Emergency Service Utilization for Pediatric Asthma Exacerbations and the Potential for Interventions

by

JAY ASHVIN JOSEPH

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ABSTRACT

Objectives: To determine whether there is a relationship between parental attendance at an asthma education clinic and repeat visits to a pediatric Emergency Department for asthma exacerbations; to explore the relationship between parental knowledge about asthma, parental information-seeking and decision-making preferences, and repeat visits to the pediatric Emergency Department for asthma exacerbations; to quantify a possible correlation between particulate matter (PM) air pollution as a result of a bog fire and pediatric Emergency Department utilization for asthma exacerbations.

Methods: The British Columbia Children's Hospital keeps a record of all emergency service utilization. Data were obtained through a combination of chart abstraction, computer system searching, and telephone follow-up with parents of children who visited the Emergency Department. PM concentration data were obtained from an air pollution monitoring stations across the Greater Vancouver Regional District.

Results: Attendance at an asthma education clinic is not associated with a reduced time to repeat ED visit but may be more effective with parents of children four years of age or older and without an established history of ED visits; Attendance at a asthma education clinic does produce measurable changes in parental asthma knowledge but parental decision-making preferences do not appear to influence repeat ED visit likelihood; Elevated PM_{10} and $PM_{2.5}$ pollution concentrations appear to be associated with an increase, although delayed, in ED visits.

Conclusions: ED visits are a viable outcome measure for healthcare utilization studies. Although asthma education and parental preferences do not affect ED visit rates elevated PM pollution concentrations during fires may result in moderate increases in ED visits.

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CHAPTER 1: INTRODUCTION

1.1 The Quality of Health Care for Children

It is often said that children are not small adults. Thus, it should surprise no one that the health care needs of children are a reflection of their growth and development, their unique pattern of expression of disease, and in many cases on their dependency on parents and guardians for their well-being.(1)

Epidemiologists have long recognized the importance of a healthy lifestyle in the formative years, and have drawn attention to issues such as childhood obesity and physical inactivity as harbingers of poor health in adulthood. Despite the obvious medical link between the health of an individual as a child and later adult health, health services researchers still find it necessary to draw attention to the value in thinking about policies and programs in terms of the life-course of individuals.(2) Competing priorities for limited budgets mean that problems that do not manifest themselves within a political term are often dealt with in an expedient manner.

It is not that progress has not been made. The Academy of Health is now into its eighth year of hosting its annual child health services research meeting, attracting health services researchers from all over the continent and further afield. Calls for research at the turn of the decade into the efficacy and effectiveness of health services for children (3), quality in health care for children (4), and methods for improving health care within health care delivery systems (5) have resulted in new research endeavours and knowledge generation.

Yet health care systems do not exist in a static environment and the delivery program that worked yesterday will not necessarily be effective in the future. Health service researchers, decision-makers, and policy-makers must put a priority on examining ways to deliver health care for children in the most efficient but effective way possible, or run the risk of providing untimely care for all.

1.2 Caring for Children with Chronic Diseases

Of particular relevance for the management of health care services are the increasing numbers of children who are chronically ill and in need of constant care and/or ongoing reassessments. The miraculous medical advances in fields as diverse as pediatric cancer care and pediatric cardiovascular surgery, as examples, have meant larger numbers of survivors of severe childhood illnesses. Given that it is rare that such individuals are able to live free of any follow-up medical care, there is a direct link between medical advances and increasing health care system demand. Beyond their physical needs, such children are also at higher risk for emotional, behavioural, or psychiatric disorders as a direct result of the difficulties in living with a chronic illness. (6)

Health care programs have to adjust to the increasing demand for services, but in addition, when dealing with chronically ill children, programs must be able to adapt to the evolving needs of patients who are growing up. Just as medical care must be delivered in a developmentally appropriate manner, health care program design and implementation should reflect the different needs of, for example, the infant with chronic disease and the adolescent with chronic illness. Michaud, Suris, and Viner (7)(8) describe the particular issues relevant to the adolescent with chronic disease and note that discussing and disclosing the disease, management of adherence to therapy, the need for an interdisciplinary team approach, lifestyles' anticipatory guidance and prevention are all important issues that are of particular importance in program delivery for adolescents.

With improvements in treatments and outcomes for many conditions, the expected lifespan for many children with serous chronic illnesses, e.g. cystic fibrosis, is moving well into adulthood, and the transition into an adult healthcare setting is becoming an increasingly important focal point for health service delivery and health services research. Rosen (9) notes that for healthy children, the switch from pediatric to adult health care facilities is usually uncomplicated but for young people with more extensive medical histories and ongoing healthcare needs involving multiple healthcare providers the transition entails some risk to the quality of care. Inadequate training of adult-healthcare providers to care for diseases of childhood onset, inadequate multi-disciplinary programs for those with complex conditions, and administrative issues can act as significant barriers to the provisioning of optimal care.

The health care service needs of the newly emerging classes of chronically ill children elicit the commonalities between such children and children afflicted with more common chronic diseases of childhood such as asthma, diabetes, or epilepsy. Many of the issues highlighted above for emerging populations of children with chronic diseases, e.g., adherence to therapy and transitioning from pediatric to adult care, are in fact mirror images of the challenges facing children with more typical chronic illnesses. It would appear that there is opportunity for cross-fertilization of ideas between care providers and program administrators involved with the care of different patient populations.

Similarly, the generation of new knowledge in program delivery for chronically ill children can be undertaken with a view to casting a wider net, both in terms of the learning from the experiences of others in different fields, and in the audience one seeks to address with new findings. Health services researchers may still focus on the direct question at hand but one can conceivably hope for at least three meaningful benefits from any study of health service delivery for chronically ill children. First, and most obvious, is that studies aim for positive findings that can be used to directly improve program delivery for the population of children in question. Second, is that it may be possible to simultaneously deliver better care and more cost-effective/efficient care, enabling resource reallocation to other priorities. Third, the results of such research may be of use to program administrators and decision-makers responsible for the care of children with different chronic illnesses but who share common health care needs.

1.3 The Burden of Asthma in Children at a Population Level

It is in the spirit of perceived potential benefit for all children with chronic diseases that the series of studies that form this dissertation are presented. As will be apparent from the evidence presented in the following sections, children with asthma represent a sizeable proportion of the pediatric population and are heavy users of health care resources -- Emergency Departments (ED), in particular. Strategies to prevent asthma exacerbations and to reduce the demand for ED services can potentially benefit both children with asthma and other children who compete for attention in the ED. Such strategies depend on evidence for the causes and triggers of asthma exacerbations and the effectiveness of interventions aimed at mitigating the effect of some or all of these triggers. As will be evident in Chapter 2, there are many potential triggers for asthma exacerbations, some universally accepted and others in dispute. This dissertation examines one controversial trigger, particulate matter (PM) pollution, as a potential trigger for asthma exacerbations. Since identifying triggers does not, in and of itself, reduce the burden of asthma on children or the ED, the effectiveness of asthma education as an intervention is also evaluated in this dissertation.

Before considering the details of these investigations it is important to establish that asthma is a burden on children and the ED. This section begins with a review of some of the evidence to support the notion that asthma is a health concern that affects a significant proportion of the pediatric population. Measuring the prevalence and incidence of disease in a population is an important tool for assessing the burden of disease in a population and there is good reason to believe that the burden of disease in the population is related to the demand for health care services. Moreover, the cost of meeting this demand in the ED may be higher than it is in other care settings. The Chapter concludes with a rationale for the studies undertaken in this dissertation in light of the population burden of disease associated with asthma.

1.3.1 The Incidence and Prevalence of Asthma in Children

The Tucson Children's Respiratory Study (10) is a large, prospective longitudinal study that has followed young children from birth to assess the relationship of risk factors and lower respiratory tract illnesses early in childhood with the development of asthma later in childhood. The inception cohort consisted of 1246 infants enrolled at or near birth in the 1980-1984 period, of which 974 are still being followed. Taussig, Wright, Holbert et al. found that of those children who had wheezing before three years of age, 59% had stopped wheezing by age six. Looking at narrower age bands, they found that 80% of children who wheezed during the first year of life did not wheeze after age three, 60% of those wheezing in the second year did not wheeze after age three, and 30% to 40% of those wheezing in the third year did not wheeze after age three. Among persistent wheezers, i.e. wheezing after three years of age, approximately 60% were atopic at the age of 6 years, and 40% were non-atopic. Although the results suggest that many early wheezers do not go on to develop asthma in later childhood, the study did confirm that most children who do develop atopic asthma have their first symptoms during the first six years of life. The most significant predictor of non-persistent wheezing was low levels of lung function (as measured by rapid thoracic compression for the measurement of forced expiratory flow, helium dilution measurement of functional residual capacity, forced oscillation measurement of respiratory conductance, and tidal breathing analysis) before any lower respiratory tract infections. Thus, some of the reduction in maximal forced expiratory flow seen later in life in those who had early wheezing may be due to congenital differences in lung function as opposed to infection-related airway damage.

Despite the obvious appeal of incidence as a measure of burden of disease in a population, prevalence is the most commonly used measure of asthma occurrence in studies because of the difficulty of clearly defining and thus ascertaining new cases in large populations.(11) Since prevalence is affected by both incidence and disease duration, it only provides a rough guide to the underlying patterns in asthma occurrence. Nevertheless, some commonalities in results across surveys from different countries have provided results that merit discussion. Table 1.1 provides a summary of the studies described below.

Using data from the U.S. National Center for Health Statistics, Akinbami and Schoendorf (12) described trends in asthma prevalence, asthma hospitalizations, and asthma deaths in the U.S. from 1980 to 2000 in children aged 0 to 17 years of age. They found that asthma prevalence increased an average of 4.3% per year from 1980 to 1996.

In the 1980s the prevalence was 36/1000 children (S.E. 3.4) rising to 75/1000 in 1995 (S.E. 5.1) but then falling to 62/1000 (S.E. 5.9) in 1996. A questionnaire redesign in the 1997 cycle makes direct comparison with previous years difficult but they found that the prevalence of 'asthma attacks over the past year' remained level over the 1997 to 2000 period. The authors concluded that the trend in increasing rates appears to have plateaued after a number of years of increases. An analysis of the same National Health Interview survey dataset by Woodruff, Axelrad, and Kyle (13) reached similar conclusions. Asthma-related deaths among children appear to show a similar trend, increasing on average 3.4% per year from 1980 to 1996 but falling in 1997 (12).

Dales, Raizenne, El-Saadany et al. (14) used data from a questionnaire administered to a sample of 18,000 families of children aged five to eight years old from communities in six regions of Canada to provide prevalence estimates for childhood asthma for 1998. As a single panel study, trends with time could not be estimated, however, the investigators found distinct regional variations in the prevalence estimates for both current asthma diagnosis and persistent wheeze. Estimates for current asthma ranged from a low of 2-4% in British Columbia to 7-8% in the Maritimes, with geographically intermediate provinces having intermediate prevalence estimates. A similar geographic gradient was observed for persistent wheeze, from a low of 3-12% for British Columbia communities to 12-19% for Maritime provinces.

Senthilselvan (15) used Medical Care Insurance data from the Saskatchewan Department of Health to estimate the trends in asthma prevalence in that province. Prevalence estimates were calculated but individuals who did not seek medical attention for more than a year were excluded from prevalence estimates for at least one year. Thus, there is the possibility that these were underestimates of the true values. The author found that between 1981 and 1990 the prevalence of physician diagnosed asthma rose from 3.0% to 5.1% in children in the 0 to 4 year old age category and from 2.6% to 4.4% in children in the 5 to 14 year old age category. The trends were significant after adjusting for gender ($p < 0.001$).

Studies done under the auspices of the International Study of Asthma and Allergies in Childhood (ISAAC) have mostly been done in Europe and have provided interesting results. Anderson, Ruggles, and Strachan et al. (16) used a self-completed questionnaire to survey 15,083 adolescents in England, Scotland, Wales, and the offshore islands of Guernsey, Isle of Man, and Jersey in 1995 and 2002 as part of an ISAAC Study about wheezing/whistling in the chest, asthma attacks in the past 12 months, and lifetime prevalence of asthma. They report that in the United Kingdom, after increases in asthma prevalence among older children (10-14 year olds) through the early 1990s, that the prevalence of asthma appears to have fallen between 1995 and 2002. It is noteworthy that the lifetime prevalence of ever having asthma increased (20.6% to 25.9%) between the two survey cycles.

In a large two-cycle Italian survey done in 1994 and 2004 using ISAAC study methodology, Galassi, De Sario, Biggerri, Bisanti et al (17) surveyed 16,115 and 11,287 six to seven year olds (via their parents) and 19,723 and 10,267 ten to 14 year olds (self-completed questionnaire) and asked them about their 12 month history of wheezing and asthma, and lifetime occurrence of asthma. The investigators found that between two survey cycles in 1994 and 2002 the prevalence of wheezing in the past 12 months in six to seven year olds appeared to have increased slightly (7.8% to 8.6%) while the prevalence of lifetime asthma remained stable (9.1% to 9.5%). No notable changes in the prevalence of asthma or wheezing were evident among adolescents.

A similar stabilization in asthma prevalence for some age groups was reported by Spanish researchers (18), in another two-cycle ISAAC survey of six to seven year olds (n=19,027 in 1994 and n=18,562 in 2002) and 10 to 14 year olds (n=23,379 in 1994 and n=24,177 in 2002). As in the Italian study, this research group found no change between the 1994 and 2002 cycles for 10 to 14 years olds in the prevalence of wheezing in the past 12 months (boys: 9.0% to 9.3%; girls: 9.6% to 9.2%). However, in contrast to Galassi, De Sario, Biggerri, Bisanti et al (17) the prevalence of lifetime diagnosis of asthma among 10 to 14 year olds did appear to increase moderately (boys: 11.7% to 13.8%; girls: 9.0 to 10.8%). In the six to seven year old age group, noticeable changes in prevalence were evident for wheezing in the past twelve months (boys: 7.0% to 10.7%; girls: 5.3% to 8.2%) and ever having been diagnosed with asthma (boys: 7.7% to 12.9%; girls: 4.9% to 9.0%).

Rounding out the collection of European ISAAC methodology-based studies are recent results from a Norwegian (19) investigation into atopic disorders among nine to eleven year olds. The study involved three cycles, one in each of 1985 (n=1794), 1995 (n=1432), and 2000 (n=3853). Only the last cycle used the ISAAC methodology. In the first two cycles, the core questions related to asthma were "Has the child ever had asthma?" and "Does the child experience wheeze, periods with cough or attacks with shortness of breath (asthma) caused by external factors?". The first question corresponds most closely to the lifetime asthma diagnosis question used in the ISAAC methodology. Assuming comparability, the investigators found that the prevalences of ever having been diagnosed with asthma were 6.7% and 4.4% for boys and girls, respectively, in 1985, 8.8% and 7.6% for boys and girls, respectively, in 1995, and 10.2% and 7.6% for boys and girls, respectively, in 2000. The results are at variance with earlier studies with the suggestion that an increase in prevalence was observable for boys from 1985 through to 2000 but that for girls the proportion ever having been diagnosed with asthma leveled off between 1995 and 2000.

In a Dutch study, investigators (20) used four administrative cycles (1989, 1997, 1999, 2001) of a school-based questionnaire to ask parents of eight to nine year olds about their child's respiratory health at the same time that they underwent a physical examination. The authors do not report results for every having been diagnosed with asthma, however, the questionnaire contained a question about wheezing over the past 12 months. The prevalences of 13.4%, 13.3%, 11.9%, and 9.1% in each of 1989, 1997, 1999 and 2001 suggest that the proportion of children aged eight to nine years of age experiencing wheezing symptoms declined over the twelve year period. The authors suggest that improved identification and/or more effective treatment may explain the decreasing trend, however, the results are puzzling in light of the results from the European studies described above.

