EXAMINING MEASLES, MUMPS, AND RUBELLA (MMR) IMMUNIZATION UPTAKE IN SASKATOON: CAN NEIGHBOURHOOD CHARACTERISTICS PREDICT COVERAGE RATES

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EXAMINING MEASLES, MUMPS, AND RUBELLA (MMR) IMMUNIZATION UPTAKE IN SASKATOON: CAN NEIGHBOURHOOD CHARACTERISTICS PREDICT COVERAGE RATES?

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By

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ABSTRACT

Immunization programs have proven to be one of the most successful public health initiatives in Canada yet continuous monitoring of coverage rates is essential to ensure high uptake and the continued success of these programs. Prior to this study, Saskatoon Public Health Services (PHS) were limited to manual calculation of coverage rates and trends and were unable to examine immunization uptake by neighbourhood. The purpose of this study was to utilize newly available data from the Saskatchewan Immunization Management System (SIMS) to examine city and neighbourhood uptake of the Measles, Mumps, and Rubella (MMR) vaccine. Once neighbourhood coverage rates were calculated, the project centred on using quantitative neighbourhood level data to determine if the neighbourhood variables of interest could significantly contribute to the explanation in variation of up-to-date immunization coverage in Saskatoon.

The study looked at 10, 287 two year-olds in Saskatoon between 1999 and 2002. The findings revealed immunization rates were relatively stable during this period. Of the approximately 90% of children who were immunized each year about 70% were considered up-to-date while approximately 20% were considered delayed or incomplete. However, significant disparities were found to exist at the neighbourhood level with areas of social and economic disadvantage having lower rates of total, complete, and up-to-date immunization uptake compared to areas of greater social and economic wealth. A slight downward trend in total immunization uptake was also noted in both the city of Saskatoon and high uptake neighbourhoods. Interestingly, high uptake neighbourhoods were also found to have the highest levels of social and economic advantage. Multivariate linear regression, used in the second phase of the analysis, revealed 80.6% of variation in up-to-date immunization uptake in Saskatoon could be explained by the proportion of single mothers and the proportion of vehicles registered in the neighbourhood. These findings are supported by the literature and may indicate the presence of real or perceived barriers to immunization for some families in Saskatoon.

Limitations of the study include: the quality of the SIMS data, general limitations of ecologic designs, and problems with child mobility within and outside of the city. The issue of mobility likely resulted in the overestimation of coverage rates in some neighbourhoods and underestimation in others even though measures were taken to mitigate the effects of potential misclassification.

Six recommendations were devised in an attempt to identify possible directions for future research and to improve the provision of immunization services for all areas of the city with particular attention focussed on high-risk neighbourhoods. It is hoped the findings of this study and recommendations provided will assist PHS in their continued efforts to improve immunization uptake in Saskatoon and throughout the entire region.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MMR	Measles, Mumps, and Rubella
MR	Measles and Rubella
PHS	Public Health Services
SHR	Saskatoon Health Region
SIMS	Saskatchewan Immunization Management System
CRS	Congenital Rubella Syndrome
ITP	Idiopathic Thrombocytopenia Purpura
US	United States
SES	Socioeconomic Status
MIMS	Manitoba Immunization Management System
SHIPS	Saskatchewan Health Information and Strategic Planning System
UTD	Up-to-Date
LPF	Lone-Parent Families
SC	Suburban Center

1. INTRODUCTION

Immunization has proven to be one of the most significant and successful advances in disease prevention ever known. The global eradication of small pox and the elimination of polio in the western hemisphere have shown the power effective immunization initiatives can have on the health of children worldwide. Canada is no exception to this success. Over the last one hundred years the incidence of vaccine-preventable diseases in Canada has decreased 95% and vaccination has become the cornerstone of preventive healthcare [1].

Measles, mumps, and rubella (MMR) are three of the many diseases that have drastically declined following the implementation of large-scale immunization programs in Canada. The three diseases are relatively rare today however, the constant threat of re-emergence remains in areas where immunization coverage is sub-standard. Therefore, evaluation of immunization programs and outcomes is of continued importance.

Research into neighbourhood effects on health has also become increasingly important to the field of epidemiology in recent years. The ecological approach lends itself to identifying differences in health status between various levels of organization (i.e. neighbourhoods, cities, municipalities) rather than individual differences alone. Saskatoon Public Health officials were interested in using an ecologic approach together with newly available Saskatchewan Health immunization data to explore the difference in immunization uptake among Saskatoon neighbourhoods. This interest resulted in the genesis of this thesis project.

1.1 Research Questions

This thesis project aims to answer a number of research questions. The questions are as follows:

a) What annual proportion of children in the city of Saskatoon and each residential neighbourhood received two doses of the MMR/MR vaccine before their second birthday between the years of 1999-2002?

b) What annual proportion of children in the city of Saskatoon and each residential neighbourhood were delayed or incomplete in receiving their MMR/MR vaccine before their second birthday between the years of 1999-2002?

c) Have immunization coverage rates remained stable, increased, or decreased in Saskatoon and each residential neighbourhood between the years of 1999-2002?

d) Which neighbourhood characteristics significantly contribute to the prediction of MMR immunization rates in Saskatoon?

e) Can the identification of neighbourhood coverage rates and characteristics related to immunization uptake be used by Public Health Departments to better plan, implement, and evaluate immunization services?

1.2 Rationale

There are a number of key points that provide rationale for this study. First, disease prevention initiatives, such as immunization programs, can only be successful when high levels of coverage are obtained and high-risk groups are targeted [2]. The Canadian Public Health Association recommended in 2001 that targeting high-risk groups and identifying ways to minimize immunization inequities was an important component of any immunization program [1]. Therefore, the identification of high-risk groups for low immunization coverage is essential for Saskatoon Public Health Services (PHS) to monitor the effectiveness of their current immunization programming. The results of this research may inform future decisions around resource allocation for the immunization program in the Saskatoon Health Region (SHR).

Saskatoon Public Health also considered it important to begin using and calculating immunization coverage rates for the health region using the newly available Saskatchewan Immunization Management System (SIMS) data. Prior to this time, Public Health had been able to calculate immunization coverage rates using manual analysis only. Learning how to use the SIMS data to efficiently and effectively calculate accurate coverage rates on both the city and neighbourhood level was essential in determining if the SIMS database was a viable research and monitoring tool.

The SIMS dataset, however, was quite large and required a focus to ensure the project was manageable. The MMR vaccine was chosen for examination in this study given the controversy over the 1998 Wakefield et al. article linking the MMR vaccine to autism [3]. Health care providers and researchers have since dispelled this incorrect association and the article was recently recanted by ten of the thirteen original authors [4]. However, media and anti-vaccination groups have affected parental confidence in the MMR vaccine to varying degrees. The research conducted in this study may provide insight into the effect the controversy has had on parents and subsequent immunization rates in Saskatoon.

Finally, geographic surveillance and research into the neighbourhood effects on health has surged in popularity in recent years [5]. However, analysis of neighbourhood characteristics in relation to immunization uptake had never previously been examined in Saskatoon. This research project will contribute to the ever-increasing body of ecologic research while providing valuable and pragmatic information to the SHR. With this additional insight, better programs and initiatives can be developed at both the individual and community level.

2. LITERATURE REVIEW

2.1 Identification of Literature

The literature review consisted of using MEDLINE, Pub Med and CINAHL to conduct searches on a variety of topics related to immunization. Key words included: MMR, measles, mumps, rubella, neighbourhood characteristics, neighbourhood and health, immunization, immunization barriers, vaccination, child health, and disease prevention. Internet searches were also conducted using the search engine "Google" which produced numerous reports. Once relevant articles and reports were identified, an extensive search of secondary sources was also carried out to ensure adequate coverage of the various topics of interest.

2.2 Measles

Measles has been recognized as a disease for over ten centuries and has had a significant impact on the health of individuals worldwide. According to the Centre for Disease Control's Morbidity and Mortality Weekly Report, measles remains the leading cause of vaccine-preventable childhood death with 770,000 deaths worldwide in 2000. Ninety-eight percent of these deaths occurred in 75 of the world's poorest countries [6]. In Canada, measles incidence has decreased substantially over the last 40 years with a range of 0.7 to 58.6 cases per 100,000 reported between 1986 and 1995. Canada had only 12 reported measles cases in

1998 – the lowest ever recorded [7]. However, the incidence of measles rose again the following year with a total of 279 cases reported between 1999 and 2002 [8].

Measles is highly contagious with estimates of approximately 12 to 18 people at risk of being infected from one measles case. Transmission is greatly affected by herd immunity, population size, concentration, mobility, and social interaction. The airborne virus is carried in droplet form and is easily transferred through sneezing and coughing and can last up to two hours in fine droplet form [9].

Measles is characterized by a fever, runny nose, cough and reddened eyes followed by a maculopapular rash around the face that spreads to the chest, arms, and legs within a few days [10]. The rash occurs approximately 14 days following infection and two to four days following onset of prodromal symptoms. Patients are usually considered to be infectious four days previous to and four days following the appearance of the rash. The most common complications of measles include otitis media and pneumonia however, more severe complications such as measles encephalitis, Subacute Sclerosing Panencephalitits (SSPE), and atypical measles syndrome (resulting from killed measles vaccine only) can also occur. Contracting measles during pregnancy can also lead to spontaneous abortion and underweight newborns [9].

2.3 Mumps

Mumps is a viral infection with clinical symptoms ranging from mild upper respiratory infection to widespread systemic involvement. Transmission occurs through contact with infected droplets that can spread the virus seven to nine days before the onset of symptoms. Prodromal symptoms include anorexia, headaches, vomiting, and myalgia progressing to fever and salivary gland swelling within 12 to 24 hours. Viral meningitis is the most common complication of mumps with approximately ten percent of individuals infected with mumps developing the disease. Other complications include: transient or permanent deafness, testes/ovary involvement, pancreatitis, and encephalitis. Complications are frequent although permanent damage or death rarely occurs [11].

Prior to vaccine availability, mumps was a common disease with high incidence rates around the world occurring primarily in children five to nine years of age. Mumps epidemics frequently occurred in crowded areas such as prisons, orphanages, military barracks, and boarding schools. Mumps incidence rates continue to remain high in countries with minimal or no access to vaccination [11]. Canada reported approximately 30,000 cases annually during the 1940s and 50s. Following the introduction of the vaccine the disease steadily declined with incidence rates ranging from 0.4 to 3.5 cases per 100,000 between the years of 1986 and 1998 [7]. Rates remained relatively stable between 1999 and 2001 with the number of cases ranging from 87 to 97 per year. However, the number of mumps cases increased once again to 203 in 2002 [8].

2.4 Rubella

Rubella is a disease which mainly affects children and young adults with approximately half of infected individuals developing clinical symptoms. The first symptoms appear within 14 to 21 days of infection and the disease can be spread up to seven days before and four days after rash development. Clinical symptoms include a non-specific often itchy rash that begins on the face and spreads to trunk and extremities. Lymphadenopathy, low-grade fever, headache, malaise, sore throat, and mild conjunctivitis are all classic prodromal symptoms. Congenital Rubella Syndrome or CRS develops in children whose mothers have been infected just prior to conception or during the first trimester of pregnancy. The development of CRS in the fetus can lead to congenital heart disease, cataracts, deafness, and mental retardation [9]. Mothers infected with rubella during this time are also at high risk for spontaneous abortions or stillbirths.

Rubella infection in Canada has remained relatively low resulting in a mean annual incidence rate of 4.0 per 100,000 between the years of 1986 and 1995. In 1998 the rate of rubella decreased to 0.2 per 100,000 which was the lowest ever reported [7]. This low rate continued between 1999 and 2002 with less than 30 cases per year reported annually [8]. Congenital Rubella Syndrome also remains rare with only 32 cases reported between 1986 and 1996 [7]. The Canadian Paediatric Surveillance Program reported only five cases of CRS between 1996 and 1999 confirming the efficacy of rubella immunization programming in Canada [12].

2.5 The MMR Vaccine and Dosing Schedule

The measles, mumps, and rubella vaccines are given in combination and administered subcutaneously by injection. The most common adverse reaction to the vaccine is a fever which occurs in approximately five to ten percent of children. Other less common side-effects include: febrile seizures, encephalitis, viral meningitis, parotitis, skin rashes, lymphadenopathy, and pain in the extremity of injection [13]. Idiopathic thrombocytopenia purpura (ITP) has also been found to have a causal association with the MMR vaccine although vaccine associated cases appear to be milder and shorter than other cases [14]. The vaccine is contraindicated in children who have had a previous anaphylactic reaction to the vaccine, are acutely ill, have had a reaction to neomycin or gelatin in the past, or are immunocompromised [13].

The first measles immunization program in Canada consisted of only one dose of the MMR vaccine. However, measles outbreaks in Quebec and Ontario in late 1980s and early 1990s proved the one-dose strategy to be insufficient. Based on compelling research, the National Advisory Committee on Immunization recommended implementing a two-dose vaccine schedule in 1992 in an effort to eliminate measles, mumps, and rubella in Canada by 2005 [15]. The two-dose strategy was also found to be the most cost effective strategy for measles, mumps, and rubella prevention in Canada [16].

Although all provinces have adopted the two-dose MMR strategy, the age at which the doses are given differs from province to province. The routine immunization schedule in Saskatchewan between 1996 and 2000 consisted of one dose of MMR at 12 months of age and one dose of MR (measles and rubella) at 18 months. In July of 2000, changes were implemented to eliminate the MR vaccine and provide the MMR vaccine at both the 12 and 18 month interval due to vaccine cost considerations. Provinces such as Alberta, Manitoba, Ontario, and Nova Scotia administer the first dose of MMR at 12 months and a second dose of MMR between four and six years of age [17].

Health Canada accepts delivery of the second MMR dose at either the 18 month interval or the four to six year interval [13]. However, Canadian researchers have found immunity levels drop significantly one year following the receipt of the first dose of MMR with sub-optimal immunity rates of 16.4% and 22.4% for measles and mumps respectively [18]. This research provides evidence that administration of the second MMR vaccine is more beneficial at the 18 month interval as it provides higher levels of protection to children at an earlier age. Based on this research and the Saskatchewan guidelines for MMR immunization, children who have received two doses of either the MMR/MR vaccine before their second birthday will be considered "up-to-date" in this study.

2.6 MMR and Autism

The debate over the relationship between the MMR vaccine and autism began with the recently recanted article published by Wakefield et al. in 1998 [3]. The study examined 12 children who had been referred to a London hospital with a history of normal development followed by a sudden loss of acquired skills and language in association with diarrhea and abdominal pain. Parents of 8 of the 12 children reported skill and language regression closely following the receipt of the MMR vaccination with an average 6.3 day interval between immunization and symptom development. Extensive testing was conducted and it was determined that all children were found to have ileal-lymphoid-nodular hyperplasia or 'leaky-gut syndrome'. In all, 9 of the 12 children were diagnosed as autistic, one had degenerative psychosis, and two had possible post-viral or vaccine encephalitis.

The authors concluded the development of the 'leaky-gut syndrome' may have been associated with the MMR vaccine. The researchers hypothesized the MMR vaccine caused the syndrome allowing for absorption of non-permeable peptides into the bloodstream. With the liver unable to filter these harmful peptides, the substances cross the blood-brain barrier resulting in genetically at-risk children to potentially develop central nervous system damage with autism as an end result [19]. However, numerous studies have refuted this finding.

In 1999, Taylor et al. found no causal association between the MMR vaccine and autism in a sample of 498 autistic children using sound epidemiological methods such as adequate sample size, consistent ascertainment of cases, and appropriate analysis [20, 21]. A retrospective analysis of Californian children born between 1980 and 1994 found no relationship between the trend of childhood immunization and the trend of autism diagnosis. The researchers found a 373% rise in autism over a 14 year period with an increase of only 14% in immunization coverage over the same time period [22]. Patja et al. reviewed adverse side-effect surveillance reports in Finland and found no reports of inflammatory bowel disease or autism over the study period in which over three million doses of MMR were administered [23]. And, once called the "definitive" study on MMR and autism, a Danish study with a sample size of 537,303 children found the relative risk of autistic disorder in the vaccinated group compared to the unvaccinated group was 0.92 (95% CI = 0.68-1.24) following adjustment for all potential confounders [24]. Numerous other studies also found no evidence the MMR vaccine is related to autism or inflammatory bowel disease [25-27]. Finally, a recent report issued by The Institute of Medicine rejected a causal relationship between the MMR vaccine and autism[28].

2.7 The Role of Media and Anti-Vaccination Groups

Although the Wakefield et al. study has been extensively critiqued for significant methodological issues such as: a small sample size, selection bias, recall bias, absence of a control group, no clear case definition, a high potential for false attribution, and the inability to provide microbiologic evidence to support the hypothesis [21, 29] the debate continues. Much of the controversy has been fuelled by the ongoing media attention to the issue with substantial amounts of time being paid to false claims and minimal attention devoted to finding and reporting the facts [30, 31]. Negative media reports have been found to adversely affect coverage rates especially in higher socio-economic groups [32].

Anti-vaccinationists have also contributed to parental confusion over the safety and efficacy of various vaccines. The anti-vaccination movement sprang to life in the mid to late 1800s in response to compulsory vaccination acts passed in both North America and Britain [33]. Beliefs that vaccinations are harmful or unnecessary remain today and have widely been communicated through the Internet. Unsubstantiated and faulty claims made by anti-vaccinationists and supported by poor research have proven to be detrimental to vaccination programs especially in the United Kingdom where there is a strong possibility of endemic measles reappearing due to the controversy [34]. A recent U.S study also found over two thirds of physicians reporting increased parental concerns over vaccine safety although far fewer noticed an increase in actual refusals [35].

Although many in the medical establishment find the anti-vaccination movement troublesome their efforts have led to safer vaccines, enhanced surveillance, and vaccine-injury compensation programs [36]. It is clear, however, that health care providers and public health officials have the responsibility to monitor the activities of both media and anti-vaccination groups as well as uptake rates to ensure inaccurate information does not misinform concerned parents.

2.8 Parental Attitudes and Beliefs

Parental attitudes and beliefs towards immunization safety are important considerations as parents are ultimately the ones who decided if the child does or does not receive vaccination. Although parental attitudes towards immunization are not able to be examined through this study, it is important to understand the effect beliefs and attitudes have on immunization uptake.

A 2001 survey commissioned by Wyeth-Ayerst Canada found Canadian parents held strong beliefs that vaccinations were both important and safe. Ninety percent of respondents stated all children should have the standard vaccinations and 59% were very confident in the benefit of vaccines (rating 9 or 10 on a scale of 0 to 10). Ninety percent of parents also believed vaccinating children may also ease the burden on the healthcare system [1].

