Respiratory Illness in Saskatoon Infants: The Impact of Housing and Neighbourhood Characteristics

by
Judith Wright and
Nazeem Muhajarine

Community – University Institute for Social Research

289 John Mitchell Building
118 Science Place
Saskatoon, SK S7N 5E2
phone (306) 966-2121
fax (306) 966-2122
e-mail cuisr.oncampus@usask.ca
www.usask.ca/cuisr

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Abstract

Respiratory illness is an important childhood illness and significant cause of infant mortality. Using a mixed retrospective and ecologic design, this study examined: (1) the relationship between small for gestational age (SGA) status and respiratory illness; and (2) the relationship between neighbourhood level variables and respiratory morbidity rates for all babies in Saskatoon. SGA preterm babies had almost four times the risk of hospitalization (OR= 3.93; 95% CI = 1.77, 8.71) compared to non-SGA term babies, but no increased risk for ambulatory visits. Infants in many West side neighbourhoods had more respiratory illnesses, as measured by proportion and frequency of hospitalization and ambulatory visits to physicians, regardless of SGA status. Predictive models for respiratory illness rates support the research hypothesis that housing characteristics, in the presence of other neighbourhood characteristics, make a significant impact on health service utilization rates for respiratory illness among Saskatoon infants.

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Introduction and Objectives

Respiratory illness is an important cause of child morbidity and a significant cause of mortality in infancy and childhood. In Canada in the 1980s, respiratory illness was the leading cause of hospitalization in young children (Hodge, 1995). A growing body of research points to the importance of neighborhood and environment in child health (O'Campo et al, 2000; Matheson et al, 1998; Pearl, 2000; Curtis, 1990). Individual risk factors in the presence of neighbourhood risk factors may increase susceptibility to adverse health outcomes in children. Low birth weight, pre-term, and small for gestational age (SGA) children, who may be immunologically or functionally compromised, may be particularly susceptible to respiratory illness due to the synergistic effect of adverse housing characteristics and immature respiratory systems.

Child health and well-being, particularly in the early years, forms the foundation for future health and development, and plays a significant role in shaping individual life opportunities. Studies that have examined associations between socioeconomic factors and morbidity suggest that child poverty increases risks for poor health. However, the actual mechanisms through which socio-economic disadvantage affect morbidity need to be more fully understood. This research examines the relationship between housing characteristics and some of the other more well-known socio-environmental risk factors for respiratory illness in Saskatoon infants, from birth to age 2 years. This study's objectives were to: (1) determine the frequency of health services utilization for respiratory illness in 33 Saskatoon neighbourhoods; (2) examine the relationship between SGA status and health service utilization for respiratory illness; and (3) examine the relationship between housing and respiratory illness in all Saskatoon infants.

Literature Review

Respiratory illness comprises a large category of diseases or conditions affecting the upper and lower respiratory tracts. Commonly included illnesses are acute respiratory infections, such as nasophyaryngitis (common cold), otitis media and severe ear, nose, and throat (ENT) infections, pneumonia, influenza, and chronic inflammatory conditions such as asthma and obstructive pulmonary disorder. Mortality rates from respiratory illness have fallen in the past sixty years in developed countries (Phelan et al, 1990), though lower respiratory tract illness is still the most common serious childhood illness (McConnochie, 1995). Asthma, the most frequent chronic condition in children (Graham, 1994; Brownell et al, 2001) has risen steadily from the 1970's to the mid-1990's internationally (Millar and Hill, 1998).

Known biological risk factors for respiratory illness in young children include male sex, low birth weight, prematurity, possibly SGA, perinatal events such as asphyxia, and other serious respiratory infection in early childhood. Known risk factors for asthma include atopy and genetic predisposition (Phelan et al, 1990; McCormick, 1985; Alberman, 1994; Esmen, 1985). SGA babies have an increased incidence of perinatal asphyxia and its sequelae, symptomatic hypoglycemia, congenital malformations, chronic intrauterine infection, and massive pulmonary hemorrhage (Arbuckle and Sherman 1989)—conditions that can compromise respiratory health in the early years. There is evidence that the combined risks—SGA and preterm, or SGA and low birth weight—constitute increased risk for poor health and development (McCormick, 1985). Low weight for gestational age is associated with higher mortality and somewhat increased risks of morbidity in infancy and childhood. Starfield et al (1982) reported that among low birth weight babies, appropriate for gestational age (AGA) and SGA infants differ in their risk for adverse subsequent outcomes. SGA infants were at greater risk of problems manifested during the first year of life (Starfield et al, 1982). Socio-environmental risk factors for respiratory illness include low socioeconomic status (SES), poor nutrition, exposure to infection through crowding and younger siblings, air pollution, psychological stress, and parental smoking (Graham, 1994). Lower socioeconomic status may lead to increased exposures to infection and decreased resistance (Cohen, 1999).

Studies have also linked adverse indoor environments to respiratory morbidity in children, especially factors such as the presence of dampness and mould (Dales et al, 1991), younger siblings and overcrowded living situations (Fuchs et al, 1996), and inadequate ventilation (Brundage et al, 1988; Wickman et al,1991). The type, age, and condition of dwellings may indicate the quality of indoor environment in which children live. Different types of housing, built in different construction periods, use different materials and energy-saving features. These features influence air circulation and ventilation in the home. This, in turn, affects levels of airborne contaminants, humidity, and the growth of microorganisms such as mites and moulds, which are airway irritants highly implicated in respiratory illness (Spengler and Sexton, 1983; Hirsch, 1999). Pollutant levels in a dwelling are influenced primarily by ventilation—specifically, the air exchange rate between indoor and outdoor air. In residential dwellings, the type of construction and age of the house influences this exchange (Esmen, 1985). The energy crisis of the 1970's had a major impact on building practices, which, in turn, has affected indoor environments (Selner, 1996). Installing additional insulation for energy conservation has reduced air exchange rates and may inadvertently have increased concentrations of indoor pollutants (Dekker et al, 1991). Using materials such as continuous vapour barriers, polyethylene-enclosed electrical outlets and fixtures, and double or triple-sealed windows may have a similar effect.

Adverse indoor air conditions may be influenced by the community environment as well as occupant behaviours (Matte and Jacobs, 2000). Lack of affordable housing has been linked to inadequate nutrition, especially among children (Krieger, 2002). As housing and energy costs increase, low-income tenants use more of their resources to obtain and maintain shelter, leaving less for other necessities. In Saskatoon, where affordable housing is an on-going problem, some parents use social assistance funds allocated for food or other needs to subsidize rent costs (Slavin, 2000).

