132,133,136,137,140-143] However, several other studies still found higher risks in adolescents after controlling socio-economic factors.[134,144-148] The results of studies about the relationship between adverse birth outcomes and older mother's age are very controversial. Among the studies that have considered risk factors for preterm delivery and low birth weight, older mother's age has been found to be related to preterm birth and low birth weight in some studies[144,146] but not in others.[147,149-151]

Parity: Parity is defined as the number of previous births. There is a general agreement that pregnancy outcomes are more favorable for multiparae than primiparae. When studying the association between parity and adverse birth outcomes, there are several other associated factors that should be taken into account, such as age, socio-economic status, and pregnancy interval. Primiparae women tend to be younger than multiparae, although age does not appear to have an influence on pregnancy outcome, young adolescents are likely to differ from the older women in term of their

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height, gestational nutrition, and cigarette and alcohol consumption. Therefore, Kramer suggests that age should be adjusted for when studying the relationship between parity and adverse birth outcomes.[17] Mothers of high parity are likely to have had a shorter pregnancy interval, therefore, birth interval should also be adjusted for. Conclusions about the association between parity and adverse birth outcomes are contradictory in different studies. Wiener's study reported a significantly negative association between parity with gestational age and birth weight although the magnitude of the association was small.[152] On the other hand, Maumelle's study noted a significant decrease in risk of preterm birth delivery with increasing parity.[153] Berkowitz, however, found no significant association between parity and gestational age.[150]

Race/ethnicity: Different racial/ethnic backgrounds show different risks associated with LBW.[154] In a prospective cohort design of 96 Aboriginal and 96 non-Aboriginal women in Australia, it was concluded that the Aboriginal neonates were on average almost 450 grams lighter than non-Aboriginals.[155,156] The issue of low birth weight and Aboriginal ancestry is a complicated one, as Aboriginal peoples in Saskatchewan have a higher rate of diabetes compared to non-Aboriginal persons. The effect of gestational diabetes significantly increases the birth weight of the baby.[156] For this reason, studies attempting to examine the relationship between low birth weight and small for gestational age and Aboriginal ancestry must be aware of the potential interaction between gestational diabetes and birth weight in the data.

Prior stillbirth: Mothers of LBW children are more likely to have had previous stillbirth deliveries, both spontaneous and induced. Previous stillbirth births, therefore, is an important confounder to control for in an analysis of LBW.[17]

Cigarette Smoking: The association between maternal cigarette smoking and low birth weight is well established.[17,18] Smoking may be associated with several other suspected factors such as alcohol consumption, age, pre-pregnancy weight, psychological stress, ethnicity, and socio-economic status. Evaluating the influence of maternal smoking therefore requires adequate control for these potential confounders. [157,158]

Socio-economic status (SES): The relationship between socio-economic status and adverse birth outcomes has been very well established through much research. Most investigators have found an increased risk of adverse birth outcomes for low socio-economic status women.[159-162] For example, in a study conducted in India, it was reported that lower SES was associated with a relative risk of 1.71 for LBW and SES had a substantial attributable risk percent for LBW of 41.4%.[163] SES is closely related to other demographic, behavioral, environmental, and medical factors that may influence pregnancy outcomes. Therefore, it is difficult to disentangle the independent effects of socio-economic status on adverse birth outcomes from those that may be due to the relationship of SES with other risk factors.

Psychological factors: A growing body of empirical evidence, based on methodologically rigorous studies of pregnant women of different ethnic, socio-economic, and cultural backgrounds, supports the premise that mothers experiencing high levels of psychological or social stress during pregnancy are at significantly

increased risk for LBW/preterm birth, even after the effects of other risk factors are adjusted for.[17,164] The effect sizes of maternal stress on LBW in recent, well-controlled prospective studies with relatively large sample sizes (>1000 subjects) have typically ranged between a 1.5 to 2 fold increase.[164,165] However, it has been noted that the literature showing an association between stress and LBW is largely limited to individual-level psychosocial definitions and measurements of stressful experiences. A more comprehensive multilevel approach that considers the potentially important influences of socio-cultural context on reproductive health outcomes is therefore needed to advance this field. [164]

5.2.3.2   *Multilevel Studies on Adverse Birth Outcomes*

Until recently, most studies on LBW and other adverse birth outcomes have focused on the individual risks factors or simply reported a crude association between LBW and area characteristics. For example, in Canada, a report on birth outcome and infant mortality in urban Canada in 1991 were jointly produced by Statistics Canada and Welfare Canada, in which urban neighbourhoods characterized by income levels were created by using census tracts along with postal code matching. The data showed a consistent relationship between low income neighbourhoods and rate of adverse birth outcomes.[166]

Only a small number of studies have examined both individual risk factors and neighbourhood of residence characteristics in one model and most of these studies have been conducted in the US or the UK. These studies have reported associations between area characteristics and LBW, after controlling individual characteristics.

However, it should also be noted that not all of these studies employed the multilevel technique in their analysis.

For example, Roberts used a logistic regression model for combining individual risk factors and neighbourhood characteristics to predict low birth weight in Chicago. He found that community economic hardship and housing cost were positively associated with low birth weight while community socio-economic status, crowded housing, and high percentages of young and African American residents were negatively associated with low birth weight. It was reported that with the individual level held constant, six neighbourhood level indicators (i.e., percentage of young residents, percentage of old residents, stability, percentage of African American residents, median rent, and crowded housing rate) predicted low birth weight, together contributing to a variation in rate of 5.5%. However, the validity of the estimation in this study may be suspect since the regression model did not take into account both macro and micro level as a multilevel model would do.[125]

Another study which examined the impact of neighbourhood support and birth weight in Chicago was done by Stephen *et al*. In this study, a household survey of adults residing in 343 Chicago neighbourhoods was conducted to assess mean levels of perceived social support. US Census data was used to estimate neighbourhood economic disadvantage. At the individual level, this study took into account mother's age, mother's marital status, mother's education level, prenatal care, parity, smoking, and race. The study results indicated that among African American mothers, mean birth weight decreased significantly as the neighbourhood level of economic disadvantage increased and among Caucasian mothers, a significant positive

association was reported between perceived levels of neighbourhood social support and infant birth weight.[167]

Another study was done by O'Campo *et al.* which examined neighbourhood risk factors for LBW in Baltimore. In this study, the contribution of the macro-level social factors to LBW were assessed by using census tract-level data on social stratification, community empowerment, and environmental stressors. Neighbourhood characteristics examined in this study were home ownership, number of community groups, unemployment rate, housing violations, crime rate, and per capita income. Among them, the number of community groups per census tract was used as an indicator of community empowerment; crime rate, housing violations, and unemployment rate were used as indicators of environment stressors; and the rest were used as indicators of social stratification. This study indicated that indicators of social stratification, particularly per capita income, were directly related to the risk of low birth weight in Baltimore. There were substantial interactions between macro level factors and individual-level risk factors for low birth weight. For example, indicators of social class, and environmental stressors such as poor housing conditions and high crime and unemployment rates, were found to modify the relationship between individual-level risk factors and low birth weight. More importantly, the authors concluded that multilevel modeling is an important tool that allows simultaneous assessment/investigation of macro- and individual-level risk factors.[50]

Pearl *et al.* employed a study sample of 22304 women delivering infants at 18 California hospitals between 1994-1995 to examine the relationships between neighbourhood socio-economic characteristics and birth weight, among 5 ethnic

groups in California. In this study, in addition to individual socio-economic factors, neighbourhood levels of poverty, unemployment, and education were examined. After adjustment for mothers' individual socio-economic characteristics, the association between less-favourable neighbourhood socio-economic characteristics and lower birth weight was reported among African Americans and Asians. However, no consistent relationship between neighbourhood socio-economic characteristics and birth weight was found among Caucasians, US-born Latinas, or foreign-born Latinas overall. The authors concluded that in addition to individual socio-economic characteristics, living in neighbourhoods that were less socio-economically advantaged may differentially influence birth weight, depending on women's ethnicity and nativity (i.e., foreign born or US born).[168]

Spencer *et al.* conducted a study using a retrospective cohort design in the UK. This study attempted to attribute LBW to social inequity. In this study, they compared the relation between birth weight and socio-economic status measured by an area-based measure of material deprivation and by the Registrar General's social class. The authors reported that the estimated proportion of LBW attributable to social inequalities were 30%. However, no individual characteristics were adjusted for in this study.[169]

Sims *et al.* conducted a study of LBW and VLBW by neighbourhood in Milwaukee, Wisconsin. They used census-block data as well as Vital statistics data to examine the differences between African American and Caucasian babies by neighbourhood and birth weight. This study was only a descriptive analysis. Their conclusion was that African American women lived in less desirable, more segregated

neighbourhoods than Caucasian women and that the rates of LBW and VLBW were almost double for African American women compared to Caucasian women.[170]

More recently, in 2004, Luo *et al.* examined the disparities in birth outcomes by neighbourhood income in British Columbia. This is the only study done in Canada, to our knowledge. This study employed a cohort of all births registered in British Columbia during the period from 1985 to 2000.[171] Neighbourhood-income quintiles were derived from the household size-adjusted average family income of each enumeration area relative to other enumeration areas within the same census metropolitan area or census agglomeration. These were developed using the Canadian census data from the closest census years. They compared the rate and relative risk of preterm birth, small for gestational age, stillbirth, and neonatal, and postneonatal death across neighbourhood-income quintles from Q1 (richest) to Q5 (poorest) by 4 year intervals in rural and urban areas. Maternal characteristics adjusted for in this study included mother's age, marital status, abortion history, infant sex, First Nations, parity, plurality, gestational age, birth weight, maternal illness, and mode of delivery Their conclusions were that maternal characteristics varied widely across neighbourhood-income quintiles in both rural and urban area and that there were moderate and persistent disparities in birth outcomes across neighbourhood-income quintiles in urban but not rural areas. However, there were several issues with this study. First, they did not explicitly state that they used multilevel design to examine the effect of neighbourhood. Second, only one neighbourhood variable, income, was examined in this study. Third, the way they defined neighbourhoods in this study was not clearly discussed. And finally and most importantly, the association between adverse birth

outcomes and neighbourhood income was not controlled for the individual's socio-economic status. Thus, one may question whether the disparities in birth outcomes across neighbourhood income quintiles observed in this study were totally attributed to the difference in the individual's SES living in those neighbourhoods.

Other studies have also reported the impact of neighbourhood on other birth outcome. For instance, in California, Wasserman *et al.* evaluated the contributions of lower socio-economic status (SES) and neighbourhood socio-economic characteristics to neural tube defect etiology. This study employed a case control design. The individual characteristics taken into account in this study were individual SES (gathered from interview), preconception multivitamin use and race/ethnicity. Reported addresses were linked to 1990 US census information to characterize neighbourhoods. The authors concluded that the risk of a neural tube defect-affected pregnancy was associated with both lower SES and residence in a SES-lower neighbourhood. More important, they also noted that there was a gradient association between SES indicators and risk of neural tube defect.[172]

5.3 Methodology

5.3.1 Independent Variables and Study Outcome

Individual variables: This focused topic examined eight individual characteristics, namely "Mother's age", "Father's age", "Aboriginal status"," Single parent"," Sex", "Family income assistance at birth"," Parity", and "Stillbirth". Details about their definition and their coding can be found in section 3.3.1. For example, "Mother's age" was a variable with three categories (i.e., '0', '1' and '2' referred to mother's age at delivery time from 20 to 40 years, less than 20, and greater than 40 years, respectively), "Family income assistance at birth" was a dichotomous variable (i.e., '1' and '0' referred to whether the family did or did not receive income assistance from the government of Saskatchewan during the year of birth), "Parity" was a dichotomous variable (i.e., '0' referred to mothers who had at least two live births and '1' referred to mothers who had only one live births)

Neighbourhood variables: Socio-economic disadvantage, social interaction, physical condition, programs and services for children and their families, unhealthy lifestyle norms, and population density. Details about the meaning and rationale of those neighbourhood variables as well as the original neighbourhood characteristics used to construct these extracted variables were given in section 3.3.2. For instance, variable "neighbourhood socio-economic disadvantage" was extracted from seven original neighbourhood characteristics (i.e., percentage of Aboriginal people, percentage of low income families, percentage of population with an education level less than grade 9, percentage of single parent, percentage of employment, percentage of owned houses, and average car per person). Variable "neighbourhood social

interaction" was extracted from five original neighbourhood characteristics (i.e.,

percentage of voter participation for Saskatoon, percentage of voter participation for

federal, percentage of mover, ethnic diversity, and crime per capital).

Study outcome: LBW was defined as less than 2500 grams at birth.

5.3.2 Analytic Method

The analytic method for this focused topic is provided in detail for each research

objective.

5.3.2.1 Analytic Method for Objective 1

Objective 1: To describe the variation in the distribution of LBW rate across Saskatoon neighbourhoods

> *Hypothesis 1: LBW rate will vary significantly across Saskatoon*
>
> *neighbourhoods with higher rates generally corresponding with low socio-*
>
> *economic status neighbourhoods.*

The hypothesis about the variation in LBW rate across Saskatoon

neighbourhoods was tested through two steps. In the first step, a thematic map was

used to visualize the variation in the distribution of LBW rate across Saskatoon

neighbourhoods. A thematic map is a map that uses color schemes or shading or scale

dots to represent the relative risk within regions of the map, and those color schemes

or shading or scale dots are translated into quintiles.[173] In the second step, the

significance of this variation was tested by examining the p-value of the chi-square test

(alpha was set to 0.05).

Objective 2: To examine the independent effects of neighbourhood factors on LBW as well as their moderating effects on the association between individual risk factors and LBW.

Hypothesis 2a (i.e., the independent effects of neighbourhood factors): Neighbourhood factors, such as its physical condition, socio-economic milieu, programs and services available, social interactions, population density, and unhealthy lifestyle norm, will be related to LBW, in addition to the effects of individual risk factors on LBW.

In order to examine the independent impacts of the neighbourhood and individual factors on low birth weight, a multilevel model for binary responses was built. By simultaneously including both neighbourhood and individual level predictors in regression equations, with individuals as the units of analysis, multilevel modeling allowed the examination of neighbourhood or area effects after controlling for individual-level confounders and vice versa.[65,115,116] Figure 5-1 indicates the hierarchical structures of the data as well as the variables examined in the multilevel analysis.

All neighbourhood variables were continuous and therefore were centered at the median, a routine practice in multilevel modeling.[65,115,116] Thus, the reference group for each continuous variable was neighbourhood at an average level. All the individual variables were dichotomous variables and were also centered at the grand mean. This centering of dichotomous variables was necessary because it adjusted the intercept of the model for the difference among the Saskatoon population and among

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each neighbourhood in the percentage of female children, low income families, Aboriginal peoples, children whom mother's age was over 40, children whom mother's age was over 20 and so on. [107]
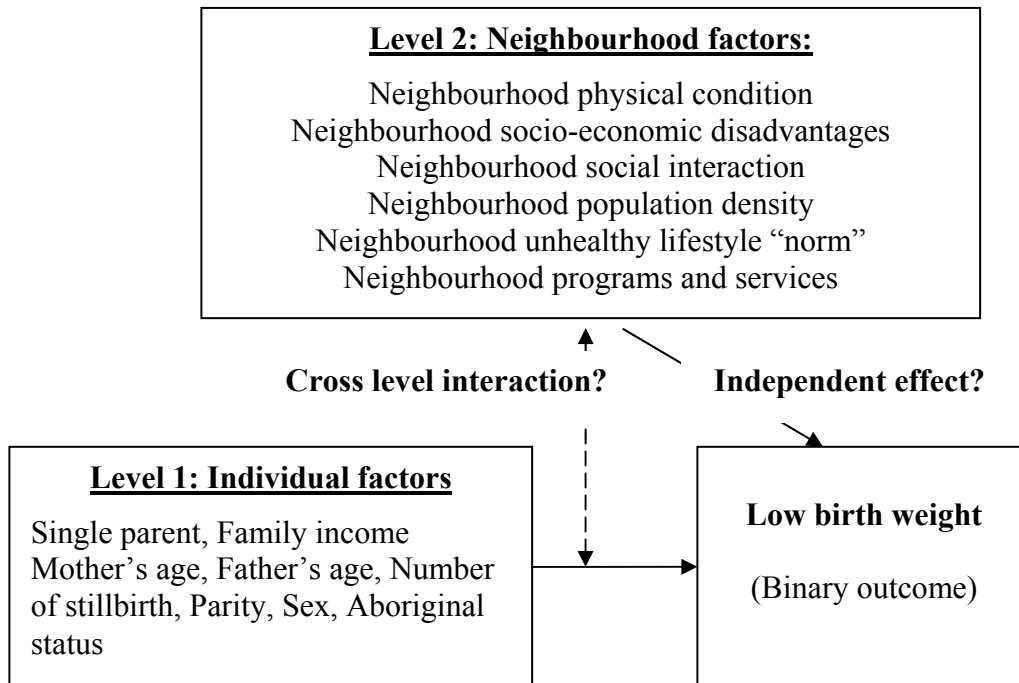
Figure 5-1. Conceptual framework for low birth weight

The multilevel modelling strategy described in section 3.5.2.4 was applied to build a hierarchical model to investigate the LBW rate across Saskatoon neighbourhoods. A set of four hierarchical logit models was estimated. Model 1 included only the estimated neighbourhood –mean probability of LBW, which provided estimates of the variance in probability of LBW observed between and within neighbourhood clusters. In the second model, only one individual risk factor, family income at birth, was added (i.e., this model estimated the crude association between family income and low birth weight outcome) as a random effect. Because the variance component of family income at birth was not significant, family income was

constrained to be fixed across neighbourhoods. Model 3 added other individual risk

factors (i.e., mother's age, father's age, single parent, Aboriginal status, parity,

stillbirth, and sex of the child) one at a time in the model a random effects; if a

significant variance component was reported, the variable was retained as a random

effect; otherwise, the variable was constrained to be fixed across neighbourhoods. All

variables, which were found to be significant or biologically important in model 3,

were retained in model 4. Also in model 4, six neighbourhood variables (i.e., social

interaction, socio-economic disadvantage, physical condition, unhealthy lifestyle

norm, population density, and programs and services) were added. Thus, model 4

investigated the attributes of the contextual effect of neighbourhood of residence to

low birth weight and estimated the adjusted association between family income at birth

and low birth weight (i.e., adjusted for all individual and neighbourhood

characteristics). Again, only significant neighbourhood variables were retained in the

final model for LBW. The variances at the neighbourhood level estimated from each

model (i.e., from model 1 to model 4) were compared to test whether adding new

variables helped to achieve a better explanatory model for LBW. The equation for the

final multilevel model for LBW (i.e., model 4) took the following form:

Level-1 Model

Probability of having a LBW baby = P

$log[P/(1-P)] = \beta 0 + \beta 1*(STILLBIRTH) + \beta 2*(PARITY) + \beta 3*(BIRTH\ INCOME) +$

$\beta 4*(SINGLE\ PARENT) + \beta 5*(SING\_MIS) + \beta 7*(MOTHER'S\ AGE\ <20) +$

$\beta 8*(MOTHER'S\ AGE>40)$

Level-2 Model

$\beta0 = \gamma00 + \gamma01*(\text{NB social interaction}) + \gamma02*(\text{NB programs and services}) + \gamma03*(\text{NB socioeconomic}) + U0$

The cross level interaction between neighbourhood social interaction and single parent

$\beta4 = \gamma40 + \gamma41*(\text{NB social interaction})$

For the fixed effects, results are reported from the population average model with robust standard errors.

Hypothesis 2b (i.e., the moderating effects of neighbourhood factors): The magnitude of the effects of individual risk factors on LBW will depend on the context of neighbourhood such as collective social interactions and socio-economic disadvantage.

Moderating effects or synergistic effects between neighbourhood factors and individual factors refer to the cross level interactions between those factors, that is the magnitude of some individual effects on LBW changes as functions of some neighbourhood factors. In order to test this hypothesis, the significance of the following cross level interactions was checked in the final multilevel model for LBW in Saskatoon:

- The cross level interaction between variable 'neighbourhood socio-economic disadvantage' and 'family income assistance at birth'

- The cross level interaction between variable 'neighbourhood socio-economic disadvantage' and 'single parent'

- The cross level interaction between variable 'neighbourhood social interaction' and 'family income assistance at birth'

- The cross level interaction between variable 'neighbourhood social interaction' and 'single parent'

These cross level interactions between individual factors and neighbourhood factors were evaluated by modeling the coefficient of individual factors as a non-randomly varying level 1-coefficient. [107]

5.3.2.3 Analytic Method for Objective 3

Objective 3: To estimate the overall contribution of neighbourhood effects to LBW compared to the contribution by individual effects. This objective is addressed by testing the following hypothesis.

> <u>*Hypothesis 3:*</u> *The overall effects of neighbourhood factors will be stronger compared to the effects of other modifiable individual risk factors, suggesting that neighbourhoods should be considered as an important target for health policy and health promotion programs which aim at reducing LBW in Saskatoon.*

The neighbourhood should become an important target for health policy only when the "true effect" of the neighbourhood on individual health is equivalent to or stronger than the effects of individual risk factors. Therefore, it is necessary to quantify the contribution of neighbourhood factors into the variation of LBW rate. If changes in one neighbourhood domain results in a significant change in the outcome, then clearly, that domain should become a target of programs, which aim at improving the birth

outcome in Saskatoon. Evaluating the contribution of the neighbourhood factors to the probability of low birth weight was produced by entering different values for each independent variable into the model equation and observing the changes in the predicted probability of having a LBW baby. All other variables were held constant at their mean or median, so that the estimated change would be due to that variable alone. Since all the variables were centered around their mean, the intercept of the model became the adjusted log odds of LBW (i.e., adjusted for all variables in the model). Thus, this centering helped to simplify these calculations because other variables were already held constant in the final model. All the comparisons were made between the 10th and 90th percentile value of each neighbourhood variable.[125]

The predicted probability of having a LBW baby was calculated by working out the antilogit function of $X\beta$: $p=[1+exp(-X\beta)]^{-1}$. For instance, the contribution of neighbourhood socioeconomic disadvantage into the predicted probability of having a LBW baby was calculated as follow:

$$A= [1+exp(-X_{90th}* \beta_{NB\,socioeconomic})]^{-1} - [1+(-X_{10th}* \beta_{NB\,socioeconomic})]^{-1}$$

Where:

A: Change in probability of having a LBW baby due to change in neighbourhood socioeconomic disadvantage

$\beta_{NB\,socioeconomic}$: Coefficient of variable "neighbourhood socioeconomic disadvantage" estimated from the final multilevel model

X_{90th}: Value of variable "neighbourhood socioeconomic disadvantage" at 90th percentile

X_{10th}: Value of variable "neighbourhood socioeconomic disadvantage" at 10th percentile

5.4 Results

The analytical results for this focused topic are presented following the same basic outline in the analytic strategy (i.e., by research objectives).

5.4.1 Analytical Results for Objective 1:

Describe the variation in the distribution of LBW rate across Saskatoon neighbourhoods

The crude rate of LBW in the total Saskatoon population was 4.7% (the crude rate doesn't take into account the difference across Saskatoon neighbourhoods in term of family income, mother's age, single parent, still birth or parity). LBW rate varied across Saskatoon neighbourhoods (i.e., the range of neighbourhood's rate of LBW was from 1.29 to 8.77%). The p-value for the variation in LBW rate across Saskatoon was 0.04, indicating that this variation was statistically significant (Chi-square test).

In Figure 5-2, the rate of LBW by neighbourhood is presented in 5 quintile groups expressed by the size of the dots on the map, the bigger the size of the dots, the higher the rate of LBW. The salient point of this map is that all neighbourhoods with the highest crude rate of LBW (i.e., neighbourhoods with the largest dots) are located on the West side of the city. Those neighbourhoods on the West side of the city are also known to be neighbourhoods with highest level of socio-economic disadvantages.[1] So this map indicates a concordance between neighbourhoods with higher level of socio-economic disadvantages and higher crude rate of LBW.
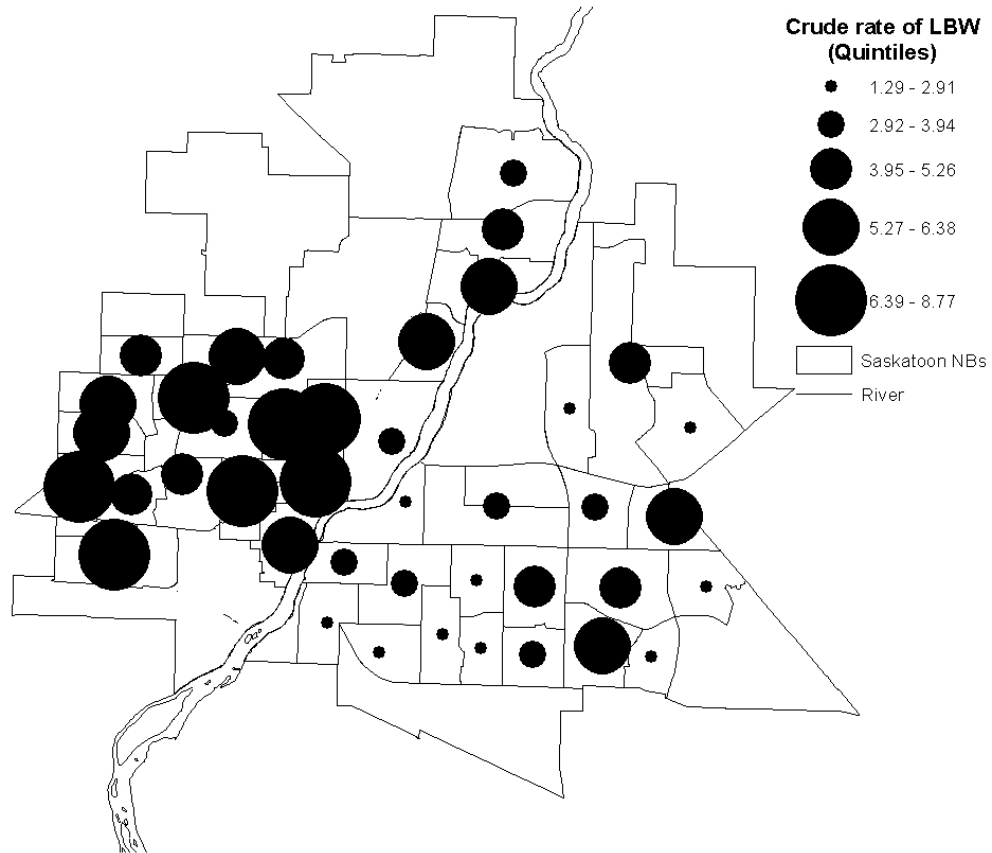
Figure 5-2: Variation in the crude LBW rate across Saskatoon neighbourhood

5.4.2 Analytical results for Objective 2

Independent effects and moderating effects of neighbourhood factors

The results of the final hierarchical logistic regression analysis for LBW in Saskatoon are shown in Table 5-1. For comparison, the coefficients estimated from the 4 models are presented.

Model 1 examined the intercept of the model and the variance component of the intercept. This model showed that there was a significant variation in the rate of LBW across Saskatoon neighbourhood as the variance at the neighbourhood level (i.e., variance component of the intercept, u_0) was 0.053(p=0.022).

Model 2 evaluated the bivariate association between family income at birth and low birth weight. In this model, the coefficient of family income was significantly positive, indicating that low family income at birth was associated with a higher risk of having a LBW infant. The variance component of family income at birth was indicated to be non significant. Thus, the effect of family income at birth was constrained to be fixed across neighbourhoods for subsequent analyses. Adding family income at birth into the model helped to achieve a better model for LBW because it helped to reduce the neighbourhood variance from 0.053 (p=0.022) to 0.043 (p=0.048).

In model 3, all other individual variables were added. This model showed that Aboriginal status, father's age, and sex of the child were not significant predictors of LBW. Thus, these variables were removed from model 4. Other variables (i.e., family income at birth, parity, stillbirth, and single parent) showed significant association with LBW and therefore, were entered in model 4. None of these individual variables was indicated to have significant random effect, that's why they were constrained to be fixed across neighbourhoods for subsequent analyses. Adding parity, stillbirth and single parent into the model was necessary in order to achieve a better model for LBW because it helped to reduce the neighbourhood variance from 0.043 to 0.038 (p=0.083).

Model 4 was the final hierarchical model for LBW, which evaluated the independent impact of individual and neighbourhood variables on LBW. The variance at the neighbourhood level in model 4 was very small and became non-significant (variance=0.008, p=0.45), indicating that including neighbourhood level variables in studies of low birth weight was useful for obtaining a better explanatory model. Figure

5-3 summarizes all the significant risk factors for LBW at the individual level and the
neighbourhood level as well as the cross level interactions among them.
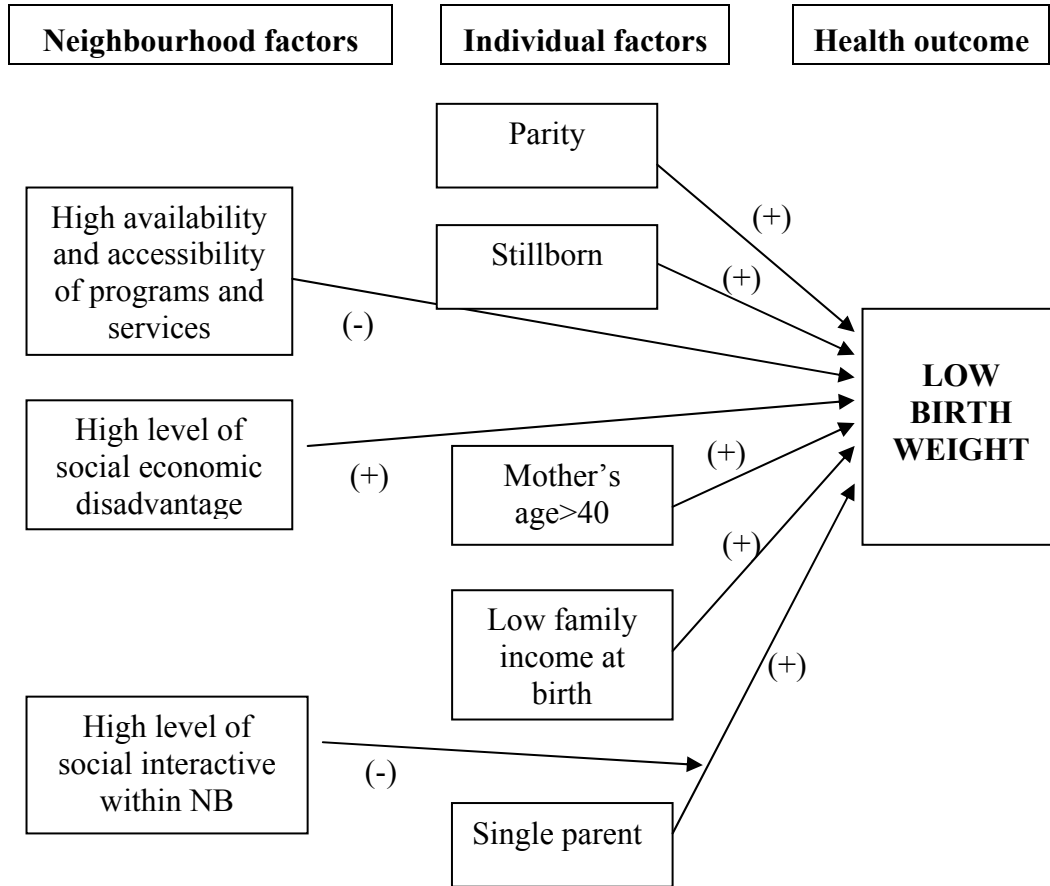
Figure 5-3: Neighbourhood and individual risk factors for LBW

Table 5-1: Estimated coefficients for individual and neighbourhood characteristics logistically regressed on having a LBW infant

Variable	Model 1 Coefficients β (SE)	Model 2 Coefficients β (SE)	Model 3 Coefficients β (SE)	Model 4 Coefficients β (SE)	Model 4 Odds ratio $e^{-\beta}$
Intercept	-3.01 (0.06)	-3.04 (0.06)	-3.09 (0.06)	-3.13 (0.06)	NA
Variance at neighbourhood level	0.053* (p=0.022)	0.043* (p=0.048)	0.036 (p=0.083)	0.008 (p=0.45)	NA
Family income at birth (low income vs. normal income)	NI	0.62 (0.12)*	0.57 (0.14)*	0.59 (0.15)*	1.80(1.35, 2.42)
Sex of the child (Female vs. Male)	NI	NI	0.08 (0.10)	NI	NA
Parity (1 liveborn vs. >1 liveborn)	NI	NI	0.36 (0.15)*	0.41 (0.14)*	1.51(1.14, 2.00)
Stillbirth (at least 1 prior stillbirth vs. no stillbirth)	NI	NI	1.42 (0.21)*	1.38 (0.19)*	3.99(2.74, 5.80)
Aboriginal status (Registered Indian vs. non RI)	NI	NI	-0.11 (0.27)	NI	NA
Single parent (single parent vs. married/common law)	NI	NI	0.39 (0.17)*	0.16 (0.15)	1.17(0.88, 1.57)
Mother's age < 20 (age <20 vs. age 20 to 40)	NI	NI	-0.12 (0.22)	-0.20 (0.20)	0.82(0.55, 1.20)
Mother's age > 40 (age >40 vs. age 20 to 40)	NI	NI	1.01 (0.40)*	1.20 (0.40)*	3.33(1.55, 7.14)

Variable	Model 1 Coefficients β (SE)	Model 2 Coefficients β (SE)	Model 3 Coefficients β (SE)	Model 4	
				Coefficients β (SE)	Odds ratio $e^{-\beta}$
Father's age <20 (age <20 vs. age 20 to 40)	*NI*	*NI*	-0.15 (0.35)	*NI*	*NA*
Father's age>40 (age >20 vs. age 20 to 40)	*NI*	*NI*	0.26 (0.19)	*NI*	*NA*
Neighbourhood socio-economic disadvantage	*NI*	*NI*	*NI*	***0.29 (0.11)****	1.34(1.07, 1.68)
Neighbourhood programs and services	*NI*	*NI*	*NI*	***-0.02 (0.01)****	0.98(0.96, 1.00)
Interaction between neighbourhood social interaction and single parent status	*NI*	*NI*	*NI*	***0.23 (0.10)****	1.25(1.02, 1.53)

Note:
* Significant variables (p<0.05)

NI: Not included in the model

NA: Not applicable

SE: Standard errors

Significant individual risk factors for LBW

At the individual level, there were 5 significant risk factors for LBW, namely family income at birth, mother's age greater than 40 years, single parent, parity, and stillbirth. Specifically, the adjusted odds ratio for family income at birth was 1.80 (95% CI: 1.35, 2.42) which indicated that the odds of having a low birth weight baby in families with low income status was 1.8 times higher than that among family with normal income status.

