SPATIAL VARIATION IN RESPIRATORY DISEASE IN HAMILTON, ONTARIO

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ABSTRACT

The main objective of this study is to examine the effects of the outdoor environment as well as confounding indoor environmental factors upon school-age children in Hamilton, Ontario. This research paper allows for the spatial variation of respiratory disease to be outlined according to five regions of Hamilton: West Mountain, East Mountain, West Lower, East Lower, and North Barton. Due to the high concentration of pollution in the East Lower region, the area north of Barton Street was considered a region in itself. Information was obtained from a study conducted by Dr. L.D. Pengelly of the Urban Air Environment Group and Department of Medicine of McMaster University in 1982. The sample used in the study consisted of 3500 school-age children in conjunction with the Hamilton Board of Education. The data was collected in two ways: a questionnaire conducted by a trained interviewer which took place in the individual household, regarding the child's health history, their home and family as well as pulmonary testing within the schools. Sample characteristics were compiled to evaluate response variations between regions. The results show that as the outdoor environment worsens or approaches the industrial core, several respiratory symptoms increase in occurrence indicating the impact of external pollution on respiratory health. The key indoor factor of parental smoking tends to have the most effect on respiratory symptoms, especially wheeziness for all five regions of Hamilton with gas stove use and forced air heating showing little if any significance.

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CHAPTER 1 : INTRODUCTION

Medical geography is concerned with the effects of the environment upon the population. The relationship between human health and air pollution has been a concern of researchers for several years. In Southern Ontario, the effects of industrial emissions on respiratory health has become a major focus of study. Specific cause and effect relationships between respiratory health and air pollution are identified through epidemiologic studies which examine the distribution and determinants of disease frequency in populations. The geographer plays a key role in identifying the spatial variation of disease outcomes. As of late, external air pollution has decreased; therefore, bringing about a research interest into indoor environmental factors and their effect on respiratory disease.

The purpose of this research is to provide a better understanding of spatial variation in respiratory disease in Hamilton, Ontario. Through this study, the effects of external air pollutants, as well as confounding indoor environmental factors such as parental smoking, gas stove use, and forced air heating upon children will be sought. Possible long-term effects based on personal histories of the children will also be considered.

This study involves a secondary analysis of data collected in a prospective cohort study of the respiratory health of children conducted by Dr. L.D. Pengelly of McMaster University. In order to observe the spatial variations of respiratory disease in Hamilton, the city was divided into five regions: West Mountain, East Mountain, West Lower, East Lower, and North Barton. Respiratory disease will be observed in two ways. The first is through pulmonary testing within the elementary schools. The second is through a questionnaire which reported several past and present respiratory symptoms. The six symptoms to be included in this study are cough in the morning, cough day or night, wheeziness, asthma, chest illness, and chest illness before the age of two. Not only did this questionnaire include past health histories, but it also accounted for indoor environmental factors such as parental smoking and gas stove use which may in turn also affect the respiratory performance of the child.

In dealing with respiratory disease, both outdoor and indoor variables affect the performance of the child. Since outdoor air pollution has been stabilizing over the past decade, the emphasis of this paper will be on indoor air pollution. With Southern Ontario as the focus of the study, the ever-changing environmental conditions play a key role in health outcomes; therefore, several ongoing studies are necessary in order to identify the key factors responsible for increased respiratory disease symptoms whether they be indoor or outdoor oriented.

This study will provide a literature review which encompasses previous studies which deal with indoor and outdoor environmental effects on the respiratory health outcomes of children, in order to see the consistency between this study and past studies. Chapter three will outline the methodology as well as present an analytical model of respiratory disease in order to identify the perspective relationships between health and relative risk factors. The data analysis will be presented in chapter four whereby the key relationships of respiratory health and environmental factors will be observed.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

The state of the environment is a concern facing not only geographers, but all of society. The relationship between human health and air pollution has been a concern of researchers for several years. Recently, a direct link has been found between respiratory disease and air pollution. (Ziegenfus, 1987) Industrial activity in cities is a major determinant of urban air quality and therefore, potentially affects the health status of the residents. In order for these relationships to be identified, epidemiological studies are conducted to examine the distribution and determinants of disease frequency in populations. Geographers in turn, study the spatial variation of disease causation, thus, providing the basis for studying the relationship between air pollution and respiratory disease. (Jones & Moon, 1987)

In order to further understand the relationship between air pollution and respiratory disease in children, an analytical model will be developed from the literature review. This model will demonstrate the interdependence of the independent variables (such as outdoor air quality), mediating variables (such as indoor air quality and the general health status of the children), and outcome assessment (health status as determined from pulmonary testing, the presence of respiratory symptoms, independent variables, and mediating variables).

The following literature review will not only examine recent studies with regard to the relationship between air pollution and the respiratory health of children, but will also demonstrate the need for examining the indoor (home and school) environment of the children before drawing conclusions.

2.2 Urban Air Pollution

In studying the effects of air pollution, a complex set of factors must be considered. These factors include particulate matter in the air, NO_2 and SO_2 concentrations, and industrial influences. A lack of consensus among experts as to the danger that various pollutants present to society exists today.

There are two main forms of urban air pollution: i) sulphuroxides and oxides of nitrogen, and ii) secondary pollutants which are photochemical oxidants that form as a result of reactions in the air (Ziegenfus, 1987). The relevance of studying these pollutants with respect to respiratory disease is that the main effect of SO_2 is as an irritant to the human respiratory system, whereas NO_2 tends to lower lung function and increase chronic bronchitis

(Massey, 1972). As a result, the size and amount of these particulates play an important role in the spatial variation of respiratory disease.

There are several ways to measure external air pollution. One way that was commonly used in past studies was a 24-hour TSP (total suspended particles) sample collected on a 6-day regular basis in various sites throughout the selected area. It was found that NO_2 was more closely monitored because SO_2 levels were less than 40 $\mu g/m^3$ which was too low to base conclusions upon. (Love et al., 1980) In contrast, Binder et al. used samplers which children carried with them in order to measure pollution. One aspect which was different among these studies was the categorical grouping into high, medium, and low exposure levels with each study having their own criteria for each group. The Ontario objective for total suspended particles in the air was 60 $\mu g/m_3$ in 1978. However, in Hamilton, the TSP measured over 77 $\mu g/m_3$ in that same year. The Ontario objective for SO_2 levels was 0.02 ppm in 1978. Hamilton measured 0.016 ppm in that year. Therefore, as the level of outdoor air quality begins to improve, the focus when studying the spatial variation in respiratory disease now shifts towards indoor air quality. (Kerigan et al., 1986).