Influences on health services utilization include availability of services and health-seeking behaviour. Andersen and Newman (1973) have proposed a model that suggests that societal determinants of utilization affect individual determinants both directly and through the health services system. At the individual level, health service utilization is influenced by: (1) the predisposition of the individual to use services, as influenced by such sociodemograhic factors as age and sex; (2) the ability to secure services (enabling factors); and (3) illness level. Social factors, such as education, also influence predisposition, as do beliefs or cultural factors, such as attitudes towards health care. The ability to secure services is influenced by household economic factors and community factors. The illness level includes both perceived and evaluated illness severity. These factors determine the type of services chosen, whether a general practitioner or specialist is sought, as well as whether it is for preventive purposes or treatment. At the societal level, technology and established norms influence both the health system and individual expectations of health care services. Available resources and organization influence the system itself with respect to specialization and type of service available (Andersen and Newman, 1973).

Methodology

The research design was a cohort study, using data measured at both individual and aggregate (ecologic) levels to assess the relationship between SGA status and respiratory illness, and between neighborhood and housing characteristics and respiratory illness. Respiratory illness, in this study, was defined using the International Classification of Disease, 9th revision (ICD-9) codes and conditions, grouped into seven meaningful respiratory disease categories: asthma (ICD-9 493); influenza (ICD-9 487-487.8); bacterial pneumonia (ICD-9 481- 483 485-486), pertussis (ICD-9 033), upper respiratory (ICD-9 460 461.9 464-465.9); ENT (381-383.9 462-463); and, a general catch-all category, other respiratory (466-472, 472.2 – 480.9, 484-484.8, 490 – 492, 494-519.9). In some analyses reported here, we treated all respiratory illnesses in a single group, which included all seven disease specific categories. SGA was defined as an infant whose birth weight was in the lower tenth percentile for gestational age (Arbuckle et al, 1993), using Saskatchewan birthweight norms for gestational age adjusted for sex. Non-SGA was defined as infants who were not born SGA. SGA was further divided into two groups: preterm and term. Preterm was defined as a birth occurring at less than 37 weeks completed gestation. Term was defined as a birth occurring at or later than 37 weeks of completed gestation.

Health services utilization measures were calculated for: (1) ambulatory visits by infants to physicians; and (2) hospital separations. These two types of services are reported separately. Respiratory illness rates, as measured via use of health services, were determined for each of the neighborhoods from data obtained from the Adverse Birth Outcomes Study. Four files of information were used from the Adverse Birth Outcome Study, including information from Vital statistics, the Health Information Registry, Hospital Discharge Abstracts, and Physician Services Claims. Neighborhood socio-environmental data came from the 1996 Canadian Census and the City of Saskatoon Neigbourhood Profiles. The independent aggregated variables assessed were median income, average persons per family household, and percentages of: male infants, SGA infants, population under age 10, employment numbers, less than grade 9 education, rental tenure, dwellings needing major repairs, and apartments, duplexes, and dwellings constructed in three separate periods (pre-1971, 1971-1985, and post-1985). All aggregated variables, as with individual variables, were selected based on previous reported relationships to respiratory illness or postulated hypotheses driving this study.

Logistic regression was used to assess the risk of hospitalization or ambulatory visits for all respiratory illness for SGA compared to non-SGA babies, and to assess the role of preterm status. Linear regression was used to build predictive models for neighbourhood rates of: (1) hospitalization for all respiratory illness; (2) ambulatory visits for asthma; and (3) ambulatory visits for bacterial pneumonia. Hospitalization for all respiratory illness was chosen because it would represent the overall severity of respiratory morbidity in Saskatoon. Ambulatory visits for asthma was most likely influenced by housing characteristics. Ambulatory visits for bacterial pneumonia was chosen because the distribution of hospitalization and ambulatory visit rates are almost identical. Bacterial pneumonia is the most frequent specific cause of hospitalization in this study.

All independent variables were entered into the regression equations simultaneously, and each assessed in terms of what was added to prediction of the dependent variable afforded by all the other independent variables. The least significant variable ($p = >0.15$) was removed from the model, and the model re-run successively until only variables with p values of <0.15 remained in the model. An exception was made for two variables—percentage male infants and percentage SGA—which remained in the model for biological reasons. The level of chance observation acceptable in the final model was 15% ($p<.15$). All final models were assessed for fit using graphical methods.

Crude rates of hospitalization and ambulatory visits to physicians were reported as incidence densities per neighbourhood over the two-year period of the study. The cumulative number of hospitalizations or ambulatory visits per neighbourhood served as the numerator, and the cumulative number of child years that infants were followed in the neighbourhood served as the denominator. Geographic information system (GIS) was used to describe the spatial variation in health services utilization rates.

The sample included 6,297 children, all singletons born to Saskatoon mothers from 1992-1994. Six hundred and fifty-five subjects were missing residential information. They were included in the analysis, but could not be mapped. Thirty-three neighbourhoods were included in the study, sixteen of which were made up of 2 or 3 similar and/or geographically contiguous neighbourhoods (necessary due to a small number of children born in the study years in these neighbourhoods and in the interest of maintaining confidentiality) and one comprised of children with missing residential information.

The latter group did not differ significantly from other children in the study. One child with cystic fibrosis was excluded because children with cystic fibrosis are not at equal risk for respiratory illness. Multiple birth research is traditionally separated from singleton birth research.

Results

Individual Level Analysis

Of the 6,297 infants in this study, there were a total of 454 SGA infants (7.2%). Of these SGA infants, 53% (240) were male and 47% (214) female. A significantly higher percent (p=.01) of SGA infants were hospitalized at least once for respiratory illness compared to non-SGA infants (11% vs. 7.6%). SGA infants were hospitalized significantly more often for three of the seven categories: ENT infections (p = .003); bacterial pneumonia (p=.075); and upper respiratory illness (p=.05). The Mann-Whitney U-test detected a significant difference in the number of hospitalizations for all respiratory illness (p=.01). The highest average number of hospitalizations was among SGA preterm babies. There were no differences in ambulatory visits between SGA and non-SGA infants for any of the respiratory illness categories (p=.328), nor was there a difference in the odds of having an ambulatory visits for all respiratory illness.