Parity and prior stillbirth were also significant predictors for LBW. The odds of being a low birth weight baby was 1.51 times higher (95% CI: 1.14, 2.00) if the baby was the first live born of the mother compared to if the baby was the second or higher live born of the mother. Among mothers who had a prior stillbirth, the odds of having a low birth weight baby was 3.99 times higher (95% CI: 2.74, 5.80) compared to that among mother's who had no prior stillbirth. The odds ratio for mother's age over 40 years versus mother's age from 20 to 40 was 3.33 (95% CI: 1.55, 7.14) which indicated that mother who had age over 40 was at a much higher risk of having a low birth weight infant, compared to mother who had age from 20 to 40. Mother's age under 20, however, did not appear to be a significant risk factor for LBW.

Independent effects of neighbourhood factors

The results indicated that the neighbourhood factors indeed had independent effects on LBW. Two significant neighbourhood factors in the final model for LBW were neighbourhood socio-economic disadvantage and neighbourhood programs and services. By looking at their coefficient, it can be concluded that mothers who lived in

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more socio-economic disadvantage neighbourhoods was at a higher risk of having a low birth weight child compared to mothers who lived in more affluent neighbourhoods. For example, adjusted for all other individual and neighbourhood variables, the odds of having a LBW baby among women living in the most socio-economic disadvantage neighbourhood (i.e., at 90th percentiles of neighbourhood socio-economic disadvantage) was 1.83 times (95% CI: 1.48, 2.28) higher than that among women living in the most affluent neighbourhood (i.e., at 10th percentile of neighbourhood socio-economic disadvantage). The level of accessibility and availability of programs and services within a neighbourhood was also associated with the risk of having a LBW baby. For instance, the adjusted odds of having a LBW baby among women living in neighbourhoods with the most available and accessible programs and services was 0.83 time lower than that among women living in neighbourhood with the least available/accessible programs and services (i.e., OR=0.83 with 95%CI: 0.68, 0.87)

The contextual effect of neighbourhood socio-economic disadvantage on having a low birth weight baby can be best visualized through the use of a map as presented in Figure 5-4. Figure 5-4 shows the distribution of socio-economic disadvantage in Saskatoon neighbourhoods (shown in shaded polygons, each representing a neighbourhood; the darker the shade the higher the level of socio-economic disadvantage) overlaid with the predicted rate of LBW babies in Saskatoon neighbourhoods (shown in circles; the larger the circle the higher the predicted rate of LBW). The map shows that neighbourhoods with a higher level of socio-economic disadvantage are generally associated with a higher rate of LBW.
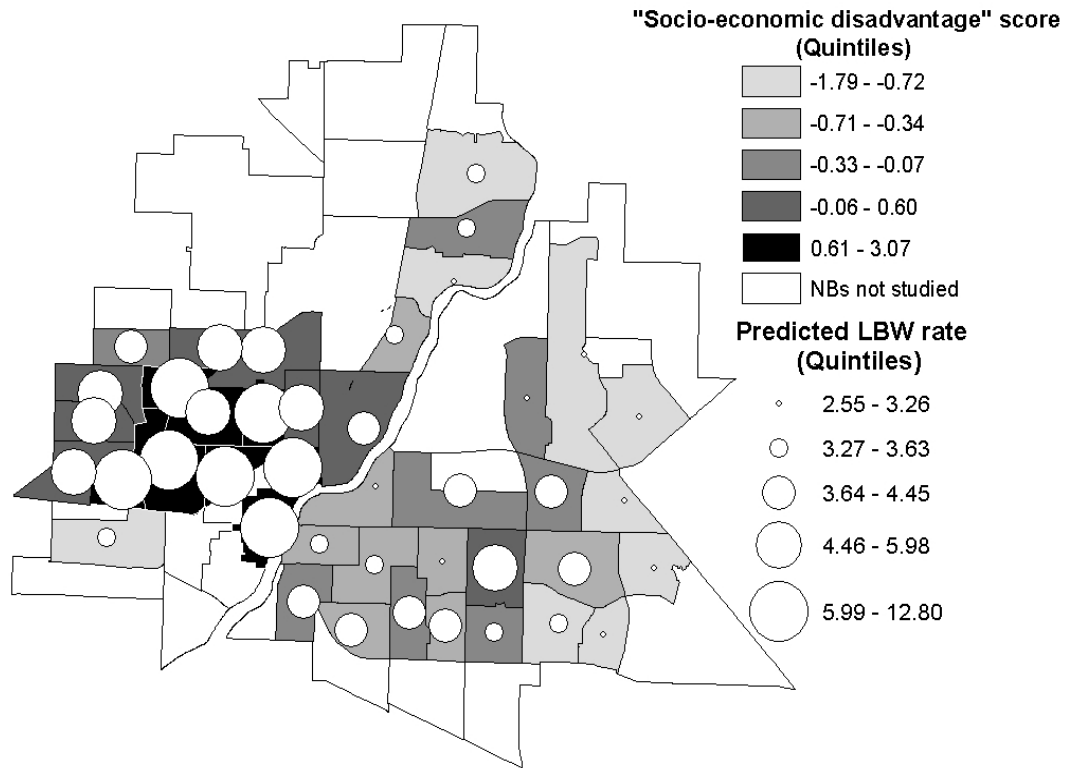
Figure 5-4: Association between the predicted LBW rate and neighbourhood socio-economic disadvantage, based on multilevel model (Table 5-1)

Figure 5-5 shows the association between the availability and accessibility of programs and services and the predicted LBW rate. In this map, the darkest shaded areas indicate the low level of availability/accessibility of programs and services in the neighbourhood. While this map clearly shows that the availability/accessibility of programs and services are varied across Saskatoon neighbourhoods, it also indicates that there is a correlation between lower percentages of LBW and higher level of availability/accessibility of programs and services for the family of children 0-6 years of age.
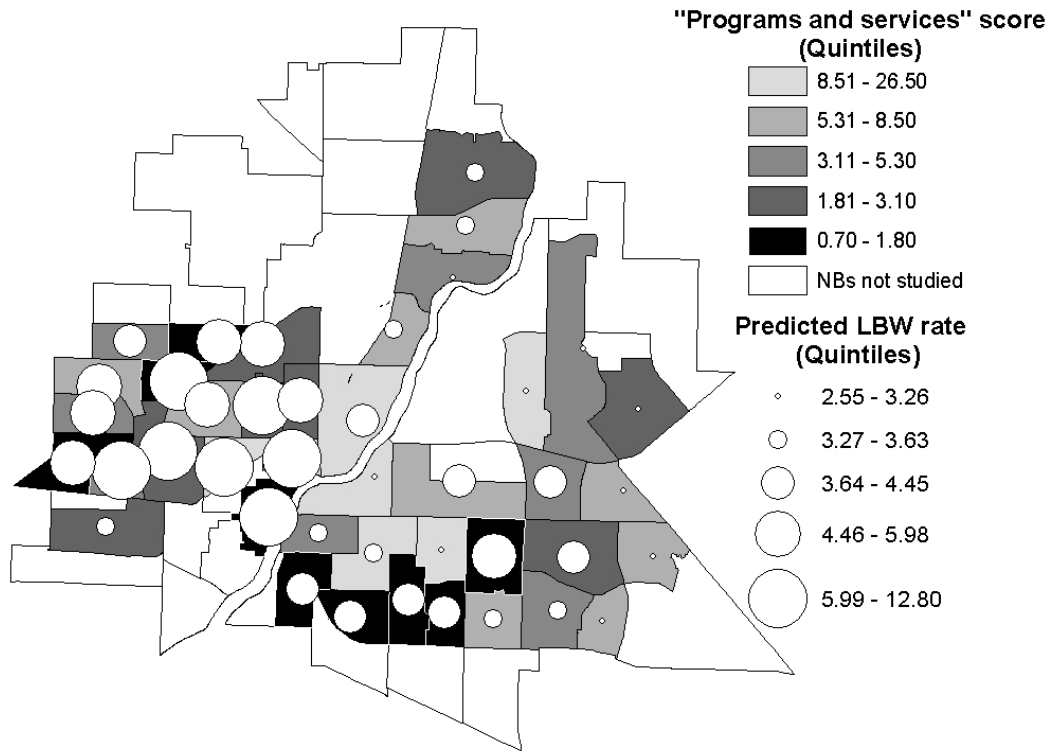
Figure 5-5: Association between the predicted LBW rate and neighbourhood programs and services, based on multilevel model (Table 5-1)

Moderating effect of neighbourhood factors

The moderating effects of neighbourhood factors on the association of some individual risk factors were checked through four cross level interactions (i.e., between neighbourhood socio-economic disadvantage and family income at birth, between neighbourhood socio-economic disadvantage and single parent, between neighbourhood social interaction and family income at birth, and between neighbourhood social interaction and single parent).

In the final multilevel model for LBW, there was only one significant cross level interaction. That was the interaction between single parent and neighbourhood social

interaction. This significant interaction indicated that neighbourhood social interaction acted as a moderator for the association between single parent and LBW or in other words, that the association between single parent and low birth weight changed as a function of the level of social interaction within a neighbourhood.

Since the score of the variable "neighbourhood social interaction" was negatively correlated with the level of social interaction within a neighbourhood (i.e., the higher the score, the lower the level of social interaction), the coefficient of 0.23 of this cross level interaction indicated that the negative impact of single parent status on birth weight was mitigated as the level of social interaction within their neighbourhood of resident was increasing. Figure 5-6 presents the estimated odds ratio of LBW for single parent by the level of social interaction within neighbourhood of residence. For instance, among neighbourhoods with high level of social interaction (at 10th percentile of score), the log odds of LBW associated with single parent was -0.11 (OR=0.89, 95%CI: 0.72, 1.17) while it was 0.44 (OR=1.57, 95%CI: 1.18, 1.93) among neighbourhoods with low level of social interaction (90th percentile of score).
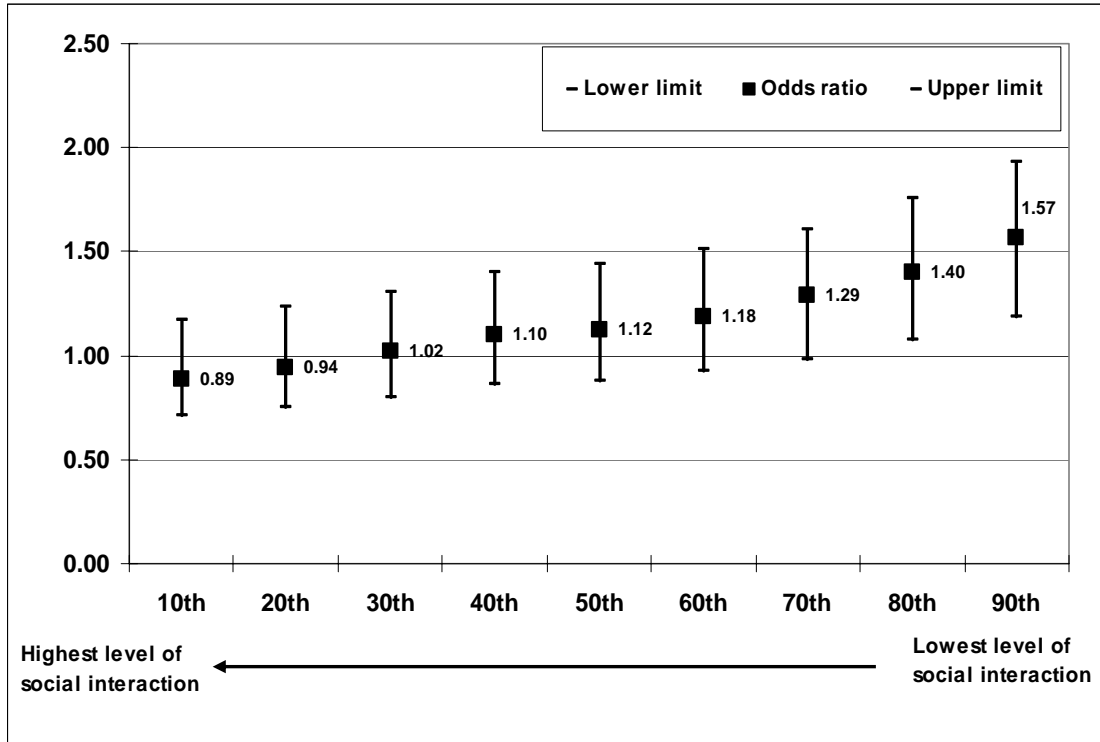
Figure 5-6: Odds ratio of LBW for single parent by the level of social interaction within neighbourhood of residence

The impact of neighbourhood social interaction on low birth weight is presented in Figure 5-7. The brightest and darkest areas of the map represent the highest and lowest level of social interaction within neighbourhood, respectively. The association between neighbourhood social interaction and LBW rate is not clearly seen on this map as in these two previous maps since there was a cross level interaction between neighbourhood social interaction and single parent. Thus, the association between neighbourhood social interaction and LBW in a neighbourhood also depended on the percentage of single parent in that neighbourhood. However, we can see that the majority of the darker shaded areas (i.e., representing a higher level of social interaction) have bigger dots, which represent the higher rate of LBW.
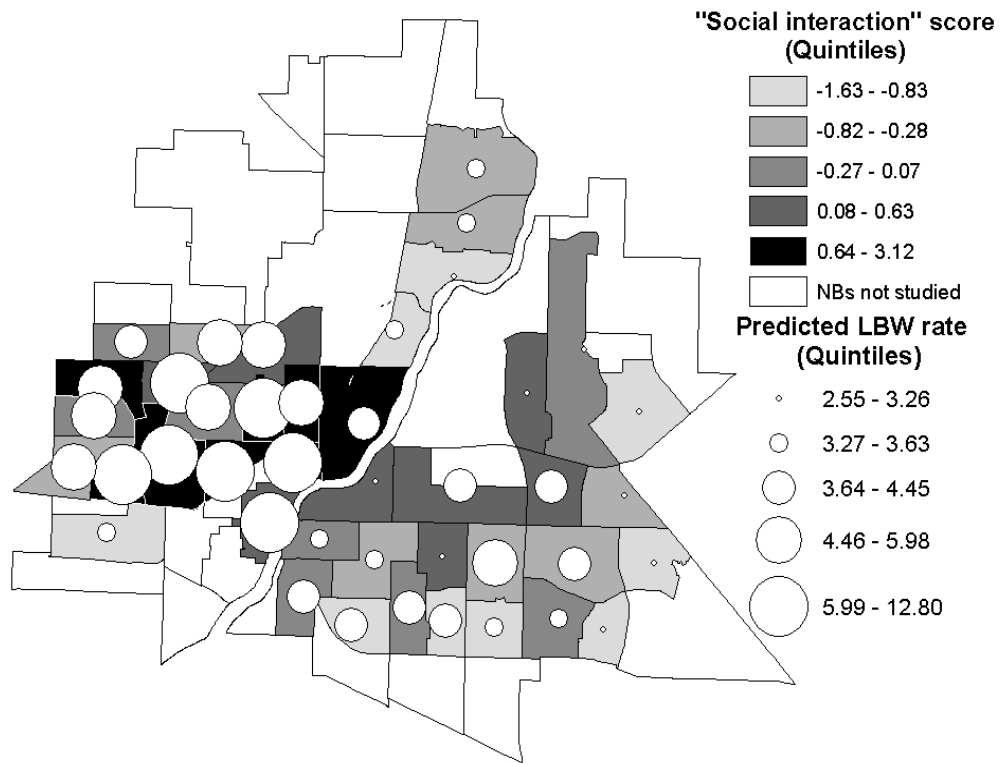
Figure 5-7: Association between the predicted LBW rate and neighbourhood social interaction, based on multilevel model (table 5-1)

5.4.3 Analytical results for Objective 3

Overall contribution of neighbourhood effects to LBW vis-à-vis the contribution of individual effects

As shown in the analytical results for objective 2, three of six neighbourhood variables had significant effect on LBW. Two of them had direct effects and one had an indirect effect through single parent status. Since the level of neighbourhood social interaction acted through single parent, the contribution of this contextual effect into the LBW rate would also depend on the prevalence of single parent in Saskatoon.

Table 5-2 presents the estimation of the predicted probability of having a LBW baby in exposed and non-exposed groups. For individual variables, the exposed group was the group with a specific characteristic (for instance, families with low income at time of birth) and the non-exposed group was the group without that characteristic (for example, families with higher income at time of birth). For neighbourhood variables, the exposed group was neighbourhood at 90th percentile and the non-exposed group was neighbourhood at 10th percentile. Specifically, when controlling for all other variables under the final multilevel model for LBW:

- The change in the status of family income at birth (i.e., from better off to low income) resulted in an increase of 2.90% in the probability of having a LBW baby.

- The change in level of neighbourhood socio-economic disadvantage (i.e., from the most affluent neighbourhoods to the most socio-economically disadvantaged neighbourhoods) resulted in an increase of 2.97% in the probability of having a LBW baby.

- The change in level of neighbourhood social interaction (i.e., from the highest to the lowest level of social interaction) resulted in an increase of 0.66% in the probability of having a LBW baby.

- The change in availability and accessibility of neighbourhood programs and services for children and their families (i.e., from the most available and accessible to the least available and accessible) resulted in a decrease of 0.81% in the probability of having a LBW baby.

Table 5-2: Estimation of the predicted probability of having a LBW baby in exposed and non-exposed groups*

Variables	β	Probability of LBW in non-exposed group	Probability of LBW in exposed group	Difference
Individual risk factors				
Family Income	0.59	3.87%	6.77%	2.90%
Mother's age >40	1.20	4.15%	12.56%	8.41%
Parity	0.41	3.56%	5.26%	1.70%
Stillbirth	1.38	4.08%	14.46%	10.38%
Neighbourhood risk factors				
Social interaction	0.23	4.76%	4.10%	-0.66%
SES disadvantage	0.29	3.52%	6.49%	2.97%
Programs and services	-0.022	4.65%	3.84%	-0.81%

The predicted probability of having a LBW baby was calculated using the formula $p=[1+exp(-X\beta)]^{-1}$. The coefficients (β) came from the final multilevel model for LBW (model 4 in table 5-1)

From those estimations, it was observed that the change in the predicted probability of having a LBW baby due to the change in the neighbourhood socio-economic status was more significant than that due to the change in family income status. More importantly, the effect of changing several neighbourhood factors at once would even be more pronounced. For example, if all of the individual level variables were held at their means, the model predicted a minimum probability of LBW of 2.62 % in Lakeridge and Briarwood and a maximum of 9.62 in Pleasant Hill, a change of 7% in absolute term.

5.5 Discussion

The goals of this paper were to estimate the independent effects of neighbourhood characteristics on LBW and to assess whether neighbourhood factors either exacerbate or mitigate the impact of well-known individual level risk factors on LBW. It was hypothesized that LBW rate would vary significantly across Saskatoon neighbourhoods and that this variation would be due to not only the differences in the characteristics of individuals living within neighbourhoods but also to the differences in the characteristics of the neighbourhoods themselves. While individual level risk factors for LBW have been well-known, it was hypothesized that some neighbourhood factors would either exacerbate or mitigate the effects of individual risk factors on LBW.

Results of the descriptive analysis (i.e., mapping) showed that LBW rate was distributed variably across Saskatoon neighbourhoods, with the higher rate concentrated in neighbourhoods in the West side of the city. Neighbourhoods in the West side of the city were also known to have higher rates of low income families, Aboriginal peoples, and single parent. However, the compositional effects of individual characteristics did not totally explain for the higher rate of LBW in these neighbourhoods. Results showed that indicators of neighbourhood socio-economic disadvantages and neighbourhood programs and services for children and parents had independent effects on LBW over and above individual risk factors. Also including neighbourhood level variables in studies of LBW was necessary in order to obtain a better explanatory model for LBW.

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Specifically, the indicator of neighbourhood programs and services for children and parents was shown to have a negative correlation with the risk of LBW. This indicator measured the availability and accessibility of the following programs and services in the neighbourhood of residence: early education, parenting, parent relief, counselling, family support, birth/prenatal, nutrition, childcare, special needs, sports and recreation for children, the higher the value of this indicator, the more accessible and available the programs and services in the neighbourhood. These kinds of programs and services could help to reduce the risk of having a LBW baby by providing mothers and their families with information regarding appropriate nutrition for pregnancy, prenatal care, material support (e.g., food, help with household work…etc), and counselling to reduce the level of stress, counselling to help with unhealthy behavior problems (e.g., smoking, alcohol consumption). One may argue that although programs were designated by their location to a neighbourhood, many programs serve a population that reside in a wider geographical location. However, while it is true that some people might use the programs and services that are available and accessible in other neighbourhoods, others might not have the facility to do so (i.e., they do not own a vehicle and public transportation is not available or not convenient). Thus, health policy makers and health promotion programmers should keep in mind the importance of the availability and accessibility of programs and services in Saskatoon neighbourhoods when designing interventions to reduce the risk of LBW.

Neighbourhood socio-economic disadvantage had a positive correlation with the risk of LBW. Neighbourhood socio-economic disadvantage reflected the high

concentration of Aboriginal peoples, low income families, populations with an education level less than grade 9, single parents, low concentration of employment, owned houses, and average car per person. There are several possible explanations for the effect of neighbourhood socio-economic disadvantage on the higher risk of having a LBW baby. Focus on neighbourhood socio-economic disadvantage as an aggregation of individual characteristics, the first explanation and the most intuitive one is compositional effect, which involves factors influencing maternal health only at the individual level. Compositional effect means that women in high-poverty, high-unemployment communities have fewer material resources and therefore run higher risks for malnutrition, lower quality health services, and stress. However, in this study, the effect of neighbourhood socio-economic disadvantage still shows significance after the effect of family income is controlled for. Thus, this observed association cannot be totally explained by the compositional effect of individual socio-economic characteristics. The second possible explanation for the impact of neighbourhood socio-economic disadvantage on LBW is the social environment experienced by the women living in socio-economic disadvantaged neighbourhoods (i.e., contextual effect). Some authors have suggested that the level of socio-economic disadvantage in a neighbourhood serve to undermine the cultural standards in that neighbourhood, which in turn has an impact on the health related behaviors of individuals living in that neighbourhood (e.g., violence, drug use, irresponsible sexual activity, smoking, alcohol consumption). This serve to destabilize families as well as to erode the support network available to an individual mother within that neighbourhood.[125,174,175] Another explanation for the observed association between neighbourhood socio-economic

disadvantage and LBW may be that communities with high concentrations of poor, single parent families, unemployment and low concentrations of well-educated professional and managerial workers and owned houses are unlikely to have or attract the resources necessary to develop and sustain high quality institutions, organizations, and services such as health clinics, supermarkets, grocery stores, and public transportations.[175-177] Moreover, the greater needs of residents in such disadvantaged neighbourhoods may overtax existing institutions, organizations, and services.[103] Others have also suggested that the socio-economic characteristics of communities can affect the physical condition of these communities (housing, road condition, park, play ground…etc)[177-179] which in turn can impact the health of all residents. However, in this study, when the impact of the physical condition of the neighbourhood was taken into account, the neighbourhood socio-economic disadvantage still showed significant association with LBW risk. This result indicated that policies and programs directed at increasing sustained economic activities and opportunities in disadvantaged neighbourhoods would be an effective strategy in enhancing maternal and children's health in these areas. The finding about the significance of the association between neighbourhood socio-economic disadvantages and less favourable birth outcomes in this study is consistent with the results of other studies. [50,125,168,172]

More interestingly, results showed that neighbourhood factors acted not only as independent predictors for LBW but also as moderators for the association between individual risk factor and LBW. Results indicated that the association between single parenthood and LBW changed as a function of the level of social interaction within a neighbourhood. In a neighbourhood with a high level of social interaction, single

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parenthood was not associated with the higher risk of having a LBW baby and in a neighbourhood with a low level of social interaction, single parenthood was a risk factor for LBW. The indicator of neighbourhood social interaction in this study was constructed from five neighbourhood variables. Of these, four were used as crude indicators for collective efficacy within the neighbourhood (i.e., percentage of voter participation for Saskatoon, percentage of voter participation for federal, percentage of mover, and ethnic diversity) and one was used as a crude indicator for social disorder within the neighbourhood (i.e., crime incidence). Thus, our measure of "neighbourhood interaction" is conceptually related to constructs of social capital[180] and collective efficacy.[21] These constructs all reflect social processes that may operate within a neighbourhood to benefit residents.

So how might the level of social interaction within the neighbourhood of residence affect the association between single parenthood and LBW? As shown in Figure 5-8, there are three general mechanisms through which social interaction may protect against the deleterious effect of single parenthood. First, social interaction may have influenced the health behaviors of single parents in a neighbourhood by facilitating the diffusion of health information[180] (e.g., taking folic acid during pregnancy, appropriate nutrition, exercise …etc) and by exerting the social control of health related behaviors[181] that could affect the health of the fetus such as smoking, drinking alcohol. For example, social support has been consistently associated with reduced cigarette smoking and substance abuse during pregnancy.[182,183] Neighbourhood social interaction could thus result in improved utilization of and compliance with medical care as well as positive health care behaviors during

pregnancy. Second, social interaction may have acted through psychosocial processes, for instance by providing emotional/appraisal, increasing self esteem/self efficacy/social competence or reducing social isolation/stress for single mother.[180] For instance, some studies suggested that good social support may directly affect intrauterine growth by dampening adverse hormonal and immunologic reactions to stressors.[183,184] Third, social interaction could have affected the availability and accessibility of resources and services such as health clinics, recreational facilities...etc that are directly relevant to health.[37]

Previous studies had shown that neighbourhood support were significantly associated with infant birth weight[167] but, to our knowledge, this is the first study which reported a buffering effect of neighbourhood social interaction among high risks group such as single parents. This finding adds to the growing evidence that the neighbourhood social processes has a positive effect on the health of residents and suggests that neighbourhood support, engagement, and collective efficacy are areas of potential impact for public health policy and practice. However, it is important to note that there are some limitations with our measure of neighbourhood social interaction and interpretation of this finding should consider these limitations. First, the information used to construct the measure of neighbourhood social interaction in this study was quantitative data and thus lacked individual perspective. While quantitative data was routinely available through Census Canada and thus offered a relatively quick and cost-effective way to study the effects of the neighbourhood, qualitative data (i.e., individual perspective) such as satisfaction with the neighbourhood, level of trust, and norms of reciprocity would provide more insightful knowledge regarding the social

processes operating within a neighbourhood to the benefit of residents. Second, the length of stay in a neighbourhood (i.e., "exposed" time to the neighbourhood social environment) was not taken into account. This may have resulted in an underestimation of the effect of the neighbourhood social interaction. Third, the use of census boundaries in this study may also have biased the estimation of this effect since the social interaction pattern of individuals may not correspond with the census area. We believe, however, that the buffering effect of the neighbourhood social interaction observed in this study may provide insight to further analyse on these aspects of birth outcome and maternal and children's health. The analytical results suggested that efforts to organize neighbourhood events or bring people to engage in local activities and thereby increasing their local interaction as well as strengthening and widening their support networks may bring numerous benefits for single parent families.

Contrary to our expectations, three other indicators of neighbourhood, physical condition, unhealthy lifestyle norms, and population density, were not significantly associated with LBW. The non-significance of these variables might be explained by the fact that there were some inter-correlations among neighbourhood variables (i.e., the most socio-economic disadvantage neighbourhoods would also be the neighbourhoods with the worst physical condition, high prevalence of unhealthy lifestyle norms). Also, neighbourhood socio-economic disadvantage, social interaction, and programs and services were probably better markers for the underlying process of neighbourhood effect on LBW. Thus, when neighbourhood socio-economic disadvantage was taken into account, other indicators of neighbourhood no longer showed significant effects.

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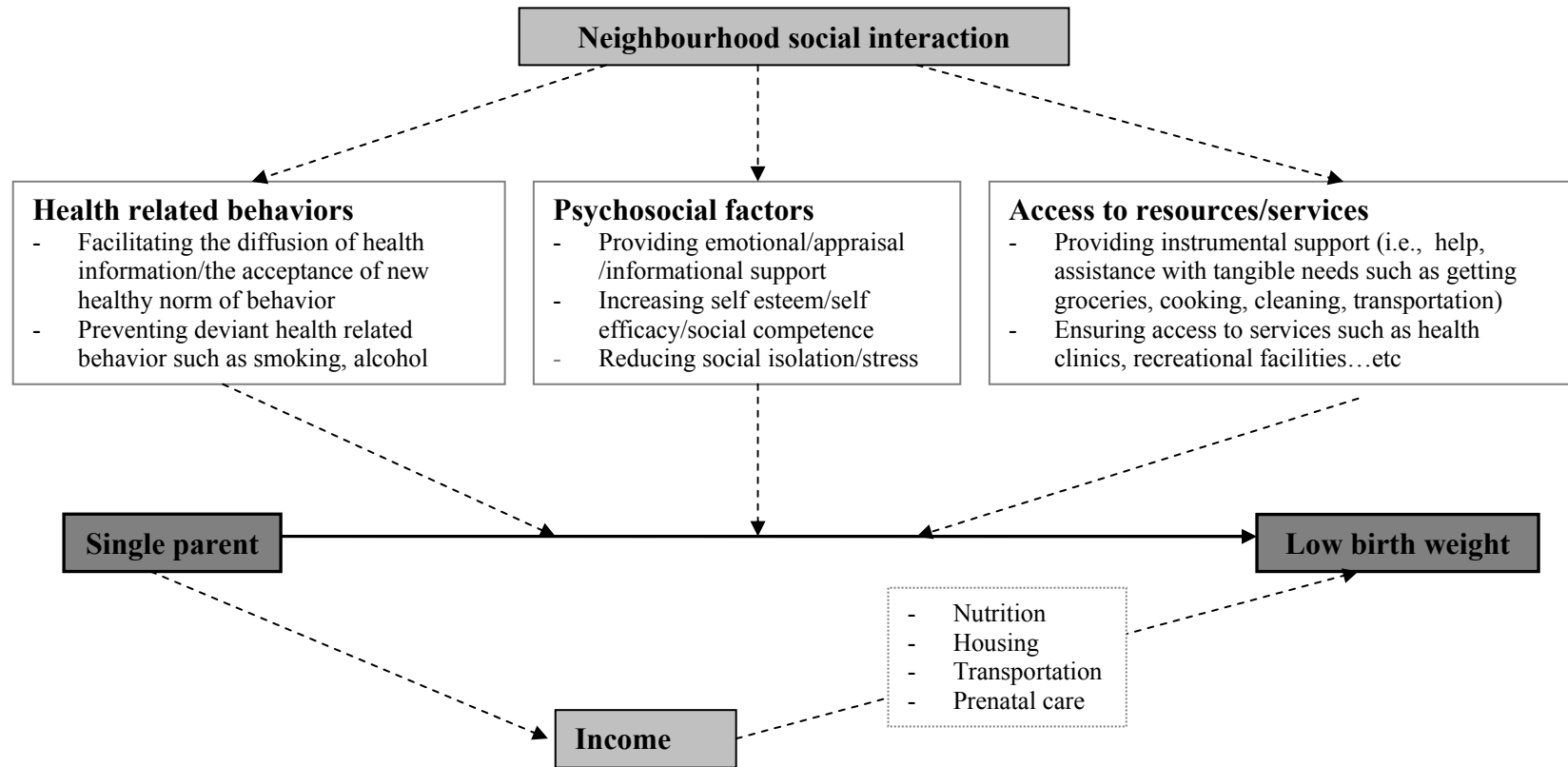
Figure 5-8: Possible pathways for the mediators/moderating effect of neighbourhood social interaction and family income at birth

Apart from these major findings about neighbourhood effects, our results also indicated that individual level variables such as parity, previous stillbirth, a more mature mother's age (i.e., over 40 year), and low family income at birth were all significantly associated with a higher risk of having a LBW baby. The finding on parity (i.e., number of previous liveborn) is consistent with the literature that pregnancy outcomes are less favourable for primiparae than for multiparae. [17,152] Other authors have also reported that prior stillbirth is a risk factor for LBW. [17]

As expected, families who relied on government assistance plans at time of birth were more likely to have LBW babies, compared to families who did not rely on financial assistance. The financial assistance variable was used as a proxy measure for family income and therefore, this association illustrated the relationship between social-economic status and adverse birth outcomes, which is well documented in the literature. [159-162] One may argue that low income is not an actual causal factor of LBW; rather, the observed association is due to confounding effects not controlled for in this study such as nutrition, toxic, and health related behaviors (smoking, alcohol consumption). However, it has also been discussed that low socio-economic status is a social "cause" of other nutritional, toxic, infectious factors, and health related behaviors (which are actual casual determinants of LBW) and that indirect causal effects may be important for intervention. [17,164]

As found in this study, the association between the mother's age and the higher risk of having a LBW baby can be supported by the evidence that older

women may have an increased risk of placental problems and may be more sensitive to adverse effects of other factors.[126,139,163,185-187] Previous studies have also reported young mother's age as a risk factor for LBW.[134,137-139] However, in this study, the results indicated that young mother's age (i.e., under 20) was not significantly associated with a higher risk of having a LBW baby. This finding is interesting because it supports the hypothesis that the increased risk in adolescent pregnancies might be attributed to socio-economic characteristics associated with teenage mothers rather than to physiologic factors[17,140,141] since in this study when family income and single parent status were taken into account, a young mother's age is no longer significantly associated with a higher risk of LBW.