2.3 Mediating Variables

There are several variables which contribute to the severity of respiratory disease. In order to study the cause and effect relationship between these variables and respiratory disease, the concepts of causation and multiple regression must be understood. Causation is the relationship between two variables in so far as a change in the independent variable (X) produces a change in the dependent variable (Y). However, with respect to this study, several independent variables are involved so that parental smoking, forced air heating, and gas stove use will interact with each other and in turn affect the respiratory health status of children.

Low concentrations of indoor air pollution, over extended periods of time, can contribute to an individual's total exposure to pollutants. Three factors can govern exposure to indoor pollutants: air-exchange rate, smoking, and household activities such as gas stove heating and/or cooking. Exposure can be defined as the amount of substance present at the point of contact with a surface through which the pollutants can penetrate. (Ziegenfus, 1987) There are three pathways to exposure: air, food and water. Understanding exposure, means accepting that every minute of every day, individuals are susceptible to the entry of pollutants into their body, either through direct or indirect means. The level of one's exposure to various pollutants, whether they be indoor or outdoor, plays a key role in determining their health status.

In a study recently conducted by Ziegenfus, it was determined that 95% of the aged, infirm, and mothers with young children are inside for the better part of the day. With these statistics, along with the fact that there is an increase of NO_2 emissions in the home within the last decade, the focus of research in studies of respiratory disease symptoms in children, has increasingly been on the effects of indoor environment.

Public awareness of individual contribution to air pollution is low. In fact, indoor activities on the part of the general public (such as parental smoking for example), will begin to affect health status more than community air pollution.

Respiratory disease is prominent in all societies and is considered a diversified non-infectious morbidity cause including such orders as asthma and bronchitis. Not only is respiratory disease considered non-infectious, but it is also part of chronic degenerative diseases which are responsible for the majority of deaths of people over age 60 in economically advanced countries (Jones and Moon, 1987). By studying respiratory disease in children, perhaps causes may be identified and controlled and therefore the mortality rates due to chronic degenerative disease in the older population may be reduced. Of the several studies reviewed, the one common feature was the decision to use children as the sample group. Children present a non-professional, non-smoking group, they have developing lungs which are more sensitive to pollution and have not been extremely mobile within the first few years; therefore, they represent a stable and generally uninfluenced sample of the population.

2.4 Outcome Assessment

Studies conducted by Melia, Ware, and Tager examined the effects of parental smoking, air pollution and gas stove use on respiratory illness. Most, if not all, have conducted questionnaires and interviews to gain personal and health history information of the children and have performed similar pulmonary testing procedures on the children as well as gathered external air pollution levels in the same manner.

With regard to the questionnaire, the type of questions asked reflect the purpose of the study. For those interested in parental smoking as the independent variable, questions involved history of respiratory symptoms, smokers in the house, medical background, quality of the dwelling to control for pollution, and demographics. (Ware et al, 1983) If the independent variable in question was the use of gas stoves, the questions involved home-cooking devices, home-heating fuels, air-conditioning presence, and ventilation. (Speizer et al., 1979) The questionnaires for all cases were conducted on a personal interview basis with the guardian(s) of the child in the home.

The methods used for measuring pulmonary function were expiratory maneuvers, one of which was spirometry which involves the child breathing into a machine to measure his/her forced expiratory flow (FEF), forced expiratory volume (FEV), and forced vital capacity (FVC) and/or multiple breath nitrogen washouts. (Pengelly et al., 1983)

Table 2.1 : Pulmonary Function Testing

TEST	DESCRIPTION	REFLECTION
Forced Vital Capacity (FVC)	The maximum volume of air exhaled followed by maximum inhalation.	Lung size. Small and large airways.
Forced Expiratory Volume (FEV_1)	Measurement taken in the first second of FVC.	Medium to large airways obstruction.
Vital Capacity (VC)	Different from forced vital capacity in that air is exhaled voluntarily.	Lung size.

In Table 2.1, the pulmonary tests used in this study are described (Polgar et al., 1971). Concentrating on the FEV_1FVC test would be beneficial for this study. This test is a combination of the two tests FEV_1 and FVC explained above. The forced expiratory volume in the first second to the forced vital capacity ratio, indicates lung size, as well as the limitations of the large, medium, and small airways. This test will allow the researcher to see the indirect effects of smoking and/or the presence of gas stove use on the respiratory health status of children. In order to interpret the results of this test correctly, the age, sex, height, and weight of the child must be considered. For example, the lung size and thus, the available volume of air carried by an older and larger child will be greater than that of a smaller child. The most common method used was spirometry which was used in several studies such as Ware et al., 1979, and Holland et al., 1965.

2.5 Determinants of Children's Pulmonary Function

2.5.1 NO_2 Exposure (Gas Stoves) as the Independent Variable

The following studies focused on the relationship between air pollution (external) and gas stove use as they effect the pulmonary function of children. Melia et al. conducted a study in 1973 with the purpose of examining the relation between respiratory illness and indoor air pollution arising from cooking fuels, specifically gas and electricity. The sample consisted of 5758 school age children from 28 randomly selected schools several of whom were found to have had more coughs, colds going to the chest, and bronchitis when gas stoves were in use. Girls in particular experienced more coughing according to Wade et al. who found the NO_2 level in kitchens to be greater than 0.05 ppm. The conclusions stated by Melia et al. were independent of other household activities and thus, supported the relationship between NO_2 emissions and respiratory illnesses.

Speizer et al. carried out a similar study in 1979. The sample consisted of 9,280 school-age children. About one-half of the homes in 6 U.S. cities had gas cooking stoves, and about one-half had electric cooking stoves. It was found that children exposed to gas stove cooking experienced greater respiratory illness before the age of two. It was also shown that NO_2 levels were four to seven times higher in the homes using gas stoves than those using electricity. Speizer et al. also considered parental smoking in their questionnaire, but the effect was independent of those for gas stoves.

2.5.2 **Parental Smoking as the Independent Variable**

The following studies focused on the relationship between air pollution and parental smoking, differentiating between paternal and maternal smoking in the home as they affect the pulmonary function of the child. Ware et al. (1983) studied 10,106 white children in 6 U.S. cities. They concluded that there was an increase of 20-35% of respiratory symptoms in children exposed to maternal smoking, with only a small increase for paternal smoking. They also found lower pulmonary function in children currently exposed to second-hand smoke than those with parents who are ex-smokers.

Tager et al. (1974) conducted a similar study. The sample consisted of 444 school-age children in Boston comprised of mostly Italian-American descent. Their results showed a significant decrease in children's pulmonary function with increased parental smoking.