The distribution of SGA babies is described in **Figure 1** using a graduated pattern to show the SGA percentages in each neighbourhood. The darker areas show the neighbourhoods with the highest percentage of SGA babies, while the lighter have lower percentages. There is a distinct concentration of SGA on the city's West side. The dark patch on the East side is an artifact of a grouping of neighborhoods that includes three neighborhoods, two of which are in the center of the city.

In order to consider the relationship between different birth outcomes and respiratory illness, SGA and preterm were dichotomized to produce four categories of outcome: non-SGA term; non-SGA preterm; SGA term; and SGA preterm. Eight percent (35) of SGA infants were born preterm. The chi-square for the Kruskal-Wallace, 63.394 (p=<.001), indicated that there was a highly significant difference in the ranked number of hospitalizations for respiratory illness between the four groups. The highest mean was found among SGA preterms, although the standard deviation in this group was also the largest. **Table 1** summarizes the mean number of hospitalizations per infant for each risk group.

Table 2 displays the odds ratios and 95% confidence intervals for each risk group compared to the reference group (non-SGA term babies). The p-value for the Wald statistic indicates that the hospitalization risk for respiratory illness for each group was significantly higher than the reference group. The highest hospitalization risk was found among babies with combined risks, SGA and preterm. SGA-preterm babies were almost four times more likely to be hospitalized for respiratory illness as non-SGA-term babies (OR = 3.931; 95% CI= 1.774, 8.712). The risk of hospitalization for non-SGA preterms was also high, almost three times that of non-SGA term babies (OR= 2.75; 95% CI = 2.047,3.706). It would appear, then, that preterm is the more important of the two risk factors. The risk of hospitalization for SGA-term babies was about one and a half times that of non-SGA term babies (OR= 1.47; 95% CI= 1.507, 2.067), indicating that only a slightly increased risk was conferred by SGA status.

Figure 1. Distribution of Small for Gestational Age (SG) in Saskatoon neighbourhoods, 1992-1994.

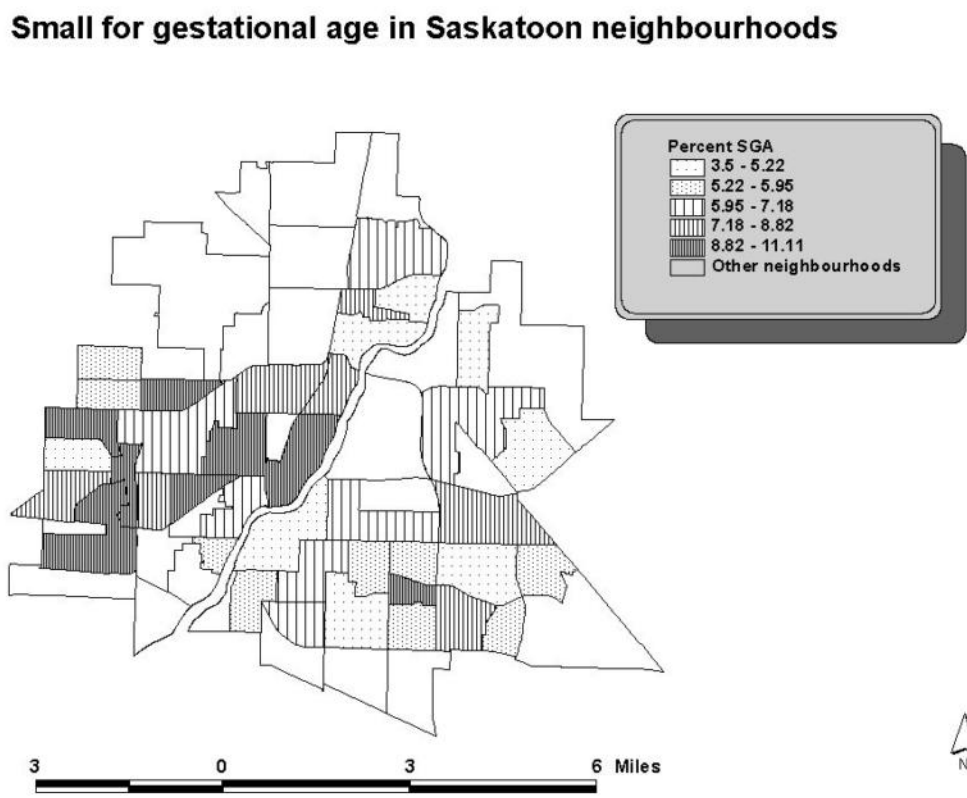


Table 1. Mean number of hospitalizations for all respiratory illness by SGA/term groups, Saskatoon, 1992-1994.

	Mean hospitalizations	Standard deviation	N
Non-SGA term	.1036	.5009	5494
Non-SGA preterm	.3410	1.1173	349
SGA term	.1456	.5748	419
SGA preterm	.4857	1.1212	35

Table 2. Odds ratios for hospitalization for respiratory illness.

	Odds ratio for hospitalization	P value for Wald statistic	95% CI for OR	
			Lower	Upper
Non-SGA preterm	2.76	<0.001	2.047	3.706
SGA term	1.47	0.022	1.057	2.067
SGA preterm	3.931	0.001	1.774	8.712

Reference group: Non-SGA term

Logistic regression was used to assess whether term status was an effect modifier or a confounder in the relationship between SGA and hospitalization for respiratory illness. The Log Likelihood ratio test indicated that there was no interaction between SGA and hospitalization for respiratory illness at different levels of term status. The crude odds ratio for SGA compared to non-SGA was 1.50 (p = .01). The adjusted odds ratio, controlling for preterm status, was 1.47 (p = .015). Because the adjusted odds ratio was not appreciably different from the crude risk ratio, preterm status was not assessed to be a confounder. Preterm status, then, is an independent risk factor for hospitalization for respiratory illness.

There was no statistical difference in the mean number of ambulatory visits for all respiratory illness. The p-value for the Wald statistic indicated that there was only one significant risk group. SGA preterms had 70% less risk of making an ambulatory visit to physicians for a respiratory illness than non-SGA term babies (OR = .303; 95% CI= .132, .699). This protective effect was not expected. One possible explanation may be the higher mortality rate among SGA babies compared to non-SGA babies (3.3% vs. 0.6%). Another explanation may be the higher proportion of all children who had visited a physician, presenting a very small variation among the SGA-term risk groups. Almost all subjects in the study (95%) visited a doctor at least once for respiratory illness on an ambulatory basis.