In one of the few Asian ISAAC studies, researchers (21) in Hong Kong administered a questionnaire to 13 to 14 year olds in two cycles in each of 1994 (n=4667) and 2002 (n=3321). The authors reported that the English term "wheeze" does not translate well, thus a video questionnaire was used to eliminate some of the problems associated with translation and interpretation. For lifetime diagnosis of asthma (asked as part of the written questionnaire), the investigators reported no significant change in prevalence between the 1994 cycle (11.2%; 95% C.I. 10.3-12.1%) and the 2002 cycle (10.2%; 95% C.I. 9.2-11.2%). However, wheezing in the past 12 months, asked as part of the video questionnaire, dropped between 1994 (10.1%; 95% C.I. 9.2-11.0%) and 2002 (6.1%; 95% C.I. 5.4-7.0%). In an earlier report, Leung, Wong, Lau et al. (22) reported a trend of increasing asthma prevalence among Hong Kong children from 1992 to 1994.

At first glance, the number of prevalence studies across different populations with roughly similar patterns appears to demonstrate that the burden of asthma at the population level has increased over the past few decades with perhaps an indication of a leveling off in more recent years. Some studies suggest that the leveling off is more apparent in adolescents than it is for children, and other studies suggest that a leveling off occurred for girls but not for boys. In an attempt to explain the observed trends some investigators have suggested a possible effect of diagnosis exchange or transfer, whereby an increased awareness of newly emerging asthma guidelines in the 1980s and 1990s among care providers may have resulted in a greater proportion of children being diagnosed as having asthma than would have been the case previously.(12)(23) However, one could argue that guidelines could have the opposite effect if they are properly followed. An alternative explanation is that a gradual destigmatization of asthma during the 1980s made a 'label' of asthma less of an issue for providers resulting in a greater willingness of clinicians to make a diagnosis.(18)

The apparent rise in the prevalence of asthma among children is a concern from a public health perspective. From a health services delivery perspective, the apparent rise in asthma prevalence may also be of concern because there is the likelihood of increased health care utilization by children diagnosed with asthma. However, if Taussig, Wright, Holbert et al. (10) are correct in their assertion that many young wheezers do not go on to experience asthma symptoms later in childhood, the effect on health service use may not be as great as expected. In Canada, the apparent east-west geographic gradient is particularly noteworthy.

1.3.2 Health Care/ED Utilization by Children with Asthma

Trends in health care utilization by children with asthma have been explored by a number of investigators. As there are different foci of interaction with the health care system, and varying degrees of data availability, some researchers have relied on hospital admission or ED visits data at either a single hospital or across institutions while others have looked at physician claims data or insurance program data.

A report on emergency care for children by the American Institute of Medicine described the relative burden on the health care system of children with different conditions.(24) Using data from the Healthcare Cost and Utilization Project, the authors determined that in the U.S., children with asthma are among the ten most frequent diagnoses for treat and release ED visits in the 1-4, 5-9, and 10-14 year old age groups. For hospital admissions that began with a visit to the ED, children diagnosed with asthma are among the three most frequent diagnoses for the same age groups.

In their U.S. population-based study, described above, Akinbami and Schoendorf (12) found that hospitalizations for asthma among children showed an average increase of 1.4% per year from 1980 to 1998, however, hospitalizations among younger children (0 to 4 years of age) increased more dramatically than among older children (38.0 to 51.4 hospitalization per 10,000). The authors also found that ED visit rates increased in the 0 to 4 age group (14.8 to 15.6 per 1000 children). Perhaps most spectacular was the increase in the number of office visits to private physicians (36.4 to 67.0 per 1000 children).

Russo, McConnochie, McBride et al. (25) suggest that for asthma-related hospitalization the stabilization in hospitalization rates may have more to do with an increase in asthma admission threshold. In a retrospective review of 2028 hospitalizations for asthma over the five year period 1991 to 1995 in Monroe County, New York, the investigators found that the annual hospitalization rate for asthma among children remained stable (p=.06) from 1991 (1.90 per 1000 children) to 1995 (2.31 per 1000 children). However, the percentage of all hospitalizations for mild asthma decreased from 14.1% to 4.7%. For moderate cases, the percentage of asthma hospitalizations decreased from 54.4% to 35.4%, and hospitalizations for severe asthma increased from 31.5% to 60.4% over the five year period. The authors suggest that despite the increase in severe episodes of asthma, overall asthma hospitalization rates may have remained stable because fewer mild and moderate cases were admitted due to an increase in asthma admission threshold.

In a Canadian study using population-based hospital discharge data for Ontario from the Canadian Institutes for Health Information (CIHI), To, Dick, Feldman, and Hernandez (26) noted that through the 1980s and into the early 1990s asthma-related hospital admissions for children increased from 4.3 per 1000 to 4.9 per 1000. Like Akinbami and Schoendorf, the authors noted a striking increase in the preschool (0-4 years old) age group from 8.6 per 1000 to 11.4 per 1000.

In a more recent Canadian study, Dik, Anthonisen, Manfreda, and Roos (23) sought to describe 14-year trends in the utilization of physician resources for asthma using the Manitoba provincial population registry linked to medical claims data. They found that in the 0-4 year old age group, and the 5-9 year old age group, the prevalence of physician resources utilization for asthma had increased from 25-30 per 1,000 in 1985 to 65-70 per 1,000 by 1993, leveling off in the following years through to 1998. The increase in prevalence over the late eighties and early nineties was also substantial among 10-14 year olds (25/1000 in 1985 to 60/1000 in 1994, and then leveling off) and the 15-19 year olds (15/1000 in 1985 to 40/1000 in 1994, leveling off to 1998).

In the province of Quebec, Laurier, Kennedy, Malo et al. (27) used a provincial hospital separation database to examine trends in hospital admissions for asthma. The authors found that the number of hospitalizations for asthma increased in two age groups of children. Among children less than a year old, the number of admissions was 584 in 1989, 521 in 1990, and 1121 in 1994. The number of admissions for asthma for children between one and four years of age increased from 3,475 in 1984, to 4,283 in 1990, and 4,315 in 1994. When rates were calculated using the population eligible for the provincial Health Insurance Program, the increases disappeared with the exception of the 1994 jump in admissions for children under the age of one year old.

Valentine, Neff, Park, Sharp et al. (28) sought to describe hospitalization patterns for children in Washington State for eight chronic conditions, including asthma. The investigators found that hospitalization rates for asthma among individuals aged 0 to 19 years old increased significantly between 1987 and 1996 (188.8 per 100,000 vs. 240.1 per 100,000). The number of individuals under 19 years of age with multiple hospital admissions within a year also appeared to increase between 1987 and 1996 but the increase was not statistically significant.

The results of a study by Lozano, Sullivan, Smith, and Weiss (29) reinforce the notion that the youngest children with asthma use the most health care services. In a nationally representative cross-sectional survey of American children, they found that among children with asthma, children aged one to four years old had an average of 0.08 hospitalizations over a one year period compared to 0.01 and 0.02 for children aged 5 to 9 years old and 10 to 17 years old, respectively. The youngest age group had 0.15 ED visits over the year on average, compared to 0.12 and 0.10 ED visits for the 5 to 9 year old and 10 to 17 year old age groups, respectively.

In a Norwegian study of hospital admissions at a general hospital for children with asthma, Englesvold and Oymar (30) found, in their sample of 1161 visits, that across all age groups there was an increase in admissions ($p < 0.05$) for asthma between 1984 (20 per 10,000 children) and 1989 (35 per 10,000) with a stabilization thereafter to 1999. However, it was noted that among the youngest children (aged 1 or 2 years old) the admission rate rose from 43 per 10,000 to 102 per 10,000 ($p < 0.001$) over the entire 15 year period.

Morrison and McCloone (31) used National Health Service data to examine hospital admission patterns in Scotland. Of the 82,241 admissions between 1981 and 1997, children under the age of 15 accounted for 44% of general population admissions. Among males aged 0 to 4 years old, admission rates increased by 200% between 1981 and 1992, but fell by 25% between 1992 and 1996. The authors found a similarly impressive increase in admissions among children aged 5 to 15 years old (100% percent increase between 1982 and 1996).

Trends in health care utilization are more difficult to ascertain from studies than trends in prevalence because of the significant variability in study methodology in health services research. For example, hospital admissions, ED visits, and family physician visits are all used as measures of health care utilization. However, an emerging theme appears to be that while asthma-related health service use has increased for children of all age groups, the greatest increases are to be found among the very young, i.e., under 5 years of age. Studies in North America by Akinbami and Schoendorf (12), To, Dick, Feldman, and Hernandez (26), and Dik, Anthonisen, Manfreda, and Roos (23) all appear to support this notion, as do some of the European studies previously mentioned. The analysis of Quebec data by Laurier, Kennedy, Malo et al. (27) does not fully corroborate the findings of others, but do not exclude the possibility of a more notable increase in health care utilization in the very young.

1.3.3 Cost of Treating Patients with Asthma

The increasing prevalence of asthma among children to at least the mid-1990s, after which there may have been a plateau, and the concomitant rise in health service utilization rate appear to support the notion of an increasing burden of asthma in children at a population level. One can legitimately ask how this translates into economic burden and whether the potential for cost savings through more effective program delivery exists. Since inflation and fluctuating currency exchange rates make absolute currency values less informative with time, the focus here is on relative costs. In particular, ED-related costs are examined although costs in other settings are mentioned as appropriate.

Among economic studies of relevance to this dissertation, there are a few that have looked at the costs associated with the treatment of asthma and there are others that have looked at the costs associated with ED visits in general. In the former category, Lozano, Sullivan, Smith, and Weiss (29) used the National Medical Expenditure Survey conducted in 1987 in the United States to try and assess the per capita impact of pediatric asthma on medical care expenditures and total expenditures. Costs of medications, ambulatory visits, ED visits, and hospital admission were all part of the assessment. Six-hundred and sixty-seven of the 7578 children (8.8%) aged one to 17 years old in the survey were reported by a parent to have asthma. Comparing children with asthma to children without asthma, the investigators found that children with asthma had 3.1 times as many prescriptions, 1.9 times as many ambulatory visits, 2.2 times as many ED visits, and 3.5 times as many hospitalizations. The proportion of the utilization differences attributable to asthma were 60.4%, 27.8%, 46.2%, and 40%, respectively.

In an asthma-specific economic study, Stanford, McLaughlin, and Okamoto (32) quantified the cost of treating adults for asthma in the ED only and the costs for those who visit the ED for asthma and are subsequently admitted as an inpatient. The data used in the analysis came from a patient-level clinic and cost database for 27 hospitals across the United States. They found that the majority of costs associated with the care of asthma patients in the ED were unavoidable fixed costs such as ED staff labour costs. Categories like diagnostic radiology and medications were found to consume a smaller proportion of total costs (3-10% and 6-10% of total costs, respectively). Costs for patients admitted after ED visits were an order of magnitude higher than for patients who were only seen in the ED.

In another American study, Coventry et al. (33) used insurance claims databases to compare the cost of treating pediatric patients with asthma in the ED versus other treatment settings like physician's offices and hospital outpatient clinics. While the study did not attempt to consider parents' lost work days or the cost of medications not covered, the results provide a rough guide to the relative cost of treatment in different settings. The investigators found that treatment costs are approximately five times higher in EDs than in physicians' offices.

In a randomized trial designed to compare the medical costs and outcomes associated with a community-based intervention among inner-city children in select U.S. cities over a two-year period, Sullivan,Weiss, Lynn, Mitchell et al. (34) found that in their sample of 1003 children the intervention did not have a statistically significant effect on scheduled and unscheduled physician visits, ED visits, or hospital admissions. As a result, a consideration of both intervention costs and potential savings to the Health

Maintenance Organization (HMO) produced a calculated net loss. However, in further analyses using a subset of the sample, children with the clinically most severe asthma, cost savings to the HMO were apparent. Most of the avoided costs were associated with reduced hospital admissions and unscheduled physician visits. The authors did not comment on the costs associated with ED visits. This study may point to the challenges inherent in intervening in populations where the ED is viewed as the primary care provider.

In an article that explores the general cost of an ED visit and whether EDs display economies of scale, i.e. whether EDs with larger volumes have lower average costs for treating patients, Bamezai, Melnick and Nawathe (35) assert that the majority of costs in the ED are fixed costs, i.e. labour driven, and only a small percentage are variable costs, i.e., capital related costs such as medical supplies. Given that economies of scale are observed only when some significant inputs can be purchased in sizeable blocks such that the unit cost is lower, e.g., a purchase of 100,000 needles has a lower per needle cost than a purchase of 1,000 needles, the authors argue that it is unlikely that EDs exhibit economies of scale. As a consequence, operational management of EDs that seek to make the most effective use of health care dollars must focus on the drivers of labour costs in the ED. Many EDs use flexible scheduling systems to adjust staffing to anticipated visit rates suggesting that the major driver of costs in the ED is patient volume and the average length of stay for patient visits.

Economic studies examining the cost of asthma and/or ED visits clearly vary in their purpose, scope, design, and data sources. However, a picture does emerge in which hospital admissions and ED visits associated with asthma appear to be relatively costly, and potentially avoidable in at least some groups of children. Structural issues seem to be a less relevant route to obtaining costs savings in the ED given that the major cost in the ED is labour.

1.3.4 Readmissions/Repeat Visits for Asthma

In chronic disease research, it is useful to make a distinction between an initial visit to the ED and repeat visits and readmissions. In the context of children with asthma, an initial exacerbation is often a reason for an initial visit to the ED. A parent who has never witnessed an asthma attack in their child would be understandably concerned and seek immediate attention. If one considers that, in addition, most asthma exacerbations occur in the evening or early morning hours when family physicians and pediatricians are generally unavailable, it becomes even less surprising that the EDs become the care venue of choice in such situations.

However, repeat visitors to the ED may represent a different population. Children who are repeatedly brought to the ED may have parents or guardians who are less able to manage their child's asthma. There are exceptional cases, of course, and it may be unreasonable to hope that parents of children who are easily triggered or who tend to have severe attacks will not need to visit the ED on a regular basis. However, asthma is considered to be a manageable condition for the majority of children diagnosed with the condition. Prophylactic measures such as the administration of medication when a child has a viral illness (36) or is about to engage in physical activity (37) (38), are known to be effective at reducing the likelihood of an attack and could potentially reduce the demand for ED services.

1.3.4a Incidence of Readmissions/Repeat Visits

To fully develop a picture of asthma in children and its related effects on the health care system, it is important to quantify the incidence of readmissions and repeat visits for children with asthma. Low repeat/readmission rates might suggest that hospital-based initiatives may not be the most effective means for achieving change since all interventions come at a cost and can be expected to benefit only a proportion of the target group. The evidence, however, seems to suggest that readmissions and repeat visits to the ED are fairly common events.

In a Canadian study using hospital separation data from the Canadian Institute for Health Information (CIHI) Chen, Dales, Stewart, Johanssen et al. (39) examined hospital readmissions for children and young adults with asthma over the 1994 to 1997 period. They found that the proportion of readmissions was highest in children under one year of age (25% per year in boys, 22% per year in girls). The one-year readmission rate fell to between 12% and 17% for children between one and nine years old, however, it is interesting to note that females between ten and nineteen years of age had higher readmission rates (17-21% per year) than both younger female cohorts (with the exception of those under 1 yr old) and boys of a similar age. Using 15 to 19 years olds as a reference category, the relative risks of readmission for males <1 year old and 1-4 years old were 2.36 (95% C.I. 2.15-2.59) and 1.54 (95% C.I. 1.41-1.69), respectively. For females, the relative risks of readmission for children <1 year old and 1-4 years old were 1.54 (95% C.I. 1.42-1.66) and 1.15 (95% C.I.1.08-1.22), respectively.