In terms of the contribution of neighbourhood or contextual effects to LBW, it was estimated that the difference in LBW probability between the most affluent and the most socio-economic disadvantaged neighbourhoods was 2.96%, which was larger than the difference in the probability of having a LBW baby between people living in low families and better off families. More remarkably, the maximum change in the probability of having a LBW baby due to all three neighbourhood factors (i.e., neighbourhood socioeconomic disadvantage, neighbourhood social interaction, neighbourhood programs and services) was 7%.

One may question whether the robust impact of neighbourhood factors on LBW observed in this study is due to selection bias or confounders. Selection bias or confounder refers to the case where there may be unmeasured factors (e.g., smoking,

alcohol consumption, drug use, violence, nutrition, prenatal care) that affect both a

person's residential choice and her birth outcome, resulting in a spurious robust

effect of neighbourhood socio-economic disadvantage and LBW. It also may be that

a neighbourhood socio-economic disadvantage is simply capturing an unmeasured

dimension of individual level or family socio-economic status such as education

level or occupation. However, all the estimations were adjusted for family income,

marital status, and the popularity of unhealthy lifestyle norms within a

neighbourhood (prevalence of smokers in the neighbourhood) and these variables

were known to be highly correlated with other potential confounders. Thus, we hope

that controlling for family income, marital status, and the popularity of unhealthy

lifestyle norms within the neighbourhood would help to reduce this selection bias.

More importantly, it has been argued that these unmeasured factors (i.e., potential

confounder) could have been shaped by the neighbourhood environment[103] and that

even though neighbourhood impact may act through some family/individual factors,

the inclusion of all possible individual factors is often impossible, redundant and

may even be counterproductive for the identification of intervention points for

public health policy and action. [25,35]

In conclusion, results of this focused topic indicated that the neighbourhood

of residence indeed had effects on the resident's birth outcome over and above

individual socio-economic characteristics, and that these effects were quite

pronounced. Thus, this study's findings suggest that future interventions aimed at

reducing LBW may be enhanced by targeting both high risk individuals and high

risk neighbourhoods.

FOCUSED TOPIC 2

6 PATTERNS AND MULTILEVEL DETERMINANTS OF CHILDHOOD HOSPITALIZATION

This chapter will present the second focused topic, which examined the distribution of hospitalizations, as well as the effects of individuals and neighbourhood risk factors on childhood hospitalization. The first section presents the research objectives as well as the rationale of the study. The second section covers the literature review for this study with an emphasis on the association between neighbourhood and some specific childhood health outcomes. Analytical methods used in this focused topic and other related issues are discussed in the third section. In the fourth section, the analytical results are presented by research objectives. This chapter is concluded with a brief discussion of study findings, strengths, limitations and policy implications.

6.1 Introduction

The objective of this thesis is to examine the independent effects of neighbourhood factors and the moderating effects of neighbourhood factors on the association between individual risk factors and children's health outcomes. In the previous chapter, the first focused topic, LBW was used as an indicator of children's

health outcomes. In this chapter, the second indicator of children's health outcome, childhood hospitalization, will be examined in order to address the overall research questions. Children's hospitalization (both incidence and volume) may be considered a good indicator of children's health status. Children's hospitalization reflects health deficit or morbidities in children, provided that there is minimum or no barrier to access health services, which is likely the case for most people residing in Saskatoon. Canada's universal health care insurance programs have removed financial barriers to accessing medically necessary health care for Canadians including residents in Saskatoon. [188] Also, unlike in rural areas where traveling long distance to the point of service is necessary, in a relatively compact city like Saskatoon accessibility of services due to distance does not figure in as a significant issue. In this context, examining hospitalization in order to understand the social impact on children's health makes sense.

Numerous studies have demonstrated that childhood morbidities in particular and childhood health outcomes in general vary across different neighbourhoods. [189-191] However, it is not clear whether these disparities result from differing neighbourhood conditions or from differing characteristics of households that tend to live in different neighbourhoods. Providing a valid answer to this question requires a multilevel approach that includes both information about the individual's socio-economic status and the measures of the neighbourhood environment. [4,20,192] Unfortunately, most previous studies examining the area/neighbourhood effects on childhood morbidities, mortalities and health care utilization employed ecological or small area designs and thus were not able to make valid inference about neighbourhood effects. Few studies

have employed multilevel analysis to examine neighbourhood/area effects on children and adolescent behaviour outcomes, [193] children's injury, [194] children's respiratory disease,[195] and children's mental health services use.[196] Thus, the role of the neighbourhood/area level characteristics in determining children's health and children's use of health care services is an under-researched area. We need to better understanding of how characteristics of the area of residence affect children's health independently and in combination with individual level factors.

Also, neighbourhood socio-economic characteristics have been the focus of most studies,[32,46] while aspects of neighbourhoods that matter to children are not just socio-economic characteristics but also physical, social, cultural, and political. Most population health research to date has not fully examined how these various contextual dimensions together influence health outcomes. In most cases, the theoretical stance taken by the researchers, or the data available, remains at the level of observation of relationships between some aspects of the individual or his/her social environment, still fairly narrowly defined, and selected health outcomes. Studies rarely include sufficient detail on the immediate contexts of people's lives to assess how these often overlapping contexts might shape the individual level associations observed by the researchers. Thus, studies which simultaneously examine various aspects of neighbourhood are needed to shed new light into our understanding with regard to neighbourhood effects.

The associations between poverty and childhood morbidities have been the focus of recent research.[16] These studies, however, have some limitations. First, previous studies were mostly cross-sectional, providing only a "snapshot" of the

association between poverty and childhood morbidity and therefore limiting any inference of causation. Second, these studies were performed at the individual level[195], even though, it is generally acknowledged that socio-economic status operates at multiple levels (societal as well as individual) to affect well-being.[16,78] Thus, there is a need for studies which employ both longitudinal and multilevel design to examine how socio-economic conditions at the individual and neighbourhood level may independently influence children's health.

The impact of adverse birth outcomes (LBW, preterm birth or small for gestational age) on children's health has been well recognized. [17,119,127] What has received little attention from researchers are (1) how the combination of adverse birth outcome (for example, children born low birth weight and preterm or children born small for gestational age and preterm) affects childhood hospitalization and (2) if children born with adverse birth outcomes commence their life with health deficit, what factors would heighten/lessen the deleterious impact of adverse birth outcome on children's health? For instance, does family income moderate the impact of adverse birth outcomes on childhood health outcomes?

In summary, research on children's health and especially on children's hospitalization has not considered simultaneously: (1) the contribution of socio-economic status at multiple levels; (2) the impact of the combination of adverse birth outcomes and factors that modify the effects of adverse birth outcomes; and (3) the role of various aspects of neighbourhood such as physical condition, programs and services, social interaction, unhealthy life style norm and population density. This

focused topic attempts to solve these issues by addressing the following four specific objectives:

Objective 1: To describe the major causes of hospitalization in children from 0 to 6 years; specifically, to identify differences in the distribution of major causes of hospitalizations between children born with adverse birth outcomes and children born without adverse birth outcomes, and between children in low income families and children in better-off families. The following hypothesis was examined to address this objective.

Hypothesis 1: Major causes of hospitalization will be different between children born with adverse birth outcomes and children born without adverse birth outcomes, and between children in low income families and children in better-off families.

Objective 2: To examine the relative impact of adverse birth outcomes and family income, and the interaction effects between them, on hospitalizations. The following hypotheses were examined to address this objective.

Hypothesis 2a: Children born with at least two adverse birth outcomes will have the highest incidence rate of hospitalization and average days of stay, while children born with only one adverse birth outcome will have the second highest and children born with no adverse birth outcome will have the lowest incidence rate of hospitalization and average days of stay..

Hypothesis 2b: Children in low income families, compared to children in better-off families, will have significantly higher incidence rates of hospitalizations and longer stays in hospital.

Hypothesis 2c: The impact of adverse birth outcomes on childhood hospitalization will change as a function of children's family income status.

Objective 3: To examine the independent effects of neighbourhood factors on hospitalizations as well as their moderating effects on the association between selected individual risk factors and childhood hospitalization. The following hypotheses were examined to address this objective.

Hypothesis 3a: Neighbourhood factors will be associated with hospitalizations, in addition to the effects of individual risk factors.

Hypothesis 3b: The effects of some individual risk factors (i.e., single parent, low income) on childhood hospitalization will change as a function of the level of socio-economic disadvantage or social interaction within a neighbourhood.

Objective 4: To compare the relative overall effects of family income status and neighbourhood factors on childhood hospitalizations. The following hypothesis was examined to address this objective.

Hypothesis 4: The overall effects of neighbourhood factors on hospitalizations will be stronger than the effects of family income status.

The three specific research objectives addressed in this focused topic are closely related to the overall research questions, which were stated in Chapter 1, "Introduction". Specifically, objective 3 will address the overall research question 1

(by testing hypothesis 1) and research question 2 (by testing hypothesis 2). Objective 4 will address the overall research question 3

Hospitalization accounts for a large portion of the expenditures for children's health care, and differences in the rate of hospitalization may produce important variations in the cost of that care. It is hoped that intervention based on this study's finding can improve health status and the children's quality of life in the first six years of life, as well as help to reduce the expenditures for children's health care.

6.2 Literature Review

6.2.1 The Model of Health Service Utilization

The determinants of hospitalization or utilization of physician services are complex, multidimensional, and not completely understood. The behavior model of utilization, developed by Andersen and other, is one of the most frequently used frameworks for analyzing the factors that are associated with patient utilization of health care services. The initial behavioral model[197] - the model of the 1960s- is expressed in Figure 6-1. This model assumes that the use of health services is dependent on three components: (1) the predisposition of the individual to use services, (2) the ability to secure services, 3) the illness level.

Predisposing Factors: Some individuals are more likely to use health services than others, even though these predisposing characteristics are not direct causes for health care service utilization. Such characteristics include demographic, social structural and attitudinal-belief variables. For example, age is considered to be a predisposing characteristic because it is intimately related to health and illness but is not a reason for seeking health care services. Social structural variables, such as

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education and occupation, reflect the status of the individual in society, and influence life style, social environment and behavior patterns, which may be related to the use of health care services. Attitudes and beliefs about medical care can also predispose individuals to a greater or lesser extent to use the health care system. Like the other predisposing variables, health beliefs are not considered to be a direct reason for using services but may result in creating differences in the inclination toward health services utilization, an individual who strongly believes in the efficacy of treatment and the capacity of doctors is likely to seek a physician sooner and more often than an individual with less faith in the results of treatment.

Enabling Factors: Although individuals may be predisposed to use health services, some conditions must be available for them to do so. Enabling conditions make health service resources available to the individual. Enabling conditions can be measured by family resources and community resources. Family resources include income, level of health insurance coverage or other sources of third-party payment, whether or not the individual has a regular source of care, the nature of that regular source of care, and the accessibility of the source. Community characteristics such as number of health personnel, availability of facilities, price of health services, urban-rural residence are also among other enabling factors.

PREDISPOSING → **ENABLING** → **ILLNESS LEVEL**

Demographic
Age
Sex
Marital Status
Past illness

Social Structure
Education
Race
Occupation

Belief
Values concerning health and illness
Attitudes toward health services
Knowledge about disease

Family
Income
Health Insurance
Type of regular source
Access to regular source

Community
Ratios of health personnel and facilities to population
Price of health services
Region of country

Perceived
Disability
Symptoms
Diagnoses
General State

Evaluated
Symptoms
Diagnoses

Figure 6-1. Andersen-Newman model of individual determinants of health service utilization

Source: Andersen R, Newman JF. Societal and individual determinants of medical care utilization in the US. Milbank Memorial Fund Quarterly 1973, 51:95-124.

Illness Level: With the presence of predisposing and enabling factors, the individual must perceive illness or the probability of its occurrence in order to seek health care services. Illness level represents the most immediate cause of health care service use. Illness level includes the perception of illness by the individual and clinical evaluation. Measures of perceived illness include the number of disability days that an individual experiences, symptoms the individual experiences in a given time

period, and a self-report of general state of health. Evaluated illness measures are attempts to evaluate the actual illness problem that the individual is experiencing and the clinically judged severity of that illness. It would include a physical examination of the individual and some expensive, alternative measures if possible.

During the 1980s-1990s, a new phase of the model, the environmental component, was added, spurred on by the explicit recognition that the external environments (including physical, political, and economic components) were an important input for the use of health services. The new model, as depicted in Figure 6-2, portrays the multiple influence on health services' use and, subsequently, on health status.[198] It also includes feedback loops showing that outcome, in turn, affects subsequent predisposing factors and perceived need for services as well as health behaviours.

The environmental component in the new model includes (a) healthcare delivery system characteristics, (b) external environment factors, and (c) community-level enabling variables. Healthcare delivery system characteristics are the policies, the resources, the organization, and the financial arrangements influencing the accessibility, availability, and acceptability of medical care services (e.g., physician supply). External environmental factors reflect the economic climate, the relative wealth, the politics, the level of stress and violence, and the prevailing norms of the society. Community-level enabling variables include the attributes of the community where the individual lives that enable the individual to obtain services (e.g., the availability of physicians in the community). These variables are often measured at the aggregate level, for example, the percentage of the population that is urban within a

state. However, they can also be measured at the individual level when they identify the context in which the individual "lodges", for instance, whether a patient lives in an urban or a rural area (which is a proxy for more specific measures such as availability of services)[199]

The introduction of environmental or contextual variables into the model has two implications for the studies on the determinants of health services utilization. First, because the environmental variables are often measured at the aggregate level while other variables in the model are measured at the individual level, advanced analytical techniques that take different levels into account should be used to better specify the relationships among variables at different levels. Second, contextual variables often have complex relationships with other variables and have indirect as well as direct associations with health services utilization. The common simple regression analysis, which has often been used to analyze the correlates of health services utilization, is less useful when analyzing these complex associations since it does not separate out the independent influence of variables or take into account the causal ordering of variables.[199]
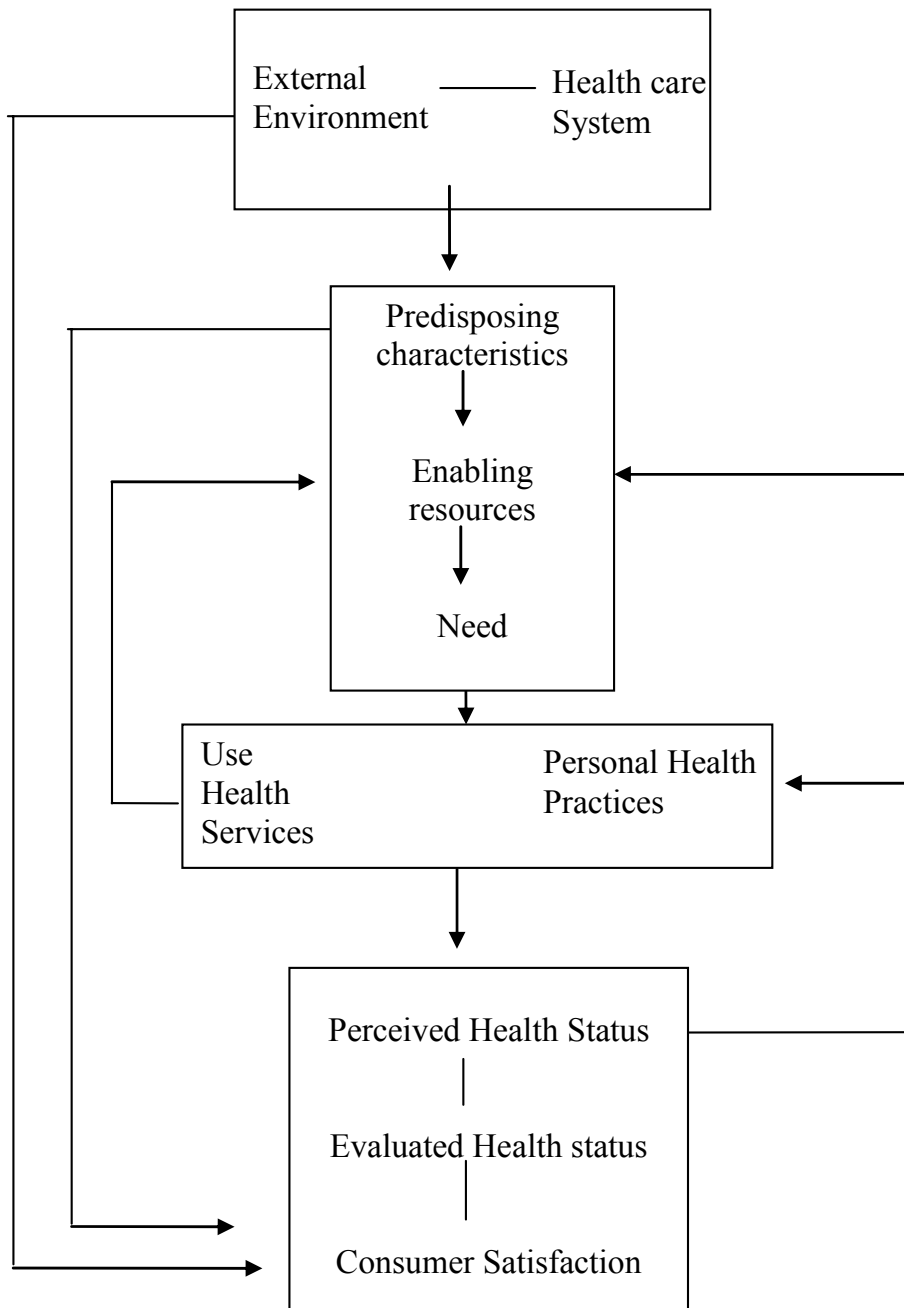
Figure 6-2: The new behavior model of health services utilization

Source: R.M. Andersen, 1995."Revisiting the Behavioral Model and Access to Medical care: Does It Matter?" Journal of Health and Social Behavior 36 (March): 1-10.

6.2.2 Socio-economic Status and Health Services Utilization

Of all the determinants of health care utilization, the role of economic factors is perhaps the most inconclusive and the most controversial.[200] Some authors have suggested that in the absence of a comprehensive insurance coverage, socio-economic factors were positively related to health services utilization despite the fact that persons of lower socio-economic status experience a much greater incidence of morbidity and mortality and therefore, a higher need for medical care.[201,202]

In Canada, universal and comprehensive public health insurance schemes, such as the hospital and medical insurance programs, have frequently been justified on the grounds that all citizens should be provided with unimpeded access to medically necessary health care and that the use of service should be based on people's medical need rather than their ability to pay. Participating health plans in Canada must satisfy the following four main principles:[188]

1) **Comprehensiveness:** provincial plans must provide all inpatient and outpatient services to which residents of the jurisdiction are entitled.

2) **Universality:** provinces must make insured services available to all residents of the province.

3) **Accessibility:** the provincial law must make "provision for insured services in a manner that does not impede or preclude, either directly or indirectly, whether by charges or otherwise, reasonable access to insured services by persons entitled thereto and eligible therefore."[203]

4)   **Portability:** a province must "make for the payment of amounts to hospital in respect of the cost of insured services, and the payment for insured services provided to residents of the province who are eligible therefore and entitled thereto by hospitals that are owned or operated by Canada or are situated outside the province."[204]

The change in the use of health services by members of different income groups after the introduction of the publicly financed hospital insurance scheme in Saskatchewan was examined in Beck's study. He noted that during the period 1963-1968, there was a general increase in contact with hospitals over time among the three lowest classes of income and concluded that members of poor families spend more time in a hospital than members of middle or upper class families.[205]

In a study about the influence of co-payment charges on the use of hospital care in Saskatchewan, after examining the determinants of hospital use by 40,000 Saskatchewan families during the period 1966-1971, Horne suggested that the likelihood of at least one admission per family is inversely related to economic status. That is, members of low income families were more likely to experience at least one hospital episode during the study period.[206]

In Boulet and Henderson's study using Statistics Canada data collected from a supplementary questionnaire to the Survey of Consumer Finances of 1975, the results of the analysis showed that poor members of society used a greater volume of care, as measured by the length of stay, than their wealthier counterparts after controlling for age and sex. [207]

In the US, Newacheck and Starfield[208] found that while a notable minority of children from all socio-economic levels suffered from multiple health problems, the impact of multiple conditions (in terms of days spent ill in bed) was much greater for children from low-income families.

More recently, Manga et *al.*. conducted a study to examine the influence of medical needs, socio-demographic, and economic factors in determining the use or non-use of hospital care and the volume of service consumed by those who experienced an episode of hospitalization during the study period. Using data from the Canada Health Survey, the results indicated that the use or non-use of hospital care was determined by medical need, marital status, but independent of economic status while volume of care consumed was dependent on economic status. The poor and the middle-income groups used more inpatient service than the wealthier members of the study.[200]

The literature regarding the impact of socio-economic status on children's health is broad, however most studies are cross-sectional studies (i.e., examining the association at one point in time), thus they are not be able to capture the dynamic nature of changing economic circumstances. This is particularly important when examine the multiple pathways from SES to poor health impacts. Longitudinal studies are required in order to further advance scientific understanding of the impact of SES on children's health, and from which to base interventions and policies.

6.2.3 Neighbourhood Impact and Childhood Outcomes

The literature relating the impact of neighbourhood on children's health outcomes is sparse and not fully consistent. The most frequently examined

neighbourhood dimension is socio-economic aspect. The outcomes examined most frequently are behavioral problems. Other outcomes examined in previous studies are morbidities such as overweight, congenital anomalies, injury, hospitalization, respiratory diseases.

Behavioral outcomes

For example Kalff *et al.* carried out a study in the city of Maastricht, the Netherlands to examine whether neighbourhood level socio-economic variables have independent effects on reported child behavioral problems over and above the effect of individual level measures of socio-economic status. The study sample included 734 children age 5-7 years. The limitation of this study was that the non-response rate was high (48.2%), thus the internal validity of the study may be suspect. Also, this study used cross sectional survey data, thus it was impossible to study the impact of the dynamic change in family income (i.e., required longitudinal data) on child behavioral problems. The authors concluded that living in a more deprived neighbourhood was associated with higher levels of child behavioral problems, irrespective of individual level socio-economic status. The additional effect of the neighbourhood may be attributable to contextual variables such as the level of social cohesion among residents. [209]

Boyle *et al.* evaluated the influence of neighbourhoods and socio-economic disadvantage on behavioral problems rated by parents and teachers in a nationally representative sample of children ages 4 to 11 years living in Canada. The study's findings were very interesting. Firstly, there was a significant variation in the study outcome among neighbourhoods and this variation was attributed to both

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neighbourhood and family characteristics. Secondly, family socio-economic status, lone-parent family status, and percentage of lone parents in neighbourhoods were strong, reliable predictors of behavioral problems. Finally, the impact on child behavioral problems of neighbourhood socio-economic status was weaker that that of the individual socio-economic status (i.e., fewer behavioral problems were assessed in children from well-off families living in disadvantaged neighbourhoods, whereas more problems were assessed in children from poor families living in advantaged neighbourhoods). [210]

Another study, which also examined the outcome behavioral problems in children, was done by Caughy *et al*. Using a sample of African American parents, the researchers examined the association between the level of attachment to the community of the study subjects, (i.e., an indicator of social capital) and the presence of behavior problems in their preschool children. The study sample was selected from a socio-economically diverse set of neighbourhoods. A multi-item scale comprised of two subscales, general sense of community and how well one knew one's neighbors was used to assess the level of attachment to the community of the subjects. It was concluded that the association between how well a parent knew her neighbors and the presence of child behavior problems differed depending on the degree of economic impoverishment of the neighbourhood. In wealthy neighbourhoods, children whose parent reported knowing few of the neighbors had higher levels of internalizing problems such as anxiety and depression compared to those who knew many of their neighbors. In contrast, in poor neighbourhoods, children whose parent reported

knowing few of the neighbors had lower levels of internalizing problems compared to those who knew many of their neighbors.[193]

Children's injury

A multilevel study was performed by Reading *et al.* to examine risk factors of accidental injury among preschool children in Norwich, UK. This study aimed at exploring the independent effect of individual characteristics and area characteristics on children's injury. It also investigated the interactions among these factors. In this study, information on individual families was extracted from the district children's health information system and "social areas" were constructed from adjacent census enumeration districts with homogeneous social and demographic characteristics. Primary analysis indicated that accidental injury rates were much higher in deprived urban neighbourhoods than in affluent areas. However, when the individual characteristics were incorporated into the same model with neighbourhood characteristics using multilevel model, it was shown that for all accidents much of the variation in rates was accounted for by factors at the individual level (i.e. male sex, young mother's age, number of elder siblings and distance from hospital); the neighbourhood variable, influence of living in a deprived neighbourhood, still remained significant in the model but it's contribution to the variation in the injury rates was small. The model for more severe injuries was similar except single parenthood was now significant at the individual level and the effect of area deprivation was stronger. The authors concluded that preschool accidental injuries were influenced by factors operating at both individual level and area level.[194]

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Another study, which also examined the injury outcome in children, was done at the aggregate level (i.e., ecological study). This study looked at the relationship between area socio-economic disadvantage and the incidence of severe childhood injury. The authors employed a small-area analysis technique to examine area the socio-economic risk factors for pediatric injury, which resulted in hospitalizations or deaths. This study took place in Northern Manhattan, New York, NY, during a 9-year period (1983 through 1991). They reported that compared to children living in areas with few low-income households, children in areas with predominantly low-income households were 2 times more likely to receive injuries from all causes and 4.5 times more likely to receive assault injuries. The effect of neighbourhood income disparities on injury risk persisted after race was controlled. [211]

More recently, Soubhi *et al.* examined independent and combined effects of child, family and neighbourhood on medically attended childhood injuries. The data used in this study were from cycles 1 and 2 of the 1996-census-linked data of the National Longitudinal Survey of Children and Youth. The study sample was a random probability sample of Canadian residential households with children aged 0-11 years. The neighbourhood border in this study was enumeration area. Neighbourhood factors examined in this study were neighbourhood socio-economic disadvantage and neighbourhood cohesion. Analysis indicated that the effect of neighbourhood characteristics may be modified by child's age and that different characteristics of neighbourhood influenced injury at different stages of childhood. Neighbourhood cohesion appeared as a salient variable that seems to buffer the effect of child difficulty among children in their early infancy, whereas neighbourhood disadvantage

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showed a strong association with injury, particularly among aggressive children. The authors therefore concluded that neighbourhood factors had independent effects on children's injury.[212]

Lead poisoning

In Massachusetts, an ecological study was done by Sargent *et al.* to examine the relationship between communities' socio-demographic, housing characteristics and incidence of lead poisoning. In this study, 238,275 children from birth through 4 years of age were screened for lead poisoning in 1991-1992 and the incidence rate of lead poisoning was calculated for each community. A logistic regression model was developed with the community as the unit of analysis, the incidence rate for lead poisoning as the dependent variable, and US census variables as the independent variables. A significant independent relationship with the incidence rate of lead poisoning was reported for seven variables: median per capita income, percentage of housing built before 1950, percentage of the population who were African American, percentage of children screened, and a "poverty index." It was estimated that living in a densely populated, high poverty community was associated with a ninefold increase in lead burden.[213]

Children's overweight problem and physical activity

Burdette and Whitaker performed a cross-sectional study of 7,020 low-income children, 36 through 59 months of age to examine the relationship between overweight in preschool children and three environmental factors--the proximity of the children's residences to playgrounds and to fast food restaurants and the safety of the children's neighbourhoods in Cincinnati, Ohio. The distance between each child's residence and

the nearest public playground and fast food restaurant was determined with geographic information systems. Neighbourhood safety was defined by the number of police-reported crimes per 1,000 residents per year in each of 46 city neighbourhoods. They reported that within a population of urban low-income preschoolers, overweight was not associated with proximity to playgrounds and fast food restaurants or with the level of neighbourhood crime.[214]

Monar *et al.* carried out a multilevel longitudinal study in Chicago to examine the association between level of physical activity and access to safe recreation areas in neighbourhood of residence. In this study, individual-level data were obtained from 1378 youth (11 to 16 year old) and their caregivers living in 80 neighbourhood clusters. Neighbourhood-level data were collected from 8782 community residents and videotapes of 15,141 block faces. The study outcome physical activity was measured by parental estimates of hours youth spent in recreational programming. A scale of residents' assessment of neighbourhood safety for children's play was created; disorder measures came from videotaped observations. The authors concluded that one mechanism for reduced physical activity among youth may be the influence of unsafe neighbourhoods. Neighbourhood interventions to increase safety and reduce disorder may be efficacious in increasing physical activity, thereby reducing risk of overweight and cardiovascular disease.[215]

Children's use of medical services

Most of studies examining the area effects on children's use of health services are ecological studies. For instance, Maclure and Stewart reported that children living in deprived districts in Glasgow were on average about nine times more likely to be

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admitted to hospital for any reason than children in non-deprived districts. The variables most strongly correlated with admission rates were overcrowding in households and parental unemployment.[216] Thakker *et al.*. (1994) also found that paediatric inpatient utilization among 20 general practices was positively correlated (though not significantly) with unemployment rates.[217] Perrin *et al.* did a study examining variations in rates of hospitalization of children in three urban communities, Boston, Rochester (N.Y) and New Haven (Conn.) in 1982. Results indicated the possibility that the variation in rates of hospitalization of children were related in part to differences in socio-economic status or access to primary care.[218]

Very few studies on children's use of health services have employed multilevel design but all of them have reported the independent effects of neighbourhood. For instance, one study by Brooks-Gunn *et al.* examined the effect of family and neighbourhood income on health care use of young children born prematurely and of low birth weight. The health care outcomes examined in this study were hospitalizations, doctor visits and emergency department visits. The data were averaged over the child's first 3 years of life. This study reported that children from poorer families were more likely to be hospitalized and to have more emergency department visits than children from more affluent families; residence in poor and middle-income neighbourhoods was associated with more emergency department visits than residence in affluent neighbourhoods; and families in middle-income neighbourhoods reported more doctor visits than families in poor or affluent neighbourhoods. [219]

More recently, van der Linden *et al*. carried out a multilevel study to assess the interactive influence of neighbourhood measures of socio-economic deprivation and social capital (i. e. informal social control, social cohesion and trust) on children's mental health service use, controlling for individual socio-economic status. This study was a case-control study in which case/control status indicated mental health service use or not. It was concluded that there was a significant association between socio-economic deprivation and higher children's mental health services use; however, this association was mitigated by strong trust and social cohesion between citizens in the neighbourhood. Thus, effects of deprivation on children's mental health cannot be interpreted without taking into account the context of social capital.[196]

Children's respiratory diseases

The impacts of neighbourhood/aggregate level on children's respiratory diseases have been reported mostly through ecological studies. For instance, in New York State, McConnochie *et al.* (1995) found higher rates of lower respiratory infection in children under 2 years in geographic areas characterized by higher poverty, than in areas with lower poverty. Unemployment rates were the strongest predictor of hospitalization for respiratory infection. McConnochie argued that physician discretion and factors associated with socio-economic status were probably major determinants of the variation in hospitalization.[189] Access to care, physician-family relationships, characteristics of telephone and after-hours coverage systems and transportation systems influence physician descretion, as does uncertainty in the home management of lower respiratory infection. In a later study, however, he determined that the marked socio-economic and racial disparity in hospitalization rates in another

city were attributable to higher incidence of severe acute asthma among inner-city children, in other words greater need, not excess utilization.[220]

Another ecological study was also done in New York city to assess the relationship between asthma hospitalization rates and socio-economic factors by Claudio *et al.* The aggregate unit in this study was postal zip code. The authors concluded that asthma hospitalization rates correlated with low median family income, the percentage of minorities in the population, and the percentage of children under the age of 18. Furthermore, they also suggested that lack of access to preventive health care, poor housing conditions, environmental exposures, and genetic susceptibility may have contributed to high incidence of asthma in some neighbourhoods. [190]

A small area analysis by Gottlieb *et al.* examined the impact of the characteristics of area on the rate of asthma hospitalization in Boston. The rate of asthma hospitalization was calculated for 22 small areas within Boston. Information of area characteristics examined in this study were extracted from the 1990 US Census, including race, age, and gender distribution of the population, per capita income, percentage of population living in poverty and education attainment. The study's results indicated that asthma hospitalization rates varied significantly within the city of Boston and that asthma rates in Boston were highest in poor inner city neighbourhoods.[191]

Most recently, Cagney *et al.* performed a study to separate the contribution of neighbourhood social context to the variation in asthma from that of the individual variables. In this study, the outcome and individual level covariates (i.e., sex, age, race, education, income, marital status, years in neighbourhood, smoking, weight problem)

came from the Metropolitan Chicago Information Centre Metro Survey, which was a

serial cross section of adults ages 18 and older who reside in the 6 county metropolitan

Chicago area; the measures of neighbourhood socio-economic structure came from

Census data; and the measures of neighbourhood collective efficacy and disorder came

from the project on Human Development in Chicago Neighbourhoods Community.