Ecologic Level Analysis

Comparison of health service utilization rates for respiratory illness by neighbourhood

Crude hospitalization rates for all respiratory illness were divided into quintiles for comparison. The chi-square for the Kruskal-Wallis test found a highly significant difference in the mean hospitalization rate for the five groups of neighbourhoods ($p < .001$). The highest hospitalization rates for all respiratory illness ranged from 107 to 170 hospitalizations per 1000 child years. The lowest rates ranged from 14 to 25 hospitalizations per 1000 child years. The distribution and location of these groups are mapped in **Figure 2**.

Figure 2. Distribution of hospitalization for all respiratory illness in Saskatoon neighbourhoods, 1992-1994.

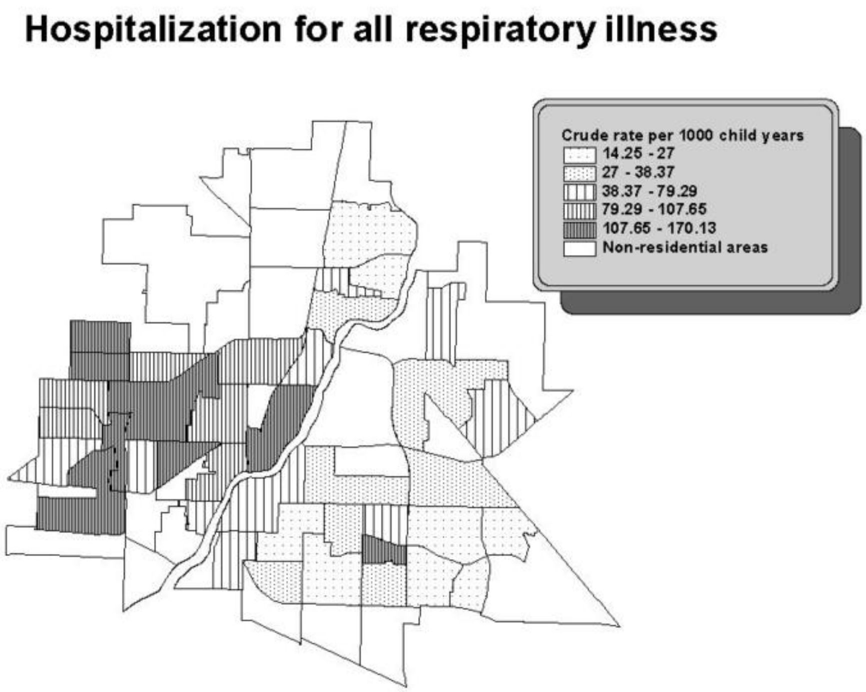


Figure 2 shows that the highest crude hospitalization rates for all respiratory illness (darkest areas) are found almost exclusively on the city's West side, while the lowest crude rates (lightest areas) are found on the south part of the city's East side and in the North end.

Crude rates of ambulatory visits to physicians for all respiratory illness were also divided into neighbourhood quintiles for comparison. The ANOVA was used to compare the mean rates of visits to physician per subject. The F-statistic, 99.967 ($p = < .001$), suggests that there is a highly significant difference in the crude rate of ambulatory visits for all respiratory illness among the five neighbourhood quintiles. Post hoc tests show that there were no differences between the second and third quintile. However, there were differences between all other quintiles.

The highest rates range from 4.66 ambulatory visits per child year to 5.16 per child year, while the lowest rates range from 2.99 to 3.52 ambulatory visits per child year. The distribution and location of these neighbourhoods is mapped in **Figure 3**. The second and third quintiles have been grouped together as the differences between these two groups were not statistically significant.

Figure 3. Crude rates of ambulatory visits for all respiratory illness by Saskatoon neighbourhoods, 1992-1994.