In a study which has already been described, To, Dick, Feldman, and Hernandez (26) also used CIHI data but focused on the province of Ontario and obtained results that concur with those of Chen, Dales, Stewart, Johanssen et al. (39). Among children age 0 to 4 years of age, the investigators found the six month probability of readmission for asthma was 20.0%. The one year probability of readmission for asthma was 25.9%.

In a Norwegian study conducted by Englesvold and Oymar (30) that has been previously described, the investigators found that readmissions varied between 61% and 49% of total admissions for children with asthma between 1984 and 1999. An observed pattern of declining percentage over the 15 year period was perhaps attributable to the greater incidence of asthma resulting in a greater proportion of initial visits for asthma.

In the study by Spurrier, Staugas, Sawyer, Wakefield et al. (40) which has been previously described, the investigators examined the pattern of planned and unplanned visits to the hospital and community health-care services for asthma. The researchers found that over a six month follow-up, 62% of children made unplanned visits to their GP for asthma and 55% of children made planned visits to their GP for asthma. They also found that 37% of children were repeat visitors to the ED in a six month period. Forty-one percent of these repeat visitors had more than one repeat visit to the ED for asthma over the six month follow-up.

Zimmerman, McCarten-Gibbs, DeNoble et al. (41) examined repeat ED visits over a one year period for all causes by children to a general hospital ED. They found that among the 5,228 visits made by 4,276 children, repeat visits accounted for 9.6% of visits during the year. Using odds ratio estimates, the investigators found that three of the five diagnoses with the greatest risk of repeat visit were respiratory-related: bronchiolitis (O.R. 1.60; 95% C.I. 1.65-3.46), asthma (O.R. 1.58; 95% C.I. 1.13-2.02), and upper respiratory tract infection (O.R. 1.51; 95% C.I. 1.13-2.21).

Readmissions and repeat ED visits are clearly a pattern of health care use that can be associated with children with asthma. Readmissions and repeat visits are highest in the young (under 5 years of age). If the reasons behind readmissions and repeat visits are amenable to change there is the real possibility that interventions could have a positive effect on health care utilization.

1.3.4b Factors Associated with Readmissions/Repeat Visits

Legitimate concerns about disease progression that parents are unable to cope with cannot realistically be viewed as opportunities to reduce the demand for ED services. However, evidence of a lack of understanding of asthma, related triggers, and therapy on the part of parents/guardians, or behaviour that is intentionally or unintentionally inappropriate, or ineffectiveness of provider care, would all point to possibilities for positive change.

In one of the earliest studies examining factors with an impact on repeat visits to the pediatric ED, Weinstock (42) found that of 100 unanticipated return visits among children at Boston City Hospital, less than half (47%) were due to natural disease progression. The remaining returns could be attributed to factors amenable to change:

provider behaviour (22%), parental/patient anxiety (18%), and parental/patient noncompliance (13%).

In an Australian study, Spurrier, Staugas, Sawyer et al. (40) prospectively recruited 135 parents and their children from a hospital ED and followed them for six months, contacting parents at one month intervals. They explored factors predicting health service utilization for children with asthma and hypothesized that factors would fall into three categories: disease variables, parental variables, sociodemographic variables. The authors found, in multivariable models, that the level of parental anxiety and parental perceptions of children's vulnerability to illness were significantly associated with unplanned visits to general practitioners. With regard to unplanned ED visits, the investigators found that the background level of asthma symptoms, whether a child was admitted on the initial ED visit, and whether the family had a planned review visit for asthma were the most important variables.

Using a sample of 445 children and parents visiting an ED of a paediatric hospital in New York City, Wasilewski, Clark, Evans, Levison et al. (43) explored the relationship between psychosocial and behavioural factors and ED visits for children with asthma. The investigators found that repeat ED visits were associated with parents not implementing home management practices, such as following guidelines for when to bring a child to the ED. For example, it was considered appropriate to bring a child to the ED if medications were given to the child but there was no improvement. Parents who did not keep medications at home were also more likely to visit the ED repeatedly. Interestingly, the investigators did not find that less parental confidence (as measured by an eight-item Likert-response scale) to manage asthma episodes was associated with increased use of the ED.

Christakis, Wright, Koepsel et al. (44) used claims-based data in a retrospective analysis of 785 children who had at least one visit to the ED at Children's Hospital and Regional Medical Center in Seattle to determine whether continuity of care, i.e. seeing same physician on repeated visits, was associated with reduced ED utilization. The study was not exclusive to children with asthma, however, 15% of the sample consisted of children diagnosed with asthma and whether or not a child had asthma was entered into multivariable models. Using a previously defined index of continuity of care (which has a value of 1 for seeing the same clinician on every visit and a value of 0 when a different clinician is seen on each visit), the authors found that, at least for staff physicians (vs. residents), continuity of care was a predictor of reduced ED utilization. The investigators also found that asthma was a significant predictor of repeat visits, although they didn't ascertain whether asthma patients in particular benefited from greater continuity of care.

Not surprisingly, there are many factors responsible for repeat visits to the ED. Parental anxiety emerges in several studies but confidence in managing asthma episodes was a not a significant factor in another. Having a defined action plan for home management and having a planned review visit for asthma emerged as factors; this is noteworthy because an underlying assumption behind interventions is that parental education and awareness will result in better management practices. Christakis, Wright, Koepsel et al. (44) make an interesting observation about continuity of care but the general inability of the ED to ensure continuity of care due to the shift-work nature of most ED staff suggests that if continuity of care is to be provided it is best provided in another setting, e.g., an asthma outpatient clinic.

1.4 Study Rationale

As the preceding sections have demonstrated, asthma exacerbations are one of the leading causes for repeat visits to the pediatric ED. Utilization reviews in Canada have documented that peak ED use, for all conditions, in pediatric institutions is between 7 p.m. and 10 p.m. (45) An American study found peak ED use was between 5.pm. and 9 p.m. (46) – results that are comparable to Canadian findings. There is no evidence to suggest that the pattern of ED use is any different for asthma patients in particular. In fact, casual observation suggests that many parents discover their child is wheezing when they put them to bed in the early evening and then make a decision to come to the ED.

It has also been established that the waiting time for assessment by a physician is longer with higher ED volume (except for acutely ill patients)(45). These two factors along with the longer average length of stay in the ED for children with asthma symptoms have led to extended waiting times for all patients during peak asthma seasons, possibly in a synergistic manner because as ED care providers become overburdened their productivity will likely decrease.

It has generally been accepted since the mid-1970s that asthma is a manageable condition. An understanding of the inflammatory basis of asthma led to improved treatments (see Section 2.8) and is likely responsible for a reduction in mortality rates (See Section 2.7). Thus, the advent of corticosteroid therapy has improved clinical outcomes in children with asthma, and one might expect that the demand for health care services would moderate as treatments improve, but frequent use of the ED by children with asthma persists.

Clinicians, researchers, and administrators must try to identify factors that lead to the frequent use of the ED, or to ED overloading, with an eye toward intervening where possible to reduce inappropriate use and/or setting up monitoring systems to assist in anticipating periods of heavy demand. Where there is controversy over potential precipitating factors, e.g. particulate matter (PM) pollution, studies must be undertaken to provide evidence for or against a causal relationship. For triggers that are more generally accepted, e.g. delays in adrenergic agonist use, studies must be done to assess the effectiveness of interventions that seek to mitigate the effect of these triggers. To date, hospital-based studies have identified a number of preventable factors for asthma hospital admissions including inappropriate preventive treatment, poor compliance, low asthma knowledge levels, and delays in both using adrenergic agonists and seeking medical care after failure of adrenergic agonist use.(47) In situations where use may be appropriate and exacerbations are not easily preventable, it may be possible to use tools for proactive management of staffing levels.

Some studies have found that asthma education improves parental asthma knowledge but the relationship of asthma knowledge to behavioural change and utilization rates is less clear.(48) The use of the ED may be precipitated by parental care preference factors that outweigh an effect of asthma knowledge. In other situations, it may be that exacerbation triggers outside of the scope of most asthma education initiatives, such as viral infections or environmental pollutants, outweigh an effect of asthma knowledge and lead to the use of the ED. In such situations, strategies for managing staffing levels may be an effective means of ensuring timely emergency care but changes to asthma education program curricula could also be considered.

This dissertation is structured to address three questions related to the utilization of the ED by children with asthma and their parents. Since it has previously been suggested that low parental asthma knowledge is associated with repeat visits to the ED the first question is "Does an outpatient asthma education program result in a reduction in pediatric ED utilization by parents of children with asthma?" In Chapter 4, several studies that have attempted to assess the effect of patient follow-up post ED visit are reviewed. The results have been equivocal. Differentiating this study from earlier studies is that a dedicated asthma education program is evaluated using a time-to-event analytical strategy. The second question of interest is "Do parental care preferences exert an influence on pediatric ED utilization?" Previous studies have not assessed parental decision-making and information-seeking preferences in relation to their ED visit behaviour and it may be that parental preferences exert a significant effect that could even outweigh parental knowledge of asthma. The last question seeks to address a controversy over a specific potential trigger for asthma exacerbations: "Are particulate matter (PM) pollution concentrations related to pediatric ED utilization for asthma?" Previous studies have focused on parental tobacco use as a risk factor for respiratory illness in children (49) and have explored seasonal variation in PM pollution concentrations in relation to pediatric ED visits for asthma (50) or continuous bushfire activity over long periods of time in relation to pediatric ED visits for asthma.(51) In British Columbia, elevated PM pollution concentrations from forest fires have posed an occasional but notable threat to air quality in the past. Conclusive evidence for PM as an asthma trigger might suggest the need for tailoring of asthma education programs as well as ED staffing in the context of the Pacific Northwest where forest fires are a regular summer occurrence. The Burns Bog Fire presents a rare opportunity to explore the question of a relationship between PM concentrations and pediatric ED visits for asthma because preliminary data suggests the spike in PM concentrations was impressive.

Moreover, the PM pollution was dispersed over a large population, i.e., the population of the Greater Vancouver Regional District.

The specific objectives of interest are:

1. *To compare the time to repeat ED visit between patients/parents who attend an asthma education clinic and those who do not attend the education clinic, after presentation in the B.C. Children's Hospital ED for asthma.*

In Chapter 4, time to event analysis techniques are used with retrospective data to compare the likelihood of repeat ED visits, with one study arm receiving extended asthma education through the Asthma Education Clinic at B.C. Children's Hospital. Asthma education clinic attendance is hypothesized to produce a small but significant preventive effect on repeat visits.

2. *To explore the relationship between asthma education clinic attendance, parental care preferences, asthma knowledge, and ED repeat visits among patients/parents who present in the B.C. Children's Hospital ED for asthma.*

In Chapter 5, prospectively collected data using validated structured questionnaires for parental care preferences and asthma knowledge, and retrospective data on ED visits, are used to explore the relationship between asthma education interventions, parental information-seeking and decision-making preferences, parental asthma knowledge, and repeat ED visits. It is hypothesized that parental care preferences have a mitigating effect on any preventive effect of asthma knowledge on ED repeat visits.

3. *To test for a possible relationship between particulate matter pollution concentrations and B.C. Children's Hospital ED visit counts for asthma and to quantify the potential impact of elevated particulate matter pollution concentrations and B.C. Children's Hospital ED visits for asthma.*

In Chapter 6, prospectively collected PM pollution data from pollution monitoring stations stationed in the Greater Vancouver Regional District and retrospectively collected ED visit count data from B.C. Children's Hospital are used to test for a correlation between PM pollution concentrations and pediatric ED visits. Daily ED visit count and $PM_{2.5}$ and PM_{10} pollution data over a three month window of time ranging over the occurrence of the Burns Bog Fire in the Lower Mainland of British Columbia in September of 2005, are used for hypothesis testing. It is hypothesized that the PM pollution concentrations will be correlated with pediatric ED visit counts.

Table 1.1 Summary of Asthma Prevalence Studies

Study	Year	Population	Age Groups	Measure	Estimate
Akinbami et al. (2002)	2000	U.S.	0-17	Attack prevalence	5.5/100
Dales, Raizenne, et al. (1994)	1988	six regions in Canada	5-8	Current asthma dx	2-8/100
Senthilselvan (1998)	1990	Saskatchewan	0-4	Drug tx in 12 mo.	5.1/100
			5-14	Drug tx in 12 mo.	4.4/100
ISAAC Studies					
Anderson et al. (2004)	2002	UK	10-14	Lifetime prevalence	25.9/100
Galassi al. (2006)	2005	Italy	6-7	Wheeze in 12 mo.	8.6/100
				Lifetime prevalence	8.6/100
Garcia-Marcos et al. (2004)	2004	Spain	6-7 M.	Wheeze in 12 mo.	10.7/100
			6-7 F.	Wheeze in 12 mo.	8.2/100
			6-7 M.	Lifetime prevalence	12.9/100
			6-7 F.	Lifetime prevalence	9.0/100
Selnes (2005)	2000	Norway	9-11 M.	Lifetime prevalence	10.2/100
			9-11 F.	Lifetime prevalence	7.6/100
Wong et al. (2004)	2002	Hong Kong	13-14	Wheeze in 12 mo.	6.2/100

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CHAPTER 2: BACKGROUND

2.1 Introduction

Since clinical concepts and definitions evolve with time, it is important to clearly specify what is meant by asthma and asthma exacerbation, and to delineate how the two may be measured in epidemiological and health services research before delving into the details of the methods used to address the objectives of the study. Subsequent sections describe the consequences of asthma for the individual child, the potential causes and triggers of asthma, and therapies for asthma. Each of these has the potential to affect expected health care usage and to dictate whether it is reasonable to expect interventions to have an impact on the type and rate of health care use. The final sections of this chapter cover some of the theoretical considerations behind the objectives of the study. For studies to be more than an exercise of searching for statistical associations there needs to be a theoretical basis for any hypothesized outcomes. Thus, the behavioural theories behind the hypothesized effects of educational programs and the pathological theories behind hypothesized effects of particulate air pollution are reviewed.

2.2 Defining Asthma in Children

Asthma is a disease characterized by airflow obstruction, bronchial hyperresponsiveness (BHR) and airway inflammation. The clinical manifestations of asthma includes recurrent episodes of one or more clinical symptoms such as wheeze, dyspnea, chest tightness, and cough.(1)(2) Airflow obstruction is due to several factors including bronchial muscle spasm, mucosal edema, and increased airway secretions and is demonstrated by lung function tests, e.g., forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC). In the context of distinguishing asthma from other conditions, BHR is normally considered to be responsiveness to β-agonists as evidenced by improved post-treatment airflow obstruction measures. Evidence of airway inflammation typically includes a higher number and proportion of eosinophils and other cells in induced sputum.(3) More recent refinements to distinguishing asthma include the use of exhaled nitric oxide as a measure of airway inflammation.(4) (5) (6) Airway inflammation is responsive to treatment with anti-inflammatory medications including corticosterioids and monteleucast. (7) This multidimensional definition of asthma is a product of our evolving understanding of its basic pathophysiological mechanisms. In the clinical setting, less stringent criteria for diagnosis are commonly employed since a complete assessment of airway inflammation can be technically difficult in young or uncooperative children.

The definition of asthma in children (8) is similar to the general definition of asthma but the diagnosis of asthma in children is complicated by the other conditions associated with wheezing in children and the infeasibility of certain tests, i.e., lung function tests in children under 5 years of age.(9) A loose index for the diagnosis of asthma that is commonly employed in fast-paced environments such as the pediatric Emergency Department is two or three distinct episodes of wheezing/dyspnea plus one or more risk factors for a diagnosis of asthma, e.g., a family history of eczema, hayfever, or asthma, and a demonstrated responsiveness to β-agonist and/or corticosteroid intervention.