This study employed a multilevel statistical approach to disentangle neighbourhood

effects from individual level effects. The results indicated that neighbourhood context,

particularly collective efficacy, might be an underlying factor that reduces

vulnerability to asthma and other respiratory diseases. Collective efficacy may enhance

the ability to garner health relevant resources, eliminate environmental hazards that

trigger asthma, and promote communication among residents which in turn, enables

dissemination of information relevant to respiratory ailments.[195]

6.3 Methodology

6.3.1 Measures and Definitions

6.3.1.1 Independent Variables

Individual variables: Eight individual variables were examined in this study. These were 'Mother's age'', ' 'Father's age'', ' 'Aboriginal status', ' Single parent', ' Sex', ' Longitudinal family income', 'Income', 'Adverse birth outcome' (please refer to section 3.4.1 for more details about their definition and coding). Here, I would like to review the definition of two variable 'longitudinal family income' and 'income' to make the difference in their definition and their use clear. The definition of variable 'adverse birth outcome' and its rationale is also necessary to review here.

Variable 'Longitudinal family income' was a time-varying variable, which would take value '1' if the child's family had received income assistance from the government during a follow up year or '0' if his family did not receive any support. Therefore, for each child, this variable took a value of either '1' or '0' for each year of follow up, to a maximum of 6 years. This variable was used to examine how the incidence of hospitalization changed over time in response to the change in the income status of the families.

Variable 'Income' was a dichotomous variable taking value '1' or '0' if the child's family ever or never received income assistance from the government during 6 years after birth, respectively. This variable was not a time-varying variable and used in the analysis for the outcome 'total days of stay in hospital'.

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Variable 'Adverse birth outcome' was a categorical variable which would take value '0' or '1' or '2' if the child was born without any adverse birth outcome, or with one adverse birth outcome, or with at least two adverse birth outcomes, respectively. The literature on adverse birth outcome had suggested that the combination of adverse birth outcome would increase the risks for children. Therefore, this variable was constructed in this way to examine the gradient association between number of adverse birth outcome and childhood hospitalization.

Neighbourhood variables: 'Neighbourhood socio-economic disadvantage', 'Neighbourhood social interaction', 'Neighbourhood physical condition', ' programs and services for children', 'unhealthy lifestyle norms and "population density'. In this analysis, only three neighbourhood variables were indicated to be significant, therefore, their definitions are reviewed here.

Neighbourhood socio-economic disadvantage was extracted from seven original neighbourhood characteristics, of them four had positive correlation (i.e., percentage of Aboriginal, percentage of low income families, percentage of population with an education level less than grade 9, percentage of single parent) and three had negative correlation with the extracted variable (i.e., percentage of employment, percentage of owned houses, and average car per person). Information on neighbourhood physical condition was gathered in the 'Understand the Early Year' study. Neighbourhood physical condition measured nine aspects of neighbourhood including condition of neighbourhood, percentage of housing in need of major repair, street width, road condition, appearance, noise, stoplight and crosswalk.

Neighbourhood population density was measured by the average number of person per household in each neighbourhood.

6.3.1.2 Outcomes

Hospitalizations were operationalized using two separate indicators, number of inpatient hospitalizations and average length of stay per hospitalization, reflecting intensity and burden of utilization respectively.[80]

- The first indicator was number of hospitalizations; hospitalization is defined as any contact in which patients had hospital stays of one or more days.[221] Thus, the incidence rate of hospitalization did not include hospital services provided on a non-patient basis, including contacts for day surgery, day care and day visits. Furthermore, if an individual was hospitalized more than once, each episode was counted as an individual hospitalization. This outcome was repeatedly measured from birth to 6 years of age.

- The second indicator was average length of stay in hospital per one hospitalization for children who had been hospitalized at least once during 6 years after birth. This outcome was calculated as follow: (1) First, length of stay for each episode was calculated by taking the difference in time from admission date to discharge date (2) Second, the total day of stay for each child was calculated by taking the sum of his/her length of stay for all episodes (3) Third, the average length of stay per hospitalization was calculated by dividing the total day of stay by the total number of hospitalizations. Unlike the incidence rate of hospitalization, this outcome was not a repeated measurement. Each individual had only 1 record for the average length of stay per hospitalization during 6

years after birth. The analysis for this outcome was performed on a sub-population only (i.e., individuals who had been hospitalized at least one time during the study time)

6.3.2 Analytic Method

6.3.2.1 Analytic Method for Objective 1

Objective 1: To describe the major causes of hospitalization in children from 0 to 6 years; specifically, to identify differences in the distribution of major causes of hospitalizations between children born with adverse birth outcomes and children born without adverse birth outcomes, and between children in low income families and children in better-off families

> *Hypothesis 1: Major causes of hospitalization will be different between children born with adverse birth outcomes and children born without adverse birth outcomes, and between children in low income families and children in better-off families.*

Graphical and tabular techniques were employed to describe the utilization patterns of inpatient hospital care by major classes of morbidity. Childhood morbidities were defined using the International Classification of Disease, 9th revision (ICD-9) codes (see appendix I). Comparisons of the distribution of hospitalization causes were made between children born with adverse birth outcome (i.e., either LBW, preterm birth, SGA or combination of them) and children born without any adverse birth outcome, and between children who lived in low income families (i.e., receiving income assistance from the government at least one during the study time) and

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children who lived in "high income" families (i.e., not receiving income assistance from the government during the study time). These comparisons were done by using tables and graphs. Microsoft Excel software was used to make bar charts and to sort disease categories by their frequency in a descending order to choose the top ten most common disease categories in each group.

6.3.2.2   Analytic Method for Objective 2

Objective 2: To examine the relative impact of adverse birth outcomes and family income, and the interaction effects between them, on hospitalizations.

> *Hypothesis 2a: (i.e., the gradient effects of number of adverse birth outcomes) Children born with at least two adverse birth outcomes will have the highest incidence rate of hospitalization and average days of stay in hospital while children born with only one adverse birth outcome will have the second high and children born with no adverse birth outcome will have the lowest.*

To examine this hypothesis, a variable that incorporated three types of adverse birth outcomes (i.e., LBW, small for gestational age, and preterm birth) was constructed. It had three values, 0 referred to the children born normal, 1 referred to the children born with only one adverse birth outcome, and 2 referred to the children born with at least two adverse birth outcomes. If this hypothesis is true, it would demonstrate a dose response relationship between the total numbers of adverse birth outcomes and hospitalization

Hypothesis 2b: Children in low income families, compared to children in better-off families, will have significantly higher incidence rates of hospitalizations and longer stays in hospital.

This hypothesis was tested by examining the adjusted association of low income with number of hospitalizations and length of stay in hospital (i.e., controlling for all other individual and neighbourhood variables).

Hypothesis 2c: (i.e., the moderating effect of family income) The impact of adverse birth outcomes on childhood hospitalization will change as a function of children's family income status.

Moderating effect or interaction is defined as a condition that exists when the relationship of interest varies according to the level of one or more covariates.[222] The moderating effect of family income on the association between adverse birth outcome and childhood hospitalization can be understood as the impact of adverse birth outcome on childhood hospitalization (i.e., number of hospitalizations and days of stay) is stronger among those children living in low income families compared to that among those children living in better off families. Thus, it means that children born with adverse birth outcomes and living in low income status families are in "double jeopardy" and would likely catch up with their friends who were born without adverse birth outcomes more slowly compared to those in better off families. More important, it means that if children born with adverse birth outcomes have to commence their life with health deficit, we can modify their family income status to help them to catch up faster and better with their peers. Thus, it would provide valuable information for health policy makers in Saskatoon.

It is important to note that since family income was a time varying variable (level 1: repeated measurement) and adverse birth outcome was a baseline variable (level 2: individual), the interaction between them was a cross level interaction and could be examined by modeling the coefficient of family income as a non-randomly varying level 1 coefficient (by adverse birth outcomes).[107]

6.3.2.3 Analytic Method for Objective 3

Objective 3: To examine the independent effects of neighbourhood factors on hospitalizations as well as their moderating effects on the association between some individual risk factors and childhood hospitalization

Hypothesis 3a: Neighbourhood factors will be associated with hospitalizations, in addition to the effects of individual risk factors.

This hypothesis was tested by using a multilevel analysis technique. Multilevel analysis allows the simultaneous examination of the effects of group level and individual level variables on individual level outcomes while accounting for the non-independence of observations within groups.[56-59] Thus, it can be used to identify significant predictors of incidence rate of hospitalization and length of stay at individual level and neighbourhood level as well as to evaluate the net effect of neighbourhood characteristics on these two study outcomes. Please refer to section 3.5.2.4 for more details in the multilevel modelling strategy.

Model for incidence rate of hospitalization

For the first outcome, incidence rate of hospitalization, a three level non-linear model was built. Level 1 accounted for repeated measurements within individual; level

2 accounted for individual/family level variables; and level 3 incorporated

neighbourhood characteristics. Number of hospitalizations was a count outcome,

which was constrained to be non-negative but if a normal model was fitted to this data,

it could produce predicted counts that were negative. Thus, model the logarithms of

the counts would be preferred. [107]A Poisson model using a log link function was

employed to model this data. Furthermore, the incidence rate of children's

hospitalization were more appropriate than the actual counts as each individual have

different exposed time and each neighbourhood unit had a different population size.

Therefore, if the raw counts were used, the neighbourhoods with larger population size

and the individual with longer exposed time would have larger counts, thus masking

the true relationship. To work with the rates rather than the counts, an additional

parameter known as an offset was used. The offset variable was calculated as follow:

(1) Offset was set to be equal to the log (base e) of 12 months if the child was in the

study the whole year; (2) If the child was in the study only for a part of a certain year

(i.e., he moved out of Saskatoon or died during that year), offset was set to be equal to

the log of the number of months during that the child was in the study.

Details about the levels of data and variables examined for this study outcome

are presented in Figure 6-3. All the variables were centered around their grand means

in order to achieve a meaningful intercept in the final model.[65,107] At all levels, the

main interest was set between socio-economic variables and the outcome. Four

increment models were built for the incidence rate of hospitalization. The first model

or the empty model had nothing but an intercept. After that, two time varying

variables, age and longitudinal income, were entered one at a time as random effects in

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model 2. If a significant variance component was reported, the variable was kept as a random effect; otherwise, the variable was constrained to be fixed across individuals and neighbourhoods. Similarly, model 3 examined other individual variables one at a time as random effects. Based on the significance of these variables's variance component, these variables were determined to have random effects or fixed effects. All variables, which were indicated to be non significant, would be removed in the subsequent analyses. In model 4, the neighbourhood characteristics were put into the model to examine the contextual effect of neighbourhoods. Finally, all variables reported non significant in model 4 would be removed to provide the final model for incidence rate of hospitalization. For the fixed effect, coefficient estimation was taken from the population average model with robust standard errors. The neighbourhood variance components of the intercept (the variance component of u_{00}), which were estimated from each model (i.e., from model 1 to model 4), were compared to test whether adding new variables helped to achieve a better explanatory model for the incidence rate of hospitalization or not.

The equation for the final multilevel for incidence rate of hospitalization (i.e., model 4) had the following form:

Level-1 Model

Incidence rate of hospitalization =   Length of expose *L

Where:

$\log[L] = \pi 0 + \pi 1*(AGE) + \pi 2*(LONGITUDINAL\ INCOME)$

$\pi0 = \beta00 + \beta01*(SEX) + \beta02*(ABORIGINAL) + \beta03*(SINGLE\ PARENT) +$

$\beta04*(ADVERSE\ BIRTH\ 1) + \beta05*(ADVERSE\ BIRTH\ 2) + \beta06*(MOM20) +$

$\beta07*(MOM40) + R0$

The random effect of variable "Age" at the individual level

$\pi2 = \beta10 + R1$

The cross level interaction between adverse birth outcomes and longitudinal income

$\pi2 = \beta20 + \beta21*(ADVERSE\ BIRTH\ 1) + \beta22*(ADVERSE\ BIRTH\ 2)$

Level-3 Model

$\beta00 = \gamma000 + \gamma001(NB\ PHYSICAL) + \gamma002(NB\ POPULATION\ DENSITY) +$

$\gamma003(NB\ SOCIOECONOMIC) + U00$
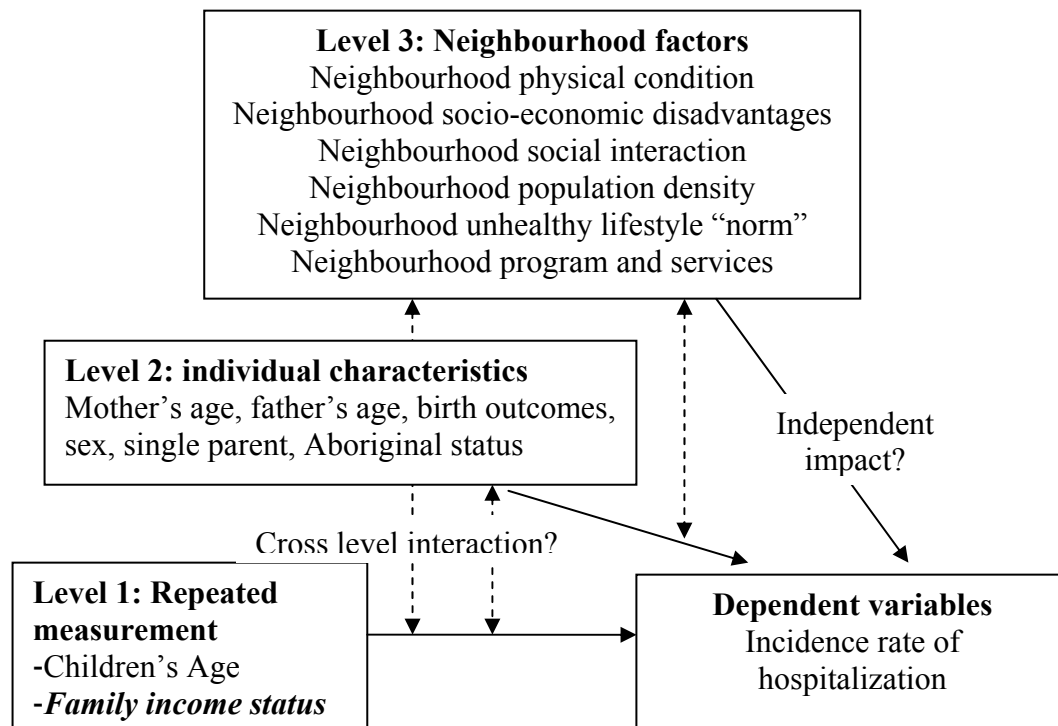
Figure 6-3: Conceptual framework for childhood hospitalization

Model for the average length of stay per hospitalization

The outcome, average length of stay per hospitalization during 6 year after birth, was a continuous outcome and not a repeated measurement. Thus, for this outcome, a hierarchical linear model with two levels (i.e., the first level is individual, the second level is neighbourhood) was employed. The analysis for this outcome was done among a sub-population only (i.e., children who had been hospitalized at least once during the study time). As for the model for the incidence of hospitalization, all the variables were centered around their grand mean and four sequent models were built in order to achieve the final model for average length of stay per hospitalization. The random effects of individual variables were examined by entering one variable at a time, if a non-significant random effect was observed; the variable was constrained to be fixed across neighbourhoods. The likelihood ratio test was used to compare alternative models for the average length of stay per hospitalization. The equation for the final multilevel for the average length of stay per hospitalization (i.e., model 4) had the following form:

> ***Level-1 Model***
>
> Length of stay = β_0 + β_1*(INCOME) + β_2*(SEX) + β_3*(ABORIGINAL) + β_4*(SINGLE PARENT) + β_5*(ADVERSE BIRTH1) + β_6*(ADVERSE BIRTH2) + β_7*(ADVERSE BIRTH 1* INCOME) + β_8*(ADVERSE BIRTH 2* INCOME) + R
>
> ***Level-2 Model***
>
> β_0 = γ_{00} + γ_{01}*(NB PHYSICAL) + γ_{02}*(NB SOCIOECONOMIC) + U0

It should be noted that the distribution of this outcome was not normal but skewed. This skewness happened due to the fact that a very small proportion of the sample had a very long length of stay in hospital. This problem was solved by grouping all number of days of stay greater than 12 into one group. Thus, the range of this outcome was from 1 to 12 days and this outcome had an acceptable distribution for statistics performances.

Hypothesis 3b: *The effects of some individual risk factors (i.e., single parent, low income) on childhood hospitalization will change as a function of the level of socio-economic disadvantage or social interaction within a neighbourhood.*

This hypothesis is about the moderating effects of some neighbourhood factors on the association of individual risk factors and childhood hospitalization. Moderating effects or synergistic effects between neighbourhood factors and individual factors refer to the cross level interaction between those factors. In order to test this hypothesis, the significance of the following cross level interaction was checked:

In the final multilevel model for number of hospitalizations:

– The cross level interaction between variable 'neighbourhood socio-economic disadvantage' and 'longitudinal family income' (i.e., interaction between level 1 and level 3 variables)

– The cross level interaction between variable 'neighbourhood socio-economic disadvantage' and 'single parent' (i.e., interaction between level 2 and level 3 variables)

- The cross level interaction between variable 'neighbourhood social interaction' and 'longitudinal family income' (i.e., interaction between level 1 and level 3 variables)

- The cross level interaction between variable 'neighbourhood social interaction' and 'single parent' (i.e., interaction between level 2 and level 3 variables)

In the final multilevel model for average length of stay per hospitalization:

- The cross level interaction between variable 'neighbourhood socio-economic disadvantage' and 'income' (i.e., between level 1 and level 2 variables)

- The cross level interaction between variable 'neighbourhood socio-economic disadvantage' and 'single parent' (i.e., between level 1 and level 2 variables)

- The cross level interaction between variable 'neighbourhood social interaction' and 'income' (i.e., between level 1 and level 2 variables)

- The cross level interaction between variable 'neighbourhood social interaction' and 'single parent' (i.e., between level 1 and level 2 variables)

These cross level interactions were evaluated by modeling the coefficient of individual factors as a non-randomly varying level 1-coefficient (for the interaction between level 1 and level 3 or level 1 and level 2) or as non-randomly varying level 2-coefficient (for the interaction between level 2 and level 3). [107]

6.3.2.4   Analytic Method for Objective 4

Objective 4: To compare the relative overall effects of family income status and neighbourhood factors on childhood hospitalizations

> *Hypothesis 4: The overall effects of neighbourhood factors on hospitalizations will be stronger than the effects of family income status.*

After addressing objective 3, the information about which individual and neighbourhood factors were the significant predictors for children's hospitalization was available and we wanted to know whether the contextual effect found were stronger that the effect of family income (i.e., modifiable individual risk factor).

For the first outcome, number of hospitalizations, I estimated the relative magnitude of neighbourhood and individual effects by comparing the appropriate attributable risks at the individual and neighbourhood levels. The attributable risks obtained at the individual level effects compared "exposed" groups, low-income families, with better off families (demonstrating the risk difference between low-income and better off families). The attributable risks obtained at the neighbourhood level compared "exposed" groups and "non-exposed" group, for instance between low socio-economic status neighbourhoods, with high socio-economic status neighbourhoods. I used bar charts to present the results for this part of the analysis. The attributable risk was calculated using the following formula:

$$AR = (RR_{exposed} - RR_{reference})/RR_{exposed}$$

In which:

$RR_{exposed}$: *the relative risk of the exposed group*

$RR_{reference}$: *the relative risk of the reference group (i.e., non-exposed)*

For the individual level effects, I calculated one set of attributable risks, in which the exposed group was families receiving income assistance from the government and the reference group was families not receiving income assistance from the government. At the neighbourhood level, I calculated two sets of attributable risks. It has been suggested that when calculating the attributable risks involving variables at the neighbourhood level, the comparison should be made for effects corresponding to

thresholds set between the 10th and 90th percentile (maximum effects).[125] Therefore, I calculated attributable risks corresponding to differences in maximum effects where the exposed group was neighbourhoods at 90th percentile and the reference group was neighbourhoods at 10th percentile. The second set of attributable risks calculated corresponding to average effects, in which the exposed group was neighbourhoods at 90th percentile and the reference group was neighbourhoods at 50th percentile (median value).

Similarly, for the second outcome, average length of stay per hospitalization during 6 years after birth, this question was answered by comparing the difference in length of stay due to the effect of family income with those due to the contextual effects of neighbourhood. Again, for neighbourhood contextual effects, two sets of difference in length of stay were calculated, the average and the maximum difference corresponding to the difference in length of stay due to the difference in contextual effects between 50th and 90th percentiles and due to the difference in contextual effect between 10th and 90th percentiles, respectively.

6.4 Analytical Results

This section follows the same basic outline as in the analytic strategy presented in section 6.2.3. Tables and graphs are used frequently to summarize the results.

6.4.1 Analytical Results for Objective 1

6.4.1.1 Frequent causes of hospitalization

Figure 6-4 presents the top ten frequent causes of hospitalization among children from 0 to 6 years of age in Saskatoon. It was evident that respiratory diseases (i.e., severe ENT infection, other diseases of respiratory system, bacteria pneumonia, upper respiratory diseases, and asthma) were the most frequent cause of hospitalization during 6 years after birth. In total, respiratory diseases accounted for about 45% of all hospitalization happening among Saskatoon children from 0 to 6 years of age. Other frequent causes of hospitalization were diseases related to digestive system, injuries, congenital anomalies, perinatal origin, disease of genitourinary system, and other infectious and parasitic diseases, respectively.

Distribution of the ten major causes of hospitalization by children's age is shown in Table 6-1. Clearly, the pattern of the most frequent causes of hospitalization changed as children grew. For example, when children were 1 year of age, perinatal origin was the most frequent cause of their hospitalization. However, from 2 to 6 years of age, the most frequent cause was severe ENT infection.
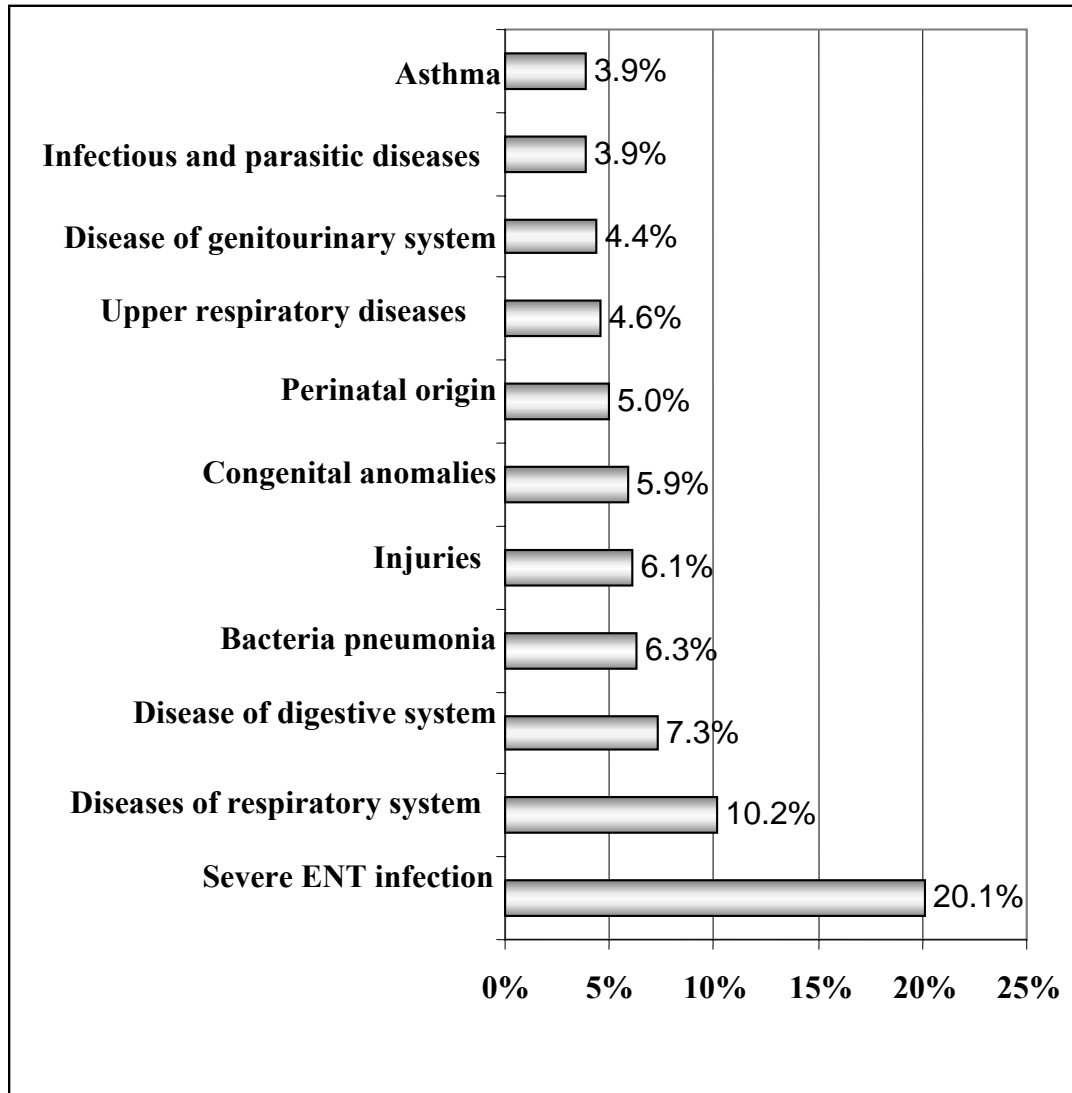
Figure 6-4: The top ten frequent causes of hospitalization in Saskatoon children during 6 years after birth

Table 6-1: The ten most frequent causes of hospitalization by age

	AGE 1		AGE 2		AGE 3		AGE 4		AGE 5		AGE 6	
	Diseases	%	Diseases	%	Diseases	%	Diseases	%	Diseases	%	Diseases	%
1	Perinatal origin	14.2	Severe ENT infection	27.9	Severe ENT infection	27.4	Severe ENT infection	26.4	Severe ENT infection	27.6	Severe ENT infection	28.6
2	Other diseases of respiratory system	13.5	Bacteria pneumonia	7.8	Injuries	8.5	Other diseases of respiratory system	10.6	Other diseases of respiratory system	9.3	Other diseases of respiratory system	8.9
3	Other disease of digestive system	9.2	Other diseases of respiratory system	7.7	Other diseases of respiratory system	7.3	Injuries	9.0	Disease of genitourinary system	7.9	Injuries	8.2
4	Bacteria pneumonia	8.4	Congenital anomalies	7.5	Other disease of digestive system	6.2	Asthma	5.8	Injuries	7.7	Other disease of nervous system	5.8
5	Congenital anomalies	7.5	Other disease of digestive system	7.2	Bacteria pneumonia	6.0	Other disease of digestive system	5.4	Diseases of oral cavity	6.1	Other disease of digestive system	5.6
6	Severe ENT infection	6.0	Injuries	6.4	Disease of genitourinary system	5.4	Disease of genitourinary system	4.7	Other disease of digestive system	5.7	Disease of genitourinary system	5.6

	AGE 1		AGE 2		AGE 3		AGE 4		AGE 5		AGE 6	
	Diseases	%	Diseases	%	Diseases	%	Diseases	%	Diseases	%	Diseases	%
7	Upper Respiratory diseases	5.7	Upper Respiratory diseases	6.3	Asthma	5.0	Bacteria pneumonia	4.4	Other disease of nervous system	4.1	Asthma	3.7
8	Other infectious and parasitic diseases	4.3	Other infectious and parasitic diseases	5.2	Congenital anomalies	4.6	Upper Respiratory diseases	3.9	Congenital anomalies	3.9	Other infectious and parasitic diseases	3.5
9	Disease of genitourinary system	3.7	Asthma	5.0	Upper Respiratory diseases	3.9	Other disease of nervous system	3.8	Asthma	3.2	Congenital anomalies	3.3
10	Injuries	3.0	Other disease of nervous system	4.2	Other disease of nervous system	3.3	Congenital anomalies	3.3	Other infectious and parasitic diseases	2.2	Diseases of oral cavity	3.1

6.4.1.2   Differences in causes of hospitalization between children born with adverse

birth outcome and children born without adverse birth outcome

The distribution of the top ten frequent causes of hospitalization among children born with adverse birth outcome and among children born with no adverse birth outcome is shown in Figure 6-5. This figure indicates that there were differences in the pattern of hospitalization between children born with adverse birth outcomes and children born without any adverse birth outcomes. For instance:

- Asthma was one of the top ten frequent causes of hospitalization for children born with adverse birth outcomes while it was not for children born without any adverse birth outcomes.

- Hospitalization because of perinatal origin was more frequent among children born with adverse birth outcomes, compared to children born with no adverse birth outcomes.