In other countries, a U.S. survey found the vast majority of parents believe vaccinations to be safe and effective but also found significant misconceptions that could negatively affect parental decision-making. The survey identified Caucasians, females, college graduates, and those with alternative medical beliefs were more likely to opt out of immunizations [37]. An Australian study examined mother's beliefs around immunizations and found that those who completed immunization routines perceive the risk of the disease to outweigh the risk of the vaccines and recognized that immunizations protect others in the community (herd immunity). Incomplete immunisers often faced barriers, "admitted to laziness", and felt their doctors did not believe immunizations were important. Non-immunisers were more concerned with long term side-effects of the vaccine, questioned the motives of the healthcare professionals, believed in alternatives medicine, and perceived vaccines to be ineffective [38].

However, Kilmartin et al. found even when mothers were highly motivated and believed immunizations were safe and effective, immunization coverage rates often did not reflect their intentions [39]. Similar results were found in another study which discovered mother's beliefs and attitudes towards immunizations are much less important than sociodemographic factors in determining the immunization status of poor urban children. The study found parental attitudes had little influence on immunization status disputing other studies that maintained education alone was the key to improving immunization rates [40]. These findings suggest that although parental attitudes and beliefs are important considerations in assessing immunization uptake, the detailed exploration of sociodemographic influences on immunization behaviour is vitally important as well.

2.9 Factors Affecting Immunization Uptake

2.9.1 Poverty

Socioeconomic status (SES) is perhaps the single most significant environmental influence on health. Those who live in low socio-economic situations often have the highest rates of morbidity and mortality across a spectrum of both infectious and non-infectious diseases [41]. Socioeconomic status is also very influential on immunization uptake amongst children and has been recognized as such in a number of studies.

A 1994 American study found poverty to be an independent predictor of immunization status at seven months despite the availability of free vaccines to most children. The authors concluded poverty affects immunization uptake beyond the simple affordability of vaccination [42]. Bates and Wolinsky also found mothers living in poverty or with income data missing were more likely to have children that were not up to date in their immunization series by two years of age (OR = 2.62, 95% CI = 1.44–4.75) based on SES at birth and adjusted for mother's age, race, and education [43].

Klevens and Luman found substantive differences in immunization coverage rates between children living in poverty and those who were not. Immunization rates for the primary vaccination series was 13.6% higher in 1996 (95% CI = 10.3-16.9) and 10% higher in 1999 (95% CI = 7.0-13.0) among children living above the poverty line compared to children considered to be living in severe poverty. Children living just above the poverty line were found to have immunization rates similar to children living in poverty with only a 1.4% difference in coverage (74.7% versus 73.3%, $p< 0.52$) [44]. On the other hand, no significant relationship was found between immunization status at two years of age and income in a study of inner-city infants in the U.S. However, the authors state the lack of significance was probably related to the homogeneity of family income within the sample [45].

The general consensus in the literature is that SES does have a significant influence on immunization rates with additional studies to support this position [46-48]. Even when no significant association is found it is usually related to homogeneity of income within the sample. Therefore, median family income, the proportion of families earning less than $10,000, and the proportion of families below the line of poverty will all be used as variables reflecting neighbourhood SES in Phase II of the analysis.

2.9.2 Family Composition

The composition of the family unit has also been shown to affect immunization rates. Factors such as family size, age of mother, and marital status of the mother have all been found to influence immunization uptake in a variety of studies. Family composition is an important aspect of immunization uptake and can also be readily analyzed on a neighbourhood level.

Family size has often been associated with immunization rates. In 1979, Marks et al. found family size inversely related to the completion of the basic immunization series. In other words, as the size of the family increased the rates of immunization in the subsequent children decreased [46]. Miller et al. also found children with two or more siblings were 3.2 times more likely to be delayed than those with no siblings within a multivariate model (95% CI = 1.6-6.3) [49]. And, after controlling for marital status and education, researchers in Oregon found first-born children consistently had higher coverage rates than siblings born after them [50].

The age of the mother may also be a contributing factor to immunization uptake. One study showed mothers under the age of 21 years at the time of the child's birth were 2.3 times more likely to have a child who was delayed in receiving the MMR vaccine by the age of two years [49]. There was also a slight increased risk of delayed immunizations for children of younger mothers in a study conducted in Kern County, California. Using multivariate logistic regression analysis researchers found children with mothers 15 to 24 years of age were 1.5 times more likely to have an incomplete immunization series compared to older mothers (95% CI = 1.0-2.3) [51].

The marital status of the mother is another important influence on immunization rates to consider. Married women are 1.95 times more likely to have initiated the immunization series by three months of age (95% CI = 1.21-3.16) and are 1.64 time more likely to have all recommended immunizations completed by seven months of age (95% CI = 1.02-2.66) [42]. In another study, researchers found 11.5% of children of unmarried mothers were not complete in their immunization series at the age of two compared to 3.2% of married mothers ($p< 0.03$) [52]. On the other hand, an American study found single mothers with low levels of education tended to be better at accessing health care for their children. However insurance coverage was an important influence on this finding [53].

2.9.3 Parental Education

In the late 1970s the effect of parental education on immunization completion was studied controlling for both family size and the education of the spouse. Fathers with less than 12 years of education had children with basic immunization completion rates of 54.1%, fathers with 12 years of education had completion rates of 77.3%, and fathers with 13 to 15 years of education produced rates of 81.7%. Fathers with 16 years of education or more faired much better with completion rates of 91.2%. Completion rates increased significantly with paternal education ($p<0.001$) [46]. Similarly, mothers with less than 12 years of education also had low basic immunization completion rates of 61.7%. Mothers with a high school diploma had rates of 77.3% while more than 13 years education increased completion rates to 83.3% ($P<0.02$) [46]. More recent studies have found similar trends.

A case-control study conducted in Colorado found maternal education of high school or less at the time of the child's birth elevated the child's risk of delayed MMR immunization at two years of age. In the bivariate analysis mothers with less than a high school education were more likely to have children who were delayed compared to those with more than a high school education (OR = 2.6, 95% CI = 1.4-4.8). However, maternal education became an insignificant risk factor within the multivariate model [49].

Among the immunized group in another study it was found only 1.1% of children had completed their basic immunization series where mothers had not obtained a high school diploma. This proportion increased to 30.1% in mothers who had graduated high school and 68.8% in mothers with post-high school education. However, respondents of the survey tended to be older, white, married and better educated. Both recall bias and small sample size (n=93) were also noted to be limitations of this study [52]. Interestingly, in a larger (n=324) and more recent study maternal education was found to be insignificant in predicting up-to-date status at three and seven months of age [45].

2.9.4 Transportation and Travel Distance

A 1993 study, conducted to examine factors that contribute to diphtheria, tetanus, pertussis and poliomyelitis immunization uptake, found problems with health care accessibility based on travel time to or distance from a health care facility did not significantly influence immunization behaviour. Moreover, the availability of a car did not affect immunization uptake based on individual-level analysis [54]. Similar results were reported in another study which found neither the travel time nor the method of travel affected immunization rates between complete and incomplete immunisers ($p= 0.13$ and 0.11 respectively) [49].

However, a number of other quantitative and qualitative studies have indicated transportation difficulties as a barrier to immunization [55-58]. Socially disadvantaged mothers, participating in a series of focus groups in North Carolina, stated travelling to immunization appointments was a considerable barrier in immunizing their children. The mothers cited both cost and the difficulty of travelling by bus with one or more children as a significant problem [59].

2.9.5 Race and Ethnicity

Race and ethnicity are important considerations when examining health behaviours within a population. Racial minorities may experience more social or economic barriers to health services or have differing cultural view of health practices that may alter their health-seeking behaviours. However, the influence of race and ethnicity on health behaviour varies greatly between countries and regions depending on the historical and cultural context of the area under study.

In Saskatoon, Aboriginals comprise 9.2% of the population [60] and the majority live in the core neighbourhoods known to be the areas of the city with the lowest levels of economic wealth and a variety of social issues [61]. Children in these neighbourhoods are often considered to be higher-risk for a number of health and social problems. Although no studies have been conducted examining the immunization behaviour of urban Aboriginals, two Canadian studies have looked at on-reserve Aboriginal issues related to immunization uptake.

The first study found Aboriginal mothers in the Sioux Lookout Zone of Ontario to have limited knowledge of how vaccines worked and the protection offered. Missed opportunities, attributed to frequent minor illnesses, also negatively affected immunization rates. Most notably, they found community Elders often had reservations about vaccinations as many felt minor side-effects related to the vaccines were associated with making the child sick rather than healthy [62].

The other study explored immunization uptake with First Nations mothers in North-Western Ontario. Results showed most mothers were highly motivated to seek immunization although some questioned the effectiveness of the vaccines. Traumatic immunization experiences, side-effects following vaccine, negative interactions with health professionals, time-constraints, and frequent minor childhood illnesses all served as deterrents in this population [63]. Although it is difficult to say if these same problems are present in other Aboriginal communities or in Saskatoon, it does shed some light on some of the immunization concerns of Aboriginal peoples in this country.

Immigrants may also face unique health and social issues which may, in turn, affect immunization behaviour. Limited research has been conducted regarding immunization behaviour within immigrant communities. A British study conducted in 1984 found significant differences between the non-immigrant British group and other ethnic groups within the health district under investigation. The researchers found Indian and Pakistani groups to have better immunization rates than the British control group (95.4%, 99.1% and 91.4% respectively) [64]. No explanation for these differences was provided in the study. Other studies have shown assessing health behaviours within an immigrant population is an extremely difficult and complex task requiring factors such as language, culture, availability of support systems, and level of integration to be taken into account [65].

2.9.6 Mobility

High levels of residential mobility have been shown to negatively affect immunization rates. In a study conducted to assess the relationship between residential mobility and primary health care in children, researchers in Rhode Island examined the frequency of care for 44,735 children using immunization visits. Three separate birth cohorts were analyzed and all three showed similar trends - as mobility increased primary care visits for immunizations decreased [66].

Mobility was also associated with delayed immunization in a study out of Colorado. Using bivariate analysis it was found two or more moves before the age of two years of age placed the child at an increased risk for delayed immunizations (OR = 2.4, 95% CI 1.4 - 4.0) [49]. Families with high levels of mobility are often lower income, have lower levels of education, and are most often headed by single mothers [67].

High levels of mobility are found more often in Aboriginals groups - especially in urban areas. Statistics Canada reports in the year before May 15, 2001 22% of Aboriginal people had moved compared to only 14% of non-Aboriginals. Two-thirds of Aboriginals who moved stayed in the same community while the remainder moved outside of the community [68]. The effect of mobility on the accurate calculation of coverage rates will be discussed further in the Limitations section (section 5.4.2). However, a neighbourhood one-year mobility variable will be used in this project to determine if high levels of mobility within a neighbourhood can assist in explaining immunization uptake.

2.9.7 Birth Weight

Data on neighbourhood low birth weight rates was also analyzed in this study. Mitchell & Franco found lower birth weights to be associated with higher immunization completion rates in urban minority children at two years of age ($p = 0.04$). The researchers believe low birth weight infants may be perceived as more fragile by parents and health care workers resulting in more home and physician visits. The increased exposure to health care professions could lead to better parental education and additional opportunities for immunization [69]. As a result, neighbourhood infant birth weight rates may contribute in some way to the prediction of immunization coverage rates and will therefore be used in this analysis.

2.9.8 Additional Barriers to Immunization

Other variables, unable to be assessed in neighbourhood analysis, may also contribute to low immunization coverage. Numerous studies have found both health care providers and parents often delay immunizations due to mild illnesses or colds [59, 70-74]. In one study 27% of parents and 89% of physicians felt colds and fevers were a significant barrier to receiving immunizations [56]. The effect of mild illness on immunization delays was also found to affect immunization uptake in an Aboriginal community in Ontario. Mothers in the study reported immunization providers often would not give the vaccine if the child was ill therefore, mothers often waited to bring the child to clinic until they were healthy [62]. Considering the high rates of respiratory and mild illness in children under two years of age, this practice can have a significant impact on the receipt of timely immunizations.

Multiple injections are also of concern to both parents and immunization providers. A 1994 survey of 32 family clinics in Minnesota found 71% of parents, 17% of nurses, and 59% of physicians believed three injections at one visit were too many. In addition, 56% of parents (n=342) would prefer to make two visits if three injections were required [75]. Health care providers may, as a result, schedule the child for additional visits in an effort to reduce the number of injections per visit.

Other perceived and real barriers to immunization identified in the literature include: lack of parental knowledge about vaccines and diseases (i.e. efficacy, side effects, scheduling), difficulty getting time off work for appointments, inconvenient office hours, long wait times, instability of the family situation, as well as problems keeping appointments and finding adequate child care for other children [55-59, 62, 63].

2.10 Validity and Reliability of Electronic Immunization Databases

Assessing the validity and reliability of the SIMS database is of critical importance to this research project to ensure accuracy in the coverage rate calculations. The SIMS data obtained by PHS has not been used for research purposes prior to this project. Therefore, an exploration of literature related to this issue is beneficial.

Researchers conducted a review of the Manitoba Immunization Management System (MIMS) in 1994. The system appears to be similar to the SIMS system used in Saskatchewan based on the description provided in the article. Comparisons between physician records and the data management system showed excellent agreement (98%) for correct service dates and immunization codes. Missing data were attributed to failure to bill (43%), miscoding (27%), migration (20%), or no immunization (10%). Overall, the quality of the electronic data was considered high [76].

Researchers in Britain also attempted to validate immunization rates by conducting a record review of their own computerized immunization system for children born between 1998 and 1999. Following data correction, MMR immunization rates were found to be 2.1% higher than previously reported (92.6% versus 90.5%) due to immunizations that were not entered into the system [77].

Another study, conducted by the Boston Department of Health and Hospitals, found the quality of data within their own immunization registry of poor quality [78]. The study examined errors in their immunization system in an effort to correct immunization rates. Computer records were compared to chart records in two separate reviews. In the first review incorrect dates and missing immunization data were examined with 59% of the records containing at least one error. Following the intervention, which included more consistent data entry practices, the error rate decreased to 18% ($P < .0001$). Types of errors identified in the second review included: 38% of shots occurring in the charts but not in the system; 34%

having inconsistent dates of immunization; and 12% having more than one error. The authors found errors in the data entry process caused an underestimate of immunization rates. These errors were effectively dealt with by improving data entry methods through training and system modifications.

3. METHODOLOGY

3.1 Study Design

This study utilized an ecological design. Phase I of the study consisted of simple rate calculations to determine the total, complete, up-to-date and not up-to-date immunization rates for the city of Saskatoon and each residential neighbourhood (see pages 33-34 for definitions and calculations). Neighbourhoods comprised the unit of analysis for Phase II of the project which centred on using quantitative neighbourhood level data to determine if the neighbourhood variables of interest could significantly contribute to explaining the variation in up-to-date immunization coverage in Saskatoon.

3.2 Sample Size

The population under investigation consisted of all two year-olds living in the city of Saskatoon between the years of 1999 and 2002 and covered by the Saskatchewan Health Plan. According to the data, provided by the Saskatchewan Health Covered Population Report, there were 10,827 two-year-olds living in the Saskatoon Health Region during this time. However, 540 records (4.9%) were not able to be linked with a residential neighbourhood in Saskatoon due to an incorrect postal code, retired postal code, post office box, address outside of the city (Martensville, Warman, Dalmeny, rural routes, etc.), or were industrial Saskatoon neighbourhoods. These cases were subsequently deleted resulting in a total sample size of 10,287 (refer to Table 3.2 for sample size by year).

3.3 Data Sources

The SIMS data, used to find the numerator for the coverage rate calculations, were given to Saskatoon Public Health Services by Saskatchewan Health. The dataset was shared with the student following the signing of two memoranda of agreement. The memoranda outlined measures of confidentiality and ensured results were shared openly with PHS throughout the project (see Appendix 1 and 2). The SIMS dataset contained all MMR/MR immunization records for each child who received the vaccine from January 1996 to the end of 2002 in the Saskatoon Health Region.

Data were also obtained through the Saskatchewan Health Covered Population Report. The Saskatchewan Health Covered Population Report counts the number of people in Saskatchewan with health care coverage on June 30th of each year and was used for the denominator as it is considered the best source of annual population data available [79]. For the purposes of this study, the number of two year-olds on June 30th for the years of 1999, 2000, 2001, and 2002 were provided by postal code. The data were then re-worked to determine the total number of two year-olds for each neighbourhood by year and used as the denominator for the rate calculations.

The third data source for this project was the Saskatchewan Health Information and Strategic Planning System (SHIPS) which provides data for research purposes within the Saskatoon Health Region. The SHIPS data was obtained from the 2001 Census and Saskatchewan Health Vital Statistics. The City of Saskatoon also provided the number of vehicles registered as well as the total population counts for 2002 to determine the vehicle to population ratio for each residential neighbourhood under study. All data received from SHIPS and the City of Saskatoon were aggregated by neighbourhood. Please refer to Appendix 3 for a complete list of neighbourhood variables, measures, and sources.

3.4 Ethics and Measures of Confidentiality

The ethics application was submitted to the University of Saskatchewan Behavioural Research Ethics Board on September 8, 2003 and was approved October 9, 2003 (Appendix 4). Measures to ensure confidentiality of the SIMS data were also taken by PHS and are stated clearly in the two memoranda of understanding (Appendix 1 and 2). All data provided by SHIPS and the City of Saskatoon were aggregated by neighbourhood or residence code geographies and were therefore unable to be linked with any individual or group. Neighbourhoods with less than ten children were also combined with similar neighbourhoods in an additional effort to protect confidentiality.

3.5 Analytic Strategy

3.5.1 Data Cleaning

Initial concerns over the quality of the SIMS data, specifically missing postal codes, were dealt with through data cleaning. Thirteen hundred and twenty-five addresses with incorrect or missing postal codes were given to the student. The phone book and Canada Post website were both used to fill in the missing or incorrect postal codes. Once the information was entered, the data were then sent back to PHS to be added to the dataset. Of the 9,447 addresses in the final SIMS dataset, 96.6% were able to be assigned to their respective neighbourhoods following this procedure.

Children under investigation that were unable to be linked to a Saskatoon neighbourhood (incorrect address, post-office box, rural route, etc) or were assigned to non-residential neighbourhoods in Saskatoon were excluded in both the SIMS dataset and the Covered Population dataset. Tables 3.1 and 3.2 report the number of excluded cases for each dataset.