Although cough-variant asthma was identified by some as unique clinical entity in the 1980s and 1990s it has been argued that a rising awareness among physicians that patients with asthma could present with cough as sole presenting symptom led to an over-diagnosis of cough-variant asthma.(10) Some researchers have concluded from prospective, investigative studies that lumping chronic cough and wheezing-related asthma may obscure important differences between the two. (11) Faniran, Peat, and Woolcock (12) conducted a cross-sectional survey of 1245 randomly selected children aged 6 to 12 years old and found that children with persistent cough had less atopy, as measured by skin prick test, and less respiratory morbidity, as ascertained via parental questionnaire, than children with wheeze. In the Tucson Children's Respiratory Study, Taussig, Wright, Holberg et al. (13) found that children with recurrent cough without wheeze were similar to children without symptoms for IgE levels, skin test response, and size-corrected forced expiratory flow measurements. Moreover, parental smoking was found to be the only significant risk factor for recurrent cough only (O.R. 1.9; 95% C.I., 1.1 to 3.5) while male gender (O.R., 3.5; 95% C.I., 1.9 to 6.6), maternal allergy (O.R., 2.3; 95% C.I., 1.2 to 4.2), wheezing lower respiratory tract infections in early life (O.R., 4.0; 95% C.I., 2.2 to 7.3), and high IgE level at age 6 years (O.R.,2.4; 95% C.I., 1.3 to 4.3) were all significant risks for recurrent cough with wheeze. The last word may not have been written on cough-variant asthma, however, the results of these prospective studies suggest that children with recurrent cough-only asthma diagnoses may represent a different population of children. The exception is children with asthma who only cough because they have airway obstruction which is so severe that exhalation is silent, i.e. no wheezing. Fortunately, this group of children represents a very small proportion of observed cases.

2.3 Defining Asthma Exacerbations in Children

A child with asthma (or hyperreactive airways disease) can respond to a trigger in an acute manner with mucosal hypersecretion, mucosal edema, and bronchospasm leading to obstruction of airflow on exhalation. Thus, an acute asthma exacerbation is characterized as the abrupt onset or significant worsening of symptoms of shortness of breath, wheezing, chest tightness and breathlessness, associated with respiratory distress and a decrease in expiratory airflow.(14)

The acute asthma episode can be divided into early and late phases. The early phase of the response is short, with rapid onset, and begins with an initial hypoxemic event which leads to tachypnea and tachycardia. Hypoxemia increases bronchospasm which causes the child to trap air and may lead to respiratory failure without proper intervention. (15)

The late phase of an acute episode occurs six hours after exposure to a trigger and can last for up to two days. It is characterized by infiltration of eosinophils and neutrophils into the peribronchial space causing swelling and edema of the bronchial walls. This immune response can result in airflow obstruction even more severe than the early phase airway obstruction and has been associated with asthma mortality.

2.4 Establishing Criteria for Asthma Diagnosis in Paediatric Studies

Asthma is a disease with recognizable characteristics that are nonetheless difficult to define. Factors that complicate the process of forming a diagnosis include the subjective/qualitative nature of patient histories, age of the patient, care setting, differential diagnoses and variable triggers, physician adherence to guidelines, and evolving definitions. These factors will also, therefore, make establishing criteria for asthma diagnosis for the purposes of research a tricky endeavour.

Since asthma, like many conditions, is diagnosed in part using a subjective impression of the patient, national guidelines have been established in various countries in an attempt to increase the reliability of asthma diagnosis. These guidelines seek to, for example, to standardize cut-off values for such variables as 'the number of prior wheezing episodes' and to define the significance of a 'parental history of asthma or eczema'.(8)(16)(17) Since reliability is a key concern for research, these guidelines may provide a starting point for study criteria. However, the subjective and qualitative assessment that parents have of their children's past history still contributes to the diagnosis and in some cases a physician's judgment will lead to conclusions that deviate from strict adherence to guidelines, e.g., situations where parents experience recall difficulties, language barriers, or families with visits to multiple different hospitals/physicians leading to a vague history.

Obviously, for very young patients the potential for a shorter patient history can also make diagnosis, and establishing research criteria for diagnosis, more difficult. The number of prior wheezing episodes forms an important part of current guidelines for asthma diagnosis thus it follows that children under two years of age are often only given a tentative diagnosis. Many clinicians prefer to use terms like 'hyperreactive airways disease' or 'reactive airways disease' (RAD) to describe a condition that resembles asthma but may or may not develop into asthma later in life. While it has been established through prospective research that the pattern of wheezing established by age six is predictive of wheezing to age 16 (18), data from the same cohort also established that 80% of children with wheezing at age one do not wheeze after age two, 60% of children with wheezing at age two do not wheeze after age three, and 35% of children age three do not wheeze after age four.(13) These results are impressive but they also represent the experience of only one cohort of children in a particular geographical environment (Arizona). The degree to which consideration is given to these results in defining study criteria will depend, in part, on the assumed generalizability of these results.

Other concerns surrounding the reliability of diagnosis that must be acknowledged include the fact that care provided in the ED is different from care provided in the family physician setting. Continuity of care in the ED is rare, thus the ED physician relies on previous ED visit records and parental questioning in diagnosing a case of asthma. The transient nature of staffing in many EDs may also lead to differences in diagnoses as can, in academic settings, a reliance on medical residents or clerks. Perhaps the most obvious difference is the time available to the Emergency-based physician for individual care as compared to the family physician. While children with wheeze may stay in the ED for extended periods for observation, clinicians are not usually able to spend more than 10 or 15 minutes with a patient in busy, urban tertiary care centers, making a thorough investigation unlikely.

In addition, the child who presents with symptoms of asthma is also the child who presents with symptoms for a long list of other possible diagnoses. Differential diagnoses include congenital anomalies such as vascular rings, bronchopulmonary dysplasia, cystic fibrosis, gastroesophageal reflux, aspiration, foreign body aspiration, heart failure, sinusitis, bronchiolitis, pertussis, pneumonia, tuberculosis, tumours, and immune system disorders. (8) Some of these are straightforward to differentiate from asthma, e.g., heart failure, however bronchiolitis can be very difficult to distinguish from virally-triggered asthma. (15) Complicating matters, different children may have different triggers that exacerbate any potential asthma, e.g., cold air, pollen, exercise. The observational skills of parents are often instrumental in establishing whether typical asthma triggers are associated with the current episode but it is unclear how one might integrate such information into a research protocol.

The inter-rater reliability of asthma diagnosis in studies can be affected by the differential adoption and use of guidelines by clinicians. Flores, Lee, Kastner, Bauchner, et al. (19) used a randomly sampled cross-sectional survey of general pediatricians across the U.S. to examine attitudes, beliefs, and stated practices regarding a variety of pediatric clinical practice guidelines. Respondents were more familiar with asthma guidelines (88% indicated familiarity) than with any other categories of guidelines, however, only 77% of respondents indicated that they used pediatric asthma guidelines. The most common reason given for not using guidelines (not asthma-specific) was a lack of flexibility in using clinical judgment. Cabana, Rand, Becher, and Rubin (20) used a randomly sampled cross-sectional survey of pediatricians across the U.S. to examine the potential barriers to greater adoption of national guidelines and found that a lack of time, support staff, educational materials, and reimbursement were barriers to the adoption of pediatric asthma guidelines. While the results of these surveys cannot be glibly extended to clinical staff in the tertiary care pediatric setting, they do suggest clinician autonomy is a potential factor in the variation in asthma diagnosis and this can affect the reliability of research measures of asthma diagnosis.

Finally, while consensus guidelines provide some measure by which to judge consistency in diagnosis, as the science evolves there are always early adopters who forgo usual practice in favour of newer protocols. The use of exhaled nitric oxide measurements represents the potential evolution in the diagnosis of asthma.(6) Recommendations for the use of exhaled nitric oxide in diagnosis have been published (21), however, controversy over the applicability of the method in younger patients exists (22) and thus this diagnostic approach has yet to be integrated into national guidelines for the diagnosis of asthma in children. Ongoing research regarding nitric oxide measurement techniques may provide refinements needed to secure greater acceptance (23) (24) (25) but in the meantime, variation in diagnoses (at least across institutions) can in part be attributable to the differential rates of adoption of new techniques of diagnosis.

Clearly, there are many issues surrounding the reliability of asthma diagnosis in relation to research studies. All of these issues must be acknowledged as potential complicating factors. The interpretation of results is dependent on the chosen criteria for diagnosis and comparisons across studies may or may not be valid dependent on the techniques used in each study.

2.5 The Causes of Asthma and Triggers of Asthma Exacerbations

A child developing asthma experiences peribronchial inflammation as a result of the release of inflammatory substances, such as leukotrienes, prostaglandins, interleukins, and histamine in the mucous of the airways. The cells which release these substances, primarily mast cells and eosinophils, appear to do so because of a genetic predisposition and/or repeated exposure to triggering factors.(15)

The past decade has witnessed an explosion in evidence from genetic studies that supports the idea of a genetic predisposition toward the development of asthma. Genetic researchers have used positional cloning to identify an association between asthma/RAD and six separate genes: the ADAM33 gene, GRPA gene, PHF11 gene, HLA-G gene, DPP10 gene, and CYFIP2 gene. In addition, over 100 genes have been identified via candidate gene association studies and the results of highly anticipated genome-wide single nucleotide polymorphism studies using case-control study designs are forthcoming.(26)

While current identified genetic factors can account for some of the observed morbidity, environmental factors also appear to play a role in the *development* of asthma. It is believed that some of the proven and hypothesized triggers for an acute episode, such as respiratory tract infections (viral), allergens (mites, mold, pollens, animal dander), pollutants (particulate, gaseous), irritants (scents, perfumes), and cold air, may also be instrumental in the development of asthma, likely through gene-environment interactions. (27) For example, studies suggest that maternal smoking during pregnancy results in prooxidant exposure *in utero* and is associated with an increased probability of an asthma diagnosis in offspring.(28)(29)

2.6 The Hygiene Hypothesis

While repeated viral infections are frequently cited as a precipitating factor for peribronchial inflammation leading to the eventual development of asthma, the hygiene hypothesis proposes that viral exposures not involving the lower respiratory tract may in fact have a protective effect against the development of asthma. The type 1 helper T-cell immune response appears to be enhanced by infection with the measles virus, hepatitis A virus, *Mycobacterium tuberculosis*, and infections acquired from siblings or in the daycare setting, resulting in a reduced incidence of allergy and asthma.(30)

The hygiene hypothesis also suggests that early exposure to animals may confer a protective effect against subsequent development of asthma.(15). Von Mutius (31) argues that studies have shown exposure to animals or other children is associated with a decreased risk of asthma. Results from sibling studies suggest that atopy risk is decreased in larger families, and in particular, as the number of older siblings increases. However, Platts-Mills, Woodfolk, and Sporik (32) argue that an examination of the public health timeline in America shows that the rise in asthma is not associated with a decreased exposure to farm animals. Taking New York City as an example, they point out that ragweed eradication efforts, cures for major infectious diseases, and a reduction in contact with farm animals occurred before 1946. However, they argue that the rise in asthma rates did not start before 1960. Moreover, they present the increase in the sedentary lifestyle with its increased exposure to indoor allergens, overeating, and reduced exercise as more likely candidates for explaining the increase in asthma incidence.

Evidence from the Tucson Children's Respiratory Study is mixed.(13) While the investigators found that children living in households with one or more indoor dogs at birth were less likely to develop frequent wheeze than those not having indoor dogs (p =

.004) a relationship was not evident for exposure to indoor cats. Additionally, the inverse association applied only to children without parental asthma (hazard ratio, 0.47; $p < .001$) and was not evident for children whose parents were diagnosed with asthma (hazard ratio, 0.96; $p = .87$).

With evidence to support both pro and con arguments, the hygiene hypothesis has yet to gain widespread acceptance. Certainly, from the perspective of therapy it matters little because animal dander is associated with exacerbations in some children who have already developed asthma.

2.7 The Consequences of Asthma for the Individual Child

Results from longitudinal studies suggest that 60% of children wheezing at least once before the age of three do not have further episodes of wheezing to age six (33) and 30% of children diagnosed with asthma at age seven "outgrow" the condition by age 42 years.(34) Moreover, transient early wheezing is a poorly predictive indicator for developing asthma and even among children with "asthma" a substantial minority will outgrow the condition. However, the probability of outgrowing asthma appears to be dependent on risk factors such as age of onset, atopic status (e.g. eosinophilia), family history, and tobacco use.(35) Prospective studies suggest that there is a difference between early childhood wheezing leading to a diagnosis of asthma and late childhood wheezing leading to the same, with a later diagnosis being more predictive of asthma into adulthood. Atopic asthma appears to be more likely to persist and a family history of asthma also predisposes one to a poorer prognosis. Tobacco use during adolescence and young adulthood is, perhaps not surprisingly, associated with an increased risk for asthma symptoms in adulthood.

Uncontrolled asthma poses a risk for death but fortunately asthma mortality rates in the current era are low, ranging between two and four per 100,000 in western developed nations. There is some indication of an upward trend in mortality rates in children over the past few decades but some argue that this pattern is an artifact of changes in asthma codes in the International Classification of Diseases (ICD) system over the same period.(35) The more immediate threat for the majority of children with asthma is acute or chronic damage to the mucosal integrity of airway epithelia. As the site of production for a number of smooth muscle relaxing factors that oppose the constrictive effect of histamine and leukotrienes, loss of mucosal surface due to eosinophil activity associated with atopic inflammation is thought to lead to reduced airway patency.(15)

While mortality rates have fallen, the perceived stigma associated with severe or chronic asthma can be a problem for some children, especially adolescents, resulting in recurrent anxiety or depression.(36)(37)(38) In a review of research on the psychosocial well-being of children with chronic illness, Barlow and Ellard (39) found that there was no evidence of elevated levels of either anxiety or depression among children with less severe asthma however these children had significantly more adjustment problems than reference groups. Asthma morbidity has also been shown to affect a child's ability to participate in typical school activities involving vigorous exercise and has been associated with lost school days and lower performance at school.(40)

2.8 Therapy for Asthma

A dominant therapy for asthma in the forty year period from 1940 to 1980 was the use of the methylxanthine class of muscle relaxants. In the 1950s, asthma was considered to be airflow obstruction that could resolve spontaneously for unknown reasons.(41) Although adrenergic agonists in pill form had been around since the 1900s, it was not until an understanding of the improved bioavailability achieved with inhaled medication in the 1910s and the invention of the metered dose inhaler in 1956 that the popularity of adrenergic agonist therapy grew.(42) At least 11 adrenergic agents were introduced over the following 20-25 years as improvements were made in the potency and duration of activity in this class of compounds. In the 1960s, airflow obstruction was attributed to underlying bronchial hyperresponsiveness (41) but therapy continued to focus on relieving intermittent bronchospasms as they occurred. It was not until the 1970s and the advent of inhaled glucocorticoids designed to minimize the side effects of earlier oral formulations (42), that preventive therapy emerged as a consideration. The 1980s witnessed the decline in use of the methylxanthines which were shown to be less efficacious than adrenergic agonists and were also thought to be associated with undesirable side effects, e.g., gastrointestinal bleeding, tachycardia. Recognition in the 1990s of the inflammatory process underlying the condition brought about a redefinition of asthma as a chronic inflammatory disease characterized by BHR and reversible airflow obstruction, and this has led to new strategies for treatment targeted at the underlying inflammatory response rather than solely relief of obstructive symptoms.

Current first-line treatment for relief of airway constriction are the short-acting adrenergic agonists like albuterol/salbutamol (trade name Ventolin® in Canada), usually administered three or four times a day, and long-acting adrenergic agonists like salmeterol and formoterol, requiring two administrations per day. Drug delivery is normally directly to the airways. In the ED, first-line treatment of acute asthma exacerbations includes oxygen administration to prevent hypoxemia (See Figure 2.1).(14) For older children, a metered-dose inhaler (MDI) which delivers medication as a microfine powder suspended in a gaseous propellant may be used. Younger children or children who having difficulty using an MDI may receive their medication using a nebulizer which delivers a mist of the medication in solution that the patient inhales from a mouthpiece or face mask. Adrenergic agonists only provide a bronchodilator effect for relief of acute symptoms(1,15).