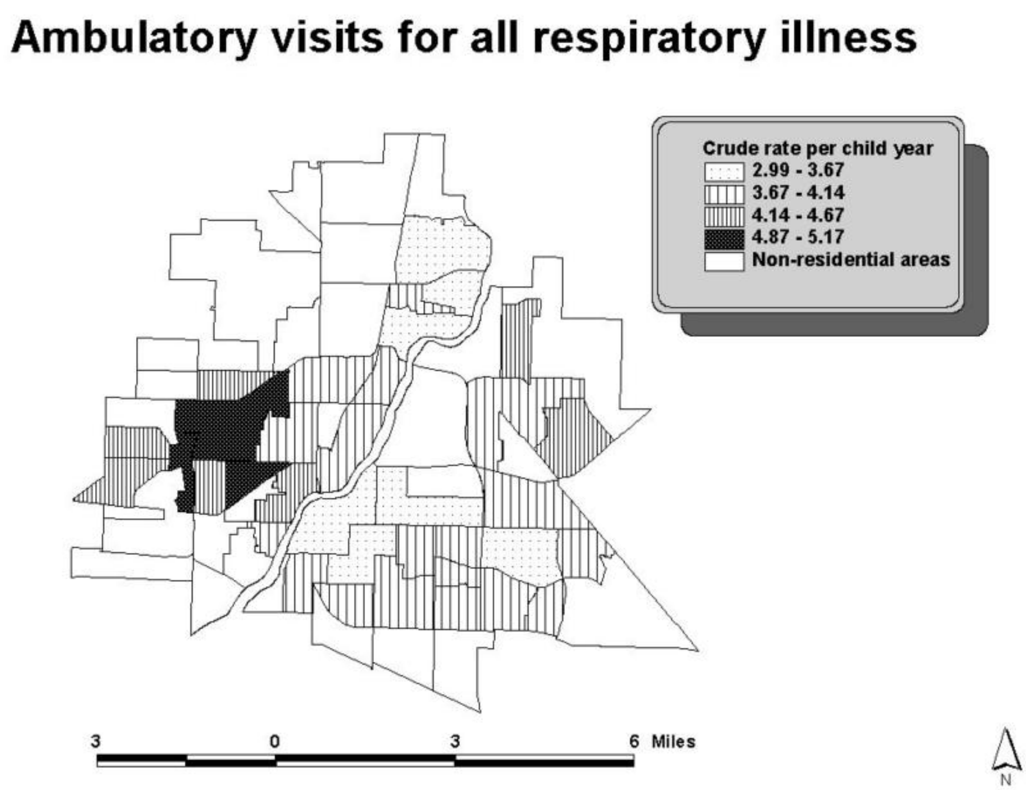
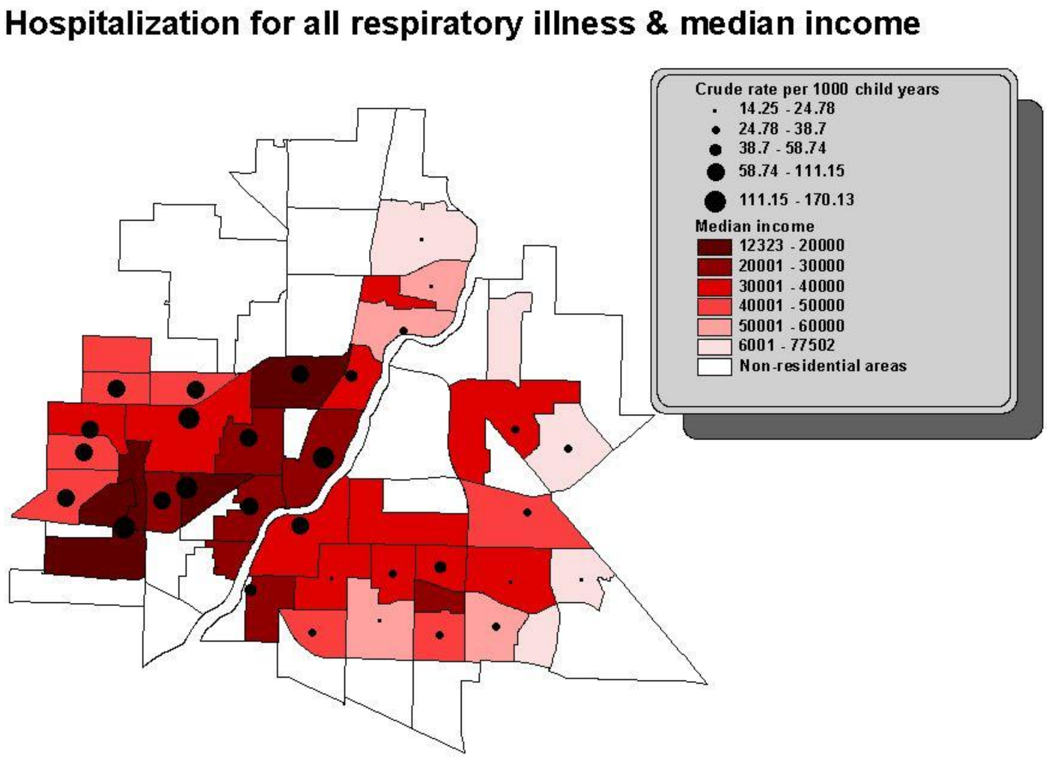


Figure 3 shows the distribution of ambulatory visits for all respiratory illness by neighbourhood. The highest crude rate of ambulatory visits is found on the city's West side, and the lowest on the East side and North end.

Figure 4. Distribution of crude rate of hospitalization and median income, Saskatoon neighbourhoods, 1992-1994.



Predictive Models

Hospitalization for all respiratory illness

The neighbourhood-level predictors of hospitalization rates for all respiratory illness were percentage of employment, percentage of dwellings constructed before 1971, percentage of population under age 10, and neighbourhood median income. The multiple correlation coefficient for the model with six predictors was estimated as .839. The adjusted square of the coefficient was .635, indicating that 63% of the variability of respiratory illness hospitalizations can be explained by the final main effects model with six predictors. For every percent increase in employment, there were two fewer hospitalizations per 1000 child years. For dwellings, there was a threshold effect. Neighbourhoods with 20-30% of dwellings constructed before 1971 had 36 more hospitalizations per 1000 child years than those with 90% of houses constructed in the same period. In other words, more houses constructed before 1971 meant fewer hospitalizations. For every $10,000 increase in neighbourhood median income, there was a decrease of 9 hospitalizations per 1000 child years. There was a threshold effect for percentage of population under age 10 years. Neighbourhoods with more than 18% population under age 10 years had 35 more hospitalizations than neighbourhoods with less than 13%. Percentage SGA and male infants did not contribute significantly to the model, but were kept due to biological significance.

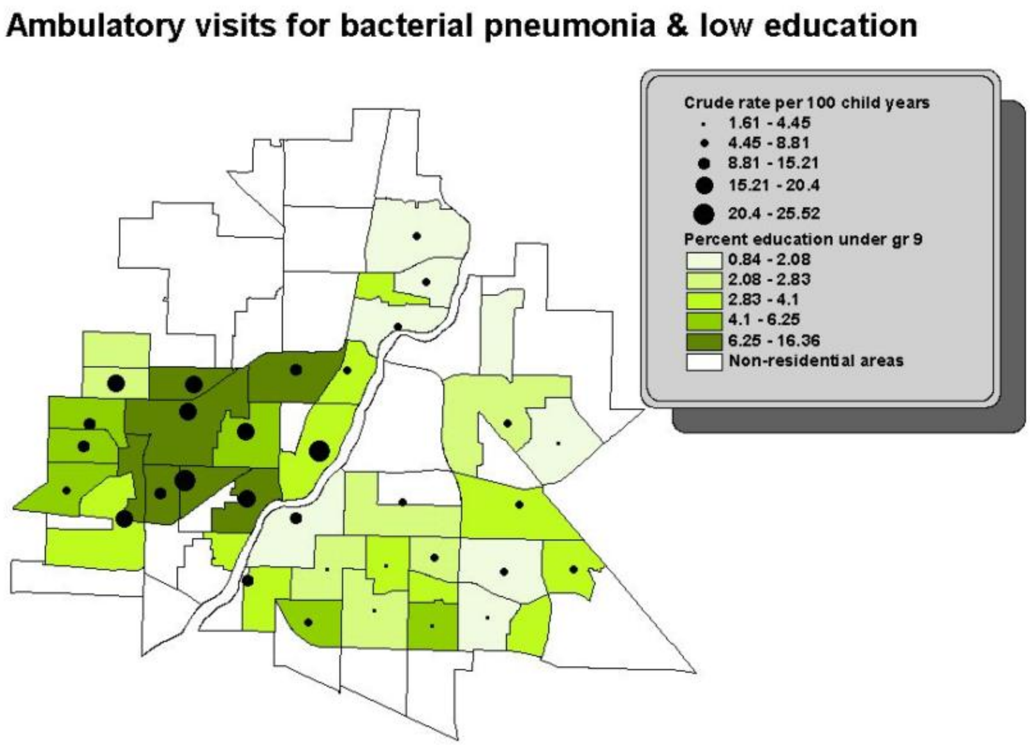
Figure 4 shows the bivariate relationship between crude hospitalization rate and one significant predictor, neighbourhood median income. Darker areas identify neighbourhoods with lower incomes. Larger dots identify higher hospitalization rates. Large dots generally correspond with dark areas, small dots with lighter coloured areas, indicating a concordance between hospitalization rates and income. The overall distribution of hospitalization shows a distinct concentration on the city's West side.