Table 3.1 Excluded Cases in SIMS Dataset

Birth Year	Cases in Original Data	Incorrect Addresses	Non-residential Addresses	Total
1996-1997	2 572	83	25	2 464
1997-1998	2 357	85	17	2 255
1998-1999	2 235	79	17	2 139
1999-2000	2 283	75	20	2 188
Total	9 447	322	79	9 046

Table 3.2 Excluded Cases in Covered Population Report Dataset

Count Year	Cases in Original Data	Incorrect Addresses	Non-residential Addresses	Total
1999	2 988	86	78	2 824
2000	2 632	96	61	2 475
2001	2 590	56	64	2 470
2002	2 617	44	55	2 518
Total	10 827	282	258	10 287

Neighbourhood data provided by SHIPS and the City of Saskatoon required no cleaning.

3.5.2 Phase I: Coverage Rates

Neighbourhood coverage rates were calculated using SIMS data for the numerator and the Saskatchewan Health Covered Population Report data for the denominator. Four birth cohorts were created for the analysis and are as follows:

- Children born between July 1, 1996 and June 30th 1997 (count year = 1999)
- Children born between July 1, 1997 and June 30th 1998 (count year = 2000)
- Children born between July 1, 1998 and June 30th 1999 (count year = 2001)
- Children born between July 1, 1999 and June 30th 2000 (count year = 2002)

Cohorts were created in this manner to ensure all children in the group were classified as at least two but no more than three years of age on June 30th of the cohort's count year. For example, all children in the first cohort (July 1, 1996 - June 30th, 1997) ranged in age from exactly two years to two years 364 days on June 30th, 1999 (count year). Therefore, all children in both the numerator and denominator were two years-old when the coverage rates were calculated. This gave each child at least a six month "grace period" between the age of 18 and 24 months in which to receive their second vaccine and still be considered "up-to-date".

Coverage rates were determined by calculating the number of days between the child's birthday and the day they received their MMR/MR vaccination. Using SPSS 11.0, the immunization date was subtracted from the birth date creating a new variable called "Age@imm". The "Age@imm" variable was then recoded into a dichotomous variable as outlined by the Memorandum of Understanding (see Appendix 2). Children considered up-to-date received the label "0" while children who were delayed received the label "1". Children found to be incomplete were later labelled "2" for further analysis. Children who had never received an MMR/MR immunization would not be included in SIMS and would, therefore, not be included in the numerator.

The following outlines the definitions used for the coverage rates in this study.

Table 3.3 Coverage Rate Definitions

Coverage Term	Definition
Total	% of children who have received at least one dose of the MMR/MR vaccine at any age.
Complete	% of children who have received two doses at any age.
Up-to-Date	% of children who received two doses before 730 days (2 years of age).
Incomplete	% of children who received only one dose at any age.
Delayed	% of children who received two doses with one or more doses after 731 days (2 years plus a day).
Not Up-to-Date	% of children who were incomplete or delayed in the receipt of their MMR/MR vaccine.

Coverage rates were calculated as follows:

$$\text{Total Immunization Coverage Rate} = \frac{\text{Number of two year-olds who received at least 1 MMR/MR immunization at any age}}{\text{Total number of covered two year-olds}} \times 100$$

$$\text{Complete Immunization Coverage Rate} = \frac{\text{Number of 2 year-olds who received two MMR/MR immunizations at any age}}{\text{Total number of covered two year-olds}} \times 100$$

$$\text{Up-to-Date Coverage Rate} = \frac{\text{Number of two year-olds who received two immunizations prior to second birthday}}{\text{Total number of covered two year-olds}} \times 100$$

$$\text{Not Up-to-Date Coverage Rate} = \frac{\text{Number of two year-olds incomplete or delayed in receiving immunization}}{\text{Total number of covered two year-olds}} \times 100$$

3.5.3 Phase II: Neighbourhood Analysis

The second phase of the study utilized the averaged up-to-date coverage rates over the period of 1999 to 2002 (derived from Phase I) to explore the relationship between immunization rates and neighbourhood variables in Saskatoon. Non-residential or industrial neighbourhoods were deleted in this phase and residential neighbourhoods with less than ten children were combined with other neighbourhoods in the city to protect confidentiality. Neighbourhoods were combined on the advice of Dr. Nazeem Muhajarine who has extensive experience and knowledge regarding neighbourhood analysis for health research in Saskatoon. Most neighbourhoods were grouped with adjacent neighbourhoods. However, the three suburban centers (SC) - Nutana SC, Lawson Heights SC, and Confederation SC were grouped together despite their distance from each other. The suburban centers have distinct and similar social profiles conducive to combination for neighbourhood analysis. In all, 49 neighbourhoods were used for the final analysis out of the original 56 (see Appendix 5).

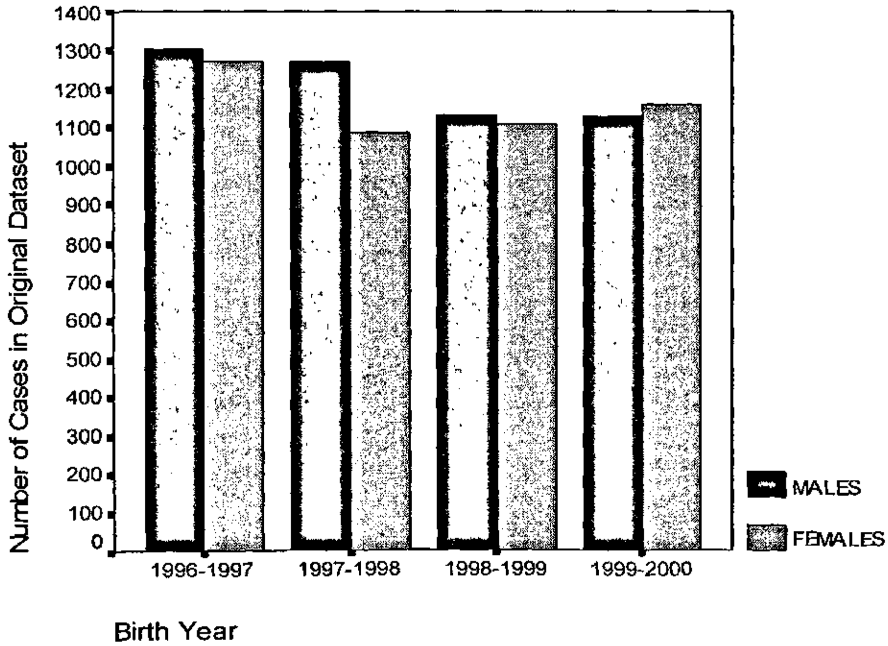
Neighbourhood variables selected for analysis were chosen based on the literature review. Data for each of the 49 residential neighbourhoods were entered into SPSS resulting in a profile for each neighbourhood with the averaged up-to-date rates as the dependant variable and all others (median income, teenage birth rate, vehicle registration, etc.) as independent variables. Once the final dataset was created, the process of data analysis could proceed.

4. RESULTS

4.1 Characteristics of Study Subjects

Limited personal information about the children in the SIMS dataset was available. As a result, the only individual information that could be analyzed was the number of children who received the immunization by gender. The following table shows the number male and female cases by birth cohort for the children who received at least one MMR/MR immunization (n = 9,447). The results reveal a relatively even number of male and female children born between July 1st, 1996 and June 30th, 2000 received at least one MMR/MR vaccine in Saskatoon.

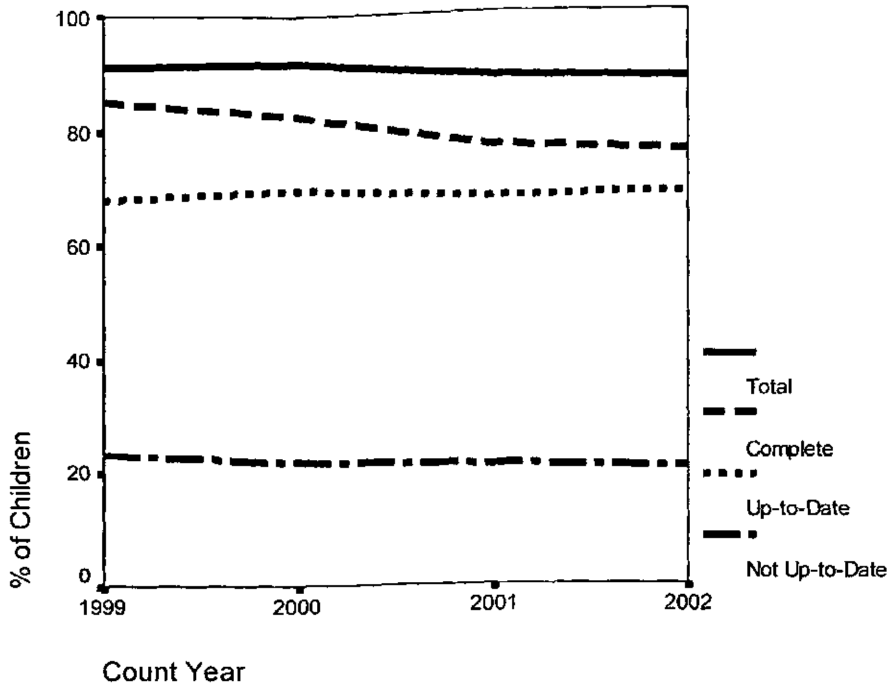
Figure 4.1 Number of Male and Female Children by Birth Cohort Who Received at Least One MMR/MR at Any Age



4.2 Saskatoon Immunization Trends

Immunization trends over time for the city of Saskatoon were examined for the period of 1999 to 2002. The results of the analysis are presented in Figure 4.2. (see Appendix 7 for data by year).

Figure 4.2 Saskatoon Immunization Trends (1999-2002).



From the above graph, total immunization rates appear to have a slight downward trend in Saskatoon. Although this decrease is very small, it could signify a slight decrease in the number of parents choosing to have their children immunized. A more notable decline can be seen in the complete immunization coverage rates. However, the decline in complete coverage is likely related to the quality of the SIMS data used for this study. Because the SIMS dataset only contained data up until the end of 2002, children in the later cohorts did not have the same amount of time in which to receive a second immunization and change their status from incomplete to delayed. Due to the fact that the complete coverage rates are cohort dependent, the complete coverage trend must be interpreted with extreme caution.

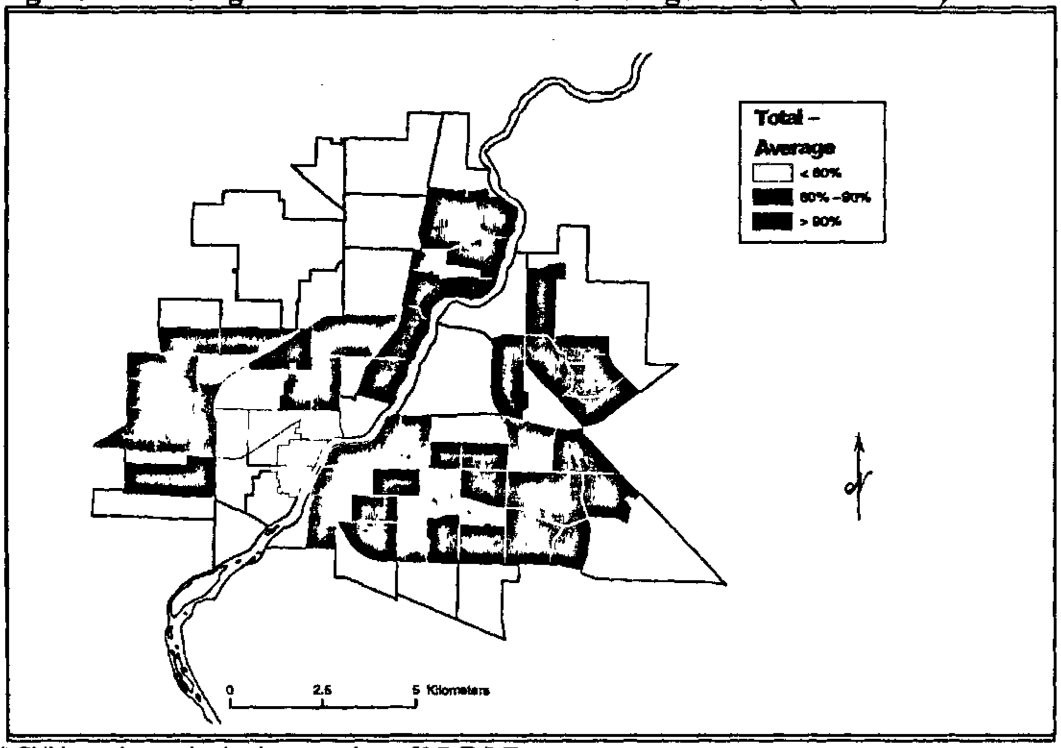
Out of the children that did receive an immunization, however, the percentage of children who received two doses before the age of two years has been relatively stable over the four year period analyzed with coverage ranging from 67.7% to 69.8%. On the other hand, not up-to-date immunization rates have been decreasing over time from 23.38% to 20.21%. The relative stability of up-to-date immunization coverage and decrease in not up-to-date coverage is a positive sign. However, a more pronounced rise in up-to-date and total immunization rates would be more encouraging.

4.3 MMR Coverage Rates by Neighbourhood

Yearly coverage rates were calculated for each residential neighbourhood between 1999 and 2002. To illustrate the results in a more visually interpretable format, maps of Saskatoon were created using ArcGIS 3.3. Neighbourhood groupings were chosen based on clinical indicators from the literature and discussions with Dr Ben Tan, infectious disease specialist in the SHR. Standardized immunization goals are unclear in the literature. Coverage goals in Canada are generally set around 95%-97% (one dose before the age of two-years). However, due to the ecological nature of this study and average rates utilized for the maps, rates greater than 90% were utilized in this study to ensure criteria was not excessively stringent. Rates less than 70% for up-to-date and complete coverage and 80% for total coverage were used for the lower grouping as these values are considered to be very poor from a clinical viewpoint (Tan B. 2004, oral communication, March 25).

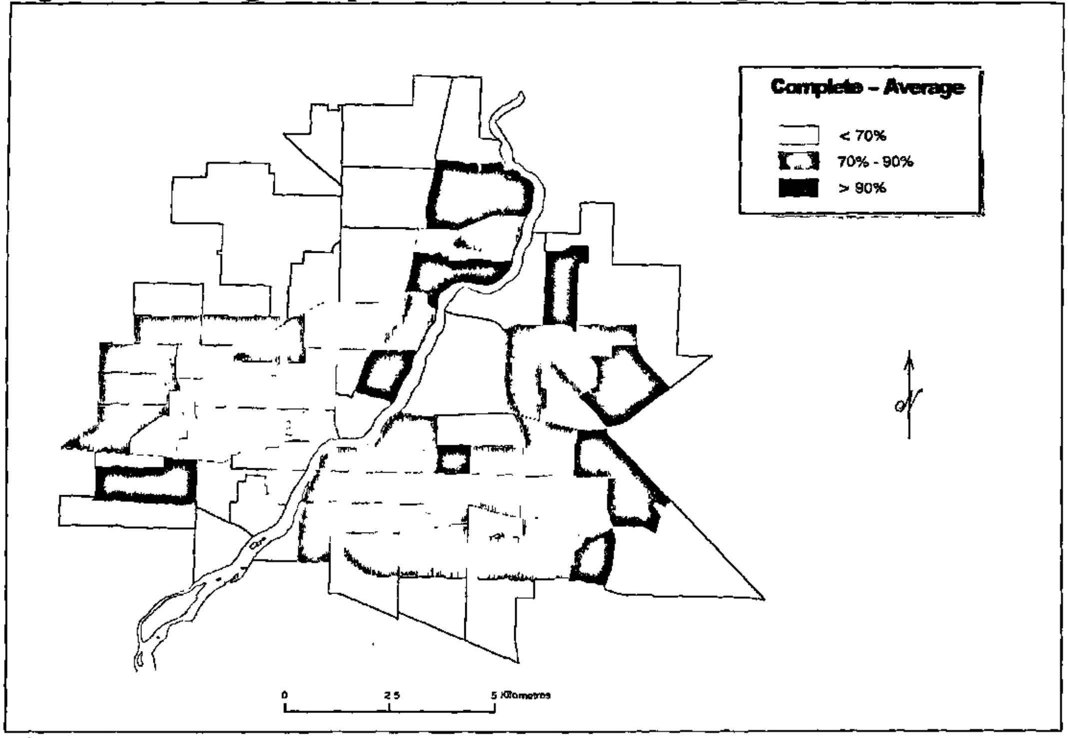
The following three maps provide the total, complete, and up-to-date coverage rates for the city of Saskatoon (Figures 4.3, 4.4, and 4.5). The coverage rates are averaged over the years of 1999 to 2002 in an attempt to reduce the impact of significant year to year variability. Areas with no data represent non-residential or industrial neighbourhoods (refer to Appendix 6 for map data).