The National Asthma Education and Prevention Program (NAEPP) in the U.S. keeps asthma clinical practice guidelines up-to-date through periodic reviews of the literature. The 2002 NAEPP expert panel report (17) concluded, on the basis of strong evidence from clinical trials, that inhaled corticosteroids (ICS) are the most effective medications for the long-term control of asthma in children. Corticosteroids are used as first-line therapy for control of chronic asthma, i.e., patients who find they must use an adrenergic agonist for symptom control more than three times a week. Commonly used products in Canada include fluticasone (trade name Flovent®) and budesonide (trade name Pulmicort®). In less severe cases, ICS are preferable to oral corticosteroids as side-effects are less common than with oral corticosteroids. Severe, acute attacks may necessitate the use of oral or intravenous preparations and adjuvant anticholinergic agents which have been shown to have a synergistic effect with albuterol. Newer products such as anti-IgE Xolair® may also hold some promise as alternative or adjuvant therapy.

Cohort studies following children for more than 10 years demonstrate that ICS do not have clinically significant, irreversible effects, i.e., any effect on growth velocity appears to be temporary and reversible. Both the NAEPP panel (17) and the authors of the Canadian Pediatric Asthma Consensus Guidelines (43) concluded that comparison studies of inhaled corticosteroids to leukotriene receptor antagonists (LTRAs) are too limited in number to make a definitive conclusion about relative effectiveness, although LTRAs do appear to hold some promise for steroid resistant asthma.

2.9 Theoretical considerations

In addition to clear definitions and measures, the underpinnings of good studies are theoretical models that either suggest testable hypotheses or support observed findings. In the following two subsections, the theories behind educational interventions for asthma and particulate pollution effects on asthma are reviewed. The specific results of previous asthma education program evaluation studies and particulate matter air pollution studies are described in Chapters 5 and 6, respectively. The models described in the first subsection are behavioural models of health education and in the latter subsection, pathophysiological models of the effects of particulate matter pollution on asthma.

2.9.1 Health Education Models with Applicability to Asthma

The rise in asthma prevalence over time, the health care utilization patterns of children with asthma, and the costs associated with ED visits for asthma all appear to suggest that children with asthma place a significant burden on the health care system. The types of factors behind readmissions/repeat visits to the ED suggest there may be opportunities for improving the asthma-management skills of parents and the high incidence of readmission/repeat visits suggest that pursuing such opportunities may be worthwhile.

The idea that better parental knowledge about asthma will result in better management of asthma and more appropriate health care use is intuitively appealing. Thus, not surprisingly, parental asthma education has been identified as an area for programming initiatives in many pediatric health care institutions. However, unlike physician-provided medical therapy, parental education naturally entails a learning process for parents. Psychologists have long studied learning and many theories of learning, education, and behaviour change exist. (44) For the implementation of a new education program, or the review of an existing program, it is useful to view education programs in the context of these theories. Theories assist in understanding the influences on health and behaviour, in selecting appropriate targets for intervention, in developing strategies and materials that increase the likelihood of program success, and in maximizing the cost-effectiveness of program implementation (45), and predict possible outcomes.

Since theories differ in their scope, and may even conflict with one another, one must ultimately select a particular theory of behaviour change as an underpinning for an asthma intervention. Some of the criteria for choosing one theory over another as a basis for a program include: whether change is sought at intrapersonal, group, community, or general population level, the setting in which the problem occurs, the site at which the intervention will be offered, the target population, and the nature of the behaviour itself, i.e. whether it is simple or complex and whether it is rare event or occurs repeatedly.(46) The explanatory capacity of a theory is also important as it seems intuitive that successful interventions will focus on the factors that cause behaviour. Some theories seek to predict behaviour may but do not necessarily explain behaviour. (47). Clark and Valerio (47) argue that successful asthma interventions are rooted in established theories of behaviour because a good theory forces one to think about how behavioural change comes about.

There are many different theories of education and behaviour with applicability to asthma. (48) (47) Some of the more popular ones are the health belief model (49), locus of control theory (50), stages of change theory/transtheoretical model (51), social learning/social cognitive theory (52), PRECEDE/PROCEED model (48), ecologic theory, and attribution theory. In addition, a number of principles of behaviour change have been explicated as potential pan-theory measures that can be used to guide the design of interventions.

Clark and Valerio (47) argue that the health belief model and the transtheoretical model are poor at offering explanations for an individual's perceptions and readiness for change, respectively. The health belief model states that perceptions about the seriousness of an illness such as asthma and one's own perceived susceptibility to an illness are predictive of behaviour change. However, Clark and Valerio assert that the health belief model does not explain how individuals arrive at these perceptions. The transtheoretical model describes the phases through which individuals pass, sometimes in a relapsing fashion, on a journey toward behavioural change. However, Clark and Valerio state that this model also provides little in the way of explanation as to why individuals perceive themselves to be ready for change. The model has in the past been criticized for the arbitrariness of the stages, the fluctuating number of stages, and for circular logic. (53) (54)

Chiang, Huang, Yeh, and Yu (55) conducted a study that supports the use of the PRECEDE/PROCEED model in parental asthma education. The investigators compared two versions of an asthma education program, one based on the PRECEDE/PROCEED model, and the other being the existing atheoretical program, in Chang Gung Children's Hospital, Taoyuan, Taiwan. Parents of children with asthma were recruited from among outpatients and repeated measures were used to compare asthma knowledge, self-efficacy, perceived effectiveness, children's cooperation, and self-management behaviors at 2 weeks, 3 months, and 6 months after education. The research group found that the theory-based program had a positive effect on self-management behaviours at three months with some effects holding through to six months.

Clark and Valerio (47) argue that social learning/social cognitive theory is well suited for asthma interventions. In their view, the theory is particularly amenable to the clinical aspects of asthma as parents must learn a range of control measures, e.g., monitoring symptoms and knowing when to initiate treatment. They must also make informed judgments that require observations skills, such as deciding when it is appropriate to take their children to see a physician or to the ED. From an explanatory perspective, social learning theory suggests mechanisms through which people come to change their behaviour. The theory suggests that motivation for change arises mostly from (a) the perception that undertaking an action will enable people to achieve desirable goals, and (b) the perception that one is capable of the action (referred to as self-efficacy in the literature).

Without stating a preference for one theory over another, Green and Frankish (48) delineate three categories of behavioural influence relevant to patients and their parents in asthma education: predisposing, enabling, and reinforcing factors. Predisposing factors describe the extent to which parents/patients have the motivation and cognitive skills to effect asthma management. Knowledge about asthma, attitudes and beliefs about the importance of risk factors, values, and perceptions about the ability to effectively manage asthma are all predisposing factors than help to ultimately determine behaviour. Enabling factors, such as financial resources and actual skills, encompasses the notion that there are necessary skills and resources needed for asthma self-management. If there are financial barriers or if there is a discrepancy between actual skills and minimum required skills for effective asthma management, enabling factors may be a barrier to behaviour change. Reinforcing factors refers to the support of family members and health professionals. This social support is particularly important for the preventive aspects of asthma management that do not yield tangible, short-term results.

Researchers differ in their educational/behavioural theory preferences. For any one particular educational challenge, there are likely multiple theories that could be used. In such situations, the selection of a theory may very well come down to the preferences of the implementation team. What is likely most important is that the effort is made to try to evaluate a proposed program, or an existing program, in light of a coherent theory of learning, behaviour, or education.

2.9.2 Models of the Effect of Particulate Matter Pollution

Particulate matter (PM) pollution has been associated in some, but not all, ecological and population-based studies with respiratory morbidity and mortality. The mechanisms by which particulate pollution may have a detrimental effect on the human body are only beginning to be understood. The most generally accepted model for the effect of PM is one in which PM is believed to instigate an inflammatory process in pulmonary epithelial tissue. This effect, in combination with oxidative stress associated with other components of environmental pollution, such as gaseous ozone, is assumed to be a precipitating factor in the human biological response to pollution.

Much of the reason for the slow progress in understanding the biological effects of particulate pollution, despite some epidemiological indications, has been related to the fact that satisfactory animal experimental models have been lacking. Animals do not spontaneously develop asthma, and in many of the animal models used to study asthma, e.g. murine models, the inflammatory and epithelial changes that are characteristic of the human disease are not present. Some progress has been made more recently in trying to develop a murine model of allergic asthma.(56) One can hope that with improved animal models a better understanding of the pathobiology of the disease in humans will emerge.

Much of the current biological evidence for the inflammatory processes comes from studies that use isolated human bronchial or lung tissue. For example, Fujii et al. (57) have demonstrated that urban particulate matter pollution < 10 μM (PM_{10}) induces proinflammatory cytokines in human alveolar macrophages and bronchial epithelial cells. More recently, researchers have concluded that the interaction of alveolar macrophage cells and bronchial epithelial cells via the intercellular adhesion molecule (ICAM)-1 enhances the release of proinflammatory mediators.(58)(59)

Investigators have postulated that any of sulfates, heavy/transition metals, acids, or volatile organic compounds in PM may be responsible for the increases in airway sensitivity, but the exact physicochemical properties of PM that promote such effects is unclear.(60) Veronesi, Haar, Lee, and Oortgiesen (61) have provided evidence that suggests differences in the surface charge carried on PM's may predict the differential release of the inflammatory cytokines in human respiratory epithelial cells.

It is worth noting that at the basic science level, research has been focused on understanding the inflammatory processes that are hypothesized to lead to the development of asthma. An asthma exacerbation entails more than just an inflammatory response, however, and is characterized by mucosal hypersecretion, mucosal edema, and bronchospasm. Current understanding of the biology underlying an asthma exacerbation is very limited. However, it seems likely that the interaction of PM with genetic predisposing factors (see section 2.5) promotes an inflammatory response and mucosal hypersecretion, mucosal edema, and bronchospasm in some children, while in other children it may only promote an inflammatory response that does not necessarily, by itself, lead to asthma or an asthma exacerbation.

Clinical studies of lung function after exposure to PM have also lent support to the idea that PM exposure is associated with airway inflammation. In a controlled exposure experiment, Ghio and Devlin (62) report finding differential inflammatory lung injury in adult subjects after bronchial instillation of different concentrations of aqueous PM via bronchoscope. Such a study would likely run into serious ethical concerns in a pediatric population, however, observational lung function-based studies in children have provided some evidence for a detrimental effect of PM. Lewis, Robins, Dvonch, Keeler et al. (63) conducted a prospective study of lung function in predominantly African-American school-age population of children. Peak flow (PF) and forced expiratory volume in 1 sec (FEV1) were measured for 14 consecutive days during 11 seasonal measurement periods. Ambient monitoring sites were established on the rooftops of the schools the children attended to measure daily $PM_{2.5}$, PM_{10}, and mean ozone levels. The investigators found that in single- and two-pollutant regression models levels of air pollutants were associated with adverse effects on pulmonary function among at-risk children with asthma.

Gauderman, Avol, Gilliland, Vora et al. (64) conducted a eight-year prospective study of 1759 school-age children in 12 southern California communities. Pulmonary function data such as forced vital capacity (FVC), FEV1, and maximal mid-expiratory flow rate (MMEF) were obtained by trained field technicians, who traveled to study schools annually. Air-pollution–monitoring stations established in each of the 12 study communities measured PM, as well as average hourly O_3, NO_2, and two-week integrated-filter samples for measuring acid vapor. On analysis, the investigators found deficits in the increase in FEV1 with growth were associated with exposure to $PM_{2.5}$, as well as to NO_2, acid vapor, and elemental carbon.

2.10 Summary

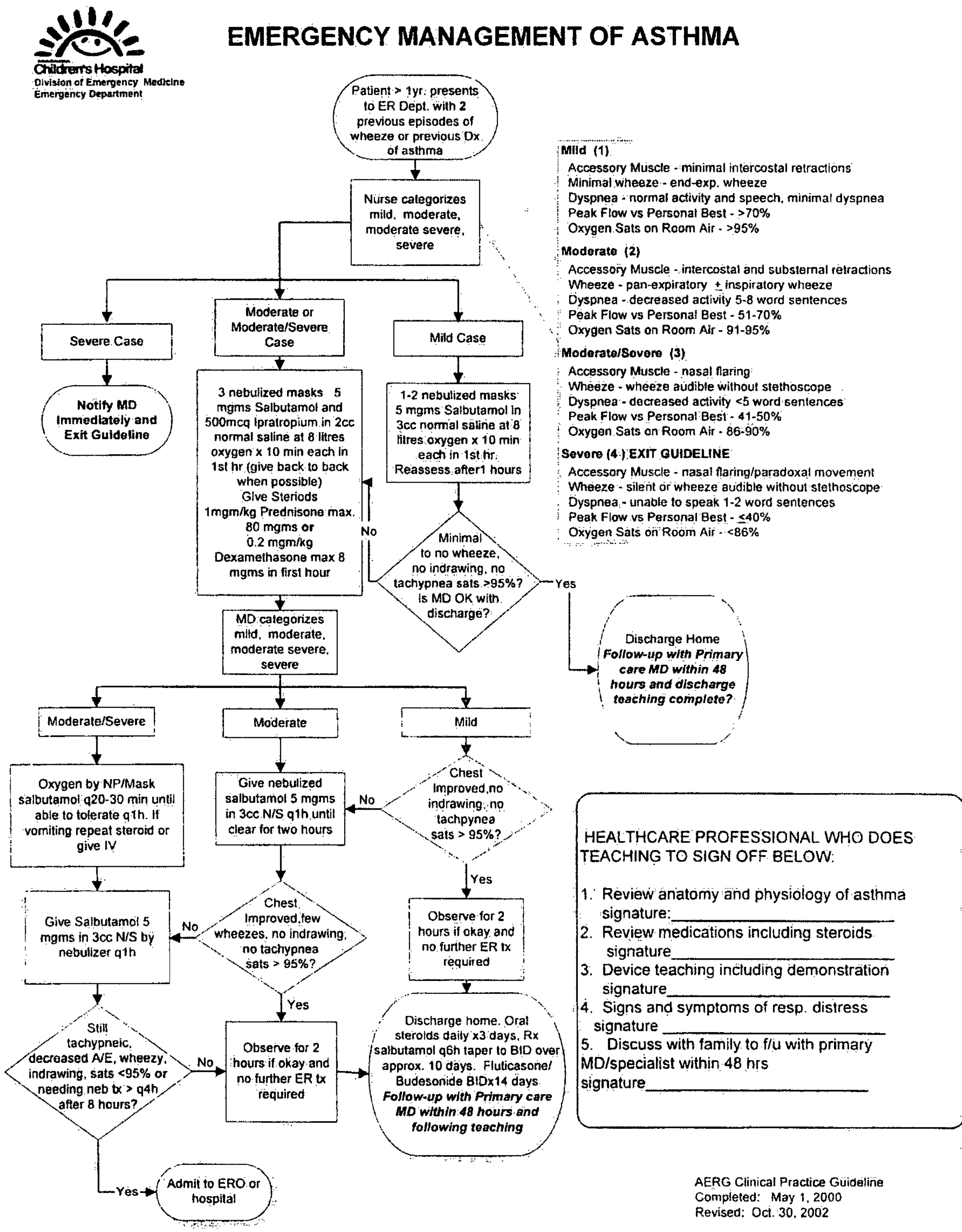
The multi-dimensional nature of asthma can make diagnosis challenging. Moreover, the infeasibility of lung function tests in younger children likely means that a greater proportion of children are diagnosed with asthma when, in fact, they do not have asthma. The evidence from the prospective study by Tausig et al. (13) certainly appears to support this assertion. Thus, it seems reasonable to expect that patients enrolled in asthma studies will show differential effects based on age.