Ambulatory visits for bacterial pneumonia

Neighbourhood ambulatory visit rates for bacterial pneumonia were predicted by percentage of low education, percentage of rental tenure, percentage of duplexes, and percentage male infants. The multiple correlation coefficient for the model with four predictors was estimated as .825. The adjusted square of the coefficient was .636, indicating that 64% of the variability of ambulatory visits for bacterial pneumonia can be explained by the final main effects model with five predictors. For every increase in percent of population with low education (less than grade 9), there was an increase of 109 ambulatory visits per 1000 child years. For every percent increase in rental tenure, there was an increase of 17 visits per 1000 child years. There was a decrease of 4 visits per 1000 child years for every percent increase in duplexes, and an increase of 3 visits per 1000 child years for every increase in percent male infants.

Figure 5 shows the distribution of crude rates of ambulatory visits for bacterial pneumonia and one significant predictor, percentage low education. The darker areas represent neighbourhoods with low education (i.e. a higher percentage of the adult population with education under grade 9). The larger dots indicate neighbourhoods with the highest rates of ambulatory visits for bacterial pneumonia. There is a strong concordance between high rates of low education and high rates of visits for bacterial pneumonia. There is a distinct concentration of high bacterial pneumonia rates on the city's West side.

Figure 5. Distribution of ambulatory visits for bacterial pneumonia and education, Saskatoon neighbourhoods, 1992-1994.



Ambulatory visits for asthma

The neighbourhood-level predictors of ambulatory visits for asthma included percentage of employment, percentage of dwellings constructed after 1985, percentage of SGA, and percentage of male infants. The multiple correlation coefficient for the model with four predictors was estimated as .470. The adjusted square of the coefficient was .11, indicating that only 11% of the variability of ambulatory visits for asthma can be explained by the final main effects model with four predictors. For every 1% increase in SGA babies in the neighbourhood, there was an increase of 7 asthma visits per 1000 child years. For every 10% increase in dwellings constructed after 1985, there was an increase of 6 visits per 1000 child years. For employment, there was a threshold effect—neighbourhoods with 75% employment had 75 more visits per 1000 child years than neighbourhoods with only 40-50% employment. Percentage of male infants was kept in the model for biological reasons.

Figure 6. Distribution of crude rate of ambulatory visits for asthma and dwellings constructed after 1985. Saskatoon neighbourhoods. 1992-1994.

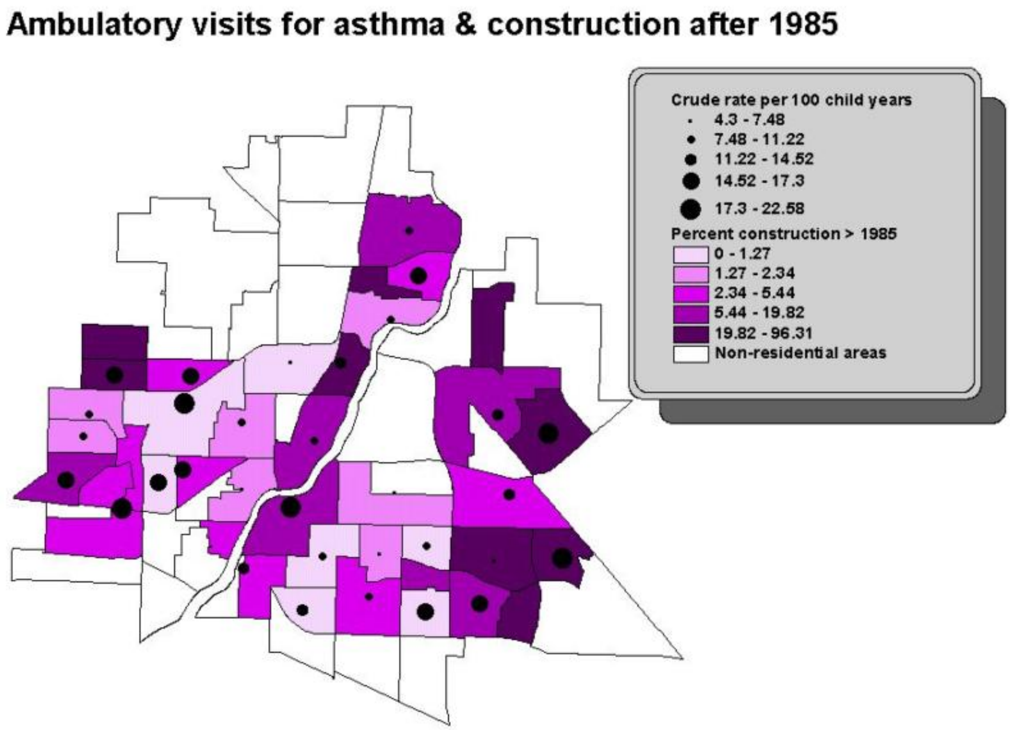


Figure 6 shows the distribution of one significant predictor—percentage of dwellings constructed after 1985—with ambulatory visits for asthma. The darker areas, depicting the highest percentage of dwellings constructed before 1985, show concordance with the larger dots that show higher rates of ambulatory visits. In contrast to the maps of hospitalization and of bacterial pneumonia, the distribution of asthma is fairly heterogeneous throughout the city.

Discussion

The two morbidity measures used in this study are hospitalization and ambulatory visits to physicians. Each measure tells us something slightly different. Hospitalization is believed to be a more accurate measure of illness severity, while ambulatory visits measure both severity and other psychosocial factors, such as attitudes towards health care and health-care-seeking behaviour. Together, they present a picture of total morbidity, though this picture is sometimes contradictory. The question of why respiratory morbidity is higher in some areas than in others is central to this research.