Binder et al. (1973), employed a unique method of data collection. The sample consisted of 265 children in Connecticut who spent 60-80% of their time indoors. The children were monitored on a 24-hour basis through a sampler that they carried with them throughout the day. Binder et al. concluded that one factor in particular affected pulmonary function -- cigarette smoke. Nineteen out of twenty children exposed to domestic smoking had exposure levels higher than those recommended by the air quality standards.

2.6 The Hamilton Study

The data for this analysis came from a study conducted by Dr. L.D. Pengelly of McMaster University between 1979 and 1983. Dr. Pengelly is a member of the Urban Air Environment Group and works in conjunction with the Department of Medicine. This study set out to answer two questions: Is there and effect on children's respiratory health of suspended particulates and SO_2, and What is the effect of various factors in the domestic environment when considered in relation to outdoor air quality?

The sample used consisted of 3500 children of school age, randomly selected from 30 of 80 possible schools as agreed upon with the Hamilton Board of Education. The city, (Figure 2.1), was divided into five regions: East and West Mountain, East and West Lower, and the industrial core with the Niagara Escarpment dividing upper and lower quadrants and Wentworth Street dividing east and west.

This study involved a questionnaire which was administered at the home of the children. The questionnaire covered a wide range of independent variables including parental smoking, gas stove use, history, health, differences in symptoms (eg. wheeze versus cough), and demographics. The pulmonary function testing consisted of four procedures: forced expiratory maneuvers, spirometry, single breath nitrogen washouts, and multiple breath nitrogen washouts conducted annually in this study.

The air pollution monitoring sites for TSP used hi-volume samplers. Readings were taken on a 24-hour, 6-day regular basis cycle in various schools throughout the city.

Several general conclusions were drawn from this

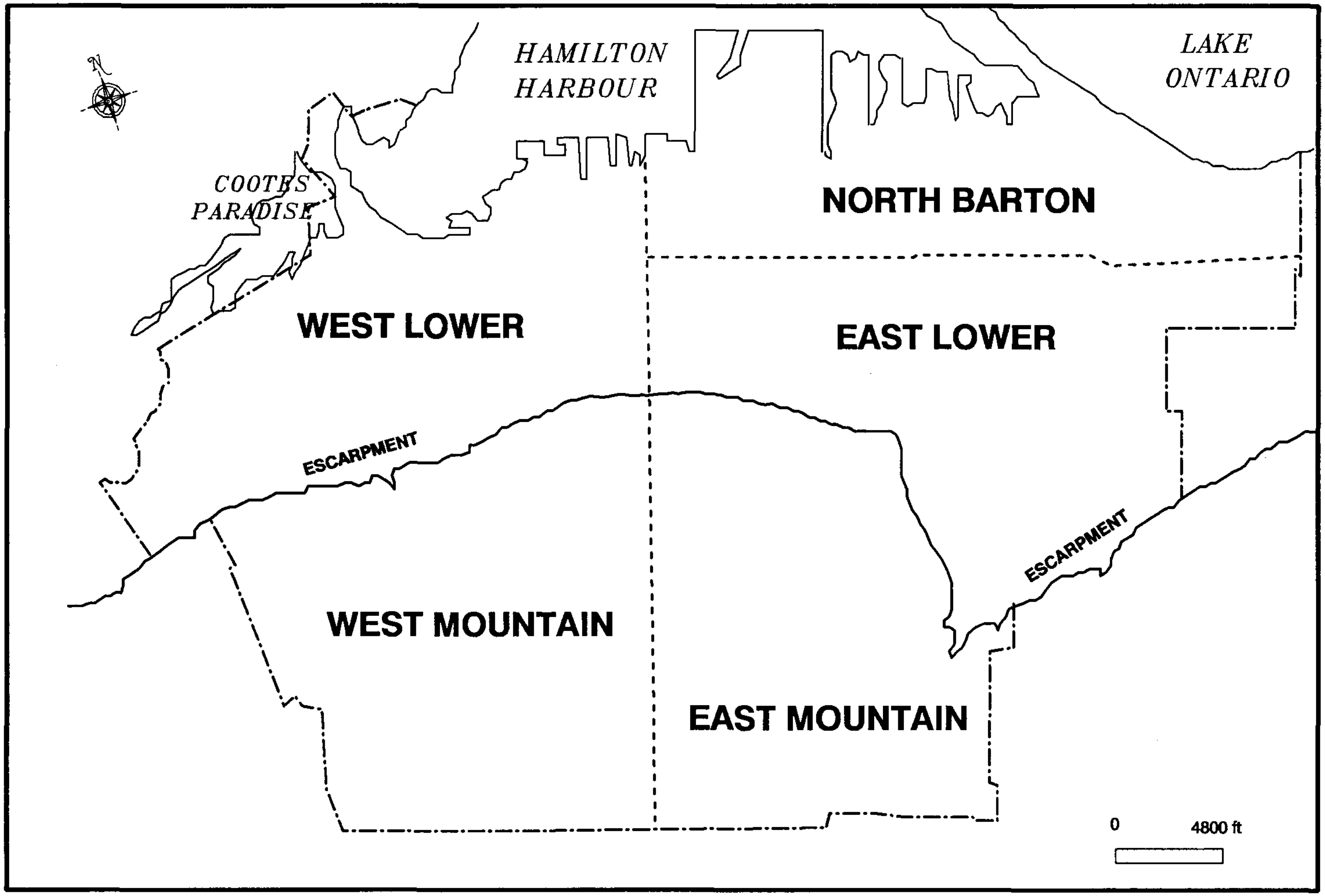

Figure 1. Selective regions of Hamilton

study. The industrial area showed the highest level of TSP, the highest prevalence of domestic smoking, parental respiratory symptoms, and gas stove use. Specific relationships between variables are still being undertaken since this study was done in three separate years. From the first two years, it was concluded that smoking in the home, particularly maternal smoking, showed the greatest effects. It was also found that the use of gas stoves showed insignificant results for all of Hamilton.

2.7 Conclusions

As the external and internal air pollution levels continue to play an important role in the health status of society, the issue of spatial variation in respiratory disease continues to be of great concern to medical geographers and health-care professionals. The literature contains a number of major issues which this research paper will address. However, several of these studies have neglected important issues. For example, Tager et al. and Speizer et al. show bias in selecting the best five of eight expiratory maneuvers performed by the children. Several researchers study certain groups (Ware et al. isolate a "white sample", Tager et al. isolate an "Italian-American" sample), therefore, not including children in the chosen area who are not of this cultural background.

As this paper will focus on the data in the Pengelly et al. study, several other issues will be addressed. Three years have been studied , however, only the second year will be addressed in this paper. Since outdoor air pollution has been stabilizing over the past decade, the emphasis of this paper will be on indoor air pollution.