Figure 4.3 Average Total* Immunization Coverage Rates (1999-2002)



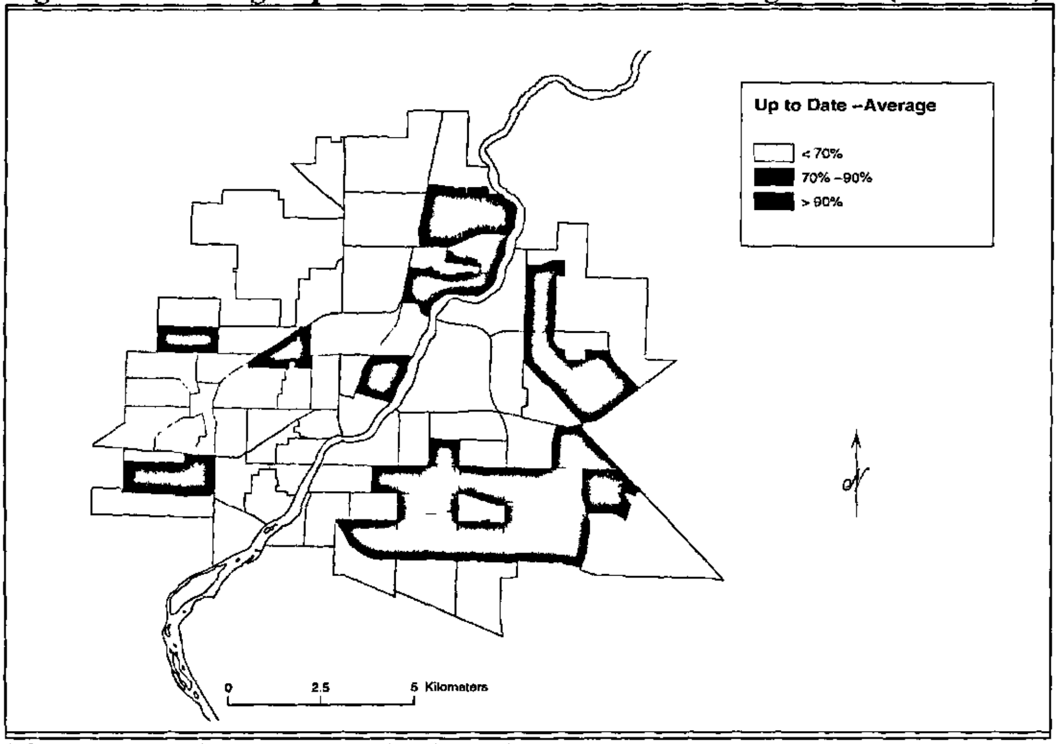
* Children who received at least one dose of MMR/MR at any age

Figure 4.4 Average Complete* Immunization Coverage Rates (1999-2002)



* Children who received two doses of MR/MMR at any age

Figure 4.5 Average Up-to-Date* Immunization Coverage Rates (1999-2002)



* Children who received two doses of MMR/MR before the age of two years

The maps highlight important differences in the uptake of the MMR vaccine in the city of Saskatoon. West-side/core neighbourhoods such as Pleasant Hill, Riversdale, King George, etc. appear to have much lower total and complete immunization rates compared to other neighbourhoods in the city. It is also evident that as the immunization uptake criterion for the study becomes increasingly stringent, more neighbourhoods are unable to meet the selected standards. All but three neighbourhoods in Saskatoon failed to achieve up-to-date immunization rates greater than 90%. The clinical implications of these findings as well as the social and contextual factors that may be contributing to the neighbourhood disparities will be discussed further in Section 5.

4.4 Neighbourhood Immunization Trends

It was also important, for the purposes of this study, to assess any increases or decreases in coverage rates over time for each residential neighbourhood. However, significant year to year coverage rate variability made this a difficult task. To compensate for this problem, Saskatoon neighbourhoods were divided into three equal groups based on total immunization rates – high uptake, middle uptake, and low uptake. The high-uptake group consisted of 16 neighbourhoods with total immunization rates >95.0%, the middle-uptake group had 17 neighbourhoods with rates of 86.46%-95.0%, and the low-uptake group was made up of 16 neighbourhoods with rates ranging between 64.5%-86.45%. The results are reported in Figures 4.6, 4.7, and 4.8 (see Appendix 7 for data by year).

Figure 4.6 Immunization Trends in High-Uptake Neighbourhoods (1999-2002)

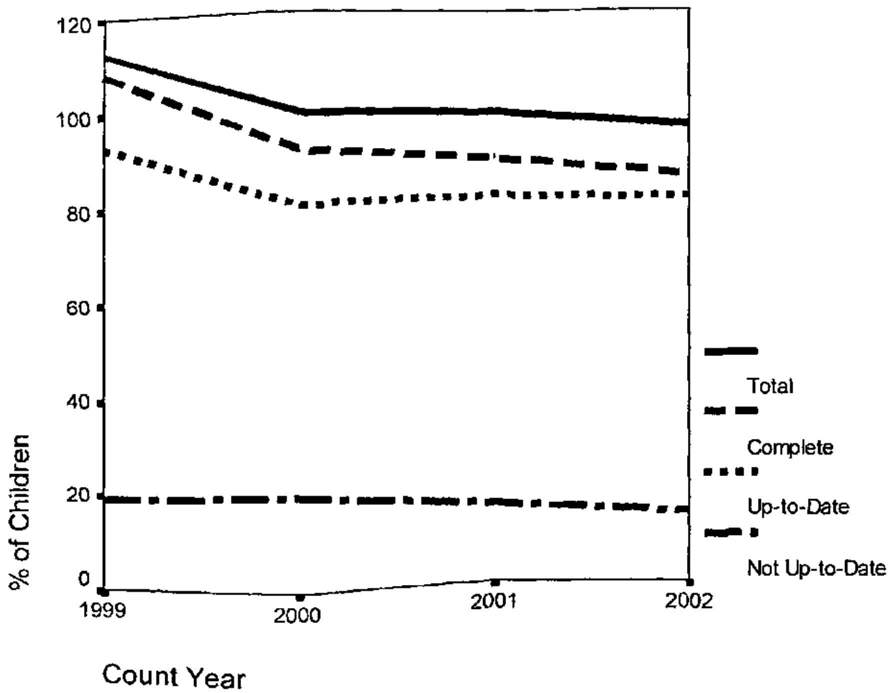


Figure 4.7 Immunization Trends in Middle-Uptake Neighbourhoods (1999-2002)

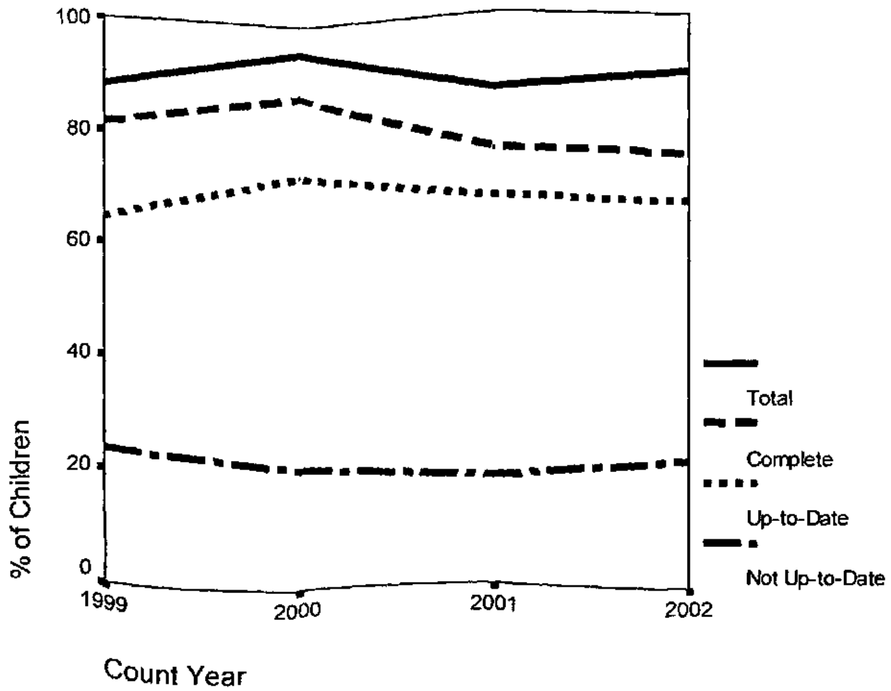
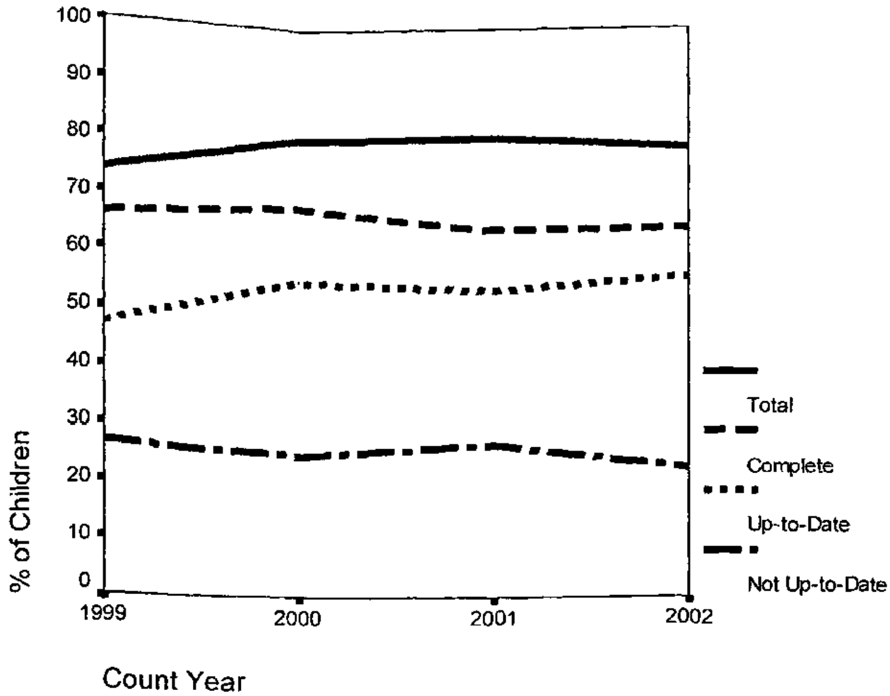


Figure 4.8 Immunization Trends in Low-Uptake Neighbourhoods (1999-2002)



First, it is important to address the data anomalies present in the neighbourhood analysis results. As can be seen in the high uptake group (Figure 4.6), total and complete immunization rates in the high-uptake neighbourhood group reached rates greater than 100% in 1999. This anomaly is a result of two issues with the data used for this project. First, Public Health continuously updates addresses into the SIMS database with each child's visit while Saskatchewan Health only updates addresses every three years unless otherwise notified by the individual or family. Therefore, if parents visit PHS following a move but do not alert Saskatchewan Health there is a strong possibility the child will be counted in the numerator but excluded in the denominator of the new neighbourhood resulting in an overestimation of the coverage rate. Children in the earliest cohort (1999) have more time to move following their respective population count resulting in a greater risk for coverage rate overestimation.

Second, newer neighbourhoods also run the risk of overestimation as there is more housing development taking place. Many of the neighbourhoods in the high-uptake group are newer. Therefore, more children are moving into these areas after the cohort's count year which, again, may result in overestimation. Combine these two factors with neighbourhoods that already achieve high total and complete coverage rates and the resulting effect is coverage rates greater than 100%.

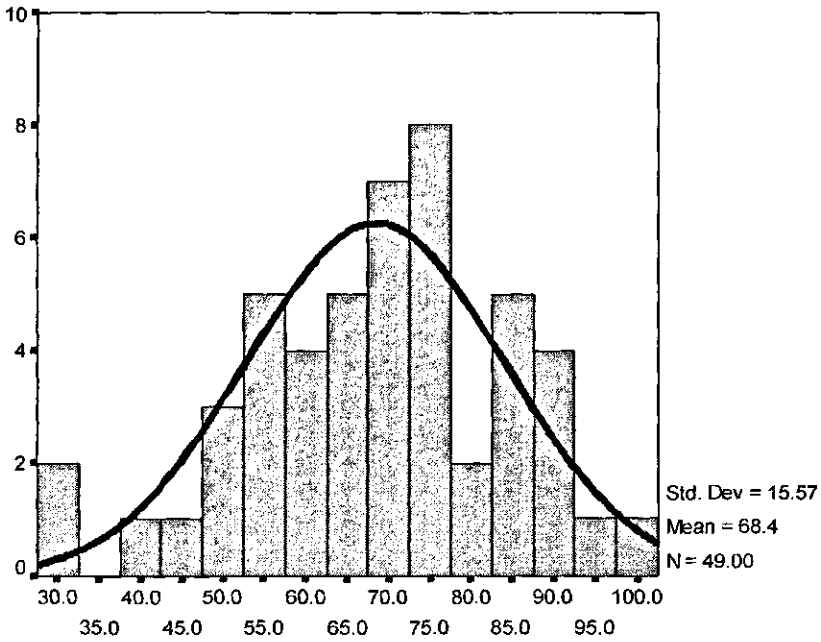
Finally, similar to the city of Saskatoon trends, complete immunization trends appear to be decreasing over time in all three neighbourhood groups. This is, once again, likely related to the shorter amount of time later birth cohorts had to change their status from incomplete to delayed with receipt of the second immunization. These complete immunization trends must therefore be interpreted with extreme caution.

Although the data limitations and anomalies pose a problem in the accurate interpretation of the trends over time, there does appear to some interesting trends in neighbourhood immunization coverage that should be noted. In the high-uptake group, total and not up-to-date immunization rates appear to be decreasing while up-to-date immunization rates have remained stable since 2000. This may indicate that for children who are being immunized more are receiving the vaccine on time. However, the decrease in total coverage may suggest a decline in the number of children who are receiving any vaccine at all. On the other hand, low-uptake neighbourhoods seem to be trending upward in both up-to-date and total immunizations uptake. This may be an encouraging sign as both total and up-to-date vaccine coverage appears to be improving in low uptake areas of the city. Middle uptake groups are relatively stable in all categories with no identifiable upward or downward trends other than complete rates due to the data issues discussed previously. Refer to Section 5.1 for further discussion.

4.5 Univariate Analysis of Variables

Univariate analysis was conducted on each variable in the final data set to assess the measures of central tendency (mean, median, mode) and the dispersion (range, variance, standard deviation, skewness and kurtosis) of each variable under investigation. Out of range values, plausible means, and standard deviations were all assessed and outliers identified during this process were corrected or confirmed. All variables were found to be relatively normally distributed including the average up-to-date immunization rates for the city of Saskatoon used as the dependent variable in the bivariate and multivariate analysis (Figure 4.9).

Figure 4.9 Distribution of Average Up-to-Date Immunization Rates (1999-2002).



4.6 Bivariate Analysis

The first step in the bivariate analysis of immunization rates and neighbourhood variables was to plot the relationship between the average up-to-date immunization rates and neighbourhood variables of interest using a scatterplot. The scatterplots revealed linear relationships between the average up-to-date immunization rates and almost all neighbourhood variables of interest. Scatterplots displaying significant relationships between neighbourhood variables and the average up-to-date immunization rates are presented in Figures 4.10 through 4.18.

Figure 4.10 Teenage Birth Rates per 1000 versus UTD Immunization Uptake

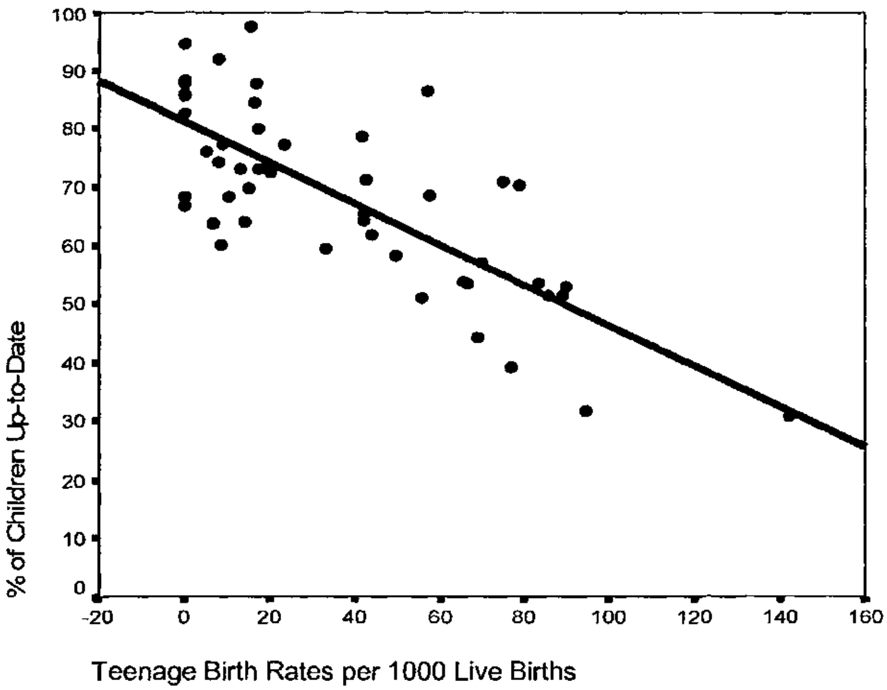


Figure 4.11 Proportion of Movers within Last Year versus UTD Immunization Uptake

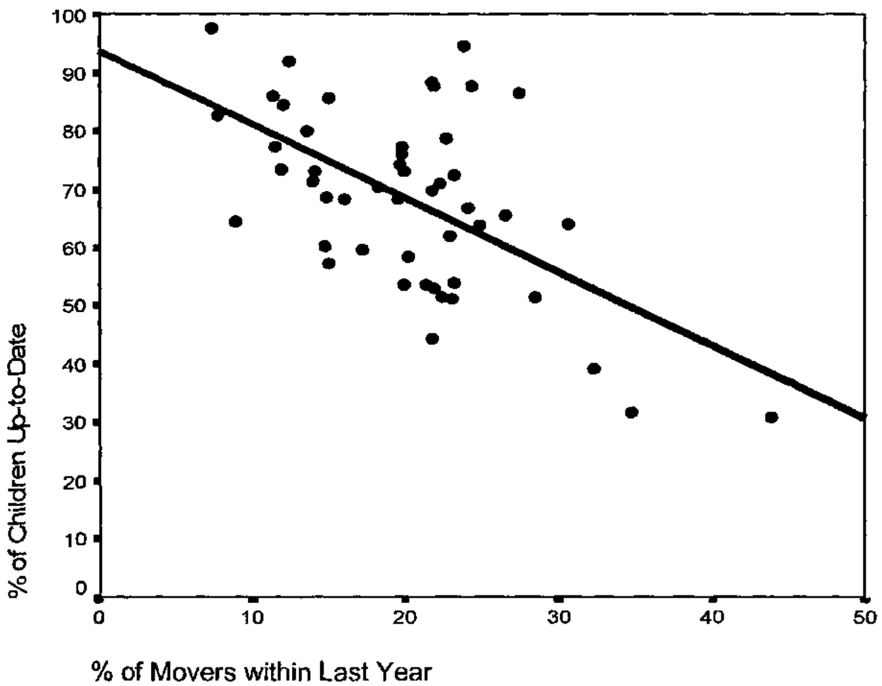


Figure 4.12 Median Family Income versus UTD Immunization Uptake

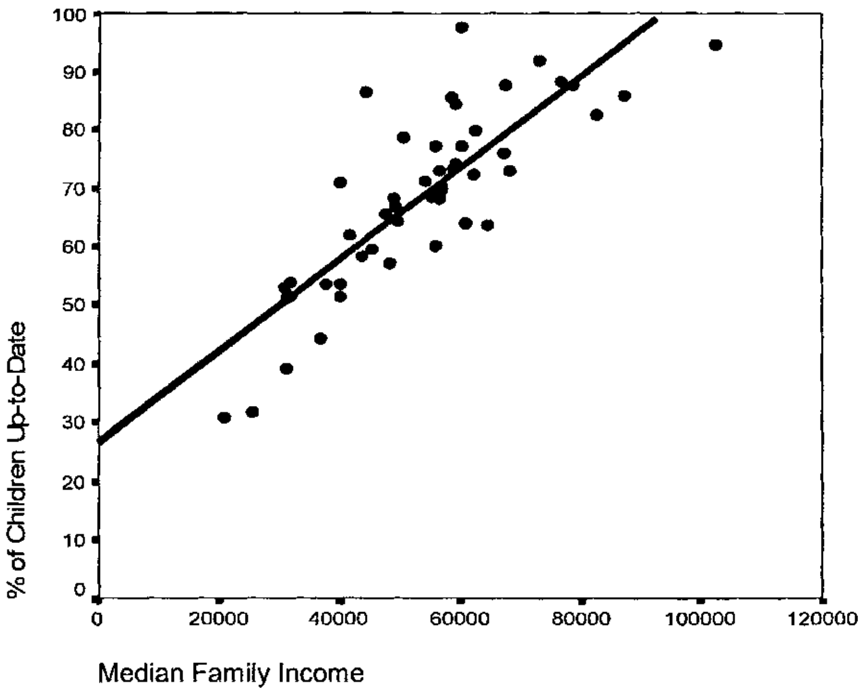


Figure 4.13 Proportion of Families Below Poverty Line versus UTD Immunization Uptake