- With the exception of severe ENT infection, hospitalization due to respiratory diseases was more common among children born with adverse birth outcomes.
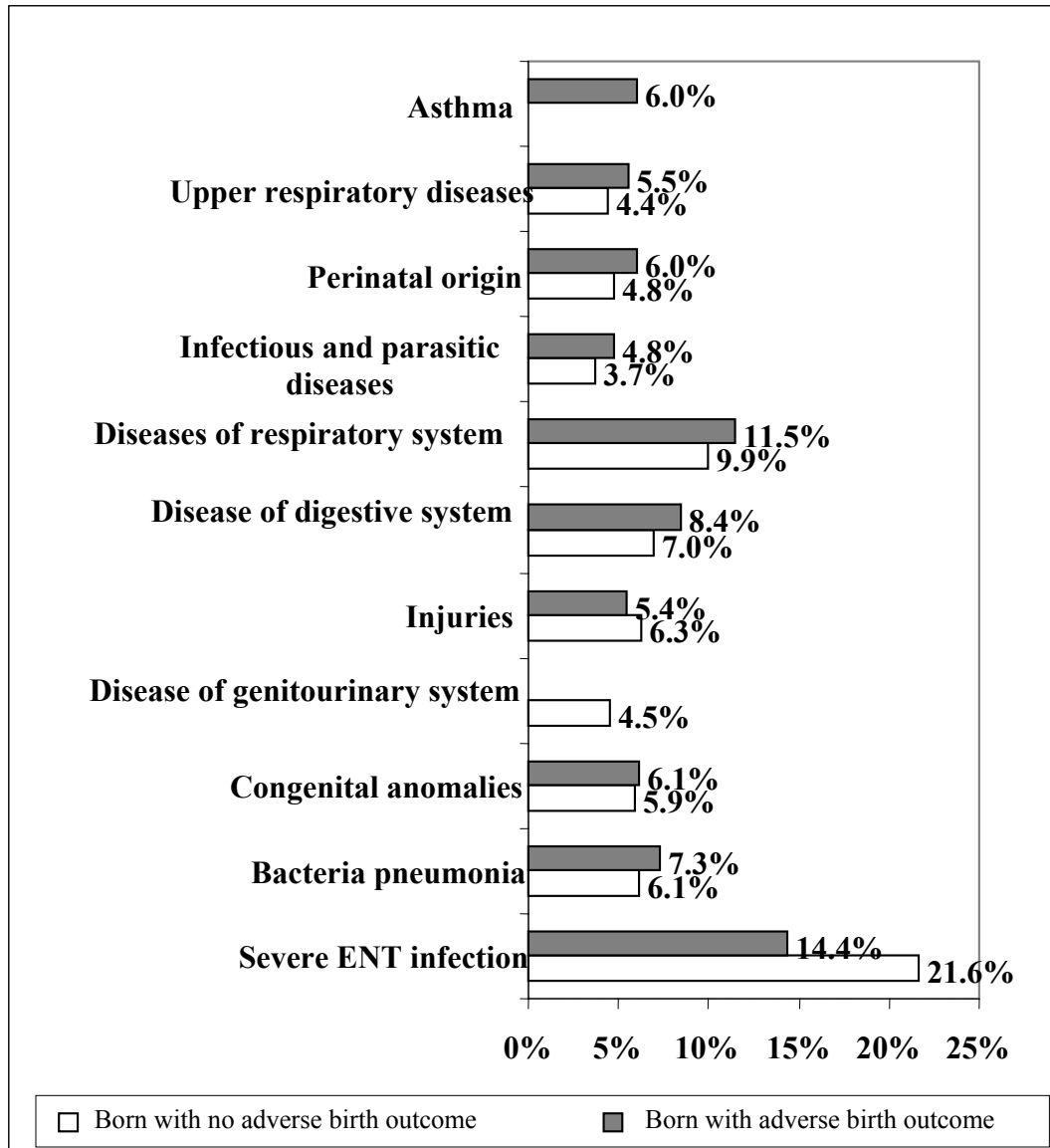
Figure 6-5: Comparison of the top ten frequent causes of hospitalization between children born with and without adverse birth outcome

6.4.1.3 Differences in causes of hospitalization between children living in low income families and children living in better off families

The differences in the distribution of hospitalization causes between children who lived in low income families and children who lived in better off families are showed in Figure 6-6. Some highlight findings were (1) asthma was a frequent cause

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of hospitalization for children living in low income families while it was not for children living in better off families (2) Infectious diseases, for instance bacteria pneumonia, were more frequent among children living in low income families.
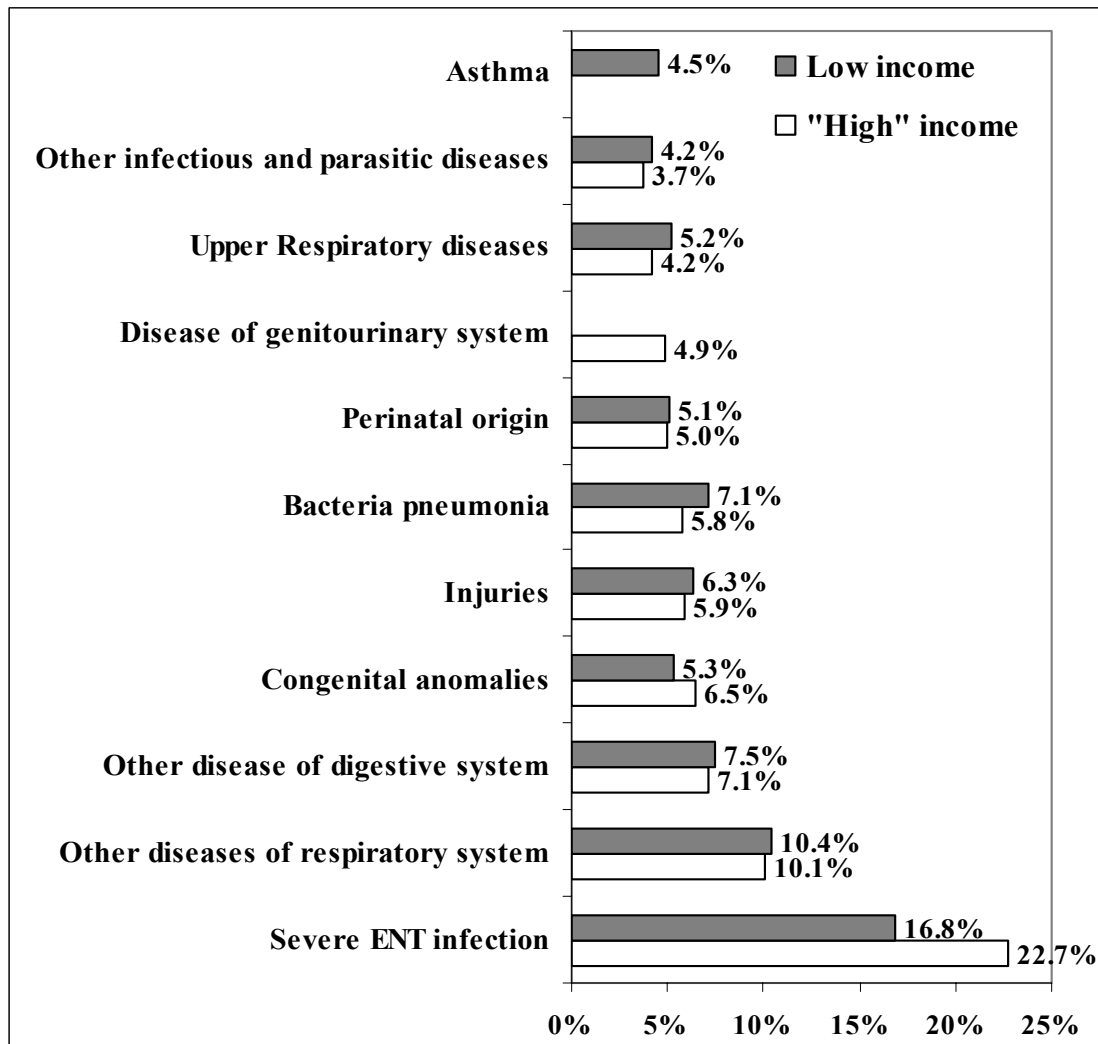
Figure 6-6: Comparison of the top ten frequent causes of hospitalization between children in low income families and those in better off families

6.4.2   Analytical Results for Objective 2

Adverse birth outcome was associated with childhood hospitalization, both incidence rate and length of stay. More importantly, there was a gradient association

between number of adverse birth outcomes and childhood hospitalization. Specifically, compared to the incidence rate of hospitalization among children born with no adverse birth outcomes, the incidence rate among children born with at least two adverse birth outcomes was 2.51 times higher while this rate among children born with only 1 adverse birth outcome was only 1.22 times higher, (Figure 6-7). Compared to children born with no adverse birth outcome, children born with 1 adverse birth outcome did not have significant longer average length of stay in hospital but as shown in Figure 6-8, children born with at least 2 adverse birth outcomes had significant longer average duration of stay in hospital (i.e., 1.2 days longer).

Low income was a significant predictor of the incidence rate of hospitalization and length of stay. The incidence rate of hospitalization among children in low income families was 1.19 times higher (95% CI: 1.07, 1.31) than that among children in better off families. Among all children who had been hospitalized at least one time during the study time, if the child whose family ever received income assistance during 6 years after birth (i.e., proxy for low income status), his average length of stay per hospitalization would be 0.6 days longer compared to a child whose family never received income assistance during that 6 years.

What figure 6-7 and figure 6-8 also show is that there was indeed an interaction between low income and adverse birth outcome. For example, the relative risk for children in low income families was 1.19 but this relative risk was 1.9 for children born with adverse birth outcomes and living in low income families. Born with 1 adverse birth outcome was not significantly associated with longer length of stay in

hospital. However, for a child born with 1 adverse birth outcome and living in a low

income family, during 6 years after birth, his length of stay in hospital would be 1.58

days longer compared to a child born with no adverse birth outcome and living in a

better off family. If a child was born with at least 2 adverse birth outcomes, his length

of stay would be 1.2 days longer than if he was born with no adverse birth outcomes.

However, if this child also lived in a low income family, his length of stay would be

3.08 days longer instead. Thus, the results demonstrate that if a child is born with

adverse birth outcomes and also lives in a low income family, the chance for him to

catch up with his peers in the health status would be lower compared to that for a child

born with adverse birth outcomes but living in a more affluent family.
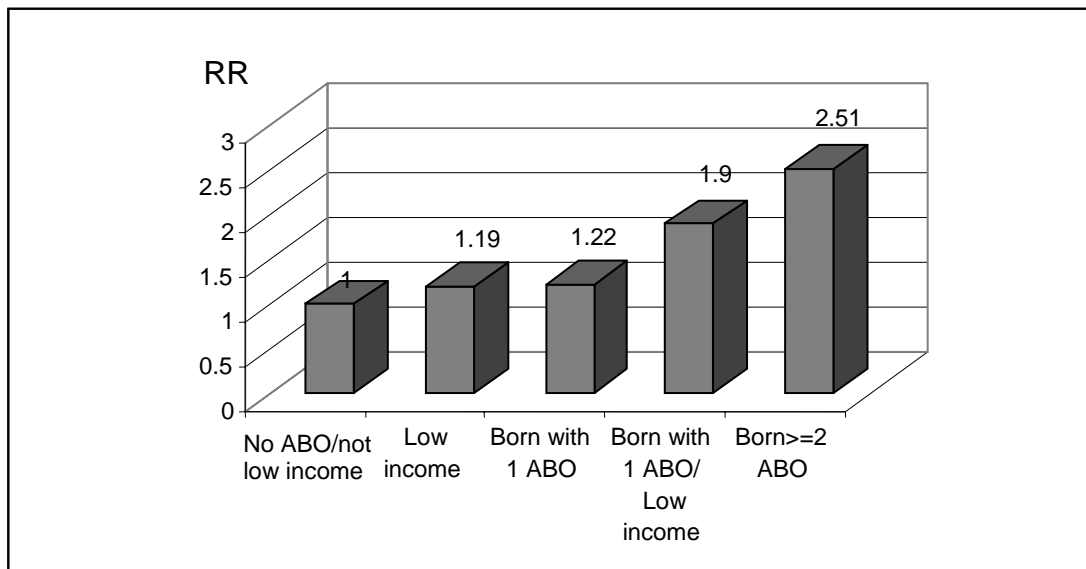
Figure 6-7: Interaction effect between adverse birth outcome and family income on incidence rate of hospitalization
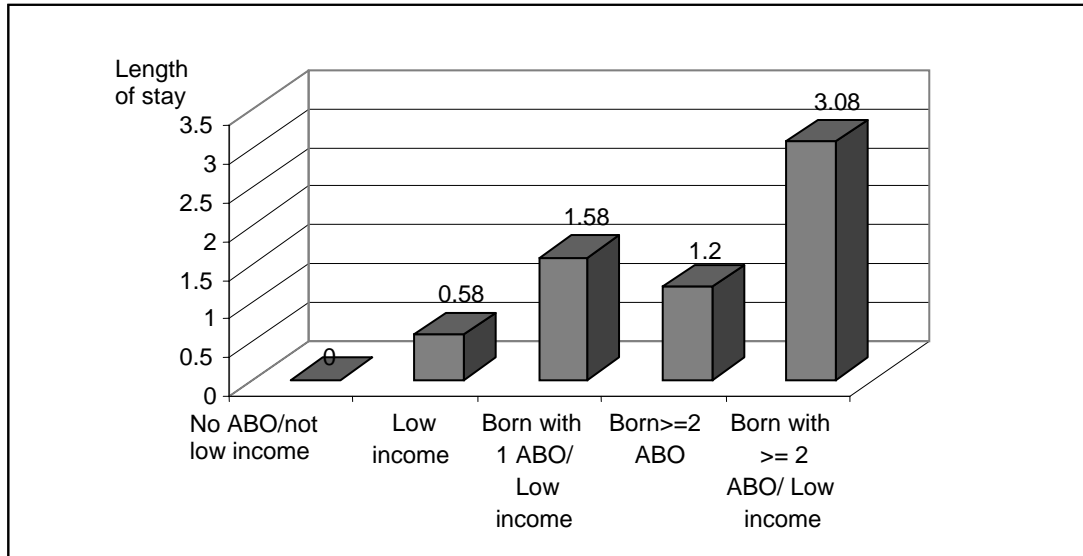
Figure 6-8: Interaction effect between adverse birth outcome and family income on days of stay in hospital

6.4.3 Analytical Results for Objective 3

6.4.3.1 The hierarchical model for the incidence rate of hospitalization

Table 6-2 presents a set of four hierarchical Poisson regression models for the incidence rate of hospitalization. The first model examined the intercept only (i.e., log of the crude hospitalization rate in Saskatoon population). In the second model, two time varying variable (i.e., age of the child and longitudinal income) were added and since both of them showed significant association with the outcome, incidence rate of hospitalization, they were retained in the third model. The variance component of variable age was identified to be significant at the individual level ($\chi^2_{(8288)}= 17012$, p<0.01) but not significant at the neighbourhood level. Therefore, variable age was kept as a random effect at the individual level (i.e., the slope varied significant across children) and constrained to be fixed across neighbourhoods. The variance component

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of variable longitudinal income was not significant at both levels, individual and neighbourhood; therefore, variable longitudinal income was constrained to be fixed across individuals and neighbourhoods.

In model 3, all other individual variables (i.e., baseline variables) were included. In this model, age of the child, longitudinal income, sex of the child, Aboriginal status, born with one adverse birth outcome, born with two adverse birth outcomes, mother's age, and interaction term between adverse birth outcome and income indicated significant associations with the outcome; therefore, they were remained in model 4. Non-significant random effect was observed for all these individual variables, therefore, these individual variables were constrained to be fixed across neighbourhoods.

In model 4, six neighbourhood variables were added to evaluate the contextual effect or the independent effect of neighbourhood factors. Model 4 showed that even when all the individual characteristics were taken into account, three of six neighbourhood variables still indicated significant impacts on the outcome (i.e., contextual effects). These neighbourhood variables were physical condition, socio-economic disadvantage, and population density. The cross level interaction between "longitudinal family income" and "neighbourhood socio-economic", between "longitudinal family income" and "neighbourhood social interaction", between "single parent" and "neighbourhood socio-economic" and between "single parent" and "neighbourhood social interaction" were also tested in model 4. None of them was indicated to be statistically significant and therefore, was not discussed further. Thus,

the final predictive model for the incidence rate of hospitalization in Saskatoon included seven individual variables (i.e., age of the child, longitudinal income, sex of the child, Aboriginal status, adverse birth outcome, mother's age, and interaction between income and adverse birth outcome) and three neighbourhood variables (i.e., physical condition, socio-economic disadvantage, and population density).

As shown in table 6-2, the variance at the neighbourhood level in model 1 was 0.0353 ($p<0.001$), indicating that there was a significant variation in the incidence rate of hospitalization across Saskatoon neighbourhoods. In model 2, when the repeated measurement variables were added, this variance decreased to 0.033 ($p<0.001$) indicating that children age and family longitudinal income only explained some of the variance in the incidence rate of hospitalization across Saskatoon neighbourhoods. This variance continued to drop to 0.01 when other individual risk factors (i.e., sex of the child, Aboriginal status, adverse birth outcome, mother's age, and interaction between income and adverse birth outcome) were added. The inclusion of three neighbourhood variables (i.e., physical condition, socio-economic disadvantage, and population density) in model 4 helped to reduce the variance at the neighbourhood level to 0 indicating that those three neighbourhood factors explained for the rest of the variance in the incidence rate of hospitalization across Saskatoon neighbourhood and the inclusion of neighbourhood factors was necessary in order to obtain a better explanatory model for the incidence rate of hospitalization.

Table 6-2: Estimation of coefficients of the predictors at neighbourhood and individual level for the incidence rate of hospitalization

Variable	Model 1 Coefficients β (SE)	Model 2 Coefficients β (SE)	Model 3 Coefficients β (SE)	Model 4 Coefficients β (SE)	Model 4 Relative Risk $e^{-\beta}$
Intercept	-4.55 (0.04)	-4.68 (0.03)	-4.8 (0.02)	-4.8 (0.02)	*NA*
Variance at the neighbourhood level	**0.036 (p<0.001)**	*0.033 (p<0.01)*	*0.01 (p=0.09)*	0.00007 (p=0.89)	*NA*
Age [a]	*NI*	*-0.30 (0.01)**	*-0.30 (0.02*)*	*-0.30 (0.01)**	0.74 (0.73, 0.76)
Longitudinal income	*NI*	*0.16(0.05)**	*0.16 (0.05)**	*0.17 (0.05)**	1.19 (1.07, 1.31)
Sex of the child (Female vs. Male)	*NI*	*NI*	*-0.38 (0.04)**	*-0.38 (0.03)**	0.68 (0.64, 0.73)
Aboriginal status (Registered Indian vs. non)	*NI*	*NI*	*0.73 (0.06)**	*0.70 (0.05)**	2.01 (1.83, 2.22)
Single parent (single parent vs. married/common law)	*NI*	*NI*	*0.03 (0.05)*	*NI*	*NA*
Born with one adverse birth outcome	*NI*	*NI*	*0.21 (0.07)**	*0.20 (0.06)**	1.22 (1.09, 1.37)
Born with >= 2 adverse birth outcome	*NI*	*NI*	*0.92 (0.08)**	*0.92 (0.08)**	2.51 (2.15, 2.94)
Mother's age < 20 (age <20 vs. age 20 to 40)	*NI*	*NI*	*0.17 (0.07)**	*0.17 (0.06)**	1.19 (1.05, 1.33)
Mother's age > 40 (age >40 vs. age 20 to 40)	*NI*	*NI*	*-0.05 (0.19)*	*-0.04 (0.17)*	*NA*

Note: [a] The slope of variable "Age" varied across individuals (i.e., random effect at the individual level)

Variable	Model 1 Coefficients β (SE)	Model 2 Coefficients β (SE)	Model 3 Coefficients β (SE)	Model 4	
				Coefficients β (SE)	Relative Risk $e^{-\beta}$
Father's age <20 (age <20 vs. age 20 to 40)	*NI*	*NI*	-0.15 (0.1)	*NI*	*NA*
Father's age>40 (age >20 vs. age 20 to 40)	*NI*	*NI*	-0.04 (0.09)	*NI*	*NA*
Interaction between income and born with one adverse birth outcome	*NI*	*NI*	***0.26 (0.12)****	***0.27 (0.11)****	1.31 (1.06, 1.63)
Interaction between income and born with >=2 adverse birth outcomes	*NI*	*NI*	0.19 (0.18)	*NI*	*NA*
Neighbourhood physical condition	*NI*	*NI*	*NI*	***0.05 (0.01)****	1.05 (1.03, 1.07)
Neighbourhood socio-economic disadvantage	*NI*	*NI*	*NI*	***0.05 (0.02)****	1.05 (1.01, 1.09)
Neighbourhood population density	*NI*	*NI*	*NI*	***0.11 (0.04)****	1.12 (1.03, 1.21)

Note: * Significant variables (p<0.05)

NI: Not included in the model

NA: Not applicable

SE: Standard errors

The coefficient of variable age of the child was negative indicating that the incidence rate of hospitalization significantly decreased as children aged. However, the association between children's age and the incidence rate of hospitalization was indicated to be varied across individuals (i.e., random effect or random slope).

Compared to male children, female children had significantly lower rate of hospitalization during 6 years after birth, specifically, the incidence rate of hospitalization among female children was 0.68 times lower (95% CI: 0.64, 0.73) than that among male children. Mother's age less than 20 years was a risk factor for hospitalization. The incidence rate of hospitalization was 1.19 times higher (95% CI: 1.05, 1.33) among children who had mother's age under 20 compared to that among children who had mother's age from 20 to 40. The incidence rate of hospitalization during 6 years following birth was also two times higher (95% CI: 1.83, 2.22) among Aboriginal population compared to that among non-Aboriginal population. The interpretation of the coefficient of adverse birth outcome, income and the interaction term between adverse birth outcome and income were presented in the previous section and therefore not repeated here.

Neighbourhood socio-economic disadvantage was indicated to have an independent effect on hospitalization rate above and over that of family income. The coefficient of this variable was 0.05, which can be interpreted as a higher level of neighbourhood socio-economic disadvantage was significantly associated with a higher rate of hospitalization among children from 0 to 6 years. Figure 6-9 presents the distribution of neighbourhood socio-economic disadvantage in Saskatoon overlaid

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with the predicted incidence rate of hospitalization among children during 6 years after birth. In this map, the shade of the polygons is used to indicate the level of socio-economic disadvantage in the neighbourhood (i.e., in quintiles); the brightest and darkest areas of the map represent the lowest and highest level of socio-economic disadvantage, respectively. The size of the dots is used to present the incidence rate of hospitalization, the bigger the dot, the higher the incidence rate (i.e., in quintiles). 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 rates of hospitalization.
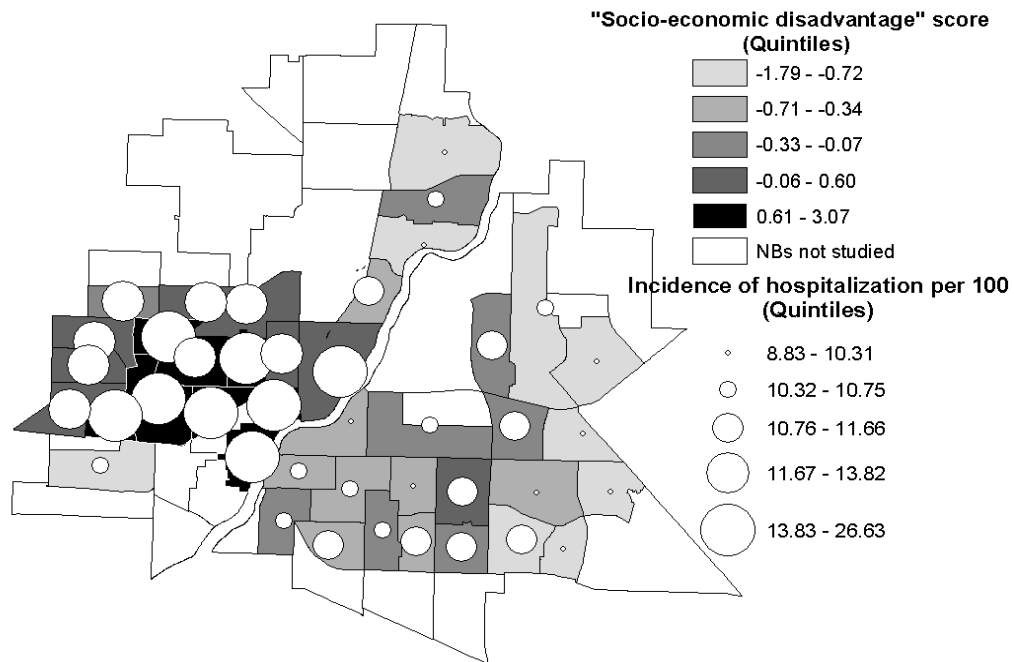
Figure 6-9: Association between neighbourhood socio-economic disadvantage and the predicted incidence of hospitalization* among children during 6 years after birth

*Based on the final multilevel model (table 6-2)

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The estimated coefficient for neighbourhood physical condition was 0.05. Since the score of this variable was negatively correlated with the physical condition of the neighbourhood (i.e., the lower the score, the better the neighbourhood condition), this positive coefficient indicated that a better neighbourhood physical condition was associated with a lower incidence rate of hospitalization. Again, the contextual impact of neighbourhood physical condition can be best visualized through the use of map as in Figure 6-10. In this figure, the brighter shaded areas represent the neighbourhoods with a better physical condition. These neighbourhoods also have smaller dots, which indicate a lower rate of hospitalization.
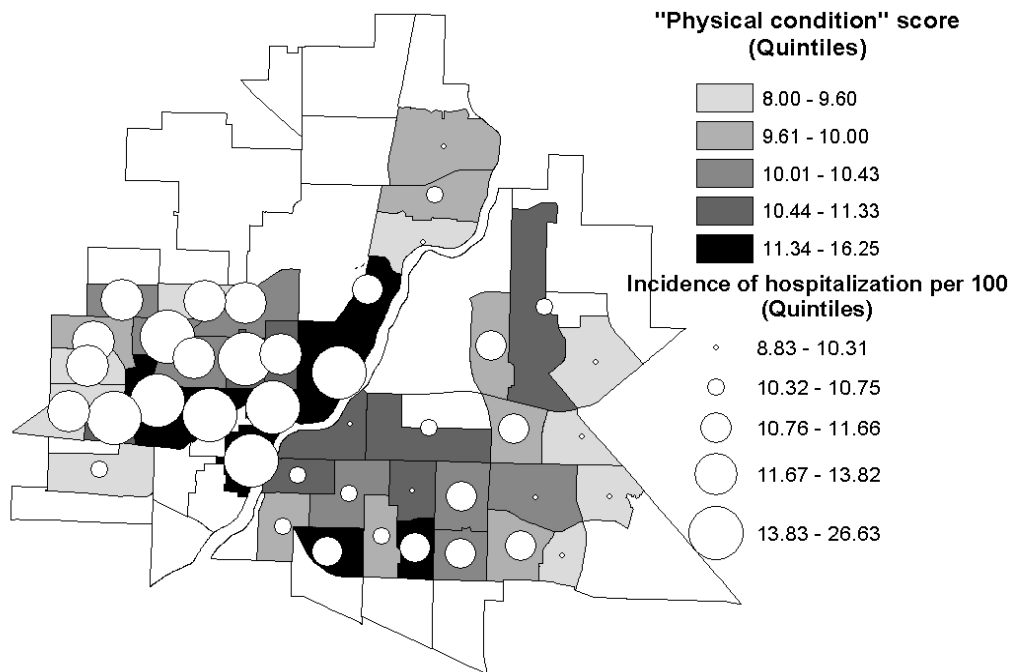
Figure 6-10: Association between neighbourhood physical condition and the predicted incidence of hospitalization* among children during 6 years after birth
*Based on the final multilevel model (table 6-2)

Similarly, the level of population density within a neighbourhood was also found to be an independent risk factor for hospitalization. As shown in Figure 6-11, generally, as the average household size of a neighbourhood increased, the incidence rate of hospitalization also increased. However, one may question why in some neighbourhoods, for instance Briarwood or Lakeridge, despite their high population density (i.e., indicated by the dark colour of the polygons), their incidence rate of hospitalization were still very low (i.e., indicated by the small size of the dots) while in some neighbourhoods, for instance City Park or Pleasant Hill, despite their low population density (i.e., indicated by the bright colour of the polygons), their incidence rate of hospitalization were very high (i.e., indicated by the large size of the dots). This paradox can be explained by the fact that the incidence rate of hospitalization in a neighbourhood depends not only on its population density but also on its physical and socio-economic condition. Although some neighbourhoods like Briarwood or Lakeridge had a dense population, they also had good physical condition and high socio-economic status, thus, they would still have lower rate of hospitalization and vice versus.
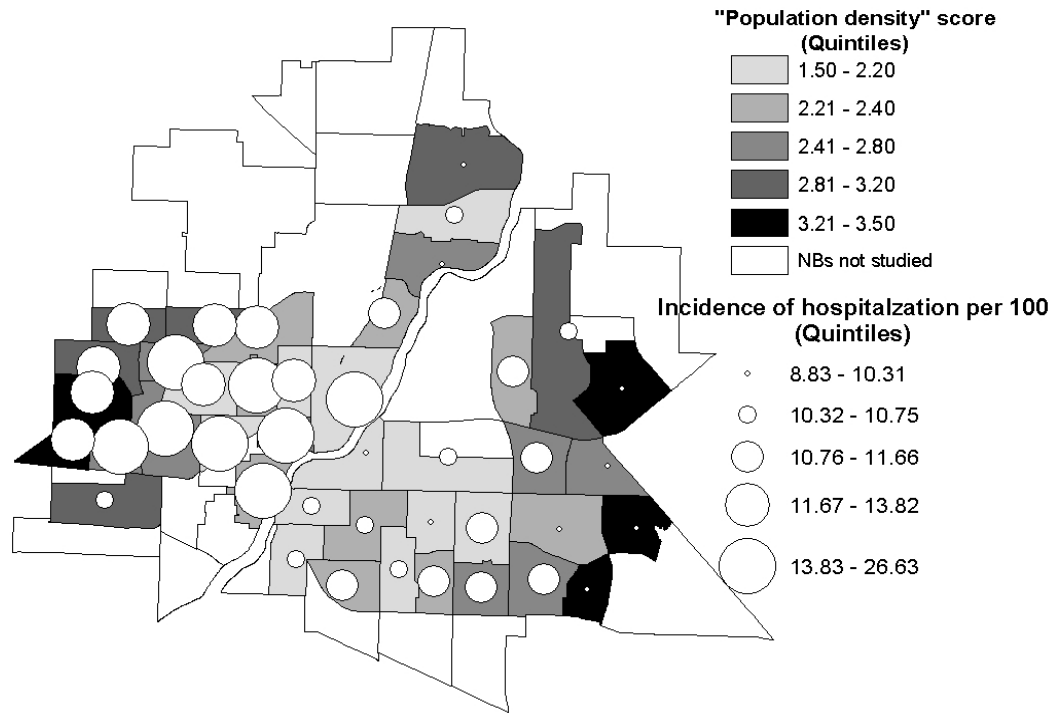
Figure 6-11: Association between neighbourhood population density and the predicted incidence of hospitalization* among children during 6 years after birth

*Based on the final multilevel model (table 6-2)

6.4.3.2 The hierarchical model for the average length of stay per hospitalization during 6 years after birth

As for the outcome incidence rate of hospitalization, a set of four increment models were built to identify the significant individual predictors as well as the contextual effect of neighbourhood of residence for the average length of stay per hospitalization. Table 6-2 presents these four increment model along with their -2*log-likelihood value. These log-likelihood values can be used to test the goodness of fit of different models:

- The -2*log-likelihood decreased from 15997.2 in model 1 to 15979 in model 2, a difference of 18.2. The new model (i.e., model 2) involved one extra parameter (i.e., income) so the change in -2*log-likelihood can be regarded as a χ^2 with 1 degree of freedom under the null hypothesis that the extra parameter have population values of zero. As such, it was very highly significant, confirming the better fit of model 2 compared to model 1.

- Similarly, the change in -2*log-likelihood between model 2 and 3 was 268, which followed a χ^2 distribution with 5 degree of freedom (since 5 extra parameters were added). This χ^2 was highly significant, indicating that the inclusion of 5 parameters at the individual level (i.e., Aboriginal, born with 1 adverse birth outcome, born with at least two adverse birth outcomes, interaction between income and born with 1 adverse birth outcome, and interaction between born with at least two adverse birth outcomes) was necessary since it resulted in a better fit of the model.

-   The change in 2*log-likelihood between model 3 and 4 was 16, which followed a χ^2 distribution with 2 degree of freedom (since 2 extra parameters were added). Again, this χ^2 was highly significant which indicated that the inclusion of neighbourhood variables in the model help to improve the fit of the model for length of stay.

As shown in Table 6-3, the final model (i.e., model 4) for average length of stay per hospitalization during 6 years following birth indicated 4 significant individual variables (i.e., income, Aboriginal status, adverse birth outcome and interaction term between adverse birth outcome and income) and 2 significant contextual effects (neighbourhood physical condition and neighbourhood socio-economic disadvantage). None of the individual variables was detected to have a significant random effect; therefore, all individual variables were constrained to be fixed across neighbourhoods.

The cross level interaction between "income" and "neighbourhood socio-economic", between "income" and "neighbourhood social interaction", between "single parent" and "neighbourhood socio-economic" and between "single parent" and "neighbourhood social interaction" were also tested in model 4. None of them was indicated to be statistically significant and therefore, would not be discussed here.

Mother's age, sex of the child and born with one adverse birth outcome were significantly predictors for the incidence rate of hospitalization however, they did not show significant association with the average length of stay per hospitalization during 6 years after birth. The average length of stay per hospitalization was 2.48 days longer for an Aboriginal child compared to a non Aboriginal child. The association between

adverse birth outcome, income and length of stay as well as the interaction between adverse birth outcome and income were already discussed in the previous section and therefore, is not included in this section.