Additionally, many younger children are prone to repeated viral infections, which may or may not lead to an asthma exacerbation in children with asthma. Clearly, asthma educational interventions and PM asthma studies are less likely to report consistent results across children with asthma who vary in their sensitivity to viral triggers.

The multitude of asthma triggers, and the emerging evidence for the genetic basis of asthma development, makes it apparent that no one study can collect and control for every single variable known to influence asthma (let alone hypothetical explanatory variables). The results of asthma studies must therefore be interpreted with care, taking careful note of missing variables that could provide alternative explanations for hypothesized results.

The numerous triggers, treatments, and preventive measures associated with asthma suggest, however, that parental asthma education is necessary as parents are bound to be either uninformed or overwhelmed by the amount of information they encounter on their own. PM, as one potential trigger, may be of particular concern for residents of British Columbia, given the fire-prone nature of the natural environment in many parts of the province in the summer months.

Figure 2.1 Flowsheet for B.C. Children's Hospital Emergency Management Asthma Guideline (in the public domain)



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CHAPTER 3: METHODS

3.1 Study Settings

The British Columbia Children's Hospital is a quaternary pediatric care center under the auspices of the Provincial Health Services Authority (PHSA). The PHSA is one of six health authorities in British Columbia and the only one not associated with a particular geographic region within the province. It is tasked with the oversight of specialized health care agencies that provide health care services to the entire province of British Columbia. In addition to the B.C. Children's Hospital, the PHSA has responsibility for other agencies such as the British Columbia Center for Disease Control and the British Columbia Cancer Agency.

In addition to caring for the most acutely ill or injured children in the province, the B.C. Children's Hospital also provides pediatric day programs, clinics, and emergency services for the Greater Vancouver Regional District (GVRD). The two services of particular interest in this study are the Emergency Department (ED), and the Asthma Education Clinic, which was transferred from Mount St. Joseph's Hospital in the fall of 2003 upon closure of pediatric services in that facility.

During the period of this study, the B.C. Children's Hospital ED had 84 nurses, two residents, six fellows, and 12 full-time equivalent (FTE) staff physicians. There were seven nurses on the day shift, nine on the evening shift, and five on night shift. Thirty-eight hours of staff physician time were available in a 24 hour period (one physician 10 a.m. to midnight and a second physician 24 hours). There was a part-time grant-funded research nurse in the department.

The asthma education clinic opened on-site in November of 2003. During the period of the study, it was staffed by three part-time nurse educators who provided a total of 1.4FTE nursing education time between them for parents of children with asthma. All three nurses were specifically trained and accredited as asthma nurse educators and reported to the Division of Infectious and Immunological Diseases. Asthma education typically took place in the clinic of the ambulatory care building but in the case of admitted patients a nurse educator provided on-site education in the General Pediatrics inpatient unit.

For the environmental impact analyses, particulate matter (PM) pollution monitoring stations in the GVRD were used to collect data on PM pollution for the region. The air pollution monitoring stations were located in Kitsilano, Richmond, Burnaby, Port Moody, Surrey, North Vancouver, Horseshoe Bay, Hope, Abottsford, Langley, and Chilliwack. Individual stations varied as to whether they captured data for PM_{10}, $PM_{2.5}$, or both types of PM pollution. Figure 3.1 presents a map of the GVRD with locations of the individual monitoring stations.

3.2 The Criteria for Asthma Diagnosis Used in the Studies

The analyses presented in this dissertation do not focus on the methodology of diagnosis. Rather, the Emergency physician's diagnosis is accepted at face value. However, the issues mentioned in Chapter 2 surrounding the definition and diagnosis of asthma must be acknowledged because the interpretation of study results is dependent on these many factors. Table 3.1 presents a comparison of the criteria used for asthma diagnosis and a history of asthma for the different analyses presented here in comparison to the B.C. Children's Hospital emergency management asthma guidelines and Canadian national consensus pediatric asthma guidelines.

The B.C. Children's Hospital emergency management asthma guidelines allow for children as young as one year of age to be given the diagnosis of, and to be treated as, patients with asthma. With evidence from prospective studies (1) that over 80% of children with wheeze at one year of age do not progress on to asthma in later years, a decision was made to adopt a more stringent criterion for the studies presented here and thus only patients who were at least two years of age are included in the analyses. On the other hand, the national consensus guidelines suggest that three or more episodes of wheeze in the first three years of life are appropriate for a diagnosis. In this study, the Emergency Physician diagnosis is assumed to be correct, regardless of whether there is a record of three or more episodes of wheeze. Given that patients may have visited other care venues, and the multitude of other factors involved in diagnosis covered in Chapter 2, it seemed unwise to try and second guess a diagnosis retrospectively on the basis of ED records. Moreover, using the ED diagnosis will, if anything, bias the analysis of the Asthma Education Clinic impact toward the null, as it is more likely that children without asthma, though wheezing, will be included in the study sample.

3.3 Informed Consent

Informed consent was obtained from the parent/guardian and the child if older than 10 years of age. Assent was obtained from children 10 years old or younger if they were capable of providing it. Figure 3.2 shows examples of consent forms used in the studies. All forms were approved for use by the UBC Behavioural Ethics Review Board and the B.C. Children's Hospital Research Board (see Appendix).

3.4 Sampling and Data Extraction

The prospective study presented in Chapter 5 was an observational study with active enrolment on site in the ED from July 1, 2005 to October 31, 2005. Potential study participants were identified at the point of registration and on assignment to an examining room. Presenting symptoms given to the triage nurse are recorded in a registration record and written on the central whiteboard. This easy access to presenting symptoms enabled the investigator to quickly identify potential study participants and maintain a rolling list of patient families to approach about participation. Most patients presenting with breathing difficulties had a stay in excess of three hours. Thus, timing was not an issue and there was little chance of potential study participants being discharged before the investigator was able to approach them about the study.

The ED nurses and attending physicians first assessed, diagnosed, and initiated treatment before parents and children were approached about participating in the study. Based on the results of the clinical assessment (resulting in updates on the whiteboard), the investigator modified the rolling list to exclude those children initially suspected of asthma exacerbation but eventually given an alternative diagnosis. If a child was given a final diagnosis of asthma, and the child was two years of age or older, the family was approached about participation in the study.

The sample was a convenience sample with patient enrolment done when the primary investigator was present in the ED. Almost all enrolment was done during weekday evenings (5 p.m. to 12 a.m.) or weekend day and/or evenings (9 a.m. to midnight). These times correspond to peak ED visitation times in a pediatric ED, likely due to the unavailability of family practitioners, and thus maximized the efficiency of participant enrolment process but did potentially introduce the possibility of biased sampling.

The data collection procedure and questionnaire administration was pilot tested in a sample of ten patients. Readability of the questionnaires was not a primary concern as the questionnaires were administered in person (or over the phone) providing ample opportunity to address any questions parents/guardian might have had. However, pilot testing did provide the opportunity to refine the enrolment process to minimize interference with care providers. No specific data analysis was done with the pilot data because of the small sample size.

For the retrospective study presented in Chapter 4, patients two years of age and older were identified in the study enrolment period November 1, 2003 to October 31, 2004 using computerized record research. However, final diagnosis for an ED visit was not available in the computerized record (because it was not entered) and thus the initial case screening was based on presenting symptoms to the ED rather than final diagnosis. Chart review was conducted to separate true asthma cases from other diagnoses. The list of presenting symptoms and descriptors used for the search (not including variation by tense, adjective/noun, short forms, or word order) include: "wheeze", "shortness of breath", "difficulty breathing", "respiratory distress", "asthma", "hyperreactive airway disease".

It is noteworthy that cough as a sole presenting symptom was not included in the list of presenting symptoms above. Given that a small proportion of children presenting with isolated cough are actually children experiencing an asthma episode, the review of thousands of charts for such a small return was deemed to be an inefficient use of time. Such an approach could be subject to criticism if there was agreement on the significance of isolated cough for asthma. However, as suggested in Chapter 2, cough-variant asthma is an entity in dispute and the decision to exclude children with isolated cough as a presenting symptom can therefore be justified.

The air pollution study presented in Chapter 6 used both ED visit and PM pollution data. Daily aggregate counts of visits for patients with a confirmed diagnosis of asthma were assembled from a computerized search based on presenting symptoms (similar to the retrospective analysis above) for the August 1st to October 31st window for each year between 1999 and 2005, inclusive. Chart review was done to confirm a diagnosis of asthma/hyperreactive airways disease. Daily average PM pollution concentrations (PM_{10} and $PM_{2.5}$) were obtained for the same period in 2005 from the Lower Fraser Valley Air Pollution Monitoring Network. Hourly PM pollution concentrations were also obtained, however, these data were deemed to be less useful given ED attendance patterns, i.e., patients with respiratory concerns stay 4-6 hours at a time and most parents bring their children to the ED after normal working hours on weekdays or on weekends.

3.5 Intervention and Monitoring

For the retrospective and prospective analyses of ED visits for asthma, in Chapters 4 and 5, respectively, the intervention of interest was asthma education through the Asthma Education Service associated with the General Pediatrics outpatient clinic (with the control group receiving only basic asthma education in the ED). Referral to the Asthma Education Clinic was based on an informal needs assessment by the attending nurse or physician. For example, if it was evident that parents did not have a good understanding of asthma and asthma exacerbations in children it was likely that a referral would be initiated. Referral consisted of filling out a referral form, placing a phone call to the Asthma Education Clinic, and leaving a message to request Asthma Education Clinic follow-up if the patient presented in the evening or nighttime. Study follow-up in the prospective cohort consisted of contact with parents a few days after enrolment in the ED and at four months post-ED visit. In contrast, the air pollution analysis did not have an investigator-controlled intervention per se, however, the particular event of interest was the Burns Bog Fire in September of 2005, and the associated elevation in PM pollution concentrations across much of the GVRD.

Extended parental asthma education occurred in the Asthma Education Clinic which was designed as a referral service, i.e. from the ED or inpatient units, for increasing asthma management skills among both parents and their children. The design of the original intervention at Mount St. Joseph's Hospital, and its subsequent transfer to the General Paediatrics Ambulatory Clinic at Children's Hospital, predates this study. It is not possible to articulate a particular health behaviour model, or model of behavioural change, that might have been the foundation for the original program as there are no documents on file regarding the design of the original program. However, a review of the content and process of the Asthma Education Service suggests compatibility with theories of behaviour change.

More specifically, the emphasis on monitoring skills, such as knowing when to initiate treatment, and medication/device use skills, was compatible with social learning/social cognitive theory, which Clark and Valerio (2) have argued is well suited for asthma interventions. As the Asthma Education Service assessment tool suggests (See Figure 3.3), the asthma nurse educators reviewed aspects of a child's asthma history that require parental monitoring, e.g., daytime and nighttime asthma symptoms, season when symptoms are the worst, triggers that affect the child and whether a trigger has been identified by child or caregiver. The importance of monitoring these different variables was conveyed to parents or guardians, especially if they were unable to accurately describe their child's history. Parents/guardians were asked questions such as "What is the first thing you notice at the start of your child's asthma attack?" and "How confident do you feel in managing your child's treatment?" as part of the assessment of whether a parent/guardian was comfortable knowing when to initiate treatment. A review of medications and devices was designed to improve parent/guardian's understanding of when to use 'preventers' and 'relievers'. Although it is not explicitly evident from the assessment tool, an important part of the education session was having the parent/guardian demonstrate the use of any devices they may need to use so that the asthma nurse educator could assess whether they are using them correctly and instruct them on proper usage in the event that there are mistakes in usage.

Basic asthma education was potentially provided to both intervention and control group in the ED by ED nurses. The variable nature of patient load in the ED meant that basic asthma education was not provided at certain times, e.g., when patient volume was high. A patient teaching flowsheet (see Figure 3.4) originally created in 1995 but revised in 2004 was used as guide for ED nurses to provide complete coverage of learning objectives for patients on the asthma guideline (see Figure 2.1). As ED nursing staff turnover was significant, a review of the asthma patient teaching flowsheet was done on an annual basis with all ED nursing staff. The general goals of basic asthma education in the ED include many of the same objectives of extended asthma education in the Asthma Educations Clinic setting: teaching about the basic physiology of the lungs/bronchi, a discussion about the child's medications and devices with an explanation about the difference between "preventers" and "relievers", potential drug side-effects, coverage of the potential triggers of an asthma attack, early warning signs of an attack, and procedures for handling an asthma attack including when to see a family physician/GP and when to seek help at the ED.

While the learning *objectives* were comprehensive and similar to those of the Asthma Education Service, in reality the amount of teaching that occurs in the ED was limited by patient volume. Casual observation of asthma education in the ED suggests that the average amount of time spent educating parents and children about asthma rarely exceeded five minutes. In comparison, appointments in the Asthma Education Clinic took place in a much more relaxed environment and initial appointments typically took an hour, thus providing much more opportunity to cover learning objectives and to address any parent/guardian or patient concerns. During extremely busy periods in the ED, no education took place at all as the focus was on delivering timely patient care to all patients. If a small amount of time was available, the learning objectives suggested (learning objectives with a double asterix in Figure 3.4) that the priorities areas for parental knowledge were understanding normal lung function, understanding their child's medications and devices including usage, and knowing what to do when an asthma attack occurs.

Questionnaire administration in the prospective study was done either in the ED or over the telephone a few days after enrolment in the study. Figures 3.5 through 3.7 show the questionnaires used to collect information from parents and children. At four months post-ED visit, parents were telephoned and a follow-up asthma knowledge questionnaire was administered.

3.6 Analytical Techniques

Analysis in epidemiological or health services research often entails the use of specific statistical techniques. In Chapter 4, survival analysis is used to examine the time between repeat visits to the ED. Since this approach has been used less often than other analytical techniques in ED-based studies, a review of the reasons for its use in repeat ED visit analysis is provided in the next subsection. In Chapter 6, Poisson regression is used in the analysis of ED visit count data over time. Since there are many options available for the analysis of count data, a rationale for the chosen approach is presented in the last subsection of this chapter.

3.6.1 Time-to-Event Analysis for Repeat ED Visits

As indicated in the previous chapter, a number of studies have examined paediatric ED repeat visit rates.(3)(4)(5)(6) However, only one paediatric asthma study has considered time to a repeat visit as an outcome measure (6) and in this study the outpatient follow-up that was evaluated was not a designed asthma education intervention but rather any claim for outpatient primary or specialty care for asthma within 30 days of an ED visit for asthma. Thus, an opportunity existed for the application of time-to-event techniques in the evaluation of a dedicated asthma education program.

Survival analysis, also known as time-to-event analysis or failure-time analysis, is a body of statistical techniques used when the outcome of interest is time to a particular event of interest. The event may be death, as the name survival analysis suggests, but equally acceptable events in epidemiological studies are post-exposure disease occurrence, disease recurrence, condition exacerbations, and threshold attainment on any number of measures of health or illness. Traditional statistical techniques, e.g. logistic regression, can be used to estimate the probability or risk of an event, or the relative risk of an event. Survival analysis techniques can be used to estimate the risk of event, or the relative risk of an event, as a function of the time-to-event.

In the ED, survival analysis lends itself to the analysis of repeat visits of patients for the same presenting problem. In this dissertation, the event of interest is a repeat visit to the ED for a confirmed asthma exacerbation.

Subject follow-up to ascertain event occurrence may be done prospectively or retrospectively. In the study in Chapter 4, retrospective review through computerized record search and chart review was undertaken. Patients were followed to the end of the study observation period, in this case, November, 2005. Those patients for whom an event, i.e. a repeat visit to the ED, does not occur are censored observations because partial information on the time to an event has been obtained for those patients. One knows that for the duration of study follow-up no event occurred but one cannot exclude the possibility that had the study follow-up period been longer an event may have occurred. It is the ability of survival analysis to handle censored data that differentiates it from traditional statistical techniques. Ignoring censored data results in biased estimates of the risk of an event with time.