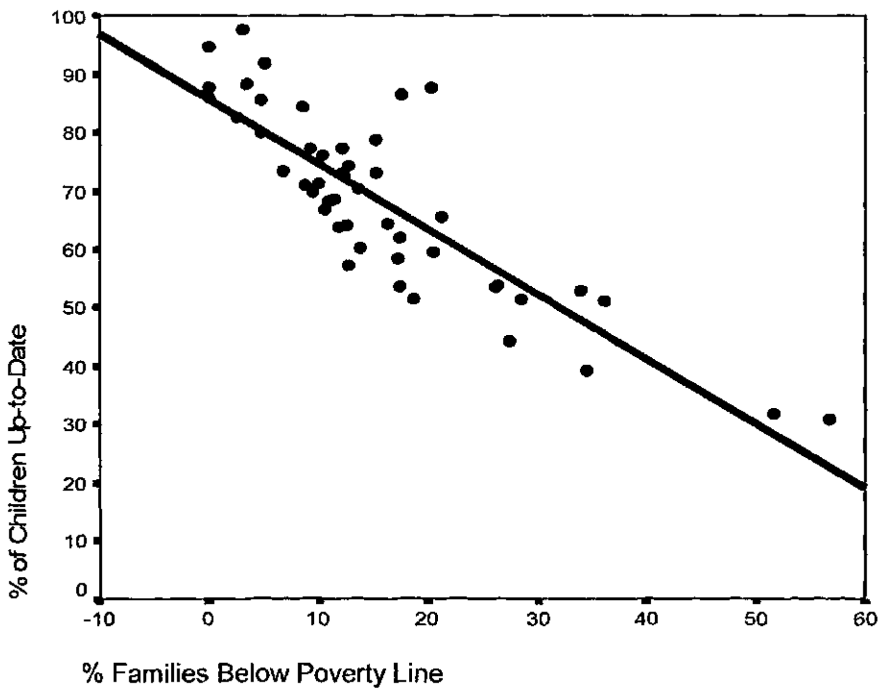


Figure 4.14 Proportion of Persons with Less than Grade 9 Education versus UTD Immunization Uptake

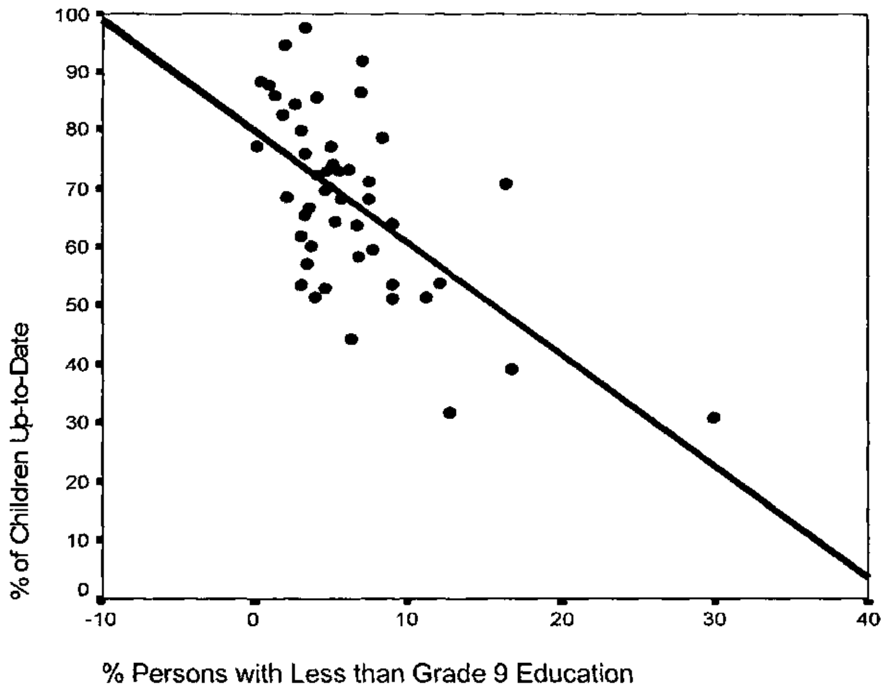


Figure 4.15 Proportion of Families with Income <$10 000 versus UTD Immunization Uptake

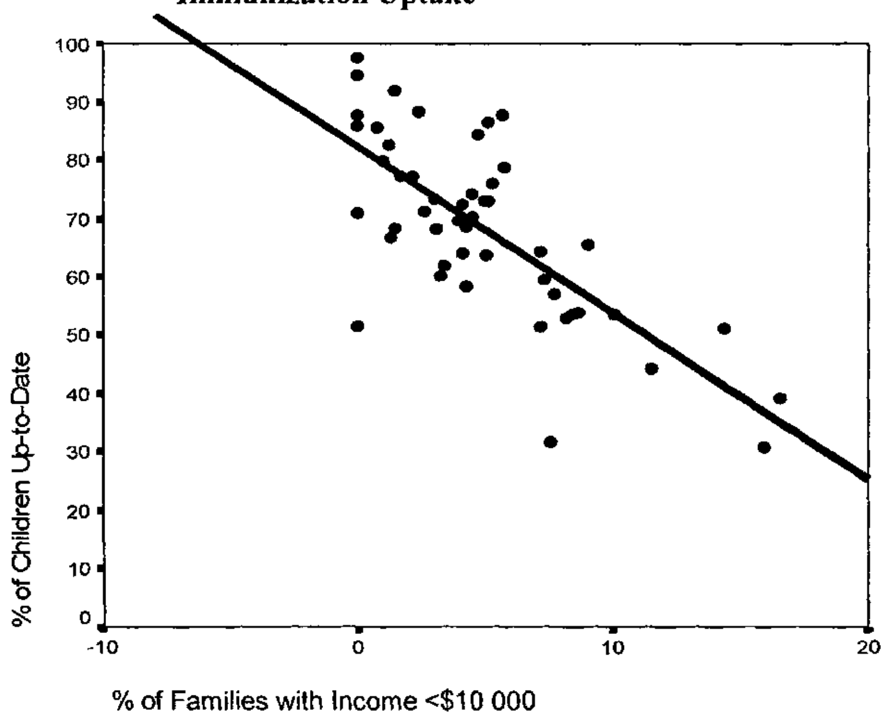


Figure 4.16 Proportion of Vehicles Registered versus UTD Immunization Uptake

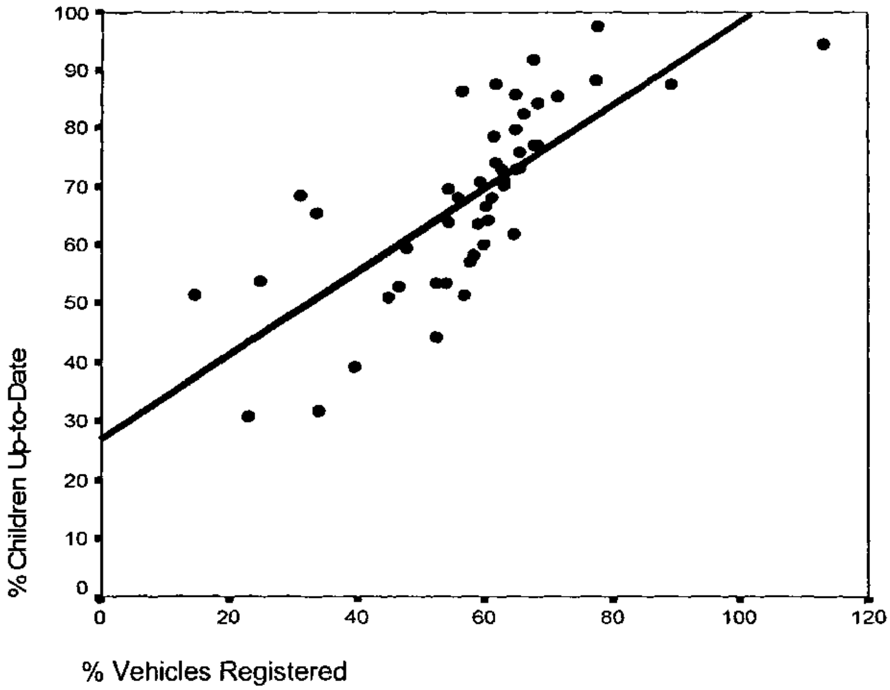


Figure 4.17 Proportion of Female-headed Lone Parent Families versus UTD Immunization Uptake

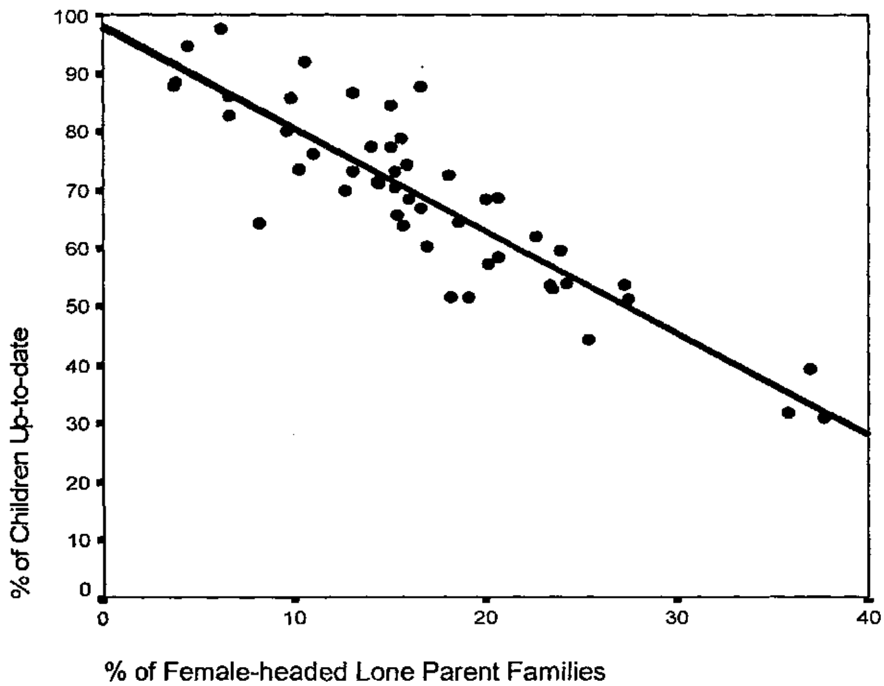
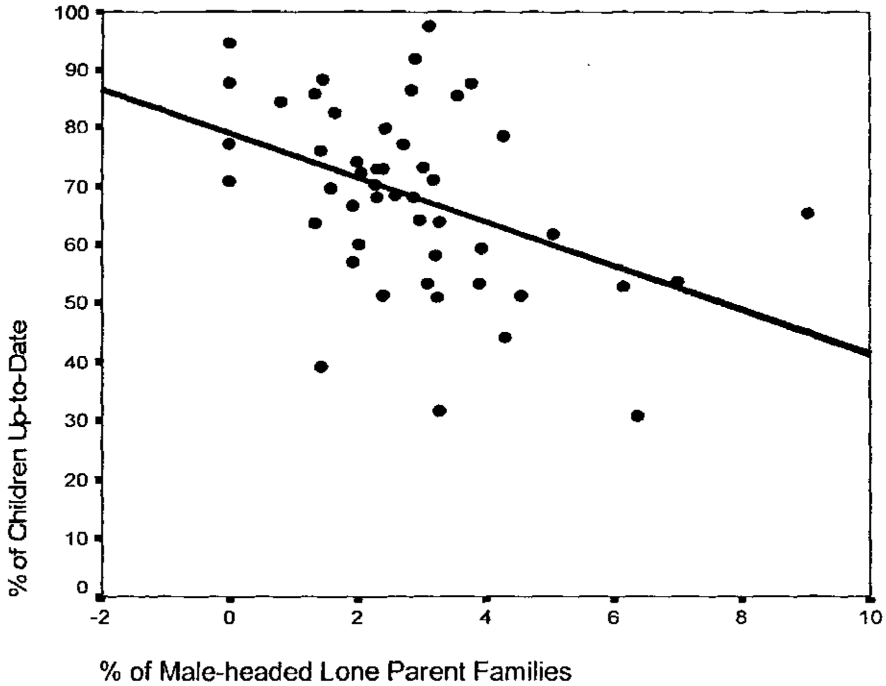


Figure 4.18 Proportion of Male-headed Lone Parent Families versus UTD Immunization Uptake



Examination of the scatterplots clearly indicates linear regression is the appropriate model for multivariate analysis. Bivariate casewise diagnostics revealed no cases more than three standard deviations away from the best fit line on any of the scatterplots. Assumptions of homoscedasticity, linearity, and normality were all considered to have been met for all associations under examination.

Further bivariate analysis continued in order to select significant neighbourhood variables for multivariate analysis. The results of the bivariate regression analysis are reported in Table 4.19.

Table 4.19 Bivariate Linear Regression Results

Variable	Adj. R^2	ß (Beta)	SE (ß)	t-value	p-value	95% CI for ß Lower	Upper
1-Year Mobility	.314	-1.263	.263	-4.794	**<.001**	-1.793	-.733
Low Birth Weight	.005	-5.175E-02	.047	-1.113	.271	-.145	.042
Median Income	.682	7.832E-04	.000	10.196	**<.001**	.0006	.0009
Families Below Line of Poverty	.717	-1.113	.101	-11.076	**<.001**	-1.315	-.911
Teenage Birth Rate	.570	-.348	.043	-8.033	**<.001**	-.435	-.261
Average Children	-.017	-3.662	8.707	-.421	.676	-21.17	13.85
Education < Grade 9	.375	-1.907	.349	-5.462	**<.001**	-2.609	-1.204
Income < $10,000	.531	-2.852	.383	-7.438	**<.001**	-3.623	-2.081
Visible Minorities	-.013	.373	.609	0.612	.543	-.852	1.597
Vehicle Registration	.552	.714	.092	7.748	**<.001**	.528	.899
Male LPF	.164	-3.750	1.161	-3.230	**.002**	-6.086	-1.415
Female LPF	.782	-1.756	.134	-13.151	**<.001**	-2.025	-1.487

The results reveal large Adjusted R^2 values demonstrating a high proportion of variation in up-to-date immunization uptake could be explained by several of the neighbourhood variables under investigation. Six variables had the ability to predict over 50% of the variation in up-to-date immunization coverage in Saskatoon. The analysis also revealed nine highly significant neighbourhood variables with p-values less than 0.01.

4.7 Multivariate Linear Regression Analysis

Based on the literature review, theoretical plausibility, and the bivariate linear regression analysis, nine variables were selected for multivariate analysis: median family income, 1-year mobility, families below the line of poverty, teenage birth rates, education less than grade 9, income less than $10,000, vehicle registration, male-headed lone parent families, and female-headed lone parent families. Sample size was another important consideration in the selection of independent variables as Kleinbaum, Kupper & Muller [80] state the number of cases in the study should be at least five to ten times greater than the number of variables entered into the model. Selecting nine variables meets these requirements as there is at least five times the number of neighbourhoods than variables entered for multivariate analysis.

Using SPSS 11.0, a forward variable selection process was chosen for the multivariate analysis. The forward selection criterion is based on the probability-of-F-to-enter. The inclusion criterion was set at = 0.05 while removal criterion was set at =0.10 which is the standard criteria in the SPSS program. The 'Proportion of Female-headed Lone Parent Families' variable was the first entered into the model since it best met the forward selection criteria and as a result achieved the highest level of significance ($p < 0.001$). With the Female-headed LPF variable entered, the significance of the remaining independent variables was examined. The 'Proportion of Vehicles Registered' variable entered the model next with a p-value of 0.011. Following this step there were no other variables that met the inclusion criteria and the selection procedure was complete. In other words, once the 'Female-headed LPF' and 'Vehicles Registered' variables were in none of the other seven variables could significantly contribute to the final model and were therefore not included. Table 4.20 reports the coefficients of the final model.

Table 4.20 Significant Variables in the Final Model

Final Model Variables	ß (Beta)	S.E (ß)	p-value	t-value	95% CI for ß Lower	Upper
Constant	79.152	7.524	<.000	10.520	64.007	94.298
Female-headed LPF	-1.420	.179	<.000	-.717	-1.780	-1.059
Vehicle Registration	.227	.086	.011	.239	0.054	0.401

Adjusted $R^2 = 0.806$

According to the final results of the analysis, 80.6% of the overall variation in up-to-date immunization uptake in Saskatoon neighbourhoods can be explained by the following model:

$$\text{UTD Immunization Uptake} = b_0 + b_1\text{female-headed LPF} + b_2\text{vehicle registration}$$

$$\text{UTD Immunization Uptake} = 79.152 - 1.420(\text{female LPF}) + .227\ (\text{vehicle registration})$$

5. DISCUSSION

5.1 Immunization Trends in Saskatoon

Overall, immunization trends in Saskatoon have been shown to be relatively stable over the years of 1999 to 2002 with total immunization rates (% of children with at least one MMR/MR immunization at any age) hovering around 90%. A very slight decrease in total immunization rates in Saskatoon may indicate more families are choosing not to immunize at all. However, more monitoring and evaluation at the individual level is required to test this hypothesis. The complete immunization rate (% of children with two MMR/MR immunizations at any age) was at 85% in 1999 with a slight downward trend over the following three years. The downward trend for complete coverage rates over time is most likely related to the shorter amount of time later birth cohorts had to enter the data base or receive a second immunization to achieve complete status.