Neighbourhood population density was a significant contextual effect for the incidence rate of hospitalization; however, it was not for the length of stay in hospital. Two other significant contextual effects (i.e., Neighbourhood physical condition and socio-economic disadvantage) for the incidence rate of hospitalization were also significantly associated with the length of stay in hospital in children 6 years following birth. In summary, for children who had been hospitalized at least once during the study time, a better physical condition of a neighbourhood of residence was associated with a shorter length of stay while a higher level of socio-economic disadvantage was associated with a longer length of stay for children who live within that neighbourhood.

Figure 6-12 demonstrates the association between neighbourhood physical condition and the predicted length of stay per hospitalization among children who had been hospitalized at least once during 6 years after birth. The size of the dots represents the length of stay in hospital, the bigger the dots, the longer the average length of stay. It can be seen that the areas with a darker shade (i.e., neighbourhoods with poorer physical condition) are also the areas that have bigger dots, corresponding to longer average length of stay in hospital. Thus, it is demonstrated that poor neighbourhood physical condition was associated with a higher risk of being

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hospitalized for a child. Once that child had been hospitalized, poor neighbourhood physical condition was a risk factor for a longer stay in hospital.
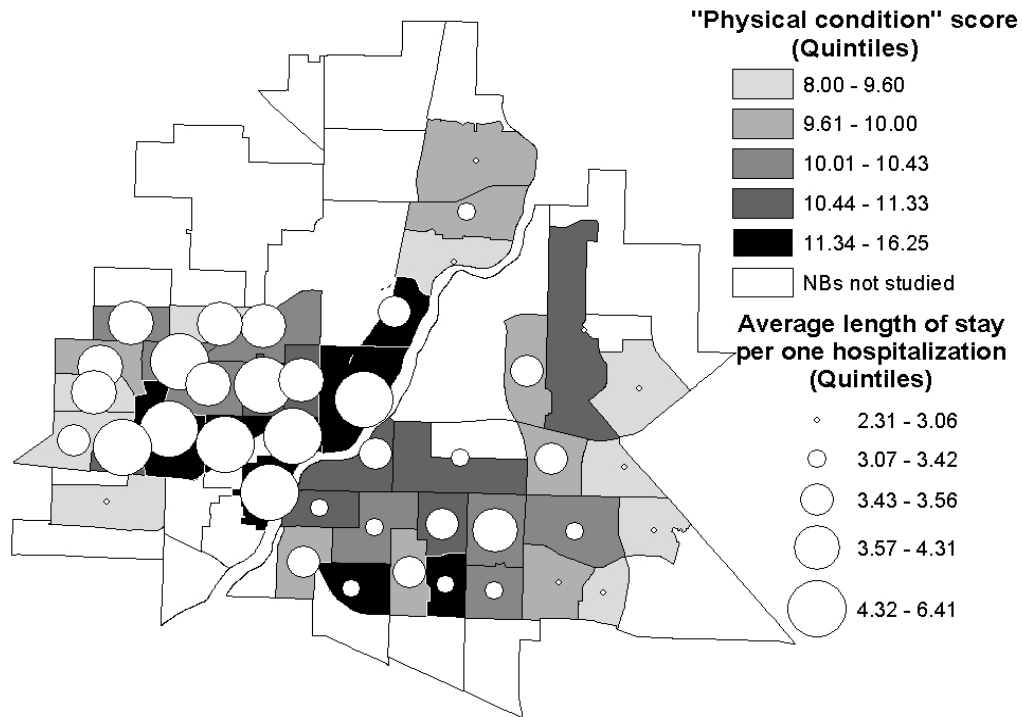
Figure 6-12: Association between neighbourhood physical condition and the predicted length of stay per hospitalization* among children hospitalized at least one during 6 years after birth

*Based on the final multilevel model (table 6-3)

The association between neighbourhood socio-economic disadvantage and the average length of stay in hospital is presented in Figure 6-13. The size of the dots and the shade of the areas are used to represent the average length of stay in hospital and the level of socio-economic disadvantage of the neighbourhood, respectively. Again, it can be observed that almost all of areas with the biggest dots exist on the Westside of

the river and those areas also are the areas with darker shade, representing higher level of socio-economic disadvantage in the neighbourhood. Thus, results showed that the level of socio-economic disadvantage in one neighbourhood was positively related to the risk of being hospitalized for children who lived in that neighbourhood, and once the children had been hospitalized, high level of socio-economic disadvantage was a risk factor for a longer stay in hospital.
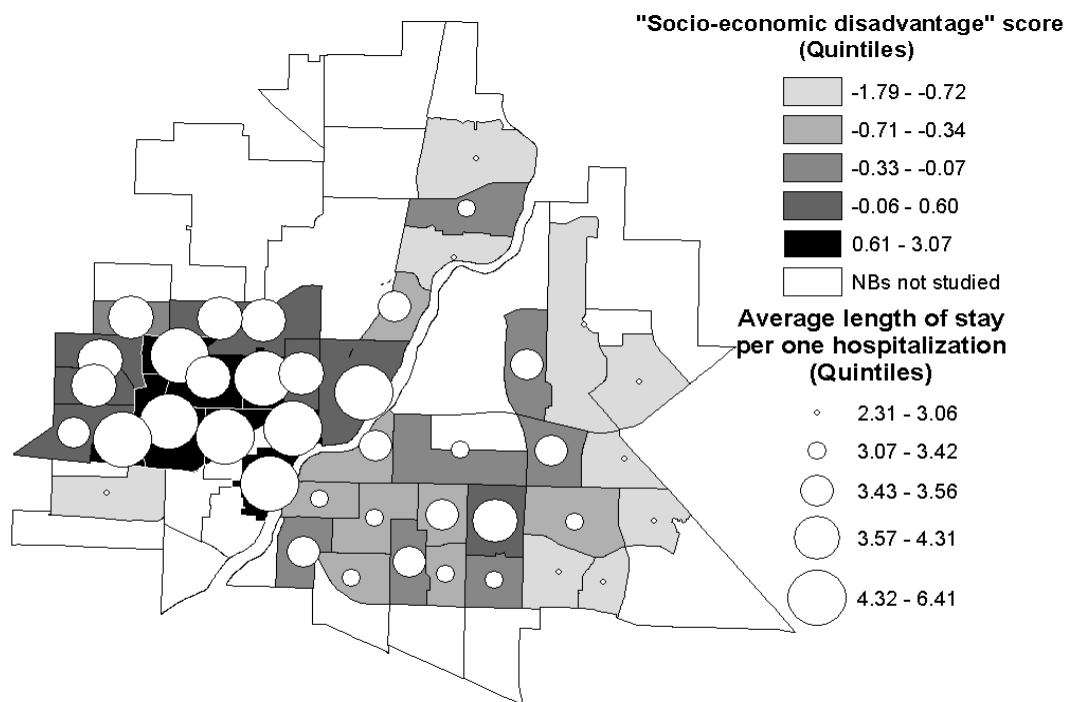
Figure 6-13: Association between neighbourhood socio-economic and the predicted length of stay per hospitalization* among children hospitalized at least one during 6 years after birth

*Based on the final multilevel model (table 6-3)

Table 6-3: Estimation of coefficients of the predictors at neighbourhood and individual level for the average length of stay per hospitalization during 6 years after birth

Variable	Model 1 β (SE)	Model 2 β (SE)	Model 3 β (SE)	Model 4 β (SE)
Intercept	3.40 (0.13)	3.40 (0.12)	3.63 (0.07)	3.64(0.07)
-2*log-likelihood	15997.2	15979.02	15711.2	15659.05
Variance at neighbourhood level	0.59 (p<0.01)	0.48 (p<0.01)	0.09 (p<0.01)	0.06 (p=0.06)
Income (received income assistance at least 1 time during 6 year vs. no)	*NI*	***0.63 (0.13)****	***0.55 (0.13)****	***0.58 (0.14)****
Sex of the child (Female vs. Male)	*NI*	*NI*	-0.06 (0.12)	*NI*
Aboriginal status (Registered Indian vs. non RI)	*NI*	*NI*	***2.45 (0.17)****	***2.48(0.17)****
Single parent (single parent vs. married/common law)	*NI*	*NI*	*0.01 (0.15)*	*NI*
Born with one adverse birth outcome	*NI*	*NI*	*0.19 (0.23)*	*NI*
Born with >= 2 adverse birth outcome	*NI*	*NI*	***1.20 (0.50)****	***1.20 (0.50)****
Mother's age < 20 (age <20 vs. age 20 to 40)	*NI*	*NI*	*0.17 (0.19)*	*NI*
Mother's age > 40 (age >40 vs. age 20 to 40)	*NI*	*NI*	*0.44 (0.66)*	*NI*
Father's age <20 (age <20 vs. age 20 to 40)	*NI*	*NI*	-0.05 (0.32)	*NI*
Father's age>40 (age >20 vs. age 20 to 40)	*NI*	*NI*	-0.2 (0.32)	*NI*

Variable	Model 1 β (SE)	Model 2 β (SE)	Model 3 β (SE)	Model 4 β (SE)
Interaction between income and born with one adverse birth outcome	*NI*	*NI*	*1.00 (0.40)**	*1.00 (0.40)**
Interaction between income and born with >=2 adverse birth outcome	*NI*	*NI*	*1.30 (0.65)**	*1.30 (0.65)**
Neighbourhood physical condition	*NI*	*NI*	*NI*	*0.11 (0.05)**
Neighbourhood socio-economic disadvantage	*NI*	*NI*	*NI*	*0.30 (0.15)**

Note: * Significant variables (p<0.05)

NI: Not included in the model

SE: Standard errors

6.4.4 Analytical Results for Objective 4

In this section, the results of an analysis that evaluated the relative impact on two children's health outcomes (i.e., incidence rate of hospitalization and average length of stay per hospitalization) due to family income status and neighbourhood variables is presented. The methodology used in estimating relative impact of family income status and neighbourhood variables is described earlier in section 6.3.2.

Briefly, for the outcome "incidence rate of hospitalization", based on the results of the final multilevel model, the attributable risks of family low-income status, and neighbourhood factors was produced. Since neighbourhood variables were measured on a continuous scale, two scenarios were relevant: risk corresponding to a difference in the neighbourhood variable from 10th to 90th percentile ("maximum" attributable risk) and risk corresponding to a difference from 50th to 90th percentile ("average" attributable risk).

Figure 6-14 presents the estimation of the attributable risk of the contextual effects as well as tha of family income. As shown in this figure, the largest attributable risk was the maximum risk due to neighbourhood physical condition. This attributable risk was larger compared to the attributable risk of family income (18.3 % vs. 15.61%). Attributable risks of other contextual effect, both the maximum and the average ones, were smaller compared to that of family income.

However, it is important to emphasize that the combination effect of these three neighbourhood factor on children's incidence rate of hospitalization would be much more significant, compared to the effect of family income. For instance, when all individual level variables were held constant at their means, the model for incidence

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rate of hospitalization among children during 6 years after birth predicted a minimum

incidence rate of hospitalization of 8.95 per 1000 in Arbor Creek and Erindale and a

maximum incidence rate of hospitalization of 14.9 per 1000 in Riverdale, range of

5.95 and attributable risk of 40%.
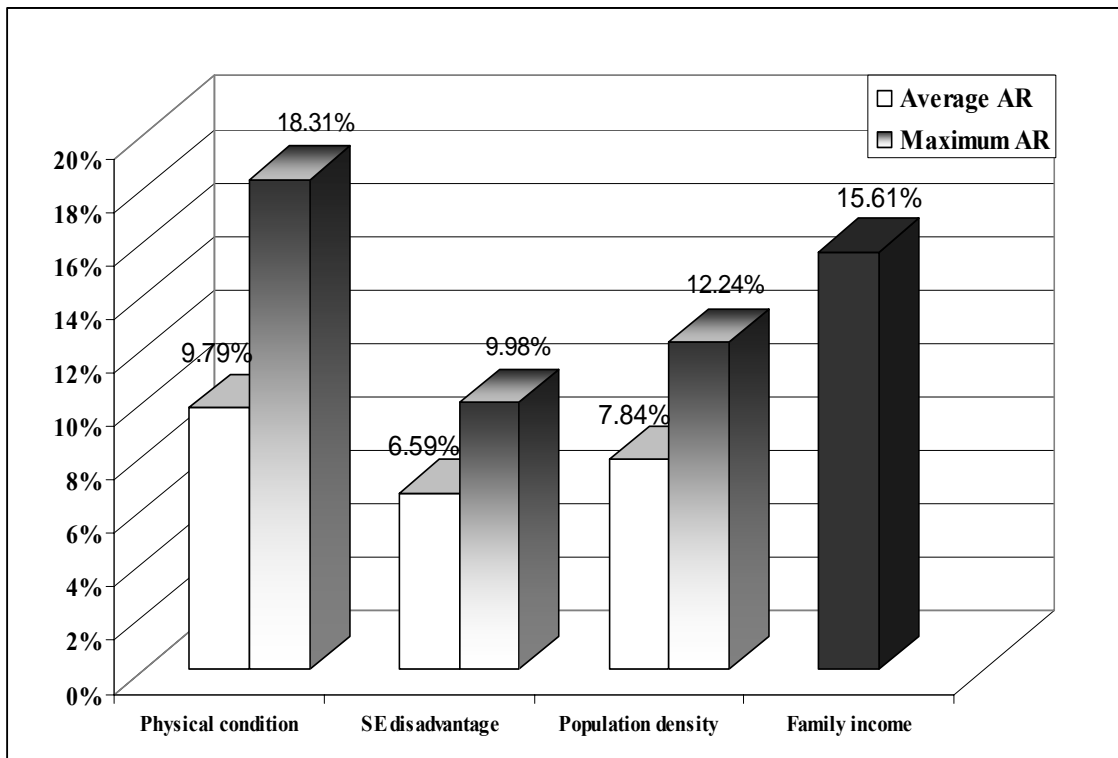
Figure 6-14: Comparison of the attributable risks due to family income and neighbourhood variables

Figure 6-15 shows the difference in average length of stay per hospitalization

during 6 years following birth due to the difference in neighbourhood characteristics

and family income among children who had been hospitalized at least once. As for the

incidence rate of hospitalization, two types of differences in length of stay were

estimated. The maximum difference was the difference between the 10th and the 90th

percentile groups while the average difference was the difference between the 50th and the 90th percentile groups.

For neighbourhood physical condition, the average and maximum difference was 0.23 days and 0.44 days, respectively. It meant that during 6 years after birth, compared to a child living in a neighbourhood with the worst physical condition in Saskatoon, a child living in a neighbourhood with the best physical condition in Saskatoon would have 0.44 days shorter in average length of stay while a child living in a neighbourhood with the average physical condition would have 0.23 days shorter in average length of stay in hospital.

Compared to a child living a neighbourhood at the lowest socio-economic level, a child living a neighbourhood at the average and highest level of socio-economic would have 0.41 and 0.63 days shorter in his length of stay, respectively. Clearly, the maximum effect of neighbourhood socio-economic disadvantage on length of stay was larger than the effect of family income.

Again, the combination effects of neighbourhood socio-economic disadvantage and physical condition was estimated to be much stronger compared to the effects of family income. When all individual level variables were held constant at their means, the multilevel model for the average length of stay predicted a minimum length of stay in hospital of 2.88 days in Arbor Creek and Erindale and a maximum length of stay in hospital of 5.18 days in Pleasant Hill, a range of 2.31 days (i.e., this difference was due to the difference in socio-economic and physical condition between those neighbourhoods).
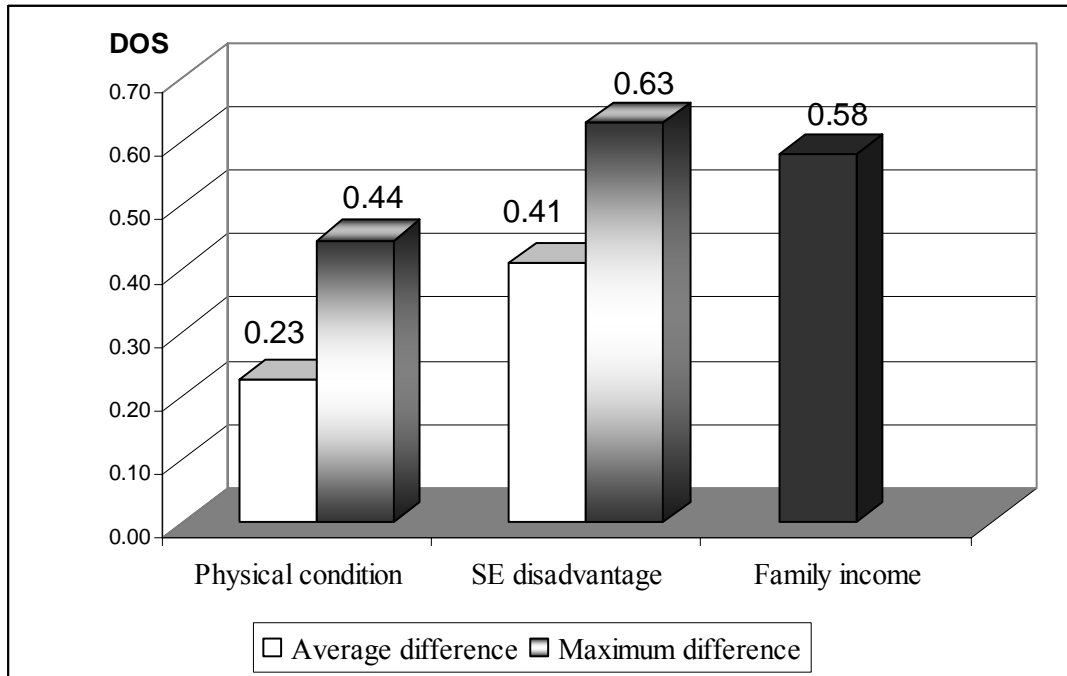
Figure 6-15: Comparison of the difference in length of stay due to the difference in family income status and to the difference in the characteristics of neighbourhood of residence

6.4.5   Summary of analytical results

This focused topic examined four research objectives and provided a wide array of research findings. Table 6-4 presents a summary of the major research findings for each research objective.

Table 6-4: Summary of research findings for focused topic 2

Research Objective	Finding
Objective 1 Describe the major causes of children's hospitalization by age, family income status and birth outcome	1. Causes of hospitalization were different for children with an adverse birth outcome compared to children with no adverse birth outcome (e.g., asthma was more common among children with adverse birth outcomes). 2. Causes of hospitalization were different for children in low-income families compared to better-off families (e.g., asthma and infectious diseases were more common among children in low-income families).
Objective 2 Examine the relative effects of adverse birth outcome and family income, and interactions between them, on childhood hospitalization.	3. Children in low income families and with an adverse birth outcome had higher rates of hospitalizations and longer length of stay in the hospital. 4. There was a gradient association between number of adverse birth outcomes and childhood hospitalization. 5. Family income moderated the association between adverse birth outcome and childhood hospitalization; the impact of adverse birth outcome on childhood hospitalization were much stronger among children in low income families.

Research Objectives	Findings
Objective 3 Examine independent and moderating effects of neighbourhood factors on childhood hospitalization	6. Neighbourhood factors have independent effects on childhood hospitalization, over and above the effects of individual risk factors. 7. For the outcome incidence rate of hospitalization, there were three significant neighbourhood risk factors: physical condition, socio-economic disadvantage, and population density. 8. For the outcome average length of stay per hospitalization, there were two significant neighbourhood risk factors: socio-economic disadvantage and physical condition. 9. Neighbourhood factors showed no moderating effects. 10. Individual risk factors for childhood hospitalization were: aboriginal status, adverse birth outcome, low income, male, and mother's age less than 20.
Objective 4 Compare the relative effects of family income and neighbourhood factors on childhood hospitalization	11. Neighbourhood effects on childhood hospitalization were estimated to be substantial in comparison to family income, especially when the effects of several neighbourhood factors were combined and compared against the effect of family income.

6.5 Discussion

This focused topic set out to explore the multilevel determinants of childhood hospitalization (i.e., incidence rate and length of stay). Several important hypotheses were examined in this study including the gradient association between the number of adverse birth outcomes and childhood hospitalization, the causation between family income and child hospitalization, the moderating effect of family income on the impact of adverse birth outcome, and the independent/moderating effects of six different domains of neighbourhood (i.e., neighbourhood socio-economic disadvantage, social interaction, physical condition, population density, unhealthy lifestyle norm and programs and services for children and their families) on childhood hospitalization. Four research objectives were addressed in this study and the analytical results will be discussed in relation to these research objectives.

Objective 1: To describe the major causes of hospitalization in children from 0 to 6 years

Results indicated that morbidities that contributed most significantly to hospitalizations in Saskatoon children under six years of age were mainly of conditions related to perinatal origin, respiratory diseases, diseases of digestive system, congenital anomalies, injuries, and diseases of nervous system. This finding is consistent with a previous Saskatoon District Health report.[223] The results showed that the pattern of hospitalization changed as children grew up. Respiratory diseases remained to be the major cause of hospitalization for children under 6 years of age.

The well-known association between adverse birth outcome (i.e., preterm birth, low birth weight, and small for gestational age) and many morbidities such as respiratory diseases, condition related to perinatal origin, congenital anomalies, neurodevelopmental handicap [18,144,185,224,225] was once again observed in this study. Children born with at least one adverse birth outcome, either preterm birth, LBW or small for gestational age, were hospitalized due to respiratory diseases (especially asthma), diseases of condition related to perinatal origin, congenital anomalies, and diseases of digestive system, more frequently than children born with no adverse birth outcomes.

Results also demonstrated that there was a difference in the major causes of hospitalization between children living in low income families and children living in more affluent families. The higher rate of hospitalization due to asthma and infectious diseases among children living in low income families found in this study may be attributed to the inadequate nutrition, instability of residence, poor housing condition, and exposure to environmental toxins that are often associated with low income status.[226]

Finally, it is important to say that in this study childhood morbidity that contributed to inpatient hospitalizations were identified using diagnosis codes recorded in administrative files kept by Saskatchewan Health. Misclassifications in childhood morbidity designations could have happened if there were errors in diagnosis codes in the Health administrative databases. However, the high validity and reliability of Saskatchewan health databases have been demonstrated in several validation studies.[99-101] Therefore, the probability that misclassification in childhood morbidity measure in

this study was low. Furthermore, in this study, the purpose was to give a preliminary description of disease categories that may have contributed significantly to health services utilizations of children during 6 years after birth and the results from this study may be used to generate some hypotheses for future research.

Objective 2: To examine the relative impact of adverse birth outcomes and family income, and the interaction effects between them, on hospitalizations.

The results indicated that adverse birth outcomes (either LBW, preterm, small for gestational age or combination) were associated with a higher incidence rate of hospitalization as well as with a longer length of stay in hospital. This finding is consistent with previous reports about the association between adverse birth outcomes and higher hospitalization, higher rate of respiratory diseases, and higher rate of perinatal complications. [17,119,127]

Results showed that more adverse birth outcomes were associated with more hospitalizations and a longer stay in hospital. Children with two adverse birth outcomes had a higher incidence rate of hospitalization and a longer length of stay in hospital compared to children born with only one adverse birth outcome. Others have also reported that the combination of preterm and small for gestational age, small for gestational age and LBW are associated with higher mortality and increased risks of morbidity in infancy and childhood. [128]

Children who were in families receiving income assistance from the Saskatchewan government had a higher number of hospitalizations and days of stay in hospital than children whose families did not receive any family income assistance.

This association is generally consistent with the findings of previous research[205,206] and may be interpreted in several ways. First, because of Saskatchewan's comprehensive health care insurance plan, the use of health services is based on medical need rather than the ability to pay. Therefore, access to health services by poor children is not limited by their family's financial status. Family income is not so much an enabling factor, as suggested in Andersen-Newman Model [197], but it may predispose individuals to use health care services. For instance, because of low income, children are more likely to live in unsafe, crowded housing, which could lead to an increase in accidental injuries, communicable diseases, respiratory disease and so on; their families cannot afford high quality food, which can lead to nutritional disorders. The advantage of this study lies in its longitudinal design. If a cross sectional study had been employed, one would have questioned whether the observed association was due to uncontrolled confounding such as poor lifestyle behaviours (including smoking, and poor diet which are more prevalent among the lower socio-economic group). The longitudinal design is required to establish causation since this design allows researchers to measures changes in hospitalization rate over time in response to the income status of the family.

The results that the effects of adverse birth outcomes on hospitalizations were modified depending on the income status of the family—heightened for children in low income families and lessened for children in "high" income families—is an important finding. The factors which facilitate/accelerate children with adverse birth outcomes catching up to their normal peers (with no adverse birth outcome) have been receiving attention from policy makers and health promotion practitioners.[227] If

children born with adverse birth outcomes commence their lives with health deficits, it is essential to understand how to reduce the consequence of adverse birth outcomes and to help them to catch up to their peers. The interaction between adverse birth outcome and family income found in this study indicates that children with adverse birth outcomes could catch up to their normal peers but this process is significantly influenced by the economic circumstances of the family.

Objective 3: To examine independent effects of neighbourhood factors on hospitalizations as well as their moderating effects on the association between some individual risk factors and childhood hospitalization

Results indicated that neighbourhood socio-economic disadvantage had an independent effect on the number of hospitalizations and days of stay over and above the effect of family income. Children living in poor neighbourhoods had a significantly higher rate of hospitalization as well as longer days of stay in hospital compared to children living in better neighbourhoods. Results also suggest that there was strong residential polarisation, with low-income families living in poorer neighbourhoods and more affluent families living in wealthier neighbourhoods. This polarisation brought up two implications for the consideration of neighbourhood effects on children's health. First, some neighbourhoods may have higher hospitalization rates than others solely because of the lower socio-economic status of the families in these neighbourhoods. However, as the results showed, this was not the case since individual income status and neighbourhood socio-economic disadvantage were independently related to hospitalization outcomes in Saskatoon children. Second, the effect of the individual socio-economic status may act through the area of residence or in other

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words, the neighbourhood socio-economic status may be a mediator for the association between individual socio-economic status and the use of the hospital. Again, this was not the case as the effect of family income on the number of hospitalizations/length of stay (i.e., reflected by the coefficient of this variable) remained the same when neighbourhood variables were added into the model.

Thus, the results of the present study provided support for the hypothesis that neighbourhood socio-economic status is associated with hospitalization outcomes (both number of hospitalizations and length of stay in hospital) over and above the effects of individual/family socio-economic status. Other studies have reported the association between neighbourhood socio-economic status with adverse birth outcome[168,172], chronic disease among adults[228], and health behaviors.[229,230] This study differed from previous studies in that (1) the study was done in Canada while almost all other studies were done in the UK or the US (2) the study subjects were children (3) the study design was longitudinal which yielded a longer term pattern of health care use, rather than a "snapshot" that a cross sectional design would produce (4) this study controlled for other aspects of neighbourhood (i.e., physical condition, social interaction, population density, programs and services for children and unhealthy lifestyle norms) and thus, added validity and reliability to the estimation of the association between neighbourhood socio-economic disadvantage and childhood hospitalization.

So what is it about a lower socio-economic neighbourhood that is detrimental to the health of children regardless of their own income level? The neighbourhood socio-economic context might affect health outcomes directly or indirectly by affecting

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the physical conditions, social environment and services, and amenities available in the neighbourhoods, and in turn having an impact on health outcomes. For instance, in terms of the physical environment, disadvantaged socio-economic neighbourhoods may offer less safe housing, work place, and recreational options, more polluted air, and more potential exposure to toxins (i.e., lead paint, asbestos and pest infestation).[53,177,231] In this study, the neighbourhood physical condition (which took into account housing condition, road and traffic condition, neighbourhood parks) was taken into account and the neighbourhood socio-economic disadvantage still showed a significant effect. Therefore the physical environment cannot totally explain the impact of the neighbourhood socio-economic context on hospital outcomes observed in this study.

The services environment of neighbourhood may also differ by socio-economic status of the neighbourhoods, affecting access to adequate or high quality services for all residents. Necessary social services may not even exist in a poor neighbourhood, even if some residents are able to pay for them.[176,231,232] In this study, the availability and accessibility of programs and services for children and families in their neighbourhoods, such as education, parenting, childcare, sports and recreation, nutrition, and counselling, were taken into account. But this study did not control for the availability and accessibility of other services such as supermarkets, grocery stores, and public transportation. Poor neighbourhoods may struggle to attract the resource necessary to develop and sustain large supermarkets, grocery stores and public transportation, leading to limited options for healthy food and other essential services. For example, it has been shown that the price of food is 3% to 7% more expensive in

local community stores (convenience stores) compared to large supermarkets,[233] and supermarkets had twice the average number of healthy food compared to neighbourhood grocery stores and four times the average number of such food compared to convenience stores.[234] Another challenge faced by those in the lowest socio-economic groups is that they are least likely to have a private vehicle to use for food shopping, making the location of food stores more critical for the poor.[235] These issues were not taken into account in measures used in this study.

Neighbourhood socio-economic disadvantage may also affect its social environment. [53,175,231] For instance, Wilson suggested that the concentration of male joblessness, poverty, and female-headed households may have led to social isolation and to a shift in neighbourhood's social and cultural norms. He posited that both the macro-structural constraints and the behavior of other jobless families in a neighbourhood influence the children and families who reside there.[236] Several studies have also reported that those lower socio-economic neighbourhoods are less likely to practice health promoting behaviors such as exercising regularly, not drinking and not smoking. [46,229,230]

Apart from neighbourhood socio-economic disadvantage, neighbourhood physical condition and neighbourhood population density were also found to have significant impact on childhood hospitalization. Children in neighbourhoods with poorer physical conditions had both a higher incidence rate of hospitalization and a longer length of stay in hospital. The neighbourhood physical condition in this study reflected the housing condition, traffic volume, road condition, availability of park and play grounds, and the level of noise and air dust within a neighbourhood. The fact that

these factors have been reported to have significant association with some morbidities in children, for instance lead poisoning or respiratory diseases,[213] [237,238] could perhaps explain the observed association. It is interesting to note that the negative effect of the poor physical condition of the neighbourhoods on childhood hospitalization observed in this study was even more pronounced than the effect of low income families.

Results also suggested that neighbourhoods with denser populations (i.e., measured by the number of people per household) had a higher incidence rate of hospitalization. This association may be explained by the unmet needs that a densely populated neighbourhood might have (e.g., child care, grocery stores, public transportation, recreational centres) in relation to the resources available. Densely populated neighbourhoods may also present a more conducive environment for communicable and respiratory diseases; for instance in a study done by Cardoso *et al.* it was reported that household crowding places young children at risk of acute lower respiratory infection. [239]

We had hypothesised that neighbourhood social interaction, unhealthy lifestyle norms, and availability and accessibility of programs and services for children 0- 6 years old and their families would also have an impact on childhood hospitalization. However, these neighbourhood variables were not indicated to be significantly associated with either incidence rate of hospitalization or length of stay in hospital. Again, the lack of significance of these variables might be explained by the fact that there were some inter-correlations among neighbourhood variables (i.e., the most socio-economic disadvantage neighbourhoods would also be the neighbourhoods with low social interaction or high prevalence of unhealthy lifestyle norms) and that

neighbourhood socio-economic disadvantage and physical condition together may capture the underlying mechanisms of neighbourhood effects on childhood hospitalization better than these other neighbourhood domains.

The moderating effects of neighbourhood factors on the association between family income and single parent status and childhood hospitalization were tested in this study. However, unlike the results for LBW, the moderating effects of neighbourhood factors were not observed in this study.

In addition to the major findings regarding the neighbourhood independent effects, it was also reported that younger children, male children, Aboriginal children, those with adverse outcomes at birth, lived in a low income family and had younger mothers were at elevated risk for hospitalizations. Children of Aboriginal ancestry, born with adverse birth outcomes, and children of low income families were at risk for longer length of stay in hospital. This study results supported the hypothesis that single parent, *per se,* may not be a risk factor for children's health status. Once low income, Aboriginal status, and young mother's age were taken into account, being a single parent was no longer associated with a higher number of hospitalizations, as well as a longer length of stay in hospital. Male children tended to have a higher number of hospitalizations than female children. This finding was not contradictory with the existing understanding of the relationship between children's health and their sex. Male children have been considered to be at a greater biological risk for some diseases such as respiratory diseases[240] and have a higher rate of injury than females.[223] Therefore, the rate of hospitalization among male children may be higher than that among female children. Aboriginal children were indicated to have both a higher

incidence rate of hospitalization and a longer length of stay in hospital compared to non Aboriginal children. While this finding was consistent with previously published reports,[241-244] it is important to emphasize that Aboriginal ancestors *per se* may not be a biological risk factor of children's health, rather it could be just a marker for many problems popular among the Aboriginal population, which are known as risk factors of children's health. These factors include socio-economic factors (low income, low education, unemployment, homelessness…etc), health risk behaviors (smoking, drug use, alcohol consumption, unsafe sexuality, unhealthy food…etc), and psychological factors.[241,245-248] Contrary to the analytical results for LBW, young mother's age (i.e., less than 20 years old) was shown to have a significant association with hospitalization rate while a mature mother's age (i.e., greater than 40) was not. There may be several possible explanations for this finding. First, adolescent pregnancy is an important indicator for early childhood development[249-251] and young mother's age is a risk factor for several childhood morbidities.[252-254] Second, teen childbearing often leads to poor economic and social outcomes for adolescent parents and their children. Adolescent mothers are less likely to complete their education and more likely to live in poverty. Finally, adolescent mothers tend to have less experience in taking care of their children and to be less emotionally mature than older mothers, as they are still dealing with developmental issues themselves. Children of adolescent mothers, therefore, may have poorer health status and, as a consequence, use more health services.