Patients followed from the same study start time to a study end time have the same potential amount of follow-up time and the censoring time is the study termination time. In studies where patients entry times are random, i.e. enrolment on a rolling basis, and patient follow-up is to a fixed study end time, censored subjects are considered to be randomly censored because the entry times are typically not under the control of the investigator.(7) As is the case for most ED-based studies, patient entry was on a rolling basis for this study. The random censoring must be *non*informative for survival time estimation to be done without bias. A study suffers from informative censoring if censoring status is itself correlated with the risk of an event with time.

A typical form of informative censoring for ED-based studies is patients who move to a different city and are thus no longer at risk for a repeat visit to the ED. If active follow-up is not done, such an individual would be considered to be a noninformatively censored observation, rather than loss to follow-up (one type of informative censoring), resulting possibly in a biased estimate of the survival time for such individuals because some are mistakenly assumed to still be at risk for a repeat visit. If active follow-up is not possible because it is a retrospective design, one can potentially mitigate the effect of such loss to follow-up by linking ED visit data to other data sources, as has been done in readmission studies (8), to verify that the individual still resided in the catchment area during the time period of interest. The patient could then be considered to be still 'at-risk' for a repeat ED visit if verified to still reside in the catchment area. Allowance still has to be made for the potential for patients to visit other hospital EDs but as has been found in multi-center studies with one pediatric acute care center, most parents within a reasonable commuting distance opt to bring their children to a pediatric ED.(9) For fairly frequent events, it may be possible to assume that the study observation time is short enough that only an insignificant proportion of the sample will have left the catchment area. It is this latter option which has been adopted for this study because the maximum length of follow-up was two years. Another reason for making this assumption is that ethics approval for patient-level linking to external datasets to verify continued residence in the GVRD was not obtained.

Chronic conditions like asthma that are associated with acute but often preventable events like exacerbations are candidates for study in the Emergency department using survival analysis techniques. Children with asthma are known to represent a significant proportion of repeat visitors.(10) Sin et al. (11) chose to use Cox Proportional hazard modeling in their analysis of readmissions for asthma and chronic obstructive pulmonary disease in all ages. In a pediatric setting, repeat visits times for asthma exacerbation have a positively skewed distribution that could also be described with a Weibull distribution in parametric modeling.

3.6.2 Poisson Regression for ED visit Counts

The test for association between particulate pollution levels and ED visit counts presented in Chapter 6 was done using Poisson regression. There are many different ways to approach the analysis of count data. The major classes include Poisson regression, moving average time series analysis, autoregressive time series analysis, mixed moving average/autoregressive time series analysis (ARMA), autoregressive integrated moving average time series analysis (ARIMA or Box-Jenkins models), general linear models (GLM) with Poisson link or Poisson link time series function, general additive models (GAM) with Poisson link or Poisson link time series function, semi-parametric methods such as spline-fitting, and parametric methods using sinusoidal functions.

Generally, speaking autoregressive techniques are used to fit a model that can be used for prediction. By definition, an autoregressive function is one that takes a particular value at time t that is dependent on a value at time t-1 (or an earlier time t – x), or some combination of previous values at prior times. Thus, a value at time t will predict to some degree some future value after time t. (12) Poisson autoregressive techniques that control for autocorrelation using autoregressive error models are well accepted and established in the air pollution literature for the analysis of long time series, e.g., daily counts for periods longer than three or four years.(13) There are investigators who have used both ARIMA models and Poisson autoregressive models for the analysis of emergency admissions (albeit in relation to environmental noise, not air pollution) and found them to produce comparable results. (14)

The motivation for the analysis in Chapter 6 was the known spike in PM pollution concentrations related to the Burns Bog Fire in Vancouver in September of 2005. Casual observation also suggested that ED visits for asthma may have also increased in the time period around the highest PM pollution levels. Practical considerations made it more viable to collect data for a shorter period of time (three month window) than is used in other time series analyses and to use a panel design for historical comparison. Thus, the time period in question is characterized as including an unusual, rarely occurring event that could not have been predicted and that was not be expected to recur (at least not very often) and the count data is a relatively short time series. An autoregressive model was not an ideal choice in this scenario since the primary objective was not prediction but rather testing for a possible correlation between particulate pollution levels and ED visit counts. Moving-average time series analysis was also rejected as method for analyzing this dataset, partly for similar 'prediction-related' concerns, but also because estimation tends to be significantly more difficult for moving-average time series analysis.

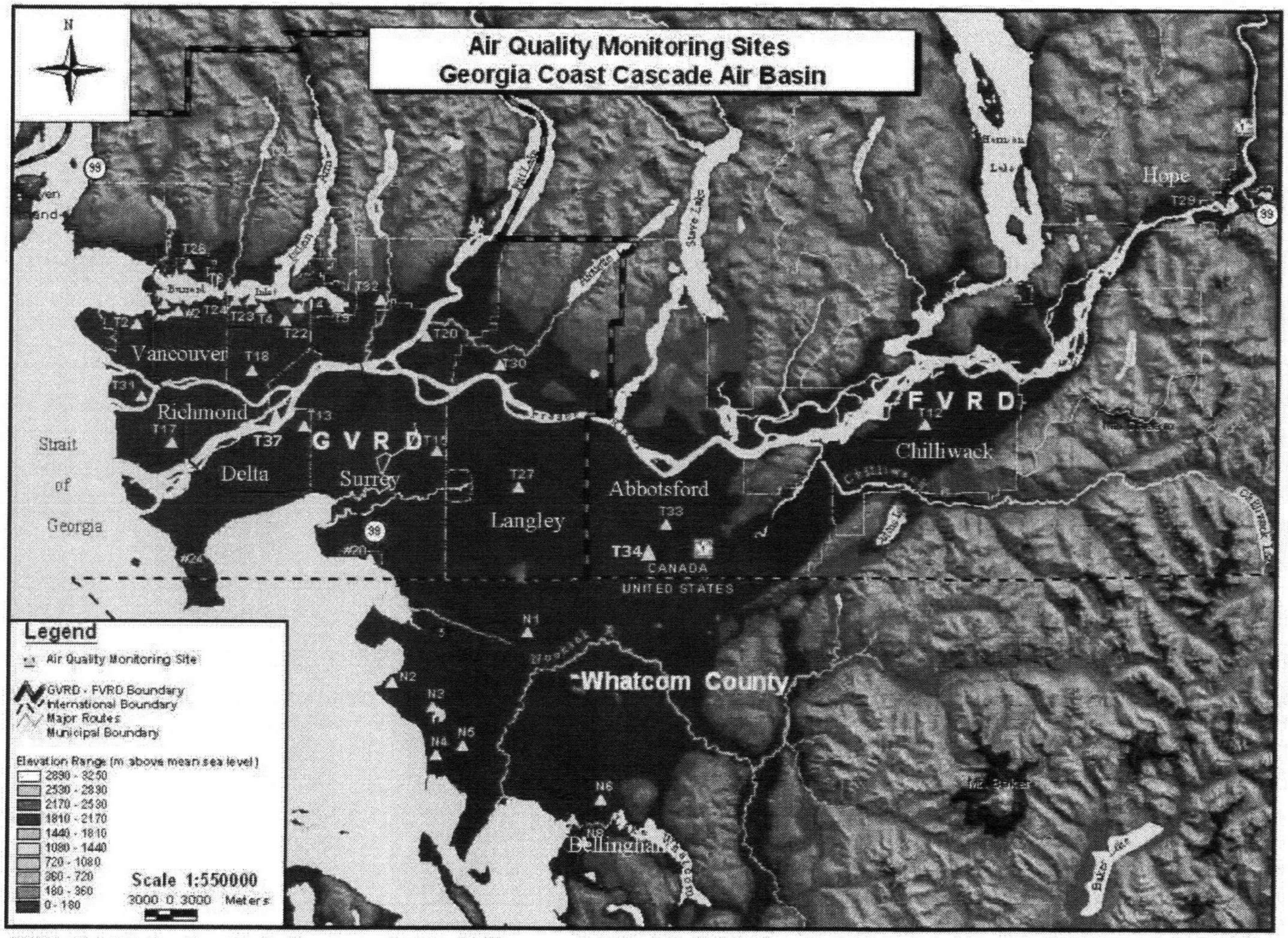
Schwartz, Spix, Touloumi et al. (13) contend that the methods most appropriate for the analysis of daily counts of deaths or hospital admissions in relation to air pollution (for longer time series) are Poisson regression, general additive models with Poisson link functions, semi-parametric approaches such as the fitting of spline functions for the time period divided up into intervals, and parametric methods using trigonometric filtering on sinusoidal functions. Kuhn ,Davidson, and Durkin (15) compared time-series analysis with Poisson regression and found that the two methods provided similar point estimates and had a good fit to the data. They suggest that Poisson regression is an attractive and viable alternative.

The choice of analytical approach for count data is tricky, and a source of considerable debate in the literature.(16) The decision to use Poisson regression can be defended and criticized on statistical grounds. For a longer time series, the consensus from the literature appears to be that Poisson autoregressive techniques are most appropriate. However, the series analysed in this dissertation is comparatively short and is not being used for prediction. Thus, Poisson regression is a viable alternative and has the significant advantage of ease of interpretation.

Table 3.1 Comparison of Study Criteria for Asthma Diagnosis with Guidelines

	Asthma Diagnosis	Prior History of Asthma
Study component		
Prospective	Emergency Physician diagnosis Older than 2 yr	Counts of RAD*/ asthma diagnosis OR Admission for asthma OR Parental statement of Dx
Retrospective	Emergency Physician diagnosis Older than 2 yr	Counts of RAD*/ asthma diagnosis OR Admission for asthma
Air Pollution	Emergency Physician diagnosis Older than 2 yr	At least two visits with RAD*/ asthma diagnosis OR admission for asthma OR parental statement of diagnosis
Guidelines		
C&W Guidelines**	Two distinct episodes of wheeze OR previous Dx asthma Older than 1 yr	
National Guidelines*** stringent criteria:	Three episodes of wheeze during first three years of life AND One of: parental history asthma/ eczema OR 2 or 3 of: eosinophilia, wheeze without cold, allergic rhinitis	
loose criteria:	Any wheeze during first three years of life AND One of: parental history asthma/ eczema OR 2 of: eosinophilia, wheeze without cold, allergic rhinitis	

* RAD is hyperreactive airways disease.
** Emergency Management Asthma Guideline
*** Canadian Network for Asthma Care/Canadian Thoracic Society



NOTE: Detailed elevation data for the area north of the FVRD was unavailable at the time of map preparation. This gives the topography a flat appearance.

Figure 3.1 Lower Fraser Valley Air Quality Monitoring Network (GVRD network image map in the public domain)

Figure 3.3 B.C. Children's Hospital Asthma Education Service Assessment Tool (BCCH Assessment Tool in the public domain)

Asthma Education Service
Kardex - outpatient
Educator Working Document

Demographics

Date of Initial visit: ____________

- Addressograph information correct? Yes ___ No ___, if no please amend in space above.

- Accompanied by(circle): parent guardian
- Parent/Guardian Name(s) and occupations: ____________________
- Other caregiver(s) involved? No __ Yes , please list: ____________________

- Language: ______________ Interpreter required? Yes ___ No ___

- School ____________________ Grade ____________
- Is school informed of asthma diagnosis? Yes ___ No ___
- Asthma Medication and devices at school? Yes ___ No ___
- Is the school nurse involved? ____________________

- Does the family have extended health benefits? Yes ____ No ___
- Has the family registered for pharmacare program? Yes ___ No ___
- Can the family pay for medications/delivery devices? Yes ___ No ___
- Is social assistance required? No ___ Yes ____, who was contacted?

____

Home Telephone: ______________ **Work telephone:** ______________
Other contacts: ____________________

Medical contacts

Family Physician: ______________ Pediatrician: ______________
Respirologist: ______________ Allergist: ______________
Other: ____________________

- Have you ever visited a walk-in clinic? No ___ Yes ___
- Where? ____________________
- Have you visited another asthma clinic? No ___ Yes ___
- Where? ____________________

Figure 3.3 (continued)

Medical History

- Premature birth? Yes ___ No ___ Gestational age: ______________
- Lower respiratory illness in first year of life? ______________
- Age when was the diagnosis of asthma made? ______________
- What were the events surrounding the diagnosis of asthma?(eg., ER visits, hospitalization, doctor visits) ______________

____

____

- Other health problems: ______________

____

____

- Other clinics visited at BCCH? ______________
- Previous hospitalizations/ER visits ______________

____

____

Family History (mother, father, siblings)

Please note any family history of the following:

- Asthma? No ___ Yes ___, ______________
- Atopic dermatitis (eczema) No ___ Yes ___. ______________
- Allergic rhinitis (nasal allergy, hay fever) No ___ Yes ___
- Immunizations: CP ___ Prevnar___ Flu shot_____ Other_____

____

Environmental Allergies

Please note allergies and reactions:

____

____

____

____

____

____

- Has allergy testing been done? No ___ Yes ___ Positive? ______________
- Tested by whom? ______________

- During which season are the asthma symptoms the worst?

____

____

____

____

Figure 3.3 (continued)

- Which asthma triggers affect the child? Identified by child or caregiver?

Air pollution ____
Animals/ birds ____
Aspirin ____
Foods, specify ____
____
Tobacco smoke ____
Cold air ____
Dusty Environments ____
Exercise/exertion ____
Infections/viruses/colds ____
Molds ____
Pollens/grasses/Weeds ____
Strong Emotion ____
Strong Odours ____
Weather changes ____
Other ____

- Please describe the child's home environment.

Air conditioner? Yes ___ No ___
Dehumidifier? Yes ___ No ___
Heating (circle): forced air, electric baseboard, gas appliances, wood stove or fireplace.

- Room humidifier/vapourizer? Yes ___ No ___
- Flooring (circle): carpet, hardwood, other ____
- Where does child sleep (circle) own room, shares room, with parent, bed canopy or bunk bed?
- Bedding (circle): wool, down/feather, washable, other ____
- Is the mattress cover mite- proof? Yes ___ No ___
- Upholstered furniture? Yes ___ No ___ other ____
- How are the windows treated (circle): venetian blinds, roller blinds, cotton curtains, other ____
- What is on the floor (circle): carpet, hardwood, other ____
- Pets? ____
- Stuffed animals ____

Do you have an Epipen? No ____ Yes ____

Asthma Symptoms

- During the daytime, does your child:

Cough? No ___ Yes ___ How many days/week? ____
Out of breath? No ___ Yes ___ How many days/week? ____
Wheeze? No ___ Yes ___ How many days/week? ____
Tightness in chest? No ___ Yes ___ How many days/week? ____

Figure 3.3 (continued)

- Do the above symptoms waken your child at night? No ___ Yes ___, how many nights/week? ___

- Does your child stop exercising because of his/her asthma? No ___ Yes ___
How many times in the last 3 months? ___

- Does your child miss time from school because of his/her asthma? No ___ Yes ___
Explain ___

- Does your child use the blue inhaler (rescue medication) 4 or more times a week?
No ___ Yes ___ How many times per week? ___
- What is the immediate response? ___
- Exacerbations? None ___ 1-2 times/year ___ monthly ___ frequently ___

- What is the first thing you notice at the start of your child's asthma attack?

___

- How do you feel when you having an asthma attack?

___

- How confident do feel in managing your child's treatment?

___

- Do you feel your child's symptoms are under control?