Up-to-date and not up-to-date immunization rates also remained relatively constant over the time period analyzed. Of the approximately 90% of children who received the MMR/MR vaccination in Saskatoon between 1999 and 2002 about 70% of those received two doses before the age of two years effectively meeting the immunization schedule guidelines in Saskatchewan. On the other hand, around 20% of children in Saskatoon were either incomplete or delayed in the receipt of at least one MMR/MR immunization. It is important to note that a decline in not up-to-date immunization rates suggests that, over time, fewer children were incomplete or delayed in their receipt of the MMR/MR vaccine in Saskatoon which is a positive finding. However, it is difficult to examine delayed and incomplete rates separately due to the data limitations with the cohorts used (i.e. as incomplete rates increase over time delayed rates decrease). More research at the individual level into the differences between these two groups may provide additional insight into parents who choose not to obtain the second vaccination as compared to those who are delayed in receiving one or more doses.

Despite the relative stability of immunization trends and moderately good up-to-date immunization rates in Saskatoon overall, there is clear evidence that disparities in immunization uptake exist at the neighbourhood level. The maps highlight these inequalities very effectively showing a number of neighbourhoods in Saskatoon did not achieve adequate total or complete MMR immunization coverage. In addition, many neighbourhoods are shown to have low average up-to-date coverage rates with only three neighbourhoods achieving average up-to-date immunization rates above 90%.

Perhaps the most important findings are related to the core neighbourhoods of Saskatoon (Pleasant Hill, Riversdale, Caswell Hill, King George, and Westmount) which have an average total immunization rate of 75%, average complete rate around 60%, and an average up-to-date coverage rate of approximately 45%. Pleasant Hill faired worst out of all neighbourhoods with average total, complete, and up-to-date immunization rates of 64%, 50% and 30%

respectively. Other west-side neighbourhoods such as Massey Place, Holiday Park, and Meadowgreen also had average total, complete, and up-to-date immunization rates far below acceptable.

These findings are important as the same west-side/core neighbourhoods also have higher levels of poverty and face a greater number of social issues including lower levels of education, higher teenage birth rates, greater mobility, and more lone-parent families according to the neighbourhood data received for this study. On the other hand, neighbourhoods with higher levels of social and economic wealth, situated primarily on the far east-side of Saskatoon, have higher coverage rates on average. It is obvious the social and economic disadvantages within the core and other west-side neighbourhoods play a role in immunization uptake. This finding is supported extensively by the literature.

Limitations with the dataset make interpreting neighbourhood trends over time challenging. However, small changes in immunization trends over the period observed may indicate changes in immunization behaviour amongst the different groups examined. Although no dramatic declines in immunization uptake was noted in any neighbourhood group in the years following the publication of the article by Wakefield et al., the slight downward trend in total immunization in the high-uptake group may indicate an increasing concern over vaccines side-effects. The literature review identified high SES families more likely to be affected by negative media reports about vaccines [32]. The median family income for the high-uptake group is $66,693 compared to $53,359 and $40,567 in the middle and low-uptake groups respectively. The downward trend in total uptake in high uptake/high SES neighbourhoods requires further investigation at the individual level to assess the validity of this hypothesis.

Conversely, low-uptake neighbourhoods appear to be improving in total and up-to-date immunization uptake. Between 1999 and 2002, total immunization rates rose from 73.59% to 79.06% while up-to-date immunization rates went from 47.01% to 56.28%. However, not up-to-date immunization rates decreased over time from 26.55% to 22.78%. Although MMR/MR immunization rates remain for lower than acceptable in many of these neighbourhoods, this finding may signify targeted interventions may be effectively improving immunization uptake in high-risk groups or neighbourhoods within the city. Continued monitoring of this trend is important to ensure immunization rates for the low-uptake group continues to rise and to assess the impact of current and future interventions developed to improve uptake for this group of neighbourhoods.

5.2 Clinical Implications

The examination of immunization uptake is vitally important to gauge the potential for measles, mumps, and rubella outbreaks in Saskatoon. As stated in the introduction, vaccine preventable diseases, such as measles, mumps, and rubella are under constant threat of re-emergence in areas where immunization levels are substandard. Reviewing the clinical implications of low coverage rates may provide added insight into the findings produced in this study.

The goal of MMR immunization coverage, established by Health Canada in 1996, is to have 97% of children receive at least one dose of the MMR vaccine before their second birthday and 99% to receive two doses by their seventh birthday [81]. Saskatoon appears to fall short in reaching both of these targets in the period analyzed. During 1999 to 2002 only about 85% of children in Saskatoon received one dose of MMR before the age of two years missing the target by approximately 12% each year. Coverage rates were also low against the established 99% target of two doses by age seven. Based on the 1999 complete coverage rate, which is likely the most representative, Saskatoon still had significant room for improvement at 85%. However, the oldest children in the first cohort had only reached six years of age when the dataset was given to PHS. Therefore, the true measurement of this target cannot be properly assessed.

The difference between one or two doses of the MMR vaccine is clinically important. Researchers studied a number of measles and mumps outbreaks amongst youth aged 10 to 19 years of age in the early to mid 1990s and found that, even with very high coverage rates, one dose of the MMR vaccine was not adequate to protect against outbreaks due to waning immunity with age or primary vaccine failure [82-88]. Therefore, two doses of the MMR vaccine is extremely important in the prevention of measles and mumps outbreaks.

The rubella vaccine, on the other hand, appears to provide a high level of protection against the disease in excess of twenty years with one dose. The Canadian Immunization Guide states the second rubella vaccination is not generally necessary but the extra dose may provide a slightly higher level of immunity in the population and is not harmful [13]. Therefore, rubella outbreaks would be more likely in areas with low total immunization rates.

Due to the fact that the one-dose vaccination strategy has proven to be inadequate in the prevention of measles and mumps outbreaks, the findings of this study suggest certain areas of Saskatoon with low complete coverage rates may be at risk for measles or mumps outbreaks in the future. In other words, if complete immunization rates do not improve in these high-risk areas measles and mumps could re-emerge as these cohorts reach adolescence. Rubella may also reappear in areas with extremely low total immunization rates as numerous children may not be receiving even a single dose of the vaccine. Low up-to-date immunization rates are less of a concern even though two doses before the age of two years is the standard in Saskatchewan. Two doses before the age of two years does provide higher levels of immunity to children at an earlier age. However, from a clinic standpoint, achieving this standard is not as imperative as ensuring all children have two doses of the MMR vaccine by the age of seven.

Clearly, neighbourhoods with the lowest total and complete immunization rates are at highest risk for measles mumps, and rubella outbreaks. Moreover, these neighbourhoods may also be at risk for other vaccine preventable diseases as vaccines such as DTP (diphtheria, tetanus, and pertussis) and Hib (Haemophilus Influenzae type B) require five visits before the age of six to obtain the scheduled doses in accordance with the Saskatchewan immunization guidelines. If factors are contributing to low MMR immunization uptake in some areas of the city it is not hard to imagine these same factors would be contributing to incomplete and delayed uptake for other vaccines as well. The high-risk populations (based on neighbourhoods) identified in this study may, therefore, be at risk for a host of other infectious diseases.

5.3 Significant Correlates of Immunization Uptake

5.3.1 Female-headed Lone Parent Families

The proportion of female-headed lone parent families within a neighbourhood proved to be one of the strongest variables in the explanation of up-to-date immunization uptake at the neighbourhood level in Saskatoon. The bivariate analysis revealed approximately 78% of variation in immunization uptake at the neighbourhood level could be explained by the proportion of single mothers within the neighbourhood utilizing the Adjusted R^2 value ($p<0.001$, $\beta = -0.756$, 95% CI = -2.225 – -1.487). The 'Female-headed LPF' variable was also found to be highly significant in the presence of all other variables during the multivariate linear analysis and was subsequently included in the final model.

Although specific statements cannot be made as to the immunization practices of single mothers in Saskatoon, this study does indicate neighbourhoods with high numbers of single mothers tend to have lower up-to-date immunization rates. The proportion of single mothers in a particular neighbourhood could be connected to many other social factors such as poverty and low levels of education.

However, neither education nor any measures of income utilized in Phase II were found to be significant in the multivariate analysis once the FLP Families and Vehicle Registration variables were entered into the model. According to the literature review, the research supports the finding that children headed by single mothers often have more difficulty attaining on-time immunization compared to children living in two-parent families [42, 52].

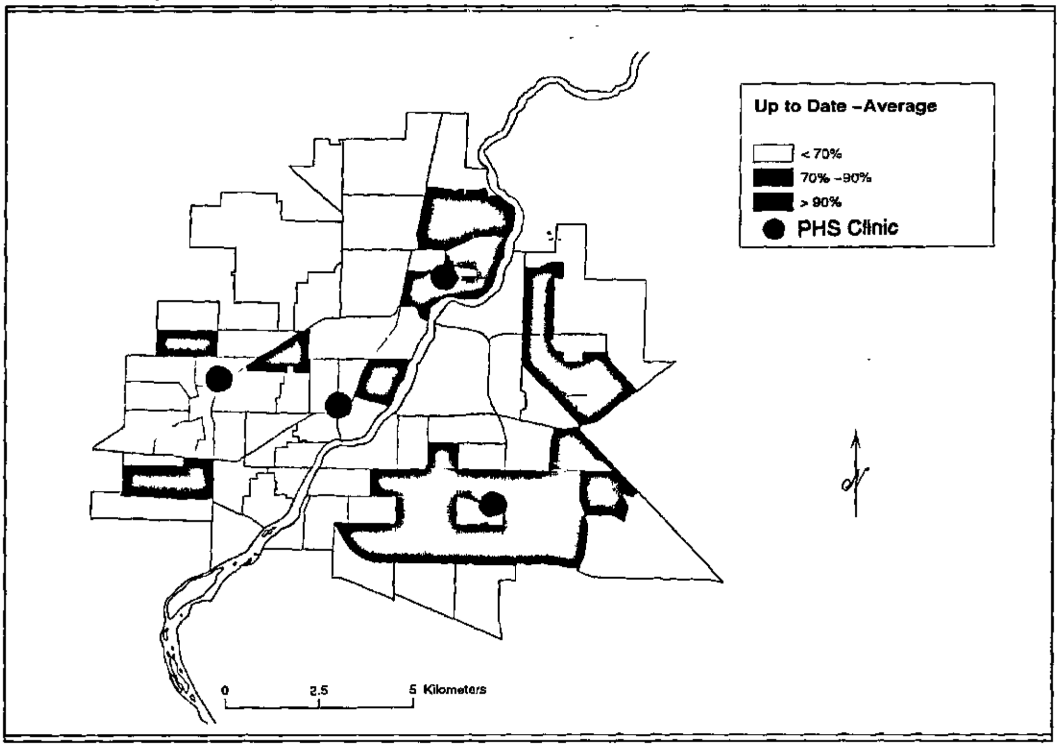
5.3.2 Vehicles Registered

The proportion of vehicles registered (# of registered vehicles/total population) within each neighbourhood also proved to be a significant variable in the explanation of variance in the up-to-date immunization rates. The bivariate analysis revealed the proportion of vehicles within a neighbourhood could explain 55% of average up-to-date immunization coverage ($p < 0.001$, $\beta = .714$, 95% CI = .528 - .899). When added into the final model during multivariate analysis, the inclusion of the 'Vehicles Registered' variable significantly contributed to the model increasing the Adjusted R^2 from 78.2% to 80.6%.

Transportation was noted to be a significant barrier to immunization for parents in a number of qualitative and quantitative studies in the literature review [55-59]. Many parents noted the cost and difficulty associated with traveling with one or more children. Yet, other researchers in Colorado and Britain found neither travel time, distance nor availability of a car significantly deterred attendance for immunization appointments [49, 54].

The availability of a car or access to transportation may be an important consideration in Saskatoon. Some Saskatoon families may have more problems in attaining on-time vaccinations due to the distance between where they live and where immunizations are offered. The following map indicates where the four main public health clinics are located in relation to the average up-to-date immunization rates (Figure 5.1).

Figure 5.1 Average UTD Immunization Rates with Primary PHS Clinic Locations



Vehicle availability is also closely linked with the socioeconomic status of the neighbourhood. Assessing the impact of transportation barriers in future research is imperative to understanding the effect on immunization in Saskatoon.

5.4 Limitations

5.4.1 General Limitations of Ecologic Studies

Ecologic studies have been used since the earliest days of epidemiology to generate and test hypotheses as they are cost effective, convenient, as well as simple to design and interpret. An ecologic design was employed for this study based on the data available and the overall research objectives. However, methodological problems with the design must be considered.

One of the most common issues frequently associated with ecologic studies is ecologic fallacy. Ecologic fallacy occurs when researchers mistakenly ascribe group characteristics to individuals who do not possess the specific characteristic [89]. For example, the median family income in Nutana is approximately $64,000 however individual families within Nutana have a variety of family incomes both lower and higher than the average. Immunization practices may also differ significantly between each family. Utilizing aggregate measures reduces the ability of ecologic studies to find the true effect at the individual level and can provide misleading results [90, 91].

This study, however, does not attempt to assert individual-level theories about immunization uptake in Saskatoon. It would be incorrect to state, based on these finings, that families in Saskatoon headed by single mothers or without a vehicle are more likely to be delayed or incomplete in their immunization uptake. The findings presented can only highlight neighbourhood disparities and guide future research towards potential individual level factors that may be influencing immunization uptake in Saskatoon. With that, concern about ecologic fallacy in the results should be minimized. Future research utilizing individual level data must be considered to assess the true effect of various factors on immunization uptake in Saskatoon.

Assessing the influence of confounding and effect modification in ecologic studies is also more problematic than at the individual level [90]. Confounding and interaction can be assessed but there is no guarantee it is either biologically meaningful or that including the terms would reduce error in the model. Due to the effect of potential effect of ecologic fallacy, there is no way to know if the confounder, outcome, and exposure are linked or if there is an interaction term at play at the individual level. For that reason, confounding and interaction were not assessed in this study because of the strong possibility of introducing more error into the model. This decision was supported by Dr. Cheryl Waldner from the College of Veterinary Medicine at the University of Saskatchewan who has expertise in the field of ecologic research.

Ecologic studies also often rely heavily on pre-existing data that can subsequently limit researchers in terms of the variables used for analysis. Data for neighbourhood variables in this study were obtained from the 2001 Census, Vital

Statistics, and the City of Saskatoon. Therefore, input into data collection procedures and measurements were not possible. Moreover, the SIMS dataset was designed as a registration/tracking system not necessarily for research purposes thereby limiting its research potential. Additional problems can also surface when data is obtained from a variety of sources. In fact, Senior et al. clearly state when immunization data is collected separately from Census data and other information it can substantially increase the risk for ecologic fallacy and any results that do appear should be cautiously interpreted [91].

5.4.2 Mobility and Coverage Rate Calculations

The effect of family mobility on accurate immunization coverage rate calculations was difficult to determine and is therefore a significant limitation of this study. Both Saskatchewan Health and Saskatoon Public Health strive to keep track of residents as they move. However, data collection and address updating practices differ within each organization resulting in the strong potential for misclassification. The extent to which misclassification affected accurate coverage rate calculations in this study must be examined.

As stated previously, the Saskatchewan Health Covered Population Report is considered the best source of annual population data available. However the data is often incomplete and subject to over-counting due to the fact that Saskatchewan Health only renews health cards every three years. If residents do not notify Saskatchewan Health of their new address the individual could be counted for up to three years after the move or until the health card is renewed [79]. Addresses were most recently updated across Saskatchewan at the end of 1999 and 2002. As a result, the most accurate year, in terms of the denominator, would have been in 2000.

Saskatoon Public Health also tries to monitor address changes as closely as possible. Addresses are updated with each visit to the clinic and when parents inform clinic staff of moves within or outside of the region. The immunization history of children who move into the city from other health regions is also back-entered into the system under their new Saskatoon address for more accurate monitoring of immunization status. Despite the best effort of both organizations, bias was likely present in this study due to the use of two different data sources in coverage rate calculation.

The different data sources for the numerator and denominator invariably led to problems with misclassification - that is, children incorrectly classified into the wrong neighbourhood for either the numerator or denominator of the coverage rate calculation. The misclassification of children into an incorrect neighbourhood likely occurred in both directions which may have resulted in coverage rate overestimation in some neighbourhoods and underestimation in others. Mobility following the birth cohort's population count on June 30th of the respective year is the biggest issue and likely most problematic in this study. If a child, immunized in neighbourhood "X", moved into neighbourhood "Y" after June 30th of the cohort's count year and went back for a subsequent immunization but did not notify Sask.

Health the resulting effect would be overestimated coverage rate in neighbourhood "Y" and underestimated coverage rate in neighbourhood "X". Overestimation would also be of concern with children moving into the SHR whereas underestimation would be a concern with children moving outside of the SHR following the cohort's respective count year.

The issues of mobility in this study are extremely complex and difficult to quantify. However, attempts were made to mitigate the effects of misclassification throughout the study. First, averaged coverage rates over 1999 through 2002 were used to create the immunization maps. Maps using averaged coverage rates were created to avoid reporting yearly coverage rates that may have been adversely affected by mobility or misclassification. By mapping average immunization uptake over time, the results highlight *general* differences in immunization uptake amongst Saskatoon neighbourhoods rather than incorrectly asserting yearly coverage rates to be accurate.

Averaged up-to-date coverage rates were also used as the dependent variable in the bivariate and multivariate analyses in an attempt to reduce the variability found within each Saskatoon neighbourhood as the population count shifted from year to year. Although this practice may have diluted the true nature of the relationship between neighbourhood variables and immunization uptake, linear relationships were still found to be present and highly significant.

Finally, an additional analysis was conducted using the SIMS dataset itself to obtain both the numerator and denominator for coverage rate calculations. The number of children who had received MMR/MR immunizations by birth cohort were divided by the total number of children in the full SIMS dataset for the same birth cohort. The full SIMS denominator included children who had received an MMR/MR vaccination and children who had received immunizations other than the MMR/MR but did not include any children who had never received an immunization.

Linear trends of immunization uptake, similar to the immunization rates using the Covered Population Report, were discovered when analysis was conducted using the full SIMS dataset. The results of the second analysis revealed a much smaller range in coverage rates however the overall rank of the neighbourhood in comparison to the others remained very similar. As a result, concerns over the effect of mobility were reduced and the Covered Population Report coverage rates were used for the study in an attempt to account for children who may have never received an immunization. It was felt using the covered population count for the denominator was more accurate and more representative of true immunization trends in Saskatoon even with the potential for misclassification.