In conclusion, the results supported the hypotheses that the characteristics of the neighbourhood of residence had independent effects on hospitalization outcomes

(both incidence and length of stay) among children in the first 6 years, over and above those of individual risk factors.

Objective 4: To compare the relative overall effects of family income status and neighbourhood factors on childhood hospitalizations

In previous sections, it was reported that children in low-income families were more likely to have poor health outcomes, and that independent of the family income effect, neighbourhood social adversity was also related to poor health outcomes. Thi section will explore which of the two effects, family low-income status or neighbourhood risk factors, had a higher impact on the children's health outcomes examined in this study.

For the outcome "incidence rate of hospitalization", this question was addressed by adapting a standard epidemiological measure, attributable risk. The attributable risk is defined as that portion of the outcome that is attributable to a risk factor; therefore, by extension, attributable risk has commonly been used to indicate the "amount" of a disease or outcome that would have been prevented had the risk factor not existed or its effect been at a minimum. This study adapted the concept of attributable risk to the multilevel setting, and compared attributable risks under three different scenarios: a) the maximum attributable risk due to neighbourhood socio-economic effect alone (defined as the amount of change in the neighbourhood measure corresponding to a change from 10th to 90th percentile), b) the average attributable risk due to neighbourhood effect alone (defined as the amount of change in the neighbourhood measure from 50th (or median) to 90th percentile), and c) the attributable risk due to family low-income status alone.

For the outcome, "length of stay in hospital", it was addressed by estimating the difference in length of stay due to the effect of family income compared to that due to the combined contextual effects of neighbourhood. The difference in length of stay due to the effect of family income, or contextual effects of neighbourhood, can be understood as the change in the length of stay that would be expected had the family income status changed, or the neighbourhood conditions changed.

For the outcome, incidence rate of hospitalization, results showed that the neighbourhood physical condition had a stronger effect on the outcome than that of family income, but the neighbourhood socio-economic disadvantage had a weaker effect on the outcome than family income. For the outcome, average length of stay in hospital, the neighbourhood socio-economic disadvantage had a stronger effect than that of family income, but the neighbourhood physical condition had a weaker effect than that of family income. In both cases, however, the combination of neighbourhood physical condition and neighbourhood socio-economic status would yield a stronger effect than family income alone.

Analytical results suggest that future efforts aimed at reducing childhood morbidity burden might be more effective if efforts are made to target neighbourhood risk factors rather than, or in addition to, the usual individual factors. However, it is important to note that the effect of neighbourhood risk factors on childhood hospitalization observed in this study might have been over- or underestimated due to study design limitations. Methodological limitations of this study may have most likely led to an underestimation of the contextual effect of the neighbourhood of residence on childhood hospitalization. For instance, the duration of residence in the

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neighbourhood (i.e., "exposed time") was not considered in this study, which could have resulted in an underestimation of the neighbourhood effect since some children may not have lived to study completion, nor have lived in a particular neighbourhood long enough to have their health affected by neighbourhood characteristics. The neighbourhood data used in this study were collected at a single point in time, and therefore did not capture the effects of stability and change in a given neighbourhood on the health of children. Besides, the contextual effect of the neighbourhood of residences may have been underestimated in this study because the effect of neighbourhood factors on childhood hospitalization through its effect on family SES and adverse birth outcome were not considered. For instance, as reported in the previous study, the neighbourhood socio-economic disadvantages affect the resident's birth outcomes. Thus, controlling for the effect of adverse birth outcomes on childhood hospitalization may have resulted in over-control for indirect effects of the neighbourhood socio-economic disadvantage on childhood hospitalization through adverse birth outcomes.

The effects of neighbourhood factors, on the other hand, could represent an overestimation due to selection bias. The neighbourhood socio-economic disadvantage variables, in theory, could have included unmeasured individual level variation in outcome. However, collectively, income level, single parent status, mother's age, and Aboriginal status in this study were likely to have captured many of the unmeasured individual level confounders such as health risk behaviors, education level, and psychosocial factors (please see section 7.1 for more discussion on study strength and

limitation). The interpretation of the study findings should be read with the

consideration of these potential biases in mind.

7 DISCUSSION AND CONCLUSION

This chapter will address the previous findings and relevant issues surrounding this thesis research. A summary of methodological issues relevant to this thesis will be presented first. Following that, a discussion of the research implications of this study will be provided. Finally, a highlight of the major findings with their policy implications will conclude the chapter.

7.1 Methodological Issues

The study design and methodology has advantages and limitations, which may have affected the study results. The main advantages and disadvantages are identified below.

7.1.1 Study Strengths

This study employs the Saskatchewan Health's administrative databases to gather individual information, which offers several advantages. First, the data include all Saskatoon children population born over the period of three years, which enables the inclusion of a population sample, and therefore increases the validity and generalizability of the study. Second, the classification of exposures and non-exposures based on a birth information file is more reliable and valid than obtaining

the information through self-report or health survey. Third, the evaluation of health services utilizations is done based on a hospital file, which may be more accurate and valid than a self-report. Finally, the socio-demographic information for all subjects in this study is extracted from routinely recorded information available through the birth registration system, which also increases the validity and reliability of this information. Using a comprehensive administrative database also enables a large study sample to be included and thus increases the study power considerably.

One type of bias in retrospective cohort studies is information bias. Information bias occurs when the quality and the extent of the information obtained are different for exposed subjects compared to non-exposed subjects.[255] The use of information from the administrative databases likely provides the same quality and the extent of information for exposed and non-exposed subjects. Therefore, information bias is reduced. No interviews are necessary in this study which minimizes the problem of recall bias, or interviewer bias. Follow-up done through data linkage reduces selection biases as well, of which the non-respondent bias and selective losses to follow-up are two major threats to validity in longitudinal studies.

Another major advantage of this study is the use of longitudinal data and multilevel design. Longitudinal data enables the measurement of changes in the hospitalization rate over time in relation to the changing income status of the family. Thus, longitudinal data captures more closely the dynamic nature of associations between income status and outcomes and would help make stronger claims on causation. The multilevel design allows the inclusion and analysis of data on both neighbourhood and individual within these neighbourhoods. In the absence of true

experiments assigning individuals to neighbourhoods at random, research design must approximate the experimental design by comparing similar individuals living in different areas. Therefore, individual information is needed to statistically examine similarities and differences in individuals across neighbourhoods, and neighbourhood level information is needed to describe the properties of neighbourhoods that account for any observed spatial differences. The combination of individual and neighbourhood variable in one model helps to separate the compositional effect and the contextual effect and increases the validity of the analytical results regarding the neighbourhood impact. Furthermore, it clarifies our understanding of how variances in outcomes are distributed across levels of social hierarchy, which in turn could inform health policy makers and health practitioners to design more effective interventions at different levels of society (i.e., community, family).

This study combines the neighbourhood information from Census Canada with two local surveys and this combination has several strengths. First, this strategy uses the best available data and offers a relatively quick and cost efficient way to study the neighbourhood impact. Second, it offers a unique opportunity to examine the effects of the different aspects of neighbourhood as well as the interaction effects among them on individual outcomes. Examining different domains of neighbourhoods and their effects on child development not only allows for more complete tests of theories but also illuminates the causal structure among neighbourhood level variables, suggesting which aspects of neighbourhoods are potential targets for policy manipulation. Third, since these data are routinely collected, they can be used to develop some common indicators, which can be easily incorporated into future research. The use of these

common indicators would enable the comparison of studies conducted in different cities.

The use of the GIS (Geographic Information System) software to demonstrate the research findings should also be considered as an advantage of this study. The rationale of using mapping as a tool to demonstrate the research finding is based on the notion that the health inequalities should be monitored and reported in a way that is meaningful to policy makers.[256] Health policy makers are not necessarily trained as epidemiologists or statisticians and thus, may not have a thorough understanding of the results reported by researchers. Researchers should meet the challenge of presenting their results in a way that serves the needs of health policy makers.[256,257] With respect to the inequalities in children's health across Saskatoon neighbourhoods, the most insightful presentation of results is through geographic maps in which the rates of diseases and the distribution of adverse birth outcomes/ childhood hospitalization are visualized through coloured patterns.

7.1.2 Study Limitations

The study is not without limitations and all study results must be read with the consideration of these limitations. First, confounding is probably the most important limitation of this study. Confounding refers to a distortion in the study effect, which results from the mixing of the exposure-disease association with the effects of extraneous variables.[258] In this study, controlling for the effects of potential confounding was limited only to the four socio-demographic factors available in the administrative database; the age of the child, sex, family income assistance and the mother's age. The potential for confounding by these variables was controlled for

through the use of multivariate analysis. Because the dataset for this study did not include information on other potentially important risk factors related to the children's health status such as the level of parent's education, housing condition, access to food, genetic make up, parents' beliefs, values concerning health and illness, attitudes towards health services, knowledge about diseases and so on, confounding may have affected the parameter estimates of both neighbourhood and individual variables.

At the neighbourhood level, this confounding effect is referred to "selection bias".[103]. Selection bias recognizes the fact that families have some degree of choice regarding the neighbourhoods in which they live. Therefore, if important unmeasured characteristics of families (potential confounders) lead them both to choose certain kinds of neighbourhoods and to have low birth weight children /children with a higher rate of hospitalization then the observed effects of neighbourhood in this study could have been distorted and the direction of this selection bias is difficult to predict (i.e., we are not sure whether this bias would result in an overestimation or an underestimation of a true effect). Some authors have argued that this selection bias would likely result in an overestimation of neighbourhood effects due to the fact that high risk populations are most likely to live in a bad neighbourhood since they cannot afford a better neighbourhood and therefore the coincidence of living in a poor neighbourhood and having an unhealthy child results from the risks associated with these parents.[103] However, we should emphasize that the three important factors controlled in this study (i.e., the mother's age, single parent status and family income) are known to be inextricably linked with other factors such as the level of education, housing condition, and access to nutritious foods. Thus, we hope that controlling for

these key variables would help reduce the potential biases that would have otherwise resulted from not controlling for some possible confounders.

Second, we should also recognize the possibility of transactional effects on our results. Transactional model states that not only individuals create and shape their own neighbourhood but also characteristics of individuals/families are shaped by their neighbourhood.[103] It has been argued that if aspects of the social environment influence health by operating as upstream determinants of individual characteristics then control for many downstream individual factors may over-adjust the true effects of the contexts.[259] This possibility is even more salient if we examine the cross level causal equation using a life course developmental framework, in which the effects of various aspects of the environment are literally embodied over time so that what is assigned as an individual level variable at one time point could equally be conceptualized as a characteristic of the past environments which the individuals grew up in.[260] Thus, the neighbourhood of residence may affect parental characteristics, for instance, persistent residence in a neighbourhood with high levels of crime, low levels of economic opportunity, and poor transportation can affect the competence and commitment of the resident to seek for a job, to stop their unhealthy lifestyle like smoking or alcohol consumption and so on. In this study, the neighbourhood effects are estimated, controlled for family income, marital status, mother's age and so on. Thus, if neighbourhoods do affect those variables which in turn affect child development, the controls for those variables may have resulted in an underestimation of neighbourhood effects.

Third, the neighbourhood level data used in this study are cross-sectional and quantitative. With cross sectional data, we are not able to capture the effects of the dynamic changes in the neighbourhood of residence and thus we have ignored potential effects of stability and change in a given community on the health of individual residents. This bias would likely result in an underestimation of the neighbourhood effect. We hope the use of routinely available data in this study would help develop some common indicators of neighbourhood domains which can be incorporated in the future research of Saskatoon children's health. However, there are some limitations with the routinely collected data since they were all quantitative data. With quantitative data, it is not possible to have individual perspectives and depth to the analytical results. Qualitative neighbourhood data are needed to shed new insight into the mechanism of the neighbourhood effects and how they "get under skin".

Fourth, we cannot fully consider how long people live in their communities. Again, this limitation may have most likely led to an underestimation of the neighbourhood impact since people living in a neighbourhood for a long time are more exposed to their neighbourhood than people who recently moved there and those "exposed" for a longer period of time are probably more likely to have their health affected by their community characteristics.

Fifth, this study examines census areas, which do not necessarily reflect the self-defined communities of individual respondents. While census boundaries seem to be appropriate for characterising the physical and services environment, it may not be so for characterising the social patterns of individuals. Some individuals may define the bounded area for social network and interactions as very small while others may

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consider it very large. However, in Saskatoon, neighbourhoods are well-defined, long standing and small-sized, thus neighbourhood residents are more likely to know/have interaction with each other. Therefore, the bias of the crude measures of neighbourhood boundaries using census boundaries (i.e., which, if it exists, would result in an underestimation of the neighbourhood effects in this study) is less likely to happen compared to studies which examine cities with bigger size and less well-defined census areas.

Finally, we should mention misclassification bias. Misclassification bias can occur if the exposure or disease status is inaccurately assigned.[258] The first and the most important misclassification bias is the assignment of the neighbourhood of residence. In this study, children were assigned to neighbourhoods using their residence address during birth. Continuing residence in the neighbourhood prior to and following the birth of the child were not taken into account. By checking the neighbourhood of residence of the study subjects at birth and study exit date, we know that around 36 % of the study sample had moved during the study time and therefore the misclassification of neighbourhood of residence could happen if some children moved from a disadvantaged neighbourhood to a more affluent neighbourhood. However, this misclassification should not affect the validity of the study results seriously due to the following reasons: (1) there are no significant differences in the distribution of family income, sex, mother's age, adverse birth outcome, Aboriginal status, and single parent status between children moved and not moved during the study time (2) comparison of the neighbourhood at birth and at study exit date indicates that the chance that a child's family moved from an extremely disadvantaged

neighbourhood to a more affluent neighbourhood is very small; the majority of the children's families moved from one neighbourhood to a similar neighbourhood in terms of it's socio-economic status, social interaction level, physical condition, programs and services, and (3) we have excluded all the subject, who had moved during the study time and repeated all the analyses and found that the results did not change significantly.

The second possible misclassification is the case of family income. In this study, the family income for each subject was not available and information from the Saskatchewan income assistance plan was used as a proxy measures for low family income. Information on the level of family income for each child was not available and may have resulted in some misclassification of the children's family income status. However, the chance of a misclassification for family income status is very small since the assignment of the Saskatchewan income assistance plan was done based on the tax filing. This misclassification, if it had happened, would have resulted in underestimating the association between low family income and a higher use of health services (for instance, some children, despite their low family income, may not have been eligible to receive the Saskatchewan family income assistance during the study time). Nevertheless, the use of the Saskatchewan income assistance plan as a proxy for family income could limit the interpretation of results.

The third misclassification may have happened due to the amalgamation of the Saskatoon neighbourhoods (as mentioned, Saskatchewan Health amalgamated adjacent neighbourhoods when cell sizes were less than 5). While this amalgamation is necessary not only to protect the confidentiality of the residents but also to ensure

substantial numbers of individuals observed within the higher level unit to provide adequate estimates of the higher level unit's characteristics[58], it may have resulted in some biases if heterogeneous neighbourhoods were assumed to be homogeneous. However, the probability of this bias is equally low, since we have examined these neighbourhoods amalgamated together and most of them were similar in terms of socio-economic status, demographics, social interaction, physical condition, and programs and services.

7.2 Research Implications

Family income and the neighbourhood's specific targeting of vulnerable children may reduce the prevalence of adverse birth outcome as well as alleviate some of the excess morbidity in children during 6 years after birth, but there is still more work to be done in order to conceptualize and measure how socio-economic status and the neighbourhood's contexts affect children's health risks and outcomes. The strengths and limitations of this study bring up some implications for future research.

First, a longitudinal measurement of children's health outcome and family socio-economic status is essential to understand how SES "get under skin". More importantly, research in the future should help explicate how SES operates through multiple mechanisms simultaneously to affect the developmental course, how those paths vary across ethnic and cultural groups, and how different components of SES function conjointly to affect different developmental systems.

Second, as promoted elsewhere,[261] future research needs to develop public health and epidemiological theories regarding the mechanism of neighbourhood effects. This theory needs to demonstrate explicitly the pathways in which political,

economic, cultural, and physical attributes of a neighbourhood are related to children's health outcomes as well as the interaction effects among different attributes of neighbourhoods. Since family may be an important link between communities and children, this theory also need to illustrate the mediator/moderating effect of the family process on the neighbourhood effect.[262] O' Campo[261] and others[263] have advocated the use of qualitative research to gather information and identify the mechanisms of neighbourhood effects.

Third, future research should focus on identifying the appropriate boundaries for neighbourhoods, characterizing neighbourhood attributes and developing techniques to measure the neighbourhoods' attributes. Defining appropriate boundaries for neighbourhoods has been a concern for researchers. [52,261] Given the relatively low cost and convenience of using census data, census tracts have been employed extensively in studies of neighbourhood effects. While census tracts may be appropriate units to accommodate the measurement of physical or services environments, they do not necessarily correspond with the self-defined communities of individual respondents and thus the social patterns of the individuals do not often correspond with census areas. Thus, even though it is difficult and expensive to do, including information about self-defined communities in future research might result in a more accurate picture of the relationship between communities. Others have promoted the use of multiple definitions of neighbourhood within the same study because it would (a) facilitate the examination of multiple neighbourhood processes, (b) enable the comparison of relationships under different definitions, and (c) test the

extent to which individuals within communities are relatively more or less isolated from competing reference groups.[261,262]

The majority of multilevel studies on neighbourhood effects and children's health have focused on the socio-economic attributes of the neighbourhood.[22,37,46] In order to fully evaluate the neighbourhood influences on children, apart from the neighbourhood socio-economic attribute, future research need to take into account all neighbourhood attributes relevant to how one or more theories explain the influence of neighbourhoods on the developing child (e.g., neighbourhood physical condition, housing market, local policy…etc). [261,262] Studying different aspects of neighbourhoods in the same study would help to test the hypotheses of neighbourhood effects more completely, examine the moderating/mediating effects among neighbourhood variables and suggest which aspects of neighbourhoods are potential targets for policy manipulation. Future work also needs to pay careful attention to the meaning and measurement of indicators of neighbourhood properties.[264] Existing literature in overlapping fields such as community psychology and urban sociology can be borrowed to facilitate the developing of these indicators as well as the techniques to measure them.

Fourth, research on neighbourhood and community influence on children's health has been hampered by the absence of data combining information at individual, family, and neighbourhood level. Multilevel models should be used in the future analyses of children's health outcomes to advance the understanding of neighbourhood effects. In order to study the neighbourhood effects, projects must be explicitly designed to collect data at multiple levels (i.e., individual children and

neighbourhoods). In addition, since family environment variables have been suggested to be an important link from neighbourhood to children, future research need to collect data on family processes as well. We may conceptualize this framework as children are nested within families and families within neighbourhoods.

Fifth, the causality of the neighbourhood effect is perhaps the most difficult challenge for researchers[192,265] but future research should explicitly make conclusions regarding the causation effect of neighbourhoods. Quasi-experimental design, which assigns individuals to neighbourhoods at random, can be used to do that since this design helps to eliminate all sources of bias that jeopardize the causal interpretation of most neighbourhood effects identified in correlational analyses. However, even though quasi-experimental designs have been considered as a golden standard to establish causation, this design is often impossible to be done on a large scale due to practical and ethical reasons (e.g., extremely high cost, subject compliance, long follow up time…etc). In the absence of a true quasi-experimental design, longitudinal design, which follows neighbourhoods and individuals over time, may be the best substitute. So far, researchers have considered neighbourhoods to have fixed characteristics. However, neighbourhoods have developmental trajectories, and neighbourhood changes may have important implications for child development. Furthermore, one major limitation often met in previous studies was the impossibility of taking into account the length of exposure to neighbourhood conditions. Longitudinal research would enable us to analyse neighbourhood effects by duration of exposure. Thus, longitudinal data on persons and neighbourhoods should be used in future studies to shed light into the causal relationship among neighbourhood change, family

environment mediating/moderating process, and children's health outcomes.[261,262,266] Most ideally, the follow up of individuals and neighbourhoods over time should be done within a study but, in some cases, for convenience and low cost, these can be done in separate studies. Some longitudinal data regarding neighbourhood socio-economic attributes can also be gathered from routinely available data (i.e., census data or routine local surveys).

Sixth, future research needs to examine the effects of both types of neighbourhood changes on children's health outcomes. These include the change that occurs within a given neighbourhood's longitudinal profile and the change that occurs among neighbourhoods with respect to their ecological positions. As pointed out by Bursik and Grasmich, these changes may not be coincident. [267] For instance poverty rate can increase within a neighbourhood over time but if the overall poverty rate for the city also increases and this change is equally distributed across all neighbourhoods then the relative position of that neighbourhood vis-à-vis other neighbourhoods does not change or there is no change between neighbourhoods.[267] As Sampson stated, "this formulation rests on the notion of an ecological structure wherein each neighbourhood holds a position that is defined by its relationship to other neighbourhoods in the city along a given parameter. Change can either stabilize or disrupt the ecological structure, depending on how it affects the interrelationships among neighbourhoods". [268] Both types of change are important to the study of neighbourhood impact as the change within the neighbourhood reflects the trajectory of neighbourhood poverty over time while the change between neighbourhoods indicates an increasing geographical stratification in social or economic status among neighbourhoods.

Finally, although difficult and costly to do, researchers should consider the combination of quantitative and qualitative approaches in future studies. Qualitative approaches to studying neighbourhoods offer the advantage of grounding neighbourhood processes within a historical context. They often provide insights that elude statistical measurement. Therefore, qualitative approaches are extremely effective in communicating to decision makers a coherent and convincing story about how places can affect people's hopes, aspirations, opportunities, and well-being.[269] However, qualitative approaches are rarely sufficient by themselves to produce action because they are limited to observations of a relatively small number of individuals within a circumscribed location.[269] The combination of both perspectives and methodologies (i.e., quantitative and qualitative) in the same study would help to provide the most convincing evidence of how neighbourhood influences operate to affect child outcomes.[268] However, given that the collection of qualitative data and analysis are often time consuming and expensive, results from qualitative studies conducted in the same geographical area might be "pooled" or drawn upon to tell a coherent and compelling story.[261]

7.3 Research Findings and Policy Implications

This research set out to examine three questions:

Question 1: Do neighbourhood factors have a significant impact on children's health outcomes in addition to those due to individual risk factors?

Question 2: Do neighbourhood factors moderate the association between individual risk factors and children's health outcomes?

Question 3: Is there enough evidence that would call for policy interventions targeted at neighbourhoods in addition to those directed at individuals?

These three overall research questions were answered by addressing specific research objectives in the focused topic 1 and focused topic 2. In summary, analytical results for those specific objectives indicated that (1) neighbourhood factors have a significant impact on children's health outcomes in addition to those due to individual risk factors, (2) that neighbourhood factors act as moderators for the association between individual risk factors and children's health outcomes, and (3) that the effect of neighbourhoods are strong enough to call for policy interventions targeted at neighbourhoods in addition to those directed at individuals. This section will highlight the major findings of this research along with their policy implication.

First, it was determined that family income was an important determinant of both LBW and childhood hospitalizations. That is, a child living in a low-income family was more likely to be a low birth weight baby as well as have a higher number of hospitalizations/longer length of stay in hospital during 6 years after birth. Poverty is the condition of not having enough income to meet basic needs for food, clothing, and shelter. Because children are dependent on others, they experience by virtue of their family's economic circumstances. Children cannot alter family conditions by themselves, at least until they approach adulthood. Therefore, from a program delivery and policy making perspective, families with children who are economically poor need to be supported because a consequence of growing up in a poor family is continuing health deficit for children, which in turn impacts on the health care system. Policy/programs/intervention to address the issue of child poverty must be part of a

greater societal approach that includes strategies to promote economic growth in all areas of the country, reduction in unemployment, wage increases, accessible and affordable high quality child care, and the removal of other barriers that prevent economically disadvantaged vulnerable groups from gaining employment.[251]

Second, results indicated that the number of live births, number of previous stillbirths, a more mature mother's age (i.e., greater than 40), and single parent status were risk factors of birth weight. Most importantly, this study reported that the elevated risk of having a low birth weight baby associated with single parent status changed as a function of the level of social interaction within the neighbourhood of residence. This implied that if a single mother lived in a neighbourhood with a high level of social interaction, she was not at risk of having a LBW baby but if she lived in a neighbourhood with a low level of social interaction, she would. Single parent families in this study referred to households comprised of a single mother and their children. The pathway leading to single parenthood could be separation, divorce, widowhood or having children out of marriage. A single parent status is often associated with social and economic disadvantage and thus, the wellbeing of children growing up in single parent families has long attracted concern. Single mothers are known to have greater risks of adverse pregnancy outcomes such as low birth weight, preterm, small for gestational age or infant mortality.[17,270,271] However, little information was provided from previous studies about the pathways from single parent status to adverse birth outcome as well as about the possible mediators/moderators for this association. More importantly, almost all of these studies were done at the individual level, which have the inherent limitation of ignoring important macro-level

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influences such as the effect of the neighbourhood of residence. The finding about the moderating effect of neighbourhood social interaction level on the association between the single parent status and low birth weight suggested that single parents would benefit from projects which address the community level of social capital, cohesion, democratic empowerment and so on. Public policy makers are now informed that the neighbourhood should be an important target of their effort to help this specific high risk group.

Third, it was shown that the number of adverse birth outcomes (i.e., low birth weight, preterm, and small for gestational age), Aboriginal status, age of the child, the child's gender, and young mother's age (i.e., less than 20) were significant predictors of childhood hospitalization during 6 years after birth. Two notable sub-findings were that (a) there was a gradient association between the number of adverse birth outcomes and childhood hospitalization and (b) family income acted as a moderator for the deleterious effect of adverse birth outcomes on childhood hospitalization. Sub-finding (b) means that if children born with adverse birth outcomes have to commence their lives with health deficits, their family income circumstances would make a significant difference in their catch up process with their normal peers. Thus, policy makers and program designers may need to consider those children born with low birth weight, preterm birth, small for gestational age, and especially with a combination of these adverse birth outcomes who live in poor families as the priority of programs and services aimed at reducing the burden of adverse birth outcomes.

The findings regarding the association between Aboriginal children and their higher risk of hospitalization underscore the need for more efforts to improve the

Aboriginal communities. It has been suggested that the priorities set by Aboriginal communities are frequently different from those developed by the government and hence, there are inappropriate strategies for delivering health programs among Aboriginal communities.[272] Programs/interventions targeting this specific population should take into account five basic areas, namely health research, a greater sensitivity to Aboriginal culture, a continuing process of control of health service transfer to the communities, increased opportunities for Aboriginal people's success in various health care professions, and an overall improvement in the socio-economic status of Aboriginal Canadians.[272]

Fourth, results demonstrated that the neighbourhood of residence had independent impact on birth outcome and childhood hospitalization over and above that of family economic status. The neighbourhood socio-economic disadvantage, programs and services, and level of social interaction showed significant associations with the risk of having a low birth weight baby and the neighbourhood physical condition and socio-economic disadvantage remained significantly associated with childhood hospitalization (i.e. both incidence rate and length of stay) after individual characteristics were taken into account. More importantly, results showed that the effects of neighbourhood on birth weight as well as childhood hospitalization estimated in this study were quite significant.

This study aimed to present the independent effects of neighbourhood in an easily comprehensible manner, thus the format of neighbourhood maps of the predicted low birth weight rate, the predicted incidence rate of hospitalization and the predicted length of stay in hospital was chosen. These maps revealed various matters

that are important to policy makers. They revealed distinct geographical patterns by local neighbourhoods of children's health outcomes. Neighbourhoods with the highest predicted rate of low birth weight and predicted incidence rate of hospitalization and longest predicted length of stay tended to cluster in the west side of the river (in the central area as well as towards the west). Policy makers are now informed that individual characteristics such as income, single parent or Aboriginal status cannot totally explain the neighbourhood health disparities and the health concerns of neighbourhoods on the west side of the river (e.g., Riverdale, Westmount, Pleasant Hill, Mount Royal, Caswell Hill or Massey Place). Acknowledging this allows better targeting of health policy and planning and enables more accurate need-based resources.

This result would provide valuable evidence/information to advocate for ongoing area-based interventions/programs in Saskatchewan now. The rationale of targeting interventions on areas with high levels of deprivation/disadvantage is that it provides the most effective way of reaching families most in need. However, area-based intervention has been criticized due to the evidence that only a minority of the poorest families live in the most deprived areas.[273] Therefore, if neighbourhood factors were found to have an independent effect on children's health outcomes over and above that of family socio-economic status, there may be an additional specific benefit of area-based preventive interventions.

In Canada, there are many programs that are "community based", which were designed on the needs of the community to provide program and services to promote children's development and growth. However, as pointed by Beauvais and Jenson,

"most of them were designed to *delivery* in a local community or to respond to *the variety* of community needs" while few of them were actually designed to *foster positive neighbourhood effects* by treating the community itself as a factor effecting outcomes.[274] Some examples of programs aimed at fostering positive neighbourhood effects in Canada are "Better beginnings, better futures", "Understanding the early years", "Success by 6", "Neighbourhood circle in Halifax". This study results underscored the need to implement more programs which focus both on children and on community development; these programs should aim at improving child outcomes as well as at shaping community environments (i.e., by changing values, attitudes, and behaviors of community members in order to create community effects).

The maps produced in this thesis also revealed that neighbourhood characteristics were inter-related. For instance, neighbourhoods with the worst socio-economic status also tended to have the lowest level of social interaction. This finding is very important since it brings up the fact that in high risk neighbourhoods (i.e., neighbourhoods with low socio-economic status), residents may be more hesitant to participate in community activities while local participation is a key to the success of any community based project. Therefore, programs which target high risk neighbourhoods should allow enough time to build trust and develop plans of action, provide support to communities to help with planning and organizational development, allow communities to identify their priorities and tailor the programs to local needs but also to balance local control with clear project ground rules to avoid confusion and potentially conflicting priorities.

In conclusion, although one may consider the neighbourhood effects found in this study as compositional effects (i.e., simply from an aggregation of individual characteristics to the neighbourhood level) which might result from not being able to control for some individual characteristics or as true contextual effects (i.e., from the social environment experienced by the residents), it is important to note that neither the differentiation of social environments nor the grouping together of people of similar social and economic standing is accidental. Rather, these phenomena represent the expression of the social structure through the geographic differentiation of the city and this expression may have been reinforced in Saskatoon through economics, immigration pressures, violence, and public policy.