CHAPTER 3 : RESEARCH METHODOLOGY

3.1 Research Hypothesis

In this study, the research hypotheses is to study the effects of external environmental conditions (regions in Hamilton) as well as confounding indoor environmental factors (gas stove use, maternal smoking, paternal smoking, heat forced air) upon the respiratory health outcomes of children. First, analyzing the external environmental effects will be done by controlling for indoor air quality through parental smoking. Secondly, analyzing the indoor environmental effects will be done by controlling for region.

3.2 Data Source

The data used in this research is based on a 1982 study conducted by Dr. Pengelly of the Urban Air Environment Group at McMaster University. The purpose of this study was to answer two questions: Is there an effect on children's respiratory health of suspended particulates and SO_2?, and What is the effect if various factors in the domestic environment when considered in relation to outdoor air quality?

The questionnaire was given orally to the guardians of 3500 school-age children in Hamilton by trained interviewers. The responses are divided into several groups: child's symptoms, child's health history, smoking in the home, familial symptoms, and home characteristics such as gas stove use.

The focus of this study will be on smoking in the home, gas stove use, and forced air heating as indicators for indoor air pollution; therefore, certain questions have been selected from the questionnaire.

In order to outline an analytical model of respiratory health, the independent variables have been identified as constructs in table 3.1 with the indicators of these independent variables being identified from the questionnaire. Some of the questions taken from the questionnaire may be indicators of more than one construct, and will therefore be referred to more than once.

3.3 Analytical Model of Respiratory Disease

Figure 3.1 is an analytical model of respiratory health which assesses the effects on a child's respiratory health status based on several factors (independent and mediating variables). This model outlines the combination of factors which either independently or collectively affect the respiratory outcome of children. As well, the combination of factors which constitute indoor air quality (parental smoking, gas stove use, and forced air heat) are demonstrated in the model.

Figure 3.1 : Analytical Model of Respiratory Health

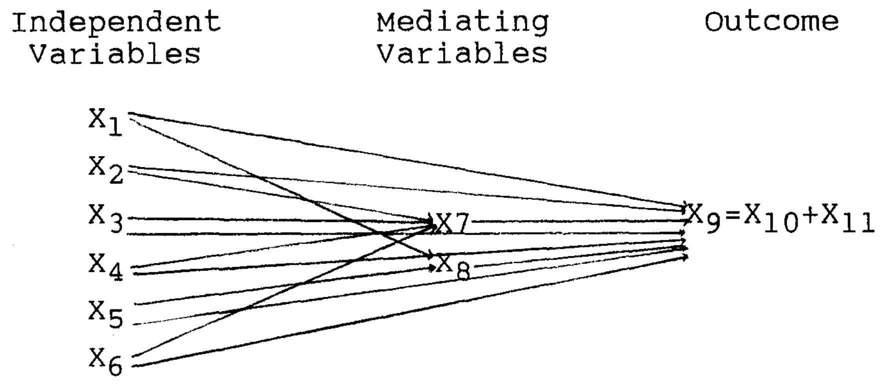

Figure 1: Analytical Model of Respiratory Health. X_1, gender; X_2, parental smoking (mother); X_3, parental (father); X_4, gas stove use; X_5, length of residence; X_6, outdoor air (region); X_7, indoor air; X_8, general health status; X_9, health status comprised of X_{10} (questionnaire of health history) and X_{11} (pulmonary function testing).

Table 3.1 : Extractions from Questionnaire

Construct	Indicator	Items from Questionnaire
--gender	-male or female	-file
	-height, weight, sex	
--parental smoking	-people in household	q. 24c
	-mother smoking	q. 24a
	-father smoking	q. 24b
--gas stove	-electricity, gas, or something else	q. 10
	-gas space heater or gas fireplace	q. 9a
--general health status	-cough in the morning	q. 1
	-cough day or night	q. 2
	-wheezing	q. 3
	-asthma attacks	q. 4
	-past year occurrences of bronchitis	q. 8
	-chest illness before the age of 2	q. 25b
--indoor air	-forced air system	q. 9
	-cooking fuels	q. 10
	-smoking in the home	q. 24
--health status	-cough in the morning	q. 1
	-cough day or night	q. 2
	-wheezing	q. 3

3.4 Methods of Analysis

The various independent tests to be performed on the questionnaire data and the pulmonary testing results are summarized in Table 3.2:

Table 3.2 : Methods of Analysis

	RESPIRATORY OUTCOMES	
Determinants	Nominal Data -symptoms	Interval Data -pulmonary testing
Nominal Data i) gas stove use ii) forced air heat iii) region	**Chi-Square Tests**	**One-way Analysis of Variance**
Interval Data i) daily cigarettes by mother ii) daily cigarettes by father	a) not categorized **One-way Analysis of Variance** b) when smoking is categorized: - non-smokers - 1-25 daily - 26-49 daily - >50 daily **Chi-Square Analysis**	**Correlation**

Chi-square tests were used to test the association between independent and dependent variables measured by nominal scales (eg. respiratory symptoms, gas stove use, forced air heat, and region). One way analysis of variance was used to test the relationships between variables where one was measured at a nominal level and the other at an interval scale (eg. nominal as stated in the above example against interval data such as parental smoking and pulmonary testing). Correlation coefficients were correlated to determine the relationship between interval scale variables (eg. parental smoking and pulmonary testing).

CHAPTER 4 : DATA ANALYSIS AND RESULTS

4.1 Introduction

This chapter will focus on the results of the data analysis. The purpose of the analysis was to test whether respiratory symptoms varied spatially in Hamilton with respect to the presence of gas stove use, forced air heating, maternal smoking, and paternal smoking. The symptoms referred to were cough in the morning, cough day or night, wheeziness, asthma, chest illness, and chest illness before the age of two. In order to fulfil the research objectives, gas stove use and forced air heating were tested against respiratory symptoms and pulmonary function testing results. Parental smoking was categorized into non-smokers, low, moderate, and high level smokers in order to be directly tested against symptoms and pulmonary testing. The tests were performed a first time for Hamilton in general and a second time including region as the dependent variable in order to account for differences between areas in Hamilton.

4.2 Sample Characteristics

In the analysis, it is important to be aware of the characteristics of the sample population in order to account for various conclusions. The sample characteristics were based on size, gender, age, income, respiratory symptoms, and the indoor environment for each of the five regions and are summarized in table 4.1. The sample sizes consisted of approximately 700 children per region, with the exception of North Barton. Due to the expected high pollution levels in this region, the area of North Barton was considered a separate area in itself, consisting of 251 children.