5.4.3 Limitations of the SIMS Dataset

Using the SIMS dataset for research purposes proved challenging. This thesis was the first opportunity anyone within the SHR had used the SIMS data for immunization research. Therefore, as both known and unknown data limitations surfaced various strategies were employed to address each predicament. Issues of confidentiality, data quality, and data analyzability played important roles in the ascertainment of the final results.

Utilizing SIMS data was not the only first in this project. It was also the first time PHS data had been shared with a graduate student. Considerations of confidentiality were of utmost importance resulting in the signing of two memoranda of understanding. However, due to the requirement that only a dichotomous variable indicating "coverage" (up-to-date or not-up-to-date) was to be used in the analysis, the ability to assess the extent of delay in each neighbourhood was not possible (refer to Appendix 2). For example, was the average length of immunization delay in Pleasant Hill 5 days, 50 days or 500 days? Having more information in terms of the degree of immunization delay in Saskatoon neighbourhoods would better inform health care providers and administrators as to the severity of the issue in Saskatoon. Restricted access to personal health care numbers also prevented any linkages with individual level data for multi-level analysis.

The quality of the SIMS data was also a concern as extensive cleaning was required. Manual data cleaning requires extensive amounts of time and also poses a high risk of data entry error. Although data cleaning was not a significant issue for this project, busy PHS units in Saskatchewan who want to use SIMS for similar projects may not have the time or resources to deal with the amount of cleaning necessary to use the data. Following data cleaning, multiple data transformations were required to make the data analyzable. Again, multiple transformations take time and pose a greater risk for error at each stage of analysis.

The SIMS dataset also does not include any personal information about the child other than gender and no family information is included (i.e. marital status of the mother, number of children in family, etc). Additional individual level data (with parental consent) could benefit future immunization research initiatives. The ability to examine specific groups at risk, such as Aboriginal children, would also be helpful.

5.5 Recommendations

The final research question for this study asked: 'Can the identification of neighbourhood coverage rates and characteristics related to immunization uptake be used by Public Health Departments to better plan, implement, and evaluate immunization services?' The results of this thesis have proven to be valuable and the findings can be used to improve immunization services and programming for all families in the city. Recommendations have been developed based on the experience of working with the SIMS dataset and overall findings of the study. Consideration of the following recommendations may provide direction for future research and inform programming decisions.

1) First, further qualitative and quantitative research at the individual level should be considered a priority to assess real and perceived barriers as well as

sociodemographic factors and parental concerns that may be affecting immunization uptake in Saskatoon. Surveys, focus groups, and interviews are all valuable research methods that would contribute to further understanding of issues related to low or decreasing immunization uptake in Saskatoon. Although this study offers guidance as to where the higher risk populations are in the city and possible factors that are influencing uptake (i.e. female-headed LPF, access to vehicles), individual and multi-level level research is key to understanding the specific issues and barriers that contribute to low immunization uptake in specific neighbourhoods. Further investigation into the possible downward trend in total immunization coverage in high uptake neighbourhoods should also be considered in an effort to minimize the fear of vaccine side-effects that may be on the rise in certain areas of the city. A more in-depth examination of age appropriate uptake as opposed to up-to-date uptake should also be considered to assess the true impact of the problem in the various neighbourhoods.

Once immunizations barriers are assessed at the individual level, specific policies and program changes may be necessary to better serve neighbourhoods that struggle to achieve high coverage rates. Possible changes may include: more drop-in clinics, extended office hours, a mobile immunization van, transportation assistance, increased efforts to educate parents about true and untrue vaccine side-effects, a permanent public health clinic in the core-neighbourhood area, improved reminder initiatives, and increased community nursing support.

2) A review of immunization practices and policies may also be worthwhile for all public health units in Saskatoon as well as for physicians who provide vaccinations. As highlighted in the literature review, inaccurate beliefs amongst health care providers about contraindications continue to hamper up-to-date immunization initiatives. Therefore, information related to true and untrue contraindications for all childhood immunizations are vital to ensure health care providers and parents in the region are not unnecessarily delaying immunization uptake for mild illnesses. It is also important to communicate to immunization providers that staggering immunization appointments to reduce the number of injections at each visit is not appropriate. More visits increases the risk for immunization delay especially in high-risk populations.

3) All health care providers throughout Saskatoon should also be encouraged to assess the immunization status of children with every interaction. Health care providers should use check-ups, sick-visits, emergency department visits, etc. as opportunities to evaluate the immunization status of the child and to encourage and educate parents about the importance of timely immunizations. Support and assistance in making immunization appointments should also be offered.

4) Additional resources should also be considered in order to provide targeted programming in high risk areas of the city. More funding for community public health nurses may be required so these health care professionals can go into high-

risk neighbourhoods on a regular basis to remind parents of immunization schedules, teach about the various vaccines and diseases they prevent, assist with minimizing barriers to immunization, and support parents in their efforts to obtain the highest levels of health and health care for their children.

This study has identified neighbourhoods in the city that have more difficulty in attaining high MMR uptake rates compared to others. The findings in this study, however, may also serve as a marker for under-immunization in the uptake of other vaccines. If barriers are affecting the uptake of the MMR vaccine, it is extremely likely the on-time and adequate uptake of the other vaccines is also being affected. Therefore, increased resources for public health programming is essential to protect against the threat of other preventable diseases as well.

5) Improvements to SIMS must also be considered should PHS choose to use the dataset be used for future research and monitoring. The dataset must become more 'research friendly' in order to be a useful tool in immunization monitoring for the SHR and other health regions in Saskatchewan. SIMS has the capacity to become an effective reminder system through the electronic generation of mail-outs. Continued efforts should be made to work out the difficulties in getting the reminder system up and running. Work must also be done to address issues of mobility in the calculation of coverage rates as well as the quality of the data (i.e. missing data, duplicate records, errors in entry, etc). The SIMS database shows

strong promise for continued use therefore, investments should be made to ensure it can be utilized to its utmost potential.

6) Once the SIMS dataset has the capacity to produce neighbourhood coverage rates in a simple and reliable manner, the Saskatoon Health Region must set specific neighbourhood immunization targets and work towards those goals. SIMS should also be used to monitor immunization trends within the city and various Saskatoon neighbourhoods to ensure total and up-to-date immunization rates increase as not up-to-date rates decrease.

Ultimately, it is in the best interest of the entire community to ensure all children in Saskatoon have equal access to health care services and addressing disparities in immunization rates is one way to start. Research has shown under-immunization can be powerful predictor of inadequate primary and preventative health care utilization [92] therefore, the issue of low immunization uptake is not only a concern for vaccine preventable disease outbreaks but a wide-range of illnesses affecting children.

Overall, the findings of this study have undoubtedly contributed to a better understanding of immunization uptake and program delivery in Saskatoon. The results provide strong evidence of significant immunization disparities between Saskatoon neighbourhoods. Targeted projects and initiatives aimed at minimizing systematic and parental barriers to immunization are possible. However, more research needs to be conducted at the individual and neighbourhood level to accurately assess the real and perceived barriers to immunization. Improvements to the SIMS database are also essential to make the system more practical for immunization monitoring and research for Saskatoon and other communities throughout Saskatchewan.

Appendix 1: Memorandum of Understanding: Part I

Memorandum of Agreement

Between, Kyla Avis, hereafter named the student, and Saskatoon Health Region (SHR). The SHR agrees to provide the student with de-identified immunization data (MMR and MR data for Saskatoon children born between July 1, 1996 and June 30, 2001) for research purposes pursuant to completion of the Masters of Science thesis proposed by the student in April 2003. The de-identified information is disclosed in accordance to Section 23 and 29 of the Health Information Protection Act. The student agrees to: 1) provide a timeline for completion of the research, 2) share the results of the research with the SHR Medical Health Officer, Deputy Medical Health Officer, and Epidemiologist in detailed consultation, 3) two presentations (one preliminary and one final results), and 4) provide a copy of the thesis (may be unbound). One of the presentations may be a student presentation at the University in fulfillment of the Masters of Science requirement, and one presentation will be for the Disease Control staff of the SHR, to be determined at a later date. The student agrees to keep the SHR epidemiologist informed about all changes in the thesis timeline and scheduled presentations. If publishing or presenting results of the study (including posters) the student agrees to acknowledge the data source (SHR) and to provide a standard disclaimer. Section 30 of the Health Information Act states: "no person to whom a trustee has disclosed personal health information about another individual shall use or disclose the information for any purpose other than the purpose for which it was disclosed…." The student agrees to comply with data privacy laws outlined by the Health Information Protection Act and understands that the data is to be used for the research agreed upon with the Health Region.

In addition the student agrees to take reasonable steps to ensure the security and confidentiality of the information and to destroy the original records and any copies of records provided by SHR at the end of the thesis research project.

This agreement is made between the Deputy Medical Health Officer, Dr. S. Whitehead, and Kyla Avis, on.

July 29/03 Date

[redacted] Kyla Avis

Dr. C Neudorf, Medical Health Officer, Saskatoon Health Region

Appendix 2: Memorandum of Understanding: Part II

COPY

Memorandum of Agreement

This agreement is an addendum to the agreement made between Kyla Avis and the Saskatoon Health Region, July 29, 2003. In addition to the de-identified immunization data (MMR and MR data for Saskatoon children born between July 1, 1997 and June 30, 2001), Kyla Avis, hereafter named the student, will have access on site to the birthdates for the above named cohort for purposes of determining immunization coverage. The student will be provided temporarily (for on site use only) with a dataset identical to the one released July 29, with the additional birthdates provided. The following conditions for on-site work will apply:

1) The student will provide in writing the working syntax and description of operations (creation of all dummy variables, steps for merging data, etc.) for extracting the information to create the dichotomous variable, "coverage" from the birthdate information. A copy of this syntax and operations will be attached to the signed memorandum of agreement, and be submitted to the Health Region before the data is released.
2) The student will perform the necessary operations at the Idylwlyd Health Centre, and will take away from the site a copy of the original dataset plus an addition variable denoting immunization "coverage" only. The birthdates will be removed from the dataset on completion of the work. No identifying variable will be taken away with the dataset that accompanies the student off site.
3) The student will use the birthdate information for purposes of extracting the immunization coverage data only. All operations will be performed on the students laptop computer on site. No copies of the birthdates will be made.

This agreement is made in accordance with the Health Information Protection Act. The student agrees to comply with these data privacy laws and understands that the data is to used only for the research agreed upon.

This agreement is made between the Deputy Medical Health Officer, Dr. S Whitehead and Kyla Avis on

Oct 21/03 ____ Date

[redacted] ____ Kyla Avis

[redacted] ____ Dr. S. Whithead, Deputy Medical Health Officer, Saskatoon Health Region

Appendix 3: Neighbourhood Data Sources

Indicator	Measure	Data Source
Visible Minorities	# of visible minorities/ total population	2001 Census
Female-headed Families with Children	# of families with children headed by females/ total # families	2001 Census
Male-headed Families with Children	# families with children headed by males/ total # families	2001 Census
1 Year Population Mobility	% of people who have moved within the previous year	2001 Census
Children per Occupied Dwelling	Avg. # of children per family dwelling	2001 Census
Family Poverty Rate	LICO families/total families	2001 Census
Median Family Income		2001 Census
Teenage Births	Teenage birth rate per 1,000 live births (15-19yrs)	Saskatchewan Health Vital Statistics
Low Birth Weight Rate	Rate of LBW (<2500g) per 1,000 live births	Saskatchewan Health Vital Statistics
Education	% of population 15 and over with less than grade 9	2001 Census
Access to Transportation	# of registered vehicles in 2002/total population in 2002	City of Saskatoon 2002
Family Income (<$10,000)	% of families with income less than $10,000	2001 Census

Appendix 4: Ethics

UNIVERSITY OF SASKATCHEWAN
BEHAVIOURAL RESEARCH ETHICS BOARD

http://www.usask.ca/research/ethics.shtml

NAME: Leonard Tan (Kyla Davis) **BSC#:** 03-1184
Community Health & Epidemiology

DATE: October 9, 2003

The University of Saskatchewan Behavioural Research Ethics Board has reviewed the Application for Ethics Approval for your study "Examining Measles, Mumps and Rubella (MMR) Immunization in the City of Saskatoon: Can Neighborhood Characteristics Predict Coverage Rates?" (03-1184).

1. Your study has been APPROVED.

2. Any significant changes to your proposed method, or your consent and recruitment procedures should be reported to the Chair for Committee consideration in advance of its implementation.

3. The term of this approval is for 5 years.

4. This approval is valid for five years on the condition that a status report form is submitted annually to the Chair of the Committee. This certificate will automatically be invalidated if a status report form is not received within one month of the anniversary date. Please refer to the website for further instructions: http://www.usask.ca/research/behavrsc.shtml

I wish you a successful and informative study.

Dr. David Hay, Acting Chair
University of Saskatchewan
Behavioural Research Ethics Board

DH/ck

Appendix 5: Neighbourhoods as Units of Analysis

1. Adelaide/Churchill
2. Arbor Creek
3. Avalon
4. Brevoort Park
5. Briarwood
6. Buena Vista
7. Caswell Hill
8. City Park
9. College Park
10. College Park East
11. Confederation Park
12. Dundonald
13. Eastview
14. Erindale
15. Exhibition
16. Fairhaven
17. Forest Grove
18. Greystone Heights
19. Grosvenor Park
20. Haultain
21. Holiday Park
22. Holliston
23. Hudson Bay Park
24. Kelsey/Woodlawn/Mayfair
25. King George
26. Lakeridge
27. Lakeview
28. Lawson Heights
29. Massey Place
30. Meadowgreen
31. Montgomery Place
32. Mount Royal
33. Nutana
34. Nutana Park
35. Nutana SC/Lawson Heights SC/ Confederation SC
36. Pacific Heights
37. Parkridge
38. Pleasant Hill
39. Queen Elizabeth
40. Richmond Heights/North Park
41. River Heights
42. Riversdale
43. Silverspring
44. Silverwood Heights
45. University Heights/Sutherland
46. Varisty View
47. Westmount
48. Westview
49. Wildwood

Appendix 6: Average Coverage Rates by Neighbourhood

NBH	Total %	Complete %	UTD %	Not UTD %
Adelaide/Churchill	89.65	83.47	80.08	9.57
Arbor Creek	97.92	93.37	87.76	10.16
Avalon	90.28	87.86	77.30	12.99
Brevroot Park	95.12	84.24	70.45	24.67
Briarwood	113.52	107.94	94.64	18.87
Buena Vista	82.14	73.97	66.62	15.51
Caswell Hill	82.49	69.32	53.62	28.87
City Park	108.08	98.97	86.45	21.63
College Park	85.45	78.54	68.19	17.25
College Park East	96.15	91.44	84.39	11.76
Confederation Park	86.57	75.60	59.59	26.97
Dundonald	88.78	82.92	72.95	15.82
Eastview	92.74	86.93	74.20	18.54
Erindale	97.74	92.52	82.67	15.07
Exhibition	89.02	73.51	62.12	26.90
Fairhaven	82.81	69.46	58.39	24.41
Forest Grove	90.74	84.81	72.53	18.21
Greystone Heights	95.52	80.62	69.74	25.78
Grosvenor Park	106.09	94.07	87.79	18.30
Haultain	94.23	87.80	78.69	15.54
Holiday Park	71.83	56.01	51.60	20.23
Holliston	86.09	80.41	71.41	14.69
Hudson Bay Park	97.57	81.84	71.08	26.49
Kelsey/Woodlawn/Mayfair	82.75	68.11	53.83	28.92
King George	76.40	61.07	52.96	23.45
Lakeridge	99.45	93.09	85.99	13.46
Lakeview	96.10	87.37	76.02	20.08
Lawson Heights	92.02	81.96	72.91	19.11
Massey Place	65.91	53.98	44.44	21.46
Meadowgreen	69.54	54.72	39.17	30.37
Montgomery Place	112.32	108.55	97.72	14.60
Mount Royal	78.94	67.08	53.72	25.22
Nutana	90.04	74.52	63.67	22.78
Nutana Park	86.45	82.15	73.36	17.97
Nutana/LH/Confed SCs	86.46	66.74	51.52	34.93
Pacific Heights	86.82	78.08	64.36	22.46
Parkridge	85.13	75.76	60.25	24.88
Pleasant Hill	64.57	50.13	30.79	33.79
Queen Elizabeth	93.33	80.80	68.12	25.22
Rich Heights/North Park	90.04	78.18	68.60	21.44
River Heights	100.64	93.13	85.50	15.13
Riversdale	74.58	53.84	31.75	42.83
Silverspring	102.35	99.12	88.42	13.92
Silverwood Heights	107.65	100.81	91.81	15.85
Univ Heights/Sutherland	94.76	80.32	65.56	29.20
Varsity View	87.51	79.92	64.15	23.37
Westmount	81.86	69.93	51.12	30.74
Westview	88.05	73.82	57.33	30.72
Wildwood	97.24	87.86	77.18	20.06

Appendix 7: Coverage Rates by Year for the City of Saskatoon and High, Middle, and Low Uptake Neighbourhoods

City of Saskatoon

Count Year	Total %	Complete %	UTD %	Not UTD %
1999	91.34	85.12	68.06	23.28
2000	91.76	82.58	69.81	21.95
2001	88.81	76.68	67.71	21.09
2002	88.30	75.36	68.09	20.21

High Uptake Neighbourhoods*

Count Year	Total %	Complete %	UTD %	Not UTD %
1999	112.43	108.05	92.82	19.29
2000	99.22	91.51	80.14	19.62
2001	98.70	89.01	81.13	16.50
2002	95.49	85.14	80.29	14.35

* High uptake neighbourhoods include: Briarwood, Montgomery Place, City Park, Silverwood Heights, Grosvenor Park, Silverspring, River Heights, Lakeridge, Arbor Creek, Erindale, Hudson Bay Park, Wildwood, College Park East, Lakeview, Greystone Heights, Brevroot Park.