Unravelling the intricacies of how factors at the level of the child, the family, the neighbourhood, and beyond interact with each other over time to influence the child's health is obviously a mammoth task, requiring the combined efforts of many ongoing research programs. Yet we need not wait until we have all the answers before we act. Indeed, the more we learn about the long-term impact of early childhood experiences, the greater the need to take immediate action. The geographical variations in children's health outcomes reported in this study are not unchangeable; they can be altered through policy and reforms and through the efforts of families and children

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Appendix I: Diagnoses of Interest

(Specific codes reported: up to three digits on the physician services file and up to four digits on the hospital file)

ICD-9 code	Description
011 -011.9	Pulmonary tuberculosis
012 - 012.8	Other respiratory tuberculosis
033 - 033.9	Whooping cough
037	Tetanus
045 - 045.9	Acute poliomyelitis
201 - 201.9	Hodgkin's disease
202.8	Non Hodgkin's lymphoma - *reported on hospital file only*
250 - 250.9	Diabetes mellitus
251 - 251.9	Other disorders of pancreatic internal secretion including hypoglycemia
260	Kwashiorkor
261	Nutritional marasmus
262	Other severe protein-calorie malnutrition - *reported on hospital file only*
268.0	Rickets, active - *reported on hospital file only*
276.5	Dehydration - *reported on hospital file only*
277.0	Cystic fibrosis - *reported on hospital file only*
280	Iron deficiency anemia
320 - 322.9	Meningitis
345 -345.9	Epilepsy

381 -382.9	Otitis media
383 -383.9	Mastoiditis and related conditions
390 - 391.9	Rheumatic fever
460	Acute nasopharyngitis (common cold)
461 - 461.9	Acute sinusitis
462	Acute pharyngitis
463	Acute tonsillitis
464 - 464.4	Acute laryngitis and tracheitis
465 - 465.9	Acute upper respiratory infection of multiple or unspecified site
472.1	Chronic pharyngitis - *reported on hospital file only*
481 - 483 485 - 486	Bacterial pneumonia
487 - 487.8	Influenza
493 - 493.9	Asthma
520 - 523.9 525 - 529.9	Diseases of oral cavity, salivary glands and jaws
761 - 779.9	Certain conditions originating in the perinatal period - *ICD-9 764 - 764.9 reported on hospital file only*
780.3	Convulsions - *reported on hospital file only*
783.4	Lack of expected normal physiological development (failure to thrive) – *reported on hospital file only*

DIAGNOSES GROUPS

(Codes converted to categories listed below)

Category	ICD-9 code	Description
DG01	001 - 009.3 019 - 032.9 034 - 036.9 038 - 041.9 046 - 139.8	Other infectious and parasitic diseases
DG02	010 - 010.9 013 - 018.9	Other tuberculosis
DG03	140 - 200.8 202 -202.7 202.9 - 203.8 210 - 239.9	Other neoplasm
DG04	204 - 208.9	Leukemia
DG05	240 - 249.9 252 - 259.9 263 - 268 268.1 - 276.4 276.6 - 277 277.1 - 279.9	Other endocrine, nutritional and metabolic diseases and immunity disorders
DG06	281 - 285.9	Other anemia
DG07	286 - 289.9	Other diseases of blood and blood-forming organs
DG08	290 -316	Mental disorders
DG09	317 - 319	Mental retardation
DG10	323 - 326	Other inflammatory diseases of the CNS
DG11	330 - 344.9 346 - 380.9 384 - 389.9	Other diseases of the nervous system and sense organs
DG12	392 - 459.9	Other diseases of the circulatory system
DG13	466 - 472.0 472.2 - 480.9	Other diseases of the respiratory system

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          484 - 484.8
          490 - 492
          494 - 519.9


DG14     524 - 524.9          Other diseases of the digestive system
          530 - 579.9


DG15     580 - 629.9          Diseases of the genitourinary system


DG16     680 - 709.9          Diseases of the skin and subcutaneous tissue


DG17  710 - 739.9             Diseases of the musculoskeletal system and
                              connective tissue


DG18     740 - 760.9          Congenital   anomalies   including   Fetal   Alcohol
Syndrome


DG19     800 - 999.9          Injury and poisoning


DG20     630 - 676.9          All others
          780 -780.2
          780.4 - 783.3
          783.5 - 799.9
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ICD-9 CODE FOR RESPIRATORY DISEASES

Category ICD- 9 Code	Description
	Asthma
	Extrinsic, Intrinsic And Chronic Obstructive
493.0-493.9	Asthma
	Influenza
487.0	Influenza With Pneumonia
487.1	Influenza With Other Respiratory Manifestations
487.8	Influenza With Other Manifestations
	Bacterial Pneumonia
481	Pnuemoccoal Pneumonia
482	Other Bacterial Pneumonia
483	Pneumonia Due To Other Specified Bacteria
485	Bronchopneumonia, Organism Unspecified
486	Pneumonia, Organism Unspecified
	Upper Respiratory Illness
460	Acute Nasopharyngitis (Common Cold)
461	Acute Sinusitis
464.0	Acute Laryngitis
464.1	Acute Tracheitis
464.2	Acute Laryngotracheitis
464.3	Acute Epiglottitis
464.4	Croup
465 - 465.9	Acute Upper Respiratory Infections Of Multiple And Unspecified Sites
	ENT
381.0 -382.9	Otitis Media Without Mastoiditis
383 - 383.9	Otitis Media With Mastoiditis
462	Acute Pharyngitis

463	Acute Tonsillitis
	Other Disease Of Respiratory System
466 -466.1	Acute Bronchitis & Bronchiolitis
470	Deviated Nasal Septum
471	Nasal Polyps
472	Chronic Pharyngitis & Nasopharyngitis
473	Chronic Sinusitis
474	Chronic Disease Of Tonsils &Adenoids
475	Peritonsillar Abscess
476	Chronic Laryngitis & Larngotracheitis
478	Other Diseases Of Upper Respiratory Tract
480 -480.9	Viral Pneumonia
484 -484.8	Pneumonia In Infectious Diseases Classified Elsewhere
490-508.9	Chronic Obstructive Pulmonary Disease And Allied Conditions
510-519.9	Pneumoconiosis & Other Lung Disease Due To External Agents

Appendix II: Data Management

Data file for study on adverse birth outcome

Apply the definitions, variable LBW was created based on birth weight recorded in the birth file. Then the birth file, subject file were merged to create a working file. This working file was linked with the neighbourhood file using the neighbourhood identification number.

Data file for incident rate of total hospitalization

Health care administration databases are not designed for research purposes. In order to create the working file for this study, the following issues were addressed. The first issue is that the first record in the hospital file for all children was for the delivery time. If the record for the delivery time were included, the accuracy of the estimation of the hospitalization rate would be affected. Thus, the first record of hospitalization was deleted from the hospital file for all children. The second issue is that computerized health services data are encounter-based rather than person based. The hospital file contained one record per hospitalization, thus had to be aggregated to produce a file with one record per child with the total number of hospitalizations recorded for each follow up year.

After addressing these issues, the longitudinal data file for hospitalization, following up the individual from birth to 6 year old, was created. This file included three variables, age, number of hospitalizations by age, and time at risk . Then, this file was merged with the vital statistics file and the subject file using the subject's

identification number. Finally, we had to deal with the problem of missing values in two variables, number of hospitalization and number of hospitalizations because of respiratory diseases. There were two reasons for a child having missing values in frequency of hospitalization and days of stay in a given year:

a)   The child died or moved out of Saskatchewan during that year, therefore, there was no record of hospitalization for this child in that year. In this case, these two variables should have a missing value.

b)   The child was healthy during that year and had no hospitalization, therefore, there was no record of hospitalization for this child in that year and these two variables should have a "0" not a missing value. In this case, the missing values in these variables were changed to indicate a value of 0.

Subject file

ID	AGE 1		AGE 2		AGE 3		AGE 4		AGE 5	
	in study	income	in study	income	in study	income	in study	income	in study	income
1	Y	L	Y	L	Y	H	Y	H	MOVED	H

Hospital file

ID	AGE	HOS
1	1	1
1	1	1
1	2	1
1	2	1
1	3	1

Longitudinal (level 1 file)

ID	AGE	INCOME	HOS
1	1	1	3
1	2	1	1
1	3	0	1
1	4	0	0
1	5	0	missing
1	6	0	missing
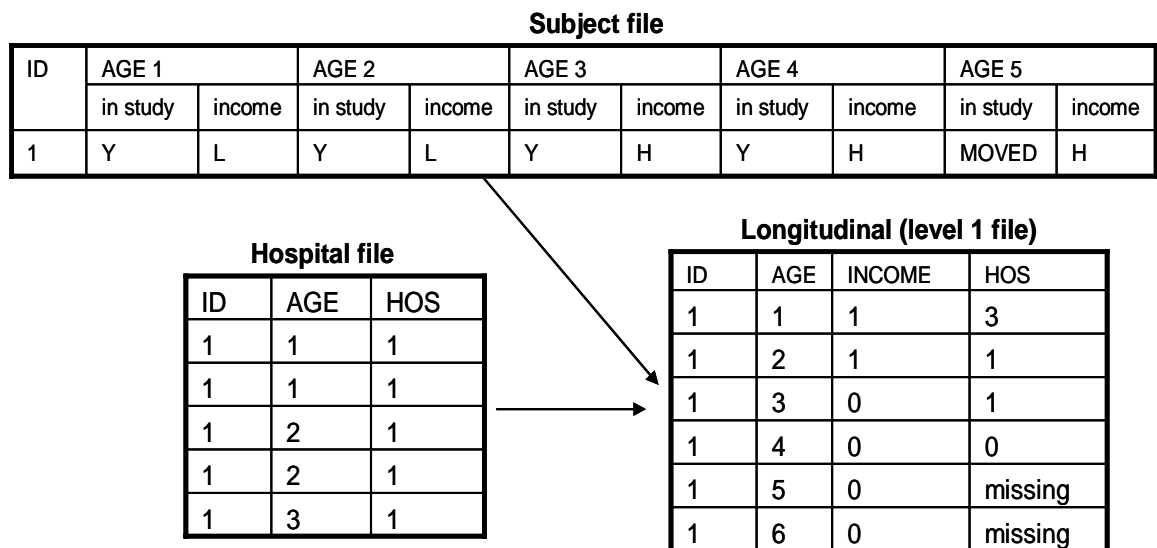
Finally, the longitudinal file with all information at the individual level will be linked to the neighbourhood characteristics file to create a complete data file for the analysis of childhood hospitalization.

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Data file for the analysis of total day of stay in hospital during 6 years after birth

After the delivery time was excluded of the hospital file, the hospital file was aggregated by study identification to create the new file. This new file had 1 record per child and the variable "day of stay" reflected the total length of stay in hospital during 6 years after birth, another important variable in this data file was variable "time" which took into account the total time each subject stayed in the study. This variable was used for weighted analysis (by time in the study). After that, this new file was merged with the subject file, birth file to the working file for the analysis of total day of stay in hospital during 6 years after birth.

Appendix III: Index Score for the Availability and Accessibility of Programs and Services for Children 0-6 and their Family in Saskatoon Neighbourhoods

1. Program type

PROGRAM TYPE	PROGRAM CATEGORY
Preschool	Early Education
Early literacy (library programs)	Early Education
Family literacy	Literacy
Parenting	Parenting
Parenting/CAR	CAR
Parent relief	Parent relief
Counselling	Counselling
Counselling/CAR	CAR
Family support (material)	Family support
Birth/prenatal counseling	Birth/prenatal
Nutrition	Nutrition
Food program	Nutrition
Childcare	Childcare
Community Ctr (playgroups)	Early education
Immigrant services/family support	Family support
Immigrant services/parenting	Parenting
Immigrant services/preschool	Early education
Immigrant services/nutrition	Nutrition
Special needs	Special needs
Sports & recreation	Sports & recreation

Music	Sports & recreation
Behaviour counseling/CAR	CAR
Dental health/CAR	CAR

Total types = 23	Total categories = 13 (Note: because there was
only one	literacy program that could not be
classified as an	
	Early Education program, Literacy was not spot-
	mapped as a separate category. The program was
	counted in the neighbourhood scores however
	the number of total number of working
	categories was 12)

*CAR: Children at risk programs

2. How the index was calculated

The number and variety of resources in neighbourhoods may influence early

child development at the neighbourhood level. The purpose of the index is to

describe the availability of resources in Saskatoon to children aged 0-6 and

their families. The index reflects access to resources in each neighbourhood,

including 1) the variety and numbers of programs, for example preschool and

parenting classes, 2) other important infrastructures, for example, libraries, and

3) the ease of access to these programs and infrastructures for all children and

their families. The index is based on a program survey conducted for the

Understanding the Early Years Research Project in July, 2001.[275,276]

 At that time, a census of Saskatoon programs offered to children 0-6 and their families

was conducted. Information on the type of program, intended age of clientele, access

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to facility by public transportation, user fees and subsidies, and other program capacity

and staffing information was collected by telephone interview. Over 200 programs

located in over 300 locations around the city were surveyed.

The index score is made up of 1) a Program Access score, which reflects the

programs offered in each neighbourhood, and 2) an Infrastructure Resource score,

which reflects more permanent structures considered resources for children 0- 6 years

and their families. There are a number of support agencies that perform important

services for children that are not included in the survey, for example, Big Brothers and

the Saskatoon Fire Department. Support agencies are not included in the index

because of the location of their services does accurately reflect availability to specific

neighbourhoods.

Each program was designated to one of the 52 Saskatoon neighbourhoods by

postal code of program location (actual program site, not administrative address,

although in some instances they are the same). To calculate the score for each

neighbourhood, each program offered was given a base score of 1, and then points

were taken off for accessibility barriers. Barriers were considered any program criteria

that may limit full accessibility of all individuals due to family income (user fee),

handicap (wheelchair accessibility) or program demand (waiting list). Each

infrastructure resource was given a base score of 2, the assumption being that

infrastructures are government supported and therefore major resources.   The score

for a given neighbourhood was cumulative based on the individual scores for each

program or infrastructure. Each score was converted to a z score to provide an

indication of the neighbourhood resources relative to the average for all of Saskatoon. Scores above 0 indicate a higher resource availability than the average, scores below 0 indicate below average. Scores above +2 or -2 indicate very high and very low resource availability respectively compared to the average for Saskatoon (over 2 standard deviations from the mean). Weighting by catchments area was considered however because we do not have full information about how local and extended use affects access to a program or infrastructure, weighting was not done.

Program resource score:

All programs receive base score of 1

Accessibility score is based on

1) waiting list: no/yes; yes = -.20

2) user fee = -.20

3) public transportation: yes/no; no = -.20

4) wheelchair access: yes/no; no = -.20

5) transportation offered: yes/no; yes =+ .20

Base score is penalized for waiting list (-.2) user fee (-.2), no access by public transportation (-.2) and no wheel chair access; lowest possible score for a program asset = .2. Additional points are given if transportation is provided (+.2)

Program score – accessibility score = resource score

Example: Program score = 1-(0+0+0) = 1

Neighbourhoodhd	Program	Waiting list	Subsidy	public	Prog score
1	Beavers	no (0)	yes (0)	yes (0)	1

*For programs with no information about waiting list/user fee/ wheelchair access scores are imputed using average of programs with similar characteristics.

Infrastructure resource score:

All infrastructure receive a base score of 2 (assumption is that these are gov supported and therefore major resources)

Accessibility score based on 1) fee for use: yes/no; yes = - .25

2) public transportation; yes/no; no = - .25

3) wheelchair access: yes/no; no = -.25

Base score is penalized for fee for uset (-.25) no access by public transportation (-.25) no wheelchair access (-.25); lowest possible score for an infrastructural asset = 1.25

Infrastructure score = base infrastructure score – accessibility score

Example: Infrastruct score = 2 – (0+0) = 2; wt = 1.25

Neighbourhoodhd	Infrastructure	Subsidy	public transport	Prog score
1	Library	0	0	2

Infrastructure total = infrastructure * weight = 2 * .8 = 1.6

Appendix IV: Instrument Used to Evaluate Neighbourhood Physical Condition

1. Question 1: How would you rate the general condition of most of the dwellings in the area:

    - Excellent condition with good repair and exterior surface (0 problems per dwelling)
    - Good condition (1 problem per dwelling)
    - Fair condition (2 problems per dwelling)
    - Poor condition and in need of repair (>=3 problems per dwelling)

Potential program include broken window/door/fence, peeling paint. Graffiti, damaged roof, evidence of arson or fire, untended lawn/garden, damaged porch, barn is not well maintained, rusty railings, rusty mailbox, broken light, broken mailbox, damaged façade/brickwork, excessive garbage/litter, cracked window sills, chipped concrete steps, etc

    1a. Mark this box if one or two dwellings observed in area.

2. Question 2: What percent of dwellings are in major need of repair (3 or more problems per dwellings)

    - None
    - Less than half
    - Half
    - More than half
    - No dwelling observed

3. Question 3: If there is a publicly maintained building in the observation area, what is the condition of the property surrounding this building(s)? (i.e., schools, hospitals, regional, and outreach program office, etc…)

- Well maintained

- Could be improved

- Not well maintained

- Not applicable

4.   Question 4: What is the volume of traffic on the street or road (# vehicles per minute)?

5.   Question 5: What type of traffic is observed on this road (mark all that apply)
    - Personal vehicles (cars, trucks, vans, motorcycles)
    - Farm equipment or vehicles
    - Large commercial vehicles
    - Pedestrians
    - Bicycles
    - All terrain vehicles
    - Heavy equipment (e.g., plough, bulldozer)

6.   Question 6: How would you rate the amount of noise from normal day to day activities (e.g., from traffic, household noise, trains, planes, industry, farm equipment, etc>) in the middle of the block faces (i.e., not at street intersection)?
    - Light- hardly noticeable
    - Moderate- somewhat noticeable
    - Excessive- causes a disturbance

    Is this noise due to unusual condition (i.e., construction)?
    - Yes
    - No

7.   Question 7: Number of stop lights/stop signs observed in this area?

8.   Question 8: Number of crosswalks observed in this area?

The crosswalk should be marked (painted, lights, or stop sign indicating crosswalk). Do not include crosswalk just outside observation area.

9. Question 9: Width of streets:
   - 1 lane
   - 2 lanes
   - 3 -4 lanes
   - 5 or more lanes
   - Not applicable

10. Question 10: What is the general condition of most public streets, roads, and sidewalks in the area?
    - Excellent: new road or very well maintained
    - Good/Fair: road not new but in good/fair shape and or some evidence of maintenance, but minor repairs needed
    - Poor: large potholes, cracks, and other evidence of neglect, little or no maintenance

11. Question 11: How would you rate the quality of outdoor equipment and buildings in parks and playgrounds:
    - Excellent- new or well maintained, clean area
    - Good: not new but evidence it's kept in good repair and condition, with minor scrapes or paint chips
    - Fair: some repairs required and/or not very clean
    - Poor: badly deteriorated showing signs of neglect, in need of many repairs: area not clean
    - Not applicable: no or minimal equipment and no building

Appendix V: Principal Component Analysis Results for

Neighbourhood Physical Condition

Factor Analysis

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Condition	1.90	.78	254
REPAIR	1.15	.73	254
Appearance	1.18	.59	254
NOISE	1.17	.39	254
Stop Lights	.48	.74	254
Crosswalk	.41	.81	254
Rd Condition	1.88	.39	254
Street Width	1.94	.53	254
TRAFFCAT	1.84	.92	254

Communalities

	Initial	Extraction
Condition	1.000	.774
REPAIR	1.000	.761
Appearance	1.000	.489
NOISE	1.000	.543
Stop Lights	1.000	.602
Crosswalk	1.000	.562
Rd Condition	1.000	.778
Street Width	1.000	.647
TRAFFCAT	1.000	.654

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.961	32.898	32.898	2.961	32.898	32.898	2.595	28.828	28.828
2	1.732	19.245	52.144	1.732	19.245	52.144	1.869	20.762	49.590
3	1.116	12.403	64.547	1.116	12.403	64.547	1.346	14.957	64.547
4	.768	8.537	73.084						
5	.675	7.496	80.580						
6	.651	7.235	87.814						
7	.457	5.082	92.897						
8	.324	3.597	96.494						
9	.316	3.506	100.000						

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component		
	1	2	3
Stop Lights	.712	-.086	-.295
Crosswalk	.693	-.251	-.137
TRAFFCAT	.693	-.416	3.247E-02
Appearance	.614	.179	-.283
NOISE	.610	-.413	-.007
Street Width	.592	-.032	.543
Condition	.379	.791	-.069
REPAIR	.385	.755	-.205
Rd Condition	.319	.299	.766

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix^a

	Component		
	1	2	3
TRAFFCAT	.776	-.101	.202
Crosswalk	.741	9.141E-02	7.071E-02
Stop Lights	.719	.289	-.044
NOISE	.714	-.120	.138
Appearance	.509	.478	-.025
REPAIR	2.881E-02	.870	5.770E-02
Condition	-.025	.859	.187
Rd Condition	-.047	.164	.865
Street Width	.392	4.605E-02	.701

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Component Transformation Matrix

Component	1	2	3
1	.855	.391	.342
2	-.462	.873	.154
3	-.238	-.290	.927

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

\

Reliability

 ****** Method 2 (covariance matrix) will be used for this analysis
******

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

		Mean	Std Dev	Cases
1.	CONDTN	1.9016	.7765	254.0
2.	REPAIR	1.1457	.7267	254.0
3.	TRAFFCAT	1.8386	.9248	254.0
4.	APPEARAN	1.1772	.5865	254.0
5.	NOISE	1.1732	.3895	254.0
6.	STOPLGHT	.4803	.7369	254.0
7.	CROSSWLK	.4055	.8081	254.0
8.	STWDTH	1.9449	.5306	254.0
9.	RD_COND	1.8819	.3899	254.0

```
                            Correlation Matrix


                   CONDTN     REPAIR     TRAFFCAT   APPEARAN   NOISE
CONDTN             1.0000
REPAIR              .6419     1.0000
TRAFFCAT           -.0112      .0292     1.0000
APPEARAN            .2728      .3009      .2643     1.0000
NOISE               .0043     -.0197      .5608      .2804     1.0000
STOPLGHT            .1796      .2010      .4332      .3693      .2736
CROSSWLK            .0828      .0673      .3947      .2981      .4038
STWDTH              .1019      .1542      .4168      .2220      .2376
RD_COND             .2748      .1168      .0565      .0919      .0832


                   STOPLGHT   CROSSWLK   STWDTH     RD_COND
STOPLGHT           1.0000
CROSSWLK            .5544     1.0000
STWDTH              .2600      .2828     1.0000
RD_COND             .0607      .1150      .3505     1.0000


R E L I A B I L I T Y    A N A L Y S I S   -   S C A L E   (A L P H A)
Item-total Statistics


                 Scale        Scale      Corrected
                 Mean         Variance   Item-          Squared        Alpha
                 if Item      if Item    Total          Multiple       if Item
                 Deleted      Deleted    Correlation    Correlation    Deleted


CONDTN           10.0472      9.3970      .3191          .4684          .7161
REPAIR           10.8031      9.5026      .3322          .4506          .7119
TRAFFCAT         10.1102      8.3198      .4394          .4671          .6955
APPEARAN         10.7717      9.4733      .4714          .2473          .6883
NOISE            10.7756     10.3091      .4231          .3781          .7039
STOPLGHT         11.4685      8.5899      .5524          .4152          .6681
CROSSWLK         11.5433      8.5811      .4826          .3909          .6822
STWDTH           10.0039      9.7984      .4332          .3094          .6961
RD_COND          10.0669     10.7742      .2317          .2066          .7228
```

Reliability Coefficients   9 items

Alpha =   .7234   Standardized item alpha =   .7327

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Appendix VI: Principal Component Analytical Results for

Neighbourhood Socio-economic Disadvantage

Correlations

		percentage of low economic family income	% of aboriginal	% of pop over 15 w/o grade 9	% of lone parent	average car per person	% of owned house	% of employment
percentage of low economic family incon	Pearson Correlati	1	.918**	.717**	.756**	-.882**	-.712**	-.698**
	Sig. (2-tailed)	.	.000	.000	.000	.000	.000	.000
	N	41	41	41	41	41	41	41
% of aboriginal	Pearson Correlati	.918**	1	.725**	.691**	-.837**	-.519**	-.606**
	Sig. (2-tailed)	.000	.	.000	.000	.000	.001	.000
	N	41	41	41	41	41	41	41
% of pop over 15 w/o grade 9	Pearson Correlati	.717**	.725**	1	.348*	-.652**	-.619**	-.873**
	Sig. (2-tailed)	.000	.000	.	.026	.000	.000	.000
	N	41	41	41	41	41	41	41
% of lone parent	Pearson Correlati	.756**	.691**	.348*	1	-.806**	-.415**	-.340*
	Sig. (2-tailed)	.000	.000	.026	.	.000	.007	.030
	N	41	41	41	41	41	41	41
average car per persc	Pearson Correlati	-.882**	-.837**	-.652**	-.806**	1	.671**	.663**
	Sig. (2-tailed)	.000	.000	.000	.000	.	.000	.000
	N	41	41	41	41	41	41	41
% of owned house	Pearson Correlati	-.712**	-.519**	-.619**	-.415**	.671**	1	.711**
	Sig. (2-tailed)	.000	.001	.000	.007	.000	.	.000
	N	41	41	41	41	41	41	41
% of employment	Pearson Correlati	-.698**	-.606**	-.873**	-.340*	.663**	.711**	1
	Sig. (2-tailed)	.000	.000	.000	.030	.000	.000	.
	N	41	41	41	41	41	41	41

**·Correlation is significant at the 0.01 level (2-tailed).

*·Correlation is significant at the 0.05 level (2-tailed).

Factor Analysis

Communalities

	Initial	Extraction
LICO_1	1.000	.954
PER_AB_1	1.000	.900
GRADE9_1	1.000	.878
PERLON_1	1.000	.911
AVE_CA_1	1.000	.914
PER_OW_1	1.000	.676
PER_EM_1	1.000	.893

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.086	72.657	72.657	5.086	72.657	72.657
2	.989	14.129	86.786			
3	.472	6.738	93.524			
4	.221	3.157	96.681			
5	.108	1.545	98.226			
6	9.428E-02	1.347	99.573			
7	2.990E-02	.427	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
percentage of low economic family income	.959
% of aboriginal	.897
% of pop over 15 w/o grade 9	.831
% of lone parent	.730
average car per person	-.928
% of owned house	-.776
% of employment	-.821

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Reliability

```
****** Method 2 (covariance matrix) will be used for this analysis
******


  R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)


  1.    PER_OWN      % of owned house
  2.    AVGCAR       average car per person
  3.    EMPLOYM      % of employment
  4.    NONAB        % of non Aboriginal
  5.    NSINGLE      % of married/common law couple
  6.    NGRADE9      % of education> grade 9
  7.    NLICO        % of non LICO families




                        Mean        Std Dev       Cases
```

```
1.    PER_OWN          61.8665          20.8418          41.0
2.    AVGCAR             .5486            .1152          41.0
3.    EMPLOYM          69.8304          11.7324          41.0
4.    NONAB            90.8589           9.8753          41.0
5.    NSINGLE          80.1204          15.0555          41.0
6.    NGRADE9          91.4776           6.0844          41.0
7.    NLICO            80.1204          15.0555          41.0
```

Correlation Matrix

```
                PER_OWN      AVGCAR      EMPLOYM      NONAB       NSINGLE

PER_OWN          1.0000
AVGCAR            .6706      1.0000
EMPLOYM           .7114       .6633      1.0000
NONAB             .5193       .8371       .6064      1.0000
NSINGLE           .7124       .8824       .6978       .9179      1.0000
NGRADE9           .6186       .6517       .8732       .7251       .7174
NLICO             .7124       .8824       .6978       .9179      1.0000
```

```
                NGRADE9      NLICO

NGRADE9          1.0000
NLICO             .7174      1.0000
```

R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)

```
       N of Cases =          41.0
                                              N of
Statistics for      Mean    Variance    Std Dev  Variables
       Scale     474.8228   4894.1094   69.9579          7
```

```
Item-total Statistics

              Scale          Scale        Corrected
              Mean          Variance        Item-         Squared         Alpha
             if Item        if Item         Total        Multiple        if Item
             Deleted        Deleted      Correlation    Correlation      Deleted


PER_OWN      412.9563      2843.7807        .7270            .            .8938
AVGCAR       474.2742      4880.1386        .8669            .            .9148
EMPLOYM      404.9924      3648.4995        .7817            .            .8638
NONAB        383.9639      3807.3680        .8117            .            .8652
NSINGLE      394.7024      3113.0332        .9252            .            .8403
NGRADE9      383.3452      4224.6176        .7997            .            .8810
NLICO        394.7024      3113.0332        .9252            .            .8403
```

Reliability Coefficients   7 items

Alpha =   .8902   Standardized item alpha =   .9544

Appendix VII: Principal Component Analytical Results for

Neighbourhood Social Interactive

Correlations

		ethnic diversity index	% of family move during the last year	crime per capita	% of voter participation for Saskatoon	% of voter participation for federal
ethnic diversity index	Pearson Correlation	1	.375*	.247	-.317*	-.261
	Sig. (2-tailed)	.	.017	.124	.046	.104
	N	40	40	40	40	40
% of family move during the last year	Pearson Correlation	.375*	1	.581**	-.513**	-.687**
	Sig. (2-tailed)	.017	.	.000	.001	.000
	N	40	40	40	40	40
crime per capita	Pearson Correlation	.247	.581**	1	-.412**	-.550**
	Sig. (2-tailed)	.124	.000	.	.008	.000
	N	40	40	41	40	40
% of voter participation for Saskatoon	Pearson Correlation	-.317*	-.513**	-.412**	1	.794**
	Sig. (2-tailed)	.046	.001	.008	.	.000
	N	40	40	40	40	40
% of voter participation for federal	Pearson Correlation	-.261	-.687**	-.550**	.794**	1
	Sig. (2-tailed)	.104	.000	.000	.000	.
	N	40	40	40	40	40

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Factor Analysis

Communalities

	Initial	Extraction
% of voter participation for Saskatoon	1.000	.662
% of voter participation for federal	1.000	.786
ethnic diversity index	1.000	.314
% of family move during the last year	1.000	.693
Crime per capita	1.000	.762

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.217	72.344	72.344	3.217	72.344	72.344
2	.846	10.123	82.467			
3	.509	8.689	91.436			
4	.279	5.574	97.010			
5	.149	2.990	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
% of voter participation for Saskatoon	-.813
% of voter participation for federal	-.887
ethnic diversity index	.560
% of family move during the last year	.832
Crime per capita	.873

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Reliability

```
****** Method 2 (covariance matrix) will be used for this analysis


 R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)


1.    ETHNIC_1     ethnic diversity index

2.    CRIME        crime per capita

3.    MOBILI_1     % of family move during the last year

4.    VOTESAS      % of not vote for Saskatoon

5.    VOTEFED      % of not vote for Federal


                        Mean        Std Dev       Cases
1.    ETHNIC_1         .9365         .3056         41.0

2.    CRIME            .1742         .2132         41.0

3.    MOBILI_1         .2183         .0765         41.0

4.    VOTESAS        79.8687        5.7852         41.0

5.    VOTEFED        42.3747        6.7298         41.0
```

```
Correlation Matrix


                   ETHNIC_1    CRIME     MOBILI_1    VOTESAS     VOTEFED


ETHNIC_1           1.0000
CRIME               .2161     1.0000
MOBILI_1            .3500      .5397     1.0000
VOTESAS             .2385      .5680      .5157      1.0000
VOTEFED             .1806      .6451      .6760       .8168      1.0000
        N of Cases =          41.0
                                            N of
Statistics for       Mean    Variance   Std Dev  Variables
        Scale      123.5723  148.5564   12.1884          5


Item-total Statistics


                  Scale       Scale      Corrected
                  Mean       Variance     Item-        Squared       Alpha
                 if Item     if Item      Total       Multiple      if Item
                 Deleted     Deleted    Correlation   Correlation   Deleted


ETHNIC_1         122.6358    146.8321      .2202        .1655        .6177
CRIME            123.3982    145.2130      .6419        .4449        .6093
MOBILI_1         123.3540    147.3648      .6388        .5340        .6195
VOTESAS           43.7037     48.7863      .8204        .6856        .0916
VOTEFED           81.1977     36.3763      .8240        .7810        .1013

—


R E L I A B I L I T Y   A N A L Y S I S   -   S C A L E   (A L P H A)


Reliability Coefficients    5 items


Alpha =   .5861          Standardized item alpha =    .8188
```

Appendix VIII: Neighbourhood Boundaries

Saskatoon Neighbourhoods

Legend

001 Holiday Park
002 Montgmoery Place
003 Fairhaven
004 Parkridge
005 Pacific Heights
006 Confederation Park
007 Dundonald
008 Westview
009 Massey Place
010 Hampton Village
011 Meadow Green
012 King George
013 Pleasant Hill
014 Riversdale
015 Mount Royal

016 Westmount
017 Caswell Hill
018 Hudson's Bay Park
019 Mayfair
025 C.B.D.
026 Nutana
027 Buena Vista
028 Exhibition
029 Avalon
030 Queen Elizabeth
031 The Willows
032 Haultain
033 Holliston
035 Grosvenor Park
036 Holliston
037 Stonbridge

038 Adelaide/Churchill
039 Nutana Park
040 Eastview
041 Nutana S.C.
042 Brevoort Park
043 Greystone Heights
044 Lakeview
045 Wildwood
046 College Park
047 College Park East
048 Sutherland
049 Forest Grove

050 City Park
051 North Park
052 Richmond Heights
053 River Heights
054 Lawson S.C.
055 Lawson Heights
056 Silverwood Heights
057 Confederation S.C.
058 Lakeridge
059 Arbor Creek
060 Erindale
061 Silverspring
062 Willowgrove
064 Briarwood

067 University Heights S.C.
068 Lakewood S.C.
100 Agriplace
101 Airport Industial
102 Central Industrial
103 CN Industrial
105 Kelsey/Woodlawn
106 North Industrial
107 Agpro Industrial
108 South West Industrial
109 Sutherland Industrial

110 Silverwood Industrial
111 West Industrial
112 Husdon Bay Industrial
113 Marquis Industrial
710 Diefenbaker Management Area
711 C.N. Yards Management Area
712 Sask Power Management Area
713 Gordie Howe Management Area
714 UofS North Management Area

715 UofS Management Area
716 UofS South Management Area
717 Airport Management Area
901 SE Development Area
902 NE Development Area
903 NW Development Area

COMMUNITY SERVICES-CITY PLANNING
Research and Information Resource Centre
City of Saskatoon