In four out of five regions, the gender division was quite similar. The majority was male. In West Mountain, the percentage of males studied was 51%, in East Mountain, 53%, in East Lower, 53%, and in North Barton, 52%. The exception was the West Lower region, with 52% of the children studied being female. The mean age for all regions was quite similar with the lowest average age being West Mountain with 9.29 and the highest being North Barton, 10.3.

The income levels were divided into four main categories. The region of North Barton had the highest percentage in the lowest income category of <9,999 (25.9%) and the lowest percentage in the highest income level of >30,000 (3.07%). The area with the lowest percentage in the low income group (11.31%) had the highest percentage in the 20,000-29,999 percentile (43.57%), East Mountain. In general, the majority fell in the two intermediate categories, with the West Mountain and West Lower regions having a similar percentage in all four categories. With respect to respiratory symptoms, the most commonly reported

Table 4.1: Sample Characteristics

STATISTICS	WEST MTN.	EAST MTN.	WEST LOWER	EAST LOWER	NORTH BARTON	TOTAL
Sample Size	851	884	727	866	251	3579
% Male	51%	53%	48%	53%	52%	51%
% Female	49%	47%	52%	47%	48%	49%
Mean Age	9.29	9.69	9.70	9.62	10.3	9.62
Income:						
<9,999	15.7%	11.3%	20.4%	15.6%	25.9%	16.2%
10,000-19,999	27.1%	32.0%	34.3%	36.2%	38.6%	32.8%
20,000-29,999	40.5%	43.6%	32.4%	40.1%	32.5%	39.0%
>30,000	16.7%	13.1%	12.9%	8.15%	3.07%	12.0%
Symptoms:						
cough morn	5.9%	6.0%	5.2%	5.9%	10.8%	6.1%
cough day/night	9.9%	8.9%	7.4%	10.0%	11.6%	9.3%
wheezy	23.4%	24.8%	24.1%	26.2%	37.8%	25.6%
asthma	4.8%	4.2%	2.8%	2.9%	3.2%	3.7%
chest illness before age 2	7.4%	7.2%	6.2%	6.6%	10.0%	7.1%
% Gas Stove	8.1%	8.3%	30.3%	15.5%	45.4%	21.5%
% Forced Air	93.5%	87.4%	66.0%	75.8%	86.1%	83.4%
Avg. Smoked Daily (mother)	6.98	8.28	8.51	9.77	13.13	8.72
Avg. Smoked Daily (father)	8.25	9.15	10.07	11.39	16.49	10.27

was wheezing, with North Barton reporting 37.8%. Overall, in Hamilton, 25.2% of those studied reported wheezing. Of the six symptoms in question, North Barton reported the highest percentage for five out of six with the one exception being asthma. Asthma was the least frequently reported symptom for all five regions. This could be accounted for by asthma having to be diagnosed and treated by a physician, and thus, other symptoms may be more justified through guardian observance.

In terms of the indoor environment, the majority of homes in all five regions used forced air heating, with the highest being the West Mountain (93.5%). In terms of gas stove use, 45.4% of North Barton responded positively. However, three out of the five regions had response levels less than 16%. Cigarettes smoked daily by the mother increased as the regions become closer in proximity to North Barton which had the highest daily average at 13.13. The lowest daily average was 6.98 in the West Mountain with 8.25 cigarettes daily and North Barton averaging 16.49 cigarettes daily respectively for paternal smoking.

Therefore, according to the sample characteristics, a few conclusions can be drawn. The North Barton area generally reported increased occurrences of respiratory symptoms, highest rates of parental smoking, highest percentage of gas stove use, the lowest average household income, and is located closest to industry. The West

Mountain area generally reported the lowest percentage of gas stove use, the highest percentage of forced air heating/air filtering systems, the lowest rates of parental smoking, low symptom occurrences, and the highest average household income. As one approaches the industrial area of the city, the outdoor and indoor environments both play a role in the respiratory health of the children due to increased exposure to industrial emissions, increased exposure to domestic smoke, and decreased socio-economic status (income level).

4.3 Gas Stove Use

The presence of gas stoves was tested against both respiratory symptoms and pulmonary function. Chi-square tests and analysis of variance respectively, were the statistical tests performed.

4.3.1 Respiratory Symptoms

Melia et al. revealed the increased prevalence of coughing and bronchitis amongst school-age children due to the presence of gas stoves. These results were also supported by a study conducted by Wade et al.. In this study, the presence of gas stoves was found to have little if any effect on respiratory symptom prevalence. As is seen in table 4.2, the chi-square results reflect no significant relationship between gas stove use and respiratory symptoms.

4.3.2 Pulmonary Testing

Table 4.2 : Effect of Gas Stove Use and Forced Air Heating on Respiratory Symptoms

Symptom (Dependent Variable)	Gas CS	Gas Prob.	Forced Air Heat CS	Forced Air Heat Prob.
Cough in Morning				
WMTN	1.203	0.273	4.992	0.025
EMTN	0.038	0.846	1.301	0.254
WLOW	3.981	0.046	0.147	0.702
ELOW	0.002	0.965	3.599	0.058
NBTN	0.081	0.763	0.019	0.890
Cough Day or Night				
WMTN	0.006	0.939	1.436	0.231
EMTN	0.426	0.514	0.141	0.707
WLOW	0.261	0.610	2.850	0.091
ELOW	2.012	0.156	8.269	0.004
NBTN	0.108	0.742	0.354	0.552
Wheezy				
WMTN	0.066	0.797	1.069	0.301
EMTN	1.337	0.248	0.017	0.895
WLOW	1.858	0.173	0.668	0.414
ELOW	0.777	0.378	0.798	0.372
NBTN	0.315	0.575	0.219	0.639
Asthma				
WMTN	0.037	0.847	1.157	0.282
EMTN	1.573	0.210	1.408	0.235
WLOW	0.270	0.603	8.825	0.003
ELOW	2.591	0.107	0.842	0.359
NBTN	0.070	0.791	0.842	0.359
Chest Illness				
WMTN	0.003	0.959	0.001	0.970
EMTN	0.114	0.736	0.170	0.680
WLOW	2.136	0.144	1.437	0.231
ELOW	0.097	0.756	0.339	0.560
NBTN	0.329	0.566	0.849	0.357
Chest Illness Before Age 2				
WMTN	0.619	0.431	0.099	0.753
EMTN	1.413	0.235	0.193	0.660
WLOW	1.071	0.301	1.383	0.240
ELOW	1.193	0.275	0.347	0.556
NBTN	1.266	0.260	1.655	0.198

Through observed respiratory symptoms, the insignificant effect of gas stove use on the respiratory health of children can be seen. Through pulmonary testing results, further biological effects would be noticed.