Respiratory illness is not a random event. If the respiratory illness rate differs significantly between neighbourhoods, there must be a set of circumstances that causes or influences the disease. Individual characteristics, such as level of illness or other biologically predisposing factors, influence health services utilization. This study's results suggest that more SGA babies are hospitalized for respiratory morbidity than non-SGA babies, but that SGA babies do not necessarily have more ambulatory visits. In this study, preterm status accounted for much of the observed increased risk for hospitalization. Prematurity was an independent risk factor, and had an additive effect. Babies who had a combined preterm and SGA risk were four times as likely to be hospitalized. However, preterm non-SGA babies also had three times the risk of hospitalization. As for the number of ambulatory visits, these preterm non-SGA babies had the highest mean number of visits per infant. In other words, whether SGA or not, preterm babies have significantly increased risk of serious respiratory morbidity.

How do these individual biological risk factors interact with socio-environmental risk factors? Biological risk factors may interact with individual level SES factors, such as family income, but they may also interact with neighbourhood SES factors. Just how a sense of neighbourhood—the immediate social environment—influences health behaviour in individuals is not well understood.

This study examines socio-economic patterns that may explain variations in respiratory illness rates. A socio-economic pattern of disease is a distribution of disease that shows close concordance to the distribution of several SES variables. In this study, there was no evidence of strong socio-economic patterns in neighbourhood percentages of SGA infants hospitalized or making ambulatory visits to physicians. However, there was a strong socio-economic pattern to the overall distribution of SGA. The highest percentages of SGA infants were concentrated in the inner city and on the West side where SES is generally lower. There was also a strong socio-economic pattern to the distribution of hospitalization rates for ENT, bacterial pneumonia, and upper respiratory illness, the three respiratory illness categories for which SGA babies were hospitalized significantly more often. In other words, these disease categories share a distribution in common with both lower SES and SGA. Therefore, socioeconomic variables may interact with the relationship between SGA and respiratory illness.

Ecologic or aggregate measures of independent variables of SES cannot act as proxies for individual level variables. However, several studies have suggested that socioeconomic characteristics of neighbourhoods predict morbidity over and above individual SES characteristics (Diez-Roux et al, 1997; O'Campo et al, 1997) as well as in interaction with individual characteristics (Pearl et al, 2001). Looking at all infants in Saskatoon, regardless of SGA or preterm status, we see definite concentrations of respiratory morbidity in West side neighbourhoods. There are clearly socioeconomic patterns for hospitalization for all respiratory illness and ambulatory visits for bacterial pneumonia, but no such patterns for asthma.

That SES distribution shows varying degrees of concordance with the different distribution of different respiratory illness categories probably indicates that SES plays a stronger role in the development of some respiratory illnesses than others. That the distribution of hospitalization and ambulatory visits are similar for one disease category but not another is likely related in part to illness severity. Low SES is an important risk factor for most illness, but it has been observed in the literature that risk associated with lower socioeconomic status is not always consistent (Graham, 1994). Different findings illustrate that different measures of socioeconomic status can behave differently in predicting respiratory illness.

An important distinction in the field of small area analysis is between compositional and contextual explanations for spatial variations. Compositional explanations for area differences assume that differences in groups of individuals account for observed differences between places. Contextual explanations argue that social or physical environment influences the health of those exposed to that environment (Macintyre and Ellaway, 2000). The research literature agrees that SES is a stronger risk factor for lower respiratory illness than upper respiratory illness (Graham, 1994; McConnochie et al, 1995). Bacterial pneumonia, for example, shows strong socio-economic patterns or "clustering" of rates and percentages of hospitalization and ambulatory visits. This clustering could be explained as a contextual effect of living in a depressed physical environment where, for example, houses are poorly heated and overcrowded. These rates could also be explained as a compositional effect of people who smoke more and breast-feed less.

We have only a theoretical understanding of how SES "gets under the skin." In this study, there was a range of differences in the use and frequency of health services across Saskatoon neighbourhoods. Large differences were seen in the percentage of children hospitalized in each neighbourhood, ranging from 2.8% to 21%. Children in West side neighbourhoods clearly had more respiratory illness, as measured by proportion and frequency of hospitalization and ambulatory visits. In other words, more children in West side neighbourhoods were hospitalized and visited doctors for respiratory illness than children living elsewhere in the city. These same children were also hospitalized and visited doctors more often. Because hospitalization is an indicator of severity, such differences indicate important differences in levels of severity of respiratory illness across Saskatoon. The neighbourhoods with the highest hospitalization rates for all respiratory illness were found exclusively on the West side of Saskatoon. Neighbourhoods with the highest ambulatory visits rates for all respiratory illness were not exclusively on the West side, but were highest for three out of seven specific respiratory illness categories. East side neighbourhoods had equally high or higher rates of ambulatory visits for ENT infections and asthma, particularly neighbourhoods on the city's eastern perimeter.

Housing is closely linked to SES. Housing characteristics were significant predictors in all three models for respiratory illness rates. To our knowledge, there have been no studies that examine the relationship between period of construction and respiratory illness. However, the literature on construction practices suggests that houses built before the energy crisis of the 1970's have higher air-exchange rates than newer housing (Esmen, 1985; CMHC, 1992). This would explain why neighbourhoods with more houses built before 1971 (i.e. with higher air exchange rates) have fewer children with respiratory illness. Air-exchange or ventilation, besides playing a critical role in controlling humidity and temperature inside homes, determines concentration of such indoor air risk factors as smoke, mould, allergens, volatile organic compounds, and other airway irritants (Seltzer, 1996; Koenig, 1997). Inadequate ventilation has been associated with increased respiratory infection rates (Fuchs et al, 1996; Brundage et al, 1988).

The volume of ambulatory visits for bacterial pneumonia decreased in neighbourhoods with higher percentages of duplexes, but increased with increase in rental tenure. At first glance, duplexes and rental tenure seem to be mutually inclusive because duplexes are usually rented in Saskatoon. However, rental tenure covers all dwellings, including houses, apartments, and duplexes. Duplexes are often low-rent accommodations in older neighbourhoods. It is not clear what exact exposures, physical or social, that duplexes may include. Duplexes may act as a surrogate for some other characteristic, such as health behaviour.