Middle Uptake Neighbourhoods*

Count Year	Total %	Complete %	UTD %	Not UTD %
1999	88.19	81.50	64.56	23.62
2000	95.19	87.41	73.47	21.72
2001	86.94	76.42	67.98	18.96
2002	90.21	76.06	67.71	22.50

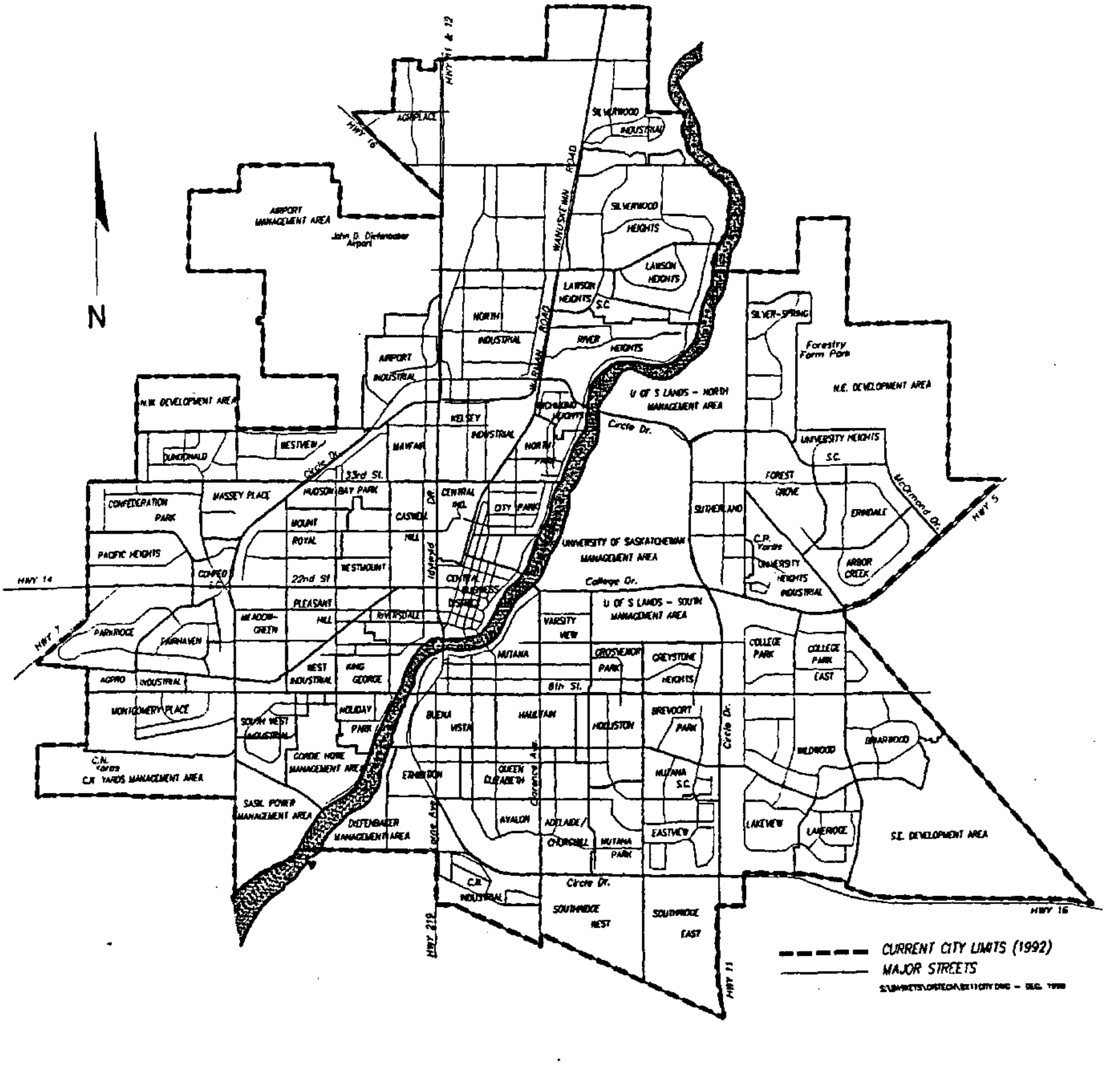
*Middle uptake neighbourhoods include: Sutherland/University Heights, Haultain, Queen Elizabeth, Eastview, Lawson Heights, Nutana Park, Forest Grove, Avalon, North Park/Richmond, Adelaide/Churchill, Exhibition, Dundonald, Westview, Varsity View, Pacific Heights, Confederation Park, Confed/Lawson Heights/Nutana SCs.

Low Uptake Neighbourhoods*

Count Year	Total %	Complete %	UTD %	Not UTD %
1999	73.59	66.03	47.01	26.55
2000	80.66	68.74	55.58	25.08
2001	80.90	64.61	54.01	26.89
2002	79.06	64.85	56.28	22.78

*Low uptake neighbourhoods include: Nutana, Holliston, College Park, Parkridge, Fairhaven, Kelsey/Woodlawn/Mayfair, Caswell Hill, Buena Vista, Westmount, Mount Royal, King George, Riversdale, Holiday Park, Meadowgreen, Massey Place, Pleasant Hill.

Appendix 8: Map of Saskatoon



References

1. Canadian Public Health Association. The value of immunization in the future of Canada's health system: Submission to the commission on the future of health care in Canada. Ottawa, Ont. Canada: Canadian Public Health Association; 2001.

2. Roos L, Traverese D, Turner D. Delivering prevention: The role of public programs in delivering care to high risk populations. Med Care 1999;37(6):264-278.

3. Wakefield A, Murch S, Anthony A, Linnell J, Casson D, Malik M, et al. Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children. Lancet 1998;351:637-641.

4. Murch S, Anthony A, Casson D, Malik M, Berelowitz M, Dhillon A, et al. Retraction of an interpretation. Lancet 2004;363(9411):750.

5. Diez Roux A. Investigating neighbourhood and area effects on health. Am J Public Health 2001;91(11):1783-1789.

6. Centre for Disease Control. Update: Global measles control and mortality reduction - worldwide, 1991-2001. MMWR Morb Mortal Wkly Rep 2003;52(20):471-475.

7. Health Canada. Vaccine preventable diseases. Available at www.hc-sc.gc.ca/pphb-dgspsp/dird-dimr/vpd-mev/index.html. Accessed August 12, 2003.

8. Health Canada Disease Surveillance Division. MMR disease incidence statistics; 2003.

9. Orenstein W, Redd S, Markowitz L, Hinman A. Diseases controlled primarily by vaccination. In: Wallace R, editor. Public Health & Preventative Medicine. 14th ed. Stamford, Conneticut: Appleton & Lange; 1998.

10. Nichols F, Zwelling E. Maternal-newborn nursing: Theory and practice. 1st ed. Philadelphia PA: W.B Saunders Company; 1997.

11. Galazka A, Robertson S, Kraigher A. Mumps and mumps vaccine: a global review. Bulletin of the World Health Organization 1999;77(1):3-14.

12. Greniers D, Medaglia A, Doherty J. Canadian paediatric surveillance program (CPSP): Congenital rubella syndrome (CRS), subacute sclerosis panencephalitis (SSPE) and acute flaccid paralysis (AFP): Relationship of frequency to vaccine status. In: Canadian Paediatric Society and Centre for Infectious Disease Prevention and Control, Health Canada; 2001.

13. Health Canada. Canadian Immunization Guide. 6th ed. Ottawa; 2002.

14. Miller E, Waight P, Farrington P, Andrews N, Stowe J, Taylor B. Idiopathic thrombocytopenic purpura and MMR vaccine. Arch Dis Child 2001;84(3):227-9.

15. Canada Communicable Disease Report. Canadian national report on immunization, 1996: Health Canada; 1997.

16. Pelletier L, Chung P, Duclos P, Manga P, Scott J. A benefit-cost analysis of two-dose measles immunization in Canada. Vaccine 1998;16(9-10):989-996.

17. Canadian Paediatric Society. Routine immunization schedule: Update 2004. Pediatrics & Child Health 2004;9(1):17-20.

18. Ratnam S, West R, Gadag V, Burris J. Measles immunization strategy: measles antibody response following MMR II vaccination of children at one year of age. Can J Public Health 1996;87(2):97-100.

19. Phelan A. MMR and autism: An overview of the debate to date. Br J of Nurs 2002;11(9):620-625.

20. Taylor B, Miller E, Farrington P, Petropoulos M, I Favot-Mayaud, Li J, et al. Autism and measles, mumps, and rubella vaccine: no epidemiological evidence for a causal association. Lancet 1999;353(9169):2026-2029.

21. Canada Communicable Disease Report. Does measles-mumps-rubella (MMR) vaccination cause inflammatory bowel disease and autism?: Health Canada; 2001 April 15.

22. Dales L, Hammer S, Smith N. Time trends in autism and in MMR immunization coverage in California. JAMA 2001;285(9):1183-1185.

23. Patja A, Davidkin I, Kurki T. Serious adverse events after measles-mumps-rubella vaccination during a 14 year prospective follow-up. Pediatr Infect Dis J 2000;19:1127-35.

37. Gellin B, Maibach E, Marcuse E. Do parents understand immunizations? A national telephone survey. Pediatrics 2000;106(5):1097-1102.

38. Boyd L, Nolan T, Pattison P, Carlin J. Vaccine preventable diseases and immunisations: A qualitative study of mothers' perceptions of severity, susceptibility, benefits and barriers. Aust N Z J Public Health 1998;22(4):441-446.

39. Kilmartin M, Woodward D, Blizzard C, Turner K. Immunisation of babies: the mothers' perspective. Aust Fam Physician 1998;27(Suppl 1):11-14.

40. Strobino D, Keane V, Holt E, Hughart N, Guyer B. Parental attitudes do not explain underimmunization. Pediatrics 1996;98(6):1076-1083.

41. Syme S, Balfour J. Social determinants of disease. In: Wallace R, editor. Public Health & Preventative Medicine. 14th ed. Stamford, Connecticut: Appleton & Lange; 1998. p. 795-809.

42. Bates A, Fitzgerald J, Dittus R, Wolinsky F. Risk factors for underimmunization in poor urban infants. JAMA 1994;272(14):1105-1110.

43. Bates A, Wolinsky F. Personal, financial, and structural barriers to immunization in socioeconomically disadvantaged urban children. Pediatrics 1998;101(4):591-595.

44. Klevens R, Luman E. U.S children living in and near poverty: Risk of vaccine -preventable diseases. Am J Prev Med 2001;20(4):41-46.

45. Brenner R, Simons-Morton B, Bhaskar B, Das A, Clemens J. Prevalence and predictors of immunization among inner-city infants: A birth cohort study. Pediatrics 2001;108(3):661-70.

46. Marks J, Halpin T, Irvin J, Johnson D, Keller J. Risk factors associated with failure to receive vaccinations. Pediatrics 1979;64(3):304-309.

47. Center for Disease Control. Vaccination coverage by race/ethnicity and poverty level among children aged 19-35 months - United States. MMWR Morb Mortal Wkly Rep 1999;47:956-959.

48. Kenyon TA, Matuck MA, Stroh G. Persistent low immunization coverage among inner-city preschool children despite access to free vaccine. Pediatrics 1998;101(4):612-616.

49. Miller L, Hoffman R, Baron A, Marine W, Melinkovich P. Risk factors for delayed immunization against measles, mumps, and rubella in Colorado two-year olds. Pediatrics 1994;94(2):213-219.

50. Bobo J, Gale J, Thapa P, Wassilak S. Risk factors for delayed immunization in a random sample of 1163 children from Oregon and Washington. Pediatrics 1993;91(2):308-14.

51. Goodman K, Wu S, Frerichs R. Compliance with childhood immunization in Kern County, California. J Immigr Health 2000;2(4):213-222.

52. Salsberry P, Nickel J, Mitch R. Inadequate immunization among 2 year old children: A profile of children at risk. J Pediatr Nurs 1994;9(3):158-165.

53. Heck K, Parker J. Family structure, socioeconomic status, and access to health care for children. Health Services Research 2002;37(1):173-187.

54. Senior M, New S, Gatrell A, Francis B. Geographic influences on the uptake of infant immunisations: 2. Disaggregate analysis. Environ Planning A 1993;25:467-479.

55. Kimmel S, Maldon-Kay D, Burns I, Admire J. Breaking the barriers to childhood immunization. Am Fam Physician 1996;53(5):1648-1660.

56. Salsberry P, Nickel J, Mitch R. Why aren't preschoolers immunized? A comparison of parents' and providers' perceptions of the barriers to immunization. J Community Health Nurs 1993;10(4):213-224.

57. Mack R, Darden P. Children's immunizations: The gap between parents and providers. Health Mark Q 1999;16(4):7-14.

58. Riportella-Muller R, Selby-Harrington M, Richardson L, Donat P, Luchok K, Quade D. Barriers to the use of preventative health care services for children. Pub Health Rep 1996;111:71-77.

59. Lannon C, Brack V, Stuart J, Caplow M, McNeil A, Bordley C, et al. What mothers say about why poor children fall behind on immunizations. Arch Pediatr Adolesc Med 1995;149:1070-1075.

60. Statistics Canada. Population by Aboriginal group, census metropolitan areas. Available at: http://www.statcan.ca/english/Pgdb/demo39b.htm. Accessed April 24, 2003.

61. Jackson M. Closer to home: Child and family poverty in Saskatoon. Saskatoon: Community-University Institute for Social Research; 2004.

62. Tarrant M, Gregory D. Mothers' perceptions of childhood immunizations in First Nations communities in the Sioux Lookout zone. Can J Public Health 2001;92(1):42-45.

63. Tarrant M, Gregory D. Exploring childhood immunization uptake with First Nations mothers in northwestern Ontario Canada. J Adv Nurs 2003;41(1):63.

64. Baker M, Bandaranyake R, Schweiger M. Differences in rate of uptake of immunisation among ethnics group. Br Med J 1984;288:1075-1077.

65. Dunn J, Dyck I. Social determinants of health in Canada's immigrant population: results from the National Population Health Survey. Soc Sci Med 2000;51(2000):1573-1593.

66. Pettit K, Kingsley G, Coulton C, Cigna J. Excerpts from neighbourhoods and health: building evidence for local policy. Washington DC: The Urban Institute; 2003.

67. Kohen D, Hertzmzan C, Wiens M. Environmental changes in children's competence: Human Resources Development Canada; 1998.

68. Statistics Canada. Aboriginal peoples of Canada: A demographic profile. Ottawa; 2003.

69. Mitchell C, Franco S. Factors associated with improved immunization rates for urban minority preschool children. Clin Pediatr 1995(September):466-470.

70. Farizo K, Stehr-Green P, Markowitz L, Patriarca P. Vaccination levels and missed opportunities for measles vaccination: a record audit in a public pediatric clinic. Pediatrics 1992;89:589-92.

71. Gamertsfelder D, Zimmerman R, DeSensi E. Immunization barriers in a family practice residency clinic. J Am Board Fam Pract 1994; 7:100-4.

72. McConnochie K, Roghmann K. Immunization opportunities missed among urban poor children. Pediatrics 1992;89:1019-26.

73. Wood D, Pereyra M, Halfon N, Hamlin J, Grabowsky M. Vaccination levels in Los Angeles Public Health Centers: The contribution of missed opportunities to vaccinate and other factors. Am J Public Health 1995;85(6):850-853.

74. Wood D, Schuster M, Donald-Sherbourne C, Duan N, Mazel R, Halfon N. Reducing missed opportunities to vaccinate during child health visits. Arch Pediatr Adolesc Med 1998;152:238-243.

75. Maldon-Kay D, Harper P. Too many shots? Parent, nurse, and physician attitudes toward multiple simultaneous childhood vaccinations. Arch Fam Med 1994;3:610-3.

76. Roberts J, Poffenroth L, Roos L, Bebchuk J, Carter A. Monitoring childhood immunizations: a Canadian approach. Am J Pub Health 1994;84(10):1666-1668.

77. Ghebrehewet S, Falconer M, Schlecht B. MMR vaccine uptake rates: a data validation study. Commun Dis Public Health 2003;6(2):144-6.

78. Samuels R, Appel L, Reddy S, Tilson R. Improving accuracy in a computerized immunization registry. Ambulatory Pediatr 2002;2(3):187-192.

79. Community Services Department City Planning Branch. How is Saskatoon's population estimated? Populace 2002;2(1):1-4.

80. Kleinbaum D, Kupper L, Muller K. Applied regression analysis and other multivariate methods. 2nd ed. Boston: PWS-Kent; 1988.

81. Health Canada. Canadian national report on immunization, 1996. Canada Communicable Disease Report 1996;23(S4).

82. Hersh B, Fine P, Kent W, Cochi S, Kahn L, Zell E, et al. Mumps outbreak in a highly vaccinated population. Epidemiol Infect 1991;115(2):315-23.

83. Briss P, Fehrs L, Parker R, Wright P, Sannella E, Hutcheson R, et al. Sustained transmission of mumps in a highly vaccinated population: Assessment of primary vaccine failure and waning vaccine-induced immunity. J Infect Dis 1994;169(1):77-82.

84. Buxton J, Craig C, Daly P, Bigham M, Bell A, Fyfe M. An outbreak of mumps among young adults in Vancouver, British Columbia, associated with 'rave' parties. Can J Pub Health 1999;90(3):160-163.

85. Cheek J, Baron R, Atlas H, Wilson D, Crider R. Mumps outbreak in a highly vaccinated school population. Arch Pediatr Adolesc Med 1995;149(7):774-8.

86. Peltola H, Heinonen OP, Valle M, Paunio M, Virtanen M, Karanko V, et al. The elimination of indigenous measles, mumps, and rubella from Finland by a 12-year, two-dose vaccination program. N Engl J Med 1994;331(21):1397-1402.

87. Matson D, Byington C, Canfield M, Albrecht P, Feigin R. Investigation of a measles outbreak in a fully vaccinated school population including serum studies before and after revaccination. Pediatr Infect Dis J 1993;12:292-99.

88. Sutcliffe P, Rea E. Outbreak of measles in a highly vaccinated secondary school population. CMAJ 1996;155(10):1407-13.

89. Gordis L. Epidemiology. 2nd ed. Philadelphia, PA: W.B Saunders Company; 2000.

90. Morgenstern H. Ecologic studies. In: Rothman K, Greenland S, editors. Modern Epidemiology. 2nd ed. Philadelphia PA: Lippincott-Raven Publishers; 1998. p. 459-480.

91. Senior M, New S, Gatrell A, Francis B. Geographic influences on the uptake of infant immunisations: 1. Concepts, models, and aggregate analysis. Environ Planning A 1993;25:425-436.

92. Rodewald L, Szilagyi P, Shiuh T, Humiston S, LeBaron C, Hall C. Is underimmunization a marker for insufficient utilization of preventative and primary care? Arch Pediatr Adolesc Med 1995;149:393-397.