Table 4.3 : Effects of Gas Stove Use and Forced Air Heating On Pulmonary Function

	Gas			
	Yes	No	F-statistic	Probability
Mean VC	2.31	2.33	0.07	0.7910
Mean FEV1FVC	0.82	0.80	0.00	0.9676
	Forced Air Heating			
	Yes	No	F-statistic	Probability
Mean VC	2.33	2.35	1.06	0.3043
Mean FEV1FVC	0.81	0.80	2.43	0.1192

The mean VC and FEV1FVC values for homes with gas stoves and without gas stoves are also shown in table 4.3. The mean values do not vary due to the use of gas stove; therefore, further supporting the insignificant relationship between respiratory disease and gas stove use.

4.4 Forced Air Heating

The presence of forced air heating systems was also tested against both respiratory symptoms and pulmonary function. Chi-square tests and variance were again used for this independent variable.

4.4.1 Respiratory Symptoms

Chi-square test results show 3 out of 30 significant relationships between forced air heating and respiratory disease which can be seen in table 4.2. The presence of forced air heating in the households dominated the majority of the reported households. In table 4.1 an average of 84% of households reported forced air systems with West Lower region reporting the least at 66%. The results shown in table 4.2, indicate that the West Lower region shows a slight relationship between chest illness, cough day or night, and asthma as the least reported occurrence of forced air systems (66%). However, it must be noted that one or two significant relationships would be expected by chance alone in 30 tests.

4.4.2 Pulmonary Testing

In contrast to the F-statistic values found for gas stove use, pulmonary function does show a slight relationship when tested against forced air heating systems, especially in the FEV1FVC test as is seen in table 4.3. However, the mean values for both VC and FEV1FVC tests remained fairly similar when the presence or absence of forced air heating was taken into account.

4.5 Parental Smoking

Several procedures were used to examine the relationship between parental smoking and respiratory outcomes. Parental smoking was operationalized in two way: (i) as a continuous variable (ie., the number of cigarettes smoked per day), (ii) as a categorical variable (0 for non-smokers, 1-25 daily for light to moderate smokers, 26-49 daily for moderate to heavy smokers, and >50 for heavy smokers). According to the results of chi-square tests for found in table 4.4 for cigarettes smoked per day, asthma (x_2 = 10.454), wheezy, and cough day or night showed significant results when tested against paternal smoking for Hamilton in general.

In contrast, maternal smoking generally showed stronger relationships between most of the symptoms. The most significant were seen with wheezy, chest illness before the age of 2, and cough day or night with chi-square values of 41.875, 37.511, and 23.112 respectively. In order to assess the magnitude of these results, 25.6% reported wheezy symptoms. The most significant symptom for paternal smoking was asthma which showed the least effect for maternal smoking. However, the symptom of wheezy showed strong

Table 4.4 : Chi-Square Values for Hamilton

Paternal Smoking

	Chi-Square	Probability
Cough in Morning	3.306	0.347
Cough Day or Night	6.735	0.081
Wheezy	7.573	0.056
Asthma	10.450	0.015
Chest Illness	5.045	0.169
Chest Illness Before Age 2	2.246	0.523

Maternal Smoking

	Chi-Square	Probability
Cough in Morning	18.872	0.000
Cough Day or Night	23.112	0.000
Wheezy	41.875	0.000
Asthma	3.076	0.380
Chest Illness	5.546	0.136
Chest Illness Before Age 2	37.511	0.000

relationships for both paternal and maternal smoking.

These findings were supported as well by the results of the pulmonary function test. According to table 4.5, the significant F-statistic values indicate a possible relationship between wheezy, asthma, and chest illness to paternal smoking. However, a strong relationship is seen in the results of maternal smoking. The only variables which did not show significant results were asthma and chest illness. Therefore, pulmonary function testing results demonstrate the direct relationships between coughing, wheezy, and chest illness before the age of 2 as being significantly related to maternal smoking.

Table 4.5 : Effects of Parental Smoking on Pulmonary Function (Paternal and Maternal Smoking)

	Paternal Smoking		Maternal Smoking	
	Yes	No	Yes	No
Mean VC	2.37	2.32	2.34	2.32
Mean FEV1FVC	0.80	0.81	0.80	0.82

Respiratory Symptom	F-statistic	Prob>F	DF
Cough in Morning	0.54	0.9969	52
Cough Day or Night	0.91	0.6563	52
Wheezy	1.26	0.0992	52
Asthma	1.11	0.2732	52
Chest Illness	1.58	0.0054	52
Chest Illness Before Age 2	0.92	0.6471	52

Respiratory Symptom	F-statistic	Prob>F	DF
Cough in Morning	2.79	0.0001	41
Cough Day or Night	1.92	0.0004	41
Wheezy	2.68	0.0001	41
Asthma	0.68	0.9390	41
Chest Illness	0.69	0.9366	41
Chest Illness Before Age 2	2.18	0.0001	41

The correlation coefficients revealed an insignificant effect of parental smoking on the pulmonary function of children especially from maternal smoking. In this case, the amount of cigarettes smoked daily was matched directly to the pulmonary testing without categories being enforced.

4.6 Effect of Paternal Smoking by Region

In analyzing paternal smoking, region was taken into account. For the symptom wheezy, a spatial pattern is observed in table 4.6. The region of North Barton shows significant results whereas the four remaining regions show very little. Chest illness displays a consistent pattern with significant results for all regions. This shows that paternal smoking in itself affects chest illness independent of location or external environmental factors. One other point to note in the occurrence of respiratory symptoms is the significant relationships for five of six symptoms in the West Lower region. This may be caused by the increase in the socio-economic status of the families in this area which enables more professional fathers to spend more time at home and thus, have a greater influence of their child's health.