The positive correlation between houses built after 1985 and asthma is biologically plausible given evidence regarding construction practices that have emphasized energy conservation and resulted in very air-tight houses. A Canadian survey of 200 houses built in the late 1980's predicted, on a mathematical model, that 70% were so air-tight that the air leakage rate during the heating season would be less than the generally recognized minimum acceptable rate of 0.3 ACH (air changes per hour). Of the 200 homes surveyed, tests showed that the tightest new houses in the early 1980s were built in Manitoba and Saskatchewan (CMHC, 1992). Poorer ventilation in combination with volatile organic compounds found in new carpeting, glue, sealants, and furnishings (common respiratory irritants in new homes) could well produce environments conducive to asthma. Although the predictive model adequately fitted the data, it explained only 11% of the variation in ambulatory visits to physicians. Clearly there are other factors influencing ambulatory visits for asthma.

As with all ecologic studies causal relationships based on aggregated characteristics of geographic areas cannot be inferred to individual level relationships for those living in these areas (ecologic fallacy). The p-value of $<.15$ was liberal compared to the standard permissible level of chance observation, .05, in most models assessing causation. The purpose of the ecologic study was not to assign causation. Ecological correlations may be valid even if they do not reflect individual correlations (Macintyre, 2000). The usefulness of ecologic studies and what they say about health lies in the inference made about the setting and interpretation of the correlations. In this study, because the joint distribution of relevant variables are missing, the most valid inference one might make is that certain neighbourhood and housing characteristics lead to subcultural factors implicated in respiratory illness in children. Subcultural factors may include parenting practices, attitudes to health care-seeking behaviour, and health behaviours such as smoking and breast-feeding. Housing is an integral part of lifestyle, influencing behaviour related to disposable income and other factors important to health.

Implications for Policy, Practice, and Research

In this study, there are some neighbourhood characteristics, such as dwelling construction period, that are static, while others, such as employment percentage, are flexible and can potentially change. Targeting certain neighbourhoods for interventions, such as adult education programs, special skills training, or employment opportunities may not only address health disparities but may also improve the quality of life for everyone in the community by "releasing" resources that might otherwise be spent on health care.

Multivariate modeling provides an opportunity to calculate the costs of health care related to SES factors. Resource intensity weights (RIWs), values derived to reflect resource use associated with a given hospitalization, can be multiplied by the cost per weighted case of the applicable fiscal year to estimate the cost of hospitalization. Based on estimates from Saskatchewan hospital services for 1995/96 the cost of hospitalization per weighted case was $2,031.47. The median cost of hospitalization for bacterial pneumonia in this study was therefore estimated to be $1,280 in 1995/96 (.63 * 2.031.47). Bacterial pneumonia, which accounted for 26% of all hospitalization for children aged under two years in this study, may have cost between $255,000 and $320,000 (based on the median and mean, respectively) over the two year period. Stating this cost estimate in terms of results from our multivariable modeling, a neighbourhood with ten excess hospitalizations for bacterial pneumonia in this time period, compared to a reference neighbourhood, incurred an increased cost of at least $13,000 for hospitalization. The total cost for ambulatory visits for bacterial pnuemonia, summarized directly from the physician services file before multiple records were removed, was $56,987.38. A neighbourhood with one hundred excess ambulatory visits would therefore have incurred a cost far in excess of between $46,875.00 ((2.5*$18.75) * 100) and $87,625.00 ((2.5*$35.05) * 100) in total services compared to a standard neighbourhood.

Consideration of cost-effectiveness may persuade some policy-makers of the financial soundness of investing in community health and development. However, the linear regression model does not provide a formula for reducing health disparities. Rather, it serves to illustrate the complexity of inter-related characteristics. Identifying significant predictors of specific types of illness may also be useful to inform and augment city planners' knowledge about the desirable composition of neighbourhoods.

While many clinicians understand the health effects of income and education on their patients, they also need to appreciate those health behaviours related to exposure to stressful challenges and the resources that the patient has to deal with such challenges. Practitioners should be aware of possible interactions between individual level risk factors, such as prematurity and SGA status, and other risk factors related to the child's environment. For example, an SGA preterm baby living in a poorer neighbourhood may benefit from some extra parental coaching on ways to improve illness management, breast-feeding's benefits, and second-hand smoke's effects.

Public health has a long history of promoting healthy environments to reduce communicable disease. In 1997, the Children and Youth Population Health Advisory Board suggested strategies for reducing respiratory disease in infants, including developing an educational strategy for parents to improve respiratory disease condition management, a continued effort to restrict smoking in public places, and educate new parents about second-hand smoke's effects. They also suggested that public health promote the removal of barriers to breast-feeding and work with other agencies to improve the environment of infants living in poor housing conditions (SDH, 1997).

Neighbourhood-specific targeting of vulnerable children may alleviate some of the excess morbidity, but there is still much work to be done to understand the pathways from SES to health. Multi-level research that examines how neighbourhood variables interact with individual characteristics has the potential to provide new evidence that will help target interventions to specific areas and groups.

CONCLUSIONS

Environmental exposures and social stressors play a part in increased susceptibility to respiratory infection. These risk factors are hazardous to all children, but some may be more vulnerable than others. Results of this study suggests that babies who are both preterm and SGA may be particularly susceptible to adverse housing and neighbourhood characteristics. There are also important geographic variations in respiratory illness for all children in Saskatoon, regardless of SGA status.

Child health in the early years is an important determinant of child development. An increasing body of literature suggests that the early years are critical to future health and development, and to long-term well-being. This study provides a preliminary understanding of the impact of housing and neighbourhood characteristics on respiratory morbidity in children aged 0-2 years. This is a first step toward understanding biological pathways that explain associations between low SES and increased respiratory morbidity. While this study supports the research hypothesis that housing characteristics in the presence of other neighbourhood characteristics show a significant impact on health service rates for respiratory illness, these findings should be interpreted cautiously.

Research on specific indoor exposures, as well as broader social exposures, will be important for developing policies and interventions that may reduce disparities in child health.

From a population health perspective, there is a strong need for continued use of local, small area information for health planning purposes. This research has benefited from, and will contribute to, various early childhood-related initiatives in Saskatoon, such as Understanding the Early Years (UEY), Saskatoon Communities for Children, and Success By Six.

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