4.7 : Effect of Maternal Smoking by Region

The strength between maternal smoking and several respiratory symptoms is seen in table 4.7. The dominant symptom reported in table 4.1 was wheezy which consequently shows the strongest relationship with maternal smoking especially in the lower regions. Cough day or night shows a similar pattern in that region does not show to be significant in respiratory symptom prevalence. With chi-square values from 5.163 to 6.801, the pattern of cough day or night occurrence demonstrates the effect of maternal smoking. Chest illness before the age of 2 shows a pattern

Table 4.6 : Chi-Square Values for Specified Regions of Hamilton

	Paternal Smoking Chi-Square	Probability
Cough in Morning:		
WMTN	4.613	0.202
EMTN	1.547	0.671
WLOW	18.133	0.000
ELOW	2.367	0.500
NBTN	1.305	0.728
Cough Day or Night:		
WMTN	2.233	0.525
EMTN	1.271	0.736
WLOW	8.941	0.030
ELOW	1.165	0.761
NBTN	2.749	0.432
Wheezy:		
WMTN	0.466	0.926
EMTN	0.412	0.938
WLOW	0.265	0.967
ELOW	2.842	0.417
NBTN	15.376	0.002
Asthma:		
WMTN	9.918	0.019
EMTN	1.995	0.574
WLOW	4.070	0.254
ELOW	5.033	0.169
NBTN	5.587	0.134
Chest Illness:		
WMTN	3.308	0.347
EMTN	7.226	0.065
WLOW	4.492	0.213
ELOW	2.034	0.565
NBTN	2.114	0.549
Chest Illness Before Age 2:		
WMTN	6.075	0.108
EMTN	3.716	0.294
WLOW	1.474	0.688
ELOW	0.647	0.886
NBTN	1.850	0.604

Table 4.7 : Chi-Square Values for Specific Regions in Hamilton

	Maternal Smoking Chi-Square	Probability
Cough in Morning:		
WMTN	9.187	0.027
EMTN	3.196	0.362
WLOW	12.736	0.005
ELOW	4.082	0.253
NBTN	3.258	0.353
Cough Day or Night:		
WMTN	5.163	0.160
EMTN	6.057	0.109
WLOW	6.015	0.111
ELOW	6.801	0.079
NBTN	6.134	0.105
Wheezy:		
WMTN	10.460	0.015
EMTN	5.190	0.158
WLOW	12.942	0.005
ELOW	15.796	0.001
NBTN	10.923	0.012
Asthma:		
WMTN	4.470	0.215
EMTN	7.319	0.062
WLOW	0.749	0.862
ELOW	2.591	0.459
NBTN	3.344	0.342
Chest Illness:		
WMTN	0.842	0.839
EMTN	2.184	0.535
WLOW	3.210	0.360
ELOW	3.016	0.389
NBTN	4.933	0.177
Chest Illness Before Age 2:		
WMTN	15.040	0.002
EMTN	6.434	0.092
WLOW	9.768	0.021
ELOW	12.891	0.005
NBTN	3.143	0.370

whereby location does not affect symptom prevalence. The West Mountain shows the strongest relationship with a chi-square value of 15.040 and North Barton shows the weakest with a chi-square value of 3.143. However, in table 4.1 it was shown that North Barton reported the highest occurrence of wheezy symptoms with 37.8% responding positively. If region played a role in occurrence, these results would have been reversed.

4.8 Locational Variations

4.8.1 Respiratory Symptoms

Table 4.8 : Effect of Region on Respiratory Symptoms

Symptom (Dependent Variable)	Independent Variable (region) Chi-Square	Probability
Cough in Morning	10.597	0.031
Cough Day or Night	5.580	0.233
Wheezy	23.319	0.000
Asthma	7.284	0.122
Chest Illness	4.505	0.342
Chest Illness Before Age 2	13.163	0.011

When considering region as the independent variable instead of as a dividing factor for the dependent variables significant results were found. According to table 4.1, the symptom most reported was wheezy. In this table 4.8, it was found that wheezy symptoms were highly dependent on region. From table 4.1, it was seen that most wheezy symptoms (37.8%) were reported in the North Barton and East Lower (26.2%) regions. Therefore, the reported occurrence of wheezy symptoms gradually increases the closer one gets to the industrial core. In terms of chest illness before age 2 and cough in morning, both are dependent on region in terms of reported incidence with chi-square values of 13.163 and 10.597 respectively. The reported frequency of these symptoms increased towards the industrial core. Through this analysis, the external environment can be seen as having a negative effect on the respiratory health outcomes of the children as reported by the guardian of the household.

Table 4.9 : <u>Effect of Region Controlling for Smoking</u>

	MATERNAL		PATERNAL	
	CS.	PROB.	CS.	PROB.
Cough in Morning:				
non-smokers	6.852	0.144	4.867	0.301
smokers	4.510	0.341	6.206	0.184
Cough Day or Night:				
non-smokers	5.184	0.269	4.684	0.321
smokers	2.283	0.684	4.368	0.358
Wheezy:				
non-smokers	2.606	0.626	1.742	0.783
smokers	17.951	0.001	24.202	0.000
Asthma:				
non-smokers	9.861	0.043	5.281	0.260
smokers	0.301	0.990	2.335	0.674
Chest Illness:				
non-smokers	1.598	0.809	1.984	0.739
smokers	6.179	0.186	8.880	0.064
Chest Illness Before Age 2:				
non-smokers	3.657	0.454	4.776	0.311
smokers	7.368	0.118	12.709	0.013

When accounting for smokers versus non-smokers, wheezy symptoms appear more prevalent with region as the independent variable. With 38.7% reporting wheezy symptoms, chi-square values of 17.951 (maternal) and 24.202 (paternal) demonstrate a strong relationship to region. Chest illness and chest illness before the age of two show similar results. Overall, asthma shows the least significance because of the nature of the diagnosis of this respiratory disease. In general, when paternal smoking is accounted for, region has less effect than when maternal smoking is taken into account.

4.8.2 Pulmonary Function

Table 4.10 : Effect of Region on Pulmonary Function

Pulmonary Test	Mean	F-Statistic	Prob>F	DF
VC	2.3287	10.58	0.0001	4
FEV1FVC	0.8110	2.45	0.0443	4

When dealing with pulmonary function, the Vital Capacity Test shows stronger results for region as is seen in table 4.10. This table considers Hamilton in general. Both pulmonary tests reflect region having an affect on pulmonary testing with the VC test values showing a stronger relationship to region than the FEV1FVC test.

4.9 Summary and Conclusions

The results of the analysis show the importance of studying the effects of indoor and outdoor air quality on the respiratory health outcomes of children. In general, the North Barton region reported increased occurrences of respiratory symptoms, highest rates of parental smoking, highest percentage of gas stove use, lowest household income, and closest proximity to the industrial area. In contrast to the North Barton region, the West Mountain region reported opposite results. In terms of symptoms, the highest reported symptom was wheeziness for all five regions of Hamilton with asthma being consistently low in terms of reported incidence across Hamilton.

In terms of gas stove use and its effect on respiratory health, little relationship was found. With respect to forced air heating, a weak relationship was found for both respiratory symptoms and pulmonary function. However, since only three significant relationships were found, this may be due to chance rather than true effects.

The results of the analysis showed significant results for parental smoking, especially maternal smoking. Maternal smoking particularly influenced wheeziness, chest illness before age 2, and cough day or night. Locational variation was identified through the increased strength in relationships between symptoms and maternal smoking in the lower regions; therefore, stressing the increased contribution of a decreased increased status with increased smoking occurrence and external air quality.

Paternal smoking affected wheeziness, coughing day or night, and surprisingly asthma, whereas asthma showed the least effect when maternal smoking was considered. Asthma is a respiratory illness which is clinically diagnosed; therefore, its prevalence was expected to be lower than the other symptoms. Locational variation was identified through the results based on the West Lower region where higher socio-economic status (income) was identified; therefore, linking paternal professional status with spending more time at home and having a greater influence over their child's health status.

With respect to the effect of region on respiratory symptoms while controlling for the indoor air quality, parental smoking, wheeziness, chest illness before the age of 2, and cough in the morning displayed the most significant relationships. Overall, when paternal smoking is accounted for, region has less effect than when region is taken into account for maternal smoking.

CHAPTER 5 : CONCLUSIONS

5.1 Summary

In summary, the analysis and results lead to the following conclusions. The importance of realizing the effects of the indoor environment separate from the outdoor environment was outlined since outdoor air quality has improved over the last decade. The results of the study identify the importance of parental smoking in the home, especially on the part of the mother with regards to the respiratory health outcomes of the children. Passive exposure to parental smoke in the home increases the risk that a child will develop respiratory symptoms and perhaps decrease pulmonary function (Pengelly et al., 1984). However, compared to the significant effects found for parental smoking, gas stove use and forced air heating showed less effects.

The spatial variation in respiratory disease in Hamilton is identified through increased prevalence of respiratory symptoms and parental smoking as one approaches the North Barton region indicating the combined influence of the outdoor environment and indoor air quality upon respiratory health.

5.2 Consistency of Results

The results of the analysis are consistent with the findings of past studies. In the initial study by Pengelly et al. in 1982, maternal smoking was identified as a key factor contributing to the respiratory health of children. As well, the use of gas for cooking and socio-economic factors were shown to have little effect. However, in contrast to the Pengelly et al. study, asthma was more prevalent and showed a stronger relationship to paternal smoking. Also, regional considerations were identified as being significant for respiratory symptom prevalence in this current study.

The study by Melia et al. regarding gas stove use and respiratory health found a significant relationship between the two. However, Pengelly et al.'s study as well as this study found little effect between the two variables.

Finally, in studies by both Tager et al. and Binder et al., parental smoking, especially maternal smoking, showed significant effects on respiratory health outcomes. This study also confirmed maternal smoking as a key component to both pulmonary function and respiratory symptoms in children.

Multivariate analysis would have been the next logical step in the data analysis however, due to time constraints this method of analysis was not able to be completed. Logit analysis would have measured the contributions of each of the independent variables (paternal smoking, maternal smoking, region with North Barton as a base due to high respiratory symptom occurrence and high external pollution, gas stove use and forced air heating) as they collectively effect respiratory symptoms and pulmonary function of children. Future studies should incorporate logit analysis to further support the findings of the bivariate analysis through multivariate analysis.

APPENDIX

Questionnaire: Children's Health Study

Section 1: Child's Health

1. Does he/she usually cough in the morning, not counting just clearing the throat or a single cough?
( ) 1. Yes
( ) 2. No
( ) 7. Refused
( ) 8. Don't Know
( ) 9. Not Applicable

2. Does he/she usually cough during the day or night, not counting just clearing the throat or a single cough?
( ) 1. Yes
( ) 2. No
( ) 7. Refused
( ) 8. Don't Know
( ) 9. Not Applicable

3. Does his/her chest ever sound wheezy or whistling?
( ) 1. Yes
( ) 2. No
( ) 7. Refused
( ) 8. Don't Know
( ) 9. Not Applicable

4. Has he/she suffered from asthmatic attacks in the last twelve months?
( ) 1. Yes
( ) 2. No
( ) 7. Refused
( ) 8. Don't Know
( ) 9. Not Applicable

<u>For clarification: has a doctor ever told you it was asthmatic?</u>

5. During the last twelve months, has he/she had any chest illness such as bronchitis or pneumonia which has key him/her at home for one week or more?
( ) 1. Yes
( ) 2. No
( ) 7. Refused
( ) 8. Don't Know
( ) 9. Not Applicable

6. Was he/she ever hospitalized for a severe chest illness or chest cold before the age of two years?
( ) 1. Yes
( ) 2. No
( ) 7. Refused
( ) 8. Don't Know
( ) 9. Not Applicable

Section Two: Home and Family

7. Is your home/apartment heated by a forced air system? If respondent says "don't know", check or ask about:

air vents, ducts = yes, forced air
electric baseboard, hot water radiator = no, not forced air

8. Do you have either a gas operated space heater or a has operated fireplace that is used regularly? (Regularly = at least every second day during the cold season)
( ) 1. Yes
( ) 2. No

9. Do you cook by electricity, gas, or something else?
( ) 1. Electricity
( ) 2. Gas
( ) 3. Electricity plus microwave
( ) 4. Gas plus microwave
( ) 5. Something else - specify ___________
( ) 7. Refused
( ) 8. Don't Know
( ) 9. Not Applicable

10. How many people altogether live in this household, including yourself?
__________ (number)

11. If there are no smokers in the household check --> ( ).

11a. How much does each smoke on an average day?

11 aa. **mother** 1. _____ age _____ # daily _____ # daily _____ pipefuls

11 bb. **father** 2. _____ age _____ # daily _____ # daily _____ pipefuls

12. Would you please look at this card. Could you tell me which letter on the card corresponds to your present total family income before taxes for 1980?

( ) 01 A. under $5,000
( ) 02 B. $5,000 - $7,499
( ) 03 C. $7,500 - $9,999
( ) 04 D. $10,000 - $12,499
( ) 05 E. $12,500 - $14,999
( ) 06 F. $15,000 - $17,499
( ) 07 G. $17,500 - $19,999
( ) 08 H. $20,000 - $22,499
( ) 09 I. $22,500 - $24,999
( ) 10 J. $25,000 - $27,499
( ) 11 K. $27,500 - $29,999
( )77 Refused ( )88 Don't Know ( )99 Not Applicable

Section Three: Individual Child Characteristics

13. What is the age of the child?

______ (number)

/ d / m / y / birth date

14. What is the approximate height and weight of the child?

______ height ______ weight

15. Is the child male/female?

( ) male
( ) female

16. In what region does the child live?

( ) 1. West Mountain
( ) 2. East Mountain
( ) 3. West Lower
( ) 4. East Lower
( ) 5. North Barton

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