___

Number of ER visits for asthma in past year ___ Which ER? ___
Number of hospitalizations in past year ___ Where? ___
Total number of hospitalizations for asthma ___

Review of Medications

Medication	**Dose**	**Times /day**	**Device**
Budesonide			
Fluticasone			
Beclomethasone			
Salbutomol			
Terbutaline			
Salmeterol (Serevent)			
Formoterol (Oxeze)			
Combination Advair or Symbicort			

Figure 3.3 (continued)

Height _____ cm Weight _____ kg
Peak flow? No ___ Yes ___ Present Range ______________
Expected Range ____________ Personal Best ____________
Chest Assessment: ____

Other:

Please document the following on ambulatory progress notes.
Identified problem areas from family and from asthma educator:

Teaching Plan:

Evaluation of plan and follow up:

EA:a /Asthmaassessmenttool.draft1

Figure 3.4 B.C. Children's Hospital Emergency Department Patient Teaching Flowsheet (BCCH ED Flowsheet in the public domain)

CHILDREN'S & WOMEN'S HEALTH CENTRE OF BRITISH COLUMBIA
AN AGENCY OF THE PROVINCIAL HEALTH SERVICES AUTHORITY

PATIENT TEACHING FLOWSHEET

Asthma

(Also use for RAD, Wheezing)
Circle Resources Given

DATE INITIATED:

Parent Handouts: (See Asthma Resource Binder)

1. About Asthma –Family Resource Library (FRL)
   - available in English and Chinese (Punjabi)
2. How can I tell if my child is having an asthma attack?
   - available in English, Chinese, Punjabi, and Vietnamese
3. Signs and symptoms of Respiratory Distress
   - available in English, Chinese, Punjabi, and Vietnamese
4. Device & Equipment Teaching Sheets
5. Medication Information (see asthma resource binder)
   i.e. Salbutamol (Ventolin)
   Fluticasone (Flovent)
   Budesonide (Pulmicort)
   Terbutaline (Bricanyl)
   Dexamethasone (Decadron)
   Pediapred (Prednisone)
   Beclomethasone (QVAR)
6. Nebulizer/ Spacer Resource List

Teaching Aids: (on 3F/3M or contact Asthma Education Service)

7. Asthma Education Kit Video (parent) – 20 minutes
8. Airway visual Chart / Airway models
9. Asthma triggers and avoidance chart

Additional Resources (on 3F/3M or contact Asthma Education Services)

10. Peak Flow home diary
11. Peak Flow record grid
12. Bedding prices resource list – dust mite prevention
13. Asthma triggers and avoidance strategies - booklet
14. Action Asthma – kids activity book
15. "Normal"- colouring page
16. Respiratory Inhaler – Quick Reference Guide
17. Asthma Education Service

FAMILIES MUST KNOW **	OBJECTIVES	Date & Sign when teaching done	COMMENTS & CONCERNS (Indicate further teaching required, referrals, notes on chart)
**	1. Understand **normal lung** function and lungs during an asthma attack.		
**	2. Discuss child's **medications and devices** - Explain the use of "preventers" for control. - Explain the use of "relievers" for rescue. - Explain common side effects and their management. - Demonstrate proper use of delivery device(s). - Explain the cleaning, storage, and purchase of the delivery device(s). - Identify any concerns re the medication.		

ESTABLISHED: march 1995
REVISED: 17/09/2004
V:\Emergency\Asthma Education\Resource Binder\Asthma Teaching Flow sheet 081904.doc

Figure 3.4(continued)

CHILDREN'S & WOMEN'S HEALTH CENTRE OF BRITISH COLUMBIA
AN AGENCY OF THE PROVINCIAL HEALTH SERVICES AUTHORITY

PATIENT TEACHING FLOWSHEET
Page 2

Asthma

**	3. Discuss **what to do when an asthma attack occurs.** - Recognize signs and symptoms of respiratory distress - Explain the steps to take when child experiences an asthma attack. - Identify when to see GP. - Identify when to seek ER help. (bring medication and devices for all hospital visits)		
	4. Identify the **early warning signs** of an asthma attack.		
	5. **Home Management** - Record and explain home medication and **Follow-up** schedule on "Instructions for discharge form" - Give 'Asthma Education for Families" pamphlet.		
	6. Explain what **triggers** an asthma attack. - Recognize potential triggers - Identify child's trigger(s). - Identify how to avoid or reduce child's triggers.		
**	7. Referral made to outpatient asthma Education clinic. (provide page 3 to family)		

ESTABLISHED: march 1995
REVISED: 17/09/2004
V:\Emergency\Asthma Education\Resource Binder\Asthma Teaching Flow sheet 081904.doc

Figure 3.5 Asthma Baseline Questionnaire

Asthma Education Baseline Questionnaire

Items are square brackets are not asked, but filled in from ADT/health record.
[Date of ED Visit ____________ (DD/MM/YYYY)]

Demographics

[Patient Name: First ________________________
Last ________________________]

[Age of Patient: _________ (circle units: months years)]

Height of Patient: _____ (circle units: cm inches)

Weight of Patient: _____ (circle units: kg lb)

Where does {child's name} live most of the time?

Address: Street ____
City ____________________
Postal Code ______________

Who else lives at this address (circle all that apply)?

Mother/Primary guardian Father/Secondary guardian Siblings: # ___

If both parents/guardians do not live at same address:

Does {child's name} spend any time living at any other address? Yes No

Parent/Guardian(s): Name: First ____________________
Last ____________________

Name: First ____________________
Last ____________________

For Mother/Guardian with custody:

What is your phone number? ( ) - -

What is the best time to call? morning (9-12) early aft. (12-3:30) late aft. (3:30-7) evening (7-10)

How old are you? ______ years

What is the first language you learnt? ______________________

If not English, when did you start learning English (year)? __________

What is the highest degree you have received?

None
Elementary
High school diploma
Associate degree
Bachelor's
Master's
Professional degree (MD, DDS, DVM, LLB, JD, DD)
Doctorate (PhD, Ed.D, DPH)

Are you currently employed? Yes No

If Yes, what is your occupation? __________________

Is this full-time employment or part-time? FT PT

If it is part-time, what describes how you spend the rest of your week? (circle any)

____

Part-time student

Part-time homemaker

Looking for work

If No, are you a:	full-time student?	Yes	No
	full-time homemaker?	Yes	No

Are you searching for work at the present time? Yes No

For/about father/Guardian 2:

How old are you? ____

What is the first language you learnt? ______________________

If not English, when did you start learning English (year)? ______

What is the highest degree you have received?

None
Elementary
High school diploma
Associate degree
Bachelor's
Master's
Professional degree (MD, DDS, DVM, LLB, JD, DD)
Doctorate (PhD, Ed.D, DPH)

Are you currently employed? Yes No

If Yes, what is your occupation? ________________

Is this full-time employment or part-time? FT PT

If it is part-time, what describes how you spend the rest of your week? (circle any)

____

Part-time student

Part-time homemaker

Looking for work

If No, are you a:	full-time student?	Yes	No
	full-time homemaker?	Yes	No

Are you searching for work at the present time? Yes No

Access to Medical Care and Medical Care Usage

How many times have you visited *any* Emergency department over the past year for your child's asthma?

___

For other reasons?

___

[Number of visits over past year to C&W ED via ADT]: ___

How many times has your child been hospitalized at *any* hospital for asthma over the past year?

___

[Number of hospitalizations over past year in C&W via health records: ____]

For other reasons?

___

Do you and your child have a family physician?

No
Yes → Name & location: ________________________________

If yes, how many times over the past year have you visited your family physician for your child's asthma symptoms?

___

[Number of visits over past year via call to family physician: __]

Do you have a paediatrician you see for {child's name}?

No
Yes → Name & location: ________________________________

If yes, how many times over the past year have you visited your paediatrician for your child's asthma symptoms?

___

[Number of visits over past year via call to family physician: __]

Medical History

Was {child's name} born prematurely – that is, much earlier than is normal?

No
Yes → Gestational Age ____________________ (weeks/months)

Did {child's name} have more than 4 lower respiratory tract infections in first year of life?

No
Yes → ______________________________

If child has been previously diagnosed with asthma,

Age of asthma diagnosis ____________ (circle unit: months years)

How was this child diagnosed?
- ER visit
- GP
- Paediatrician
- Hospitalization

Other health problems of patient: ______________________________
____
____

Family (father, mother, siblings) Medical History

Do other members of the biologically immediate family have asthma, or have they had asthma in the past?

No
Yes → Who (circle all that apply)?
Mother Father Siblings → #: ___ of # ___

Do other members of the biologically immediate family have eczema, or have they had asthma in the past?

No
Yes → Who (circle all that apply)?
Mother Father Siblings → #: ___ of # ___

Do other members of the biologically immediate family have allergic rhinitis i.e. hay fever, or have they had hay fever in the past?

No
Yes → Who (circle all that apply)?
Mother Father Siblings → #___ of # ___

Environmental Allergies

Has your child had allergy testing done?

No
Yes → Allergist name & location ______________________________

List known allergies: ______________________________
____
____
____

What triggers {child's name} asthma symptoms as far as you know?

Animals	Aspirin	Foods → _______________
Tobacco smoke	Cold air	Dust
Exercise	Infections	Molds
Pollens	Emotion	Odours
Weather changes		Other → _______________

Home Environment

Do you have an air conditioner where {child's name} lives?

Yes No

Do you have a dehumidifier where {child's name} lives?

Yes No

Heating type (circle):
Forced Air
Electric baseboard
Gas
Woodstove/fireplace

Do you have a humidifier/vaporizer in your child's bedroom? Yes No

What type of flooring is in the house?

Mostly hardwood/tile
Mostly carpet
Half and half

What type of flooring is in {child's name} bedroom?

Hardwood/tile
Carpet

What type of bedding does your child have on his/her bed?

Wool
Down/feather
Washable

Do you have a mite-proof cover on your child's mattress? Yes No

Do you have upholstered furniture where your child lives? Yes No

Does child have stuffed toys? Yes No Approximate #: ____

If yes, does child play with them regularly? Yes No

Are there pets in the house? No Yes → Type: ________________
#: ________

Asthma Symptoms

How many days a week does {child's name}:

Cough during the daytime? 0 1 2 3 4 5 6 7

Seem out of breath in the daytime? 0 1 2 3 4 5 6 7

Wheeze in the daytime? 0 1 2 3 4 5 6 7

Have tightness in chest in the daytime? 0 1 2 3 4 5 6 7

How many days a week does {child's name} wake up at night with a cough or wheeze or tightness in chest or breathlessness?

0 1 2 3 4 5 6 7

List most common symptoms and nights/week

____

Has you ever observed {child's name} stopping active playing or exercising because of his/her asthma symptoms?

No

Yes → How many times in the past three months? ________

For school age children (i.e. > 6 years old):

Has your child missed school because of asthma-like symptoms?

No

Yes → Details ________________________________

For children previously diagnosed with asthma:

Asthma Management

Has your GP or paediatrician established an action plan for managing {child's name} asthma?

No Yes → Established by: GP
Paediatrician

[Does the family GP and/or paediatrician confirm that an action plan for managing {child's name} asthma has been established?

No Yes → Established by: GP
Paediatrician]

What medications is {child's name} currently taking for asthma?

Medication	Dose	Times/day	Device (circle most commonly used)
Budesonide			None / MDI / MDI & spacer / Nebulizer
Fluticasone			None / MDI / MDI & spacer / Nebulizer
Beclomethasone			None / MDI / MDI & spacer / Nebulizer
Salbutomol			None / MDI / MDI & spacer / Nebulizer
Terbutaline			None / MDI / MDI & spacer / Nebulizer
Salmeterol (Serevent)			None / MDI / MDI & spacer / Nebulizer
Formoterol (Oxeze)			None / MDI / MDI & spacer / Nebulizer
Combination Advair or Sybicort			None / MDI / MDI & spacer / Nebulizer

Do you use a peak flow meter at home for monitoring {child's name} asthma?

Yes No

Post-Interview Assessment

English Language Ability of

Mother/Primary Guardian:	1 Poor	2	3	4	5 Excellent
Father/Guardian:	1 Poor	2	3	4	5 Excellent
Patient (if > 5 years):	1 Poor	2	3	4	5 Excellent

Figure 3.6 Asthma Knowledge Questionnaire

Asthma Knowledge Questionnaire

I am going to give you some statements about asthma and I would like you to tell me whether you think each statement is true or false.

1.	Left untreated, asthma will eventually go away.	T	**F**
2.	Asthma is a nervous or psychological illness	T	**F**
3.	Asthma is a breathing problem that may be triggered by strong emotions.	**T**	F

During an asthma attack....

4.	..the muscles around the airtubes tighten and the tubes become narrow	**T**	F
5.	...more mucus is produced in the airtubes	**T**	F
6.	...the lining of the airtubes becomes swollen	**T**	F
7.	...the changes in the airtubes make it difficult to get air out of the lungs	**T**	F
8.	...the airtubes collapse	T	**F**
9.	...the changes in the airtubes make it difficult to get air into the lungs	**T**	F
10.	Medications returns the airtubes to normal and no permanent damage usually occurs	**T**	F
11.	Your child can become addicted to asthma medications if he/she uses them all the time	T	**F**
12.	Asthma medications do not work as well if your child uses them all the time	T	**F**
13.	Although it can not be cured, asthma can usually be controlled by taking the correct medication	**T**	F
14.	Side-effects are less likely with inhaled medication than with tables because inhaled medication is not absorbed into the body	**T**	F
15.	Syrups and tablets work about as quickly as inhaled medications	T	**F**
16.	If your child get a cold or flu, you should increase his/her asthma medications	**T**	F
17.	A doctor is best able to measure how bad asthma is by listening to the chest with a stethoscope	T	**F**
18.	Measuring the amount of air in the lungs with a peak flow meter or spirometer is the most accurate way of measuring how bad asthma is	**T**	F
19.	Most asthma deaths could have been prevented	**T**	F

20.	If a person has died from an asthma attack, it usually means that the attack must have begun so quickly that there was no time to start treatment.	T	**F**
21.	Your child may have fewer asthma attacks if you can identify and avoid things that trigger them	**T**	F
22.	When asthma is well controlled by medication it is not triggered so easily	**T**	F

When you know that your child is going to be exposed to something that triggers his or her asthma,...

23.	..your child should take medication just before exposure	**T**	F
24.	..you should wait until your child develop symptoms before taking medication	T	**F**
25.	Regular exercise such as swimming can cure asthma	T	**F**
26.	Exercise can help keep your child fit and well and better able to cope with asthma	**T**	F
27.	Your child exercising until he/she becomes breathless can damage the heart and / or lungs	T	**F**
28.	Your child should not exercise if exercise brings on even the occasional asthma attack.	T	**F**
29.	Some medications taken 10 minutes before exercising, can stop your child getting asthma when he/she exercises	**T**	F
30.	Some medications can be used during exercise if your child gets asthma	**T**	F
31.	Only a doctor can call an ambulance for your child.	T	**F**

Figure 3.7 Asthma Autonomy Preference Index

Asthma Autonomy Preference Index

[CASE #:]

For parent: I'm going to read you a number of different statements. After I read, the statement I want you to tell me when you agree, disagree, strongly agree, or strongly disagree with the statement, or if you don't have an opinion either way.

The important medical decisions about your asthma should be made by your physician not you.

Decision-making Preference	Disagree				Agree
1. The important medical decisions about your child's asthma should be made by your physician, not you.	1	2	3	4	5
2. You should go along with your physician's advice even if you disagree with it.	1	2	3	4	5
3. If your child is hospitalized for asthma, you should not be making decisions about your child's care.	1	2	3	4	5
4. You should feel free to make decisions about everyday problems with your child's asthma.	1	2	3	4	5
5. If your child was sick and if his/her asthma became worse you would want your physician to take greater control.	1	2	3	4	5
6. You should decide how frequently your child needs a checkup for his/her asthma.	1	2	3	4	5
Information-seeking Preference					
7. If your child was sick and if his/her asthma worse, you should be told more and more about your asthma.	1	2	3	4	5

8. You should understand what is happening inside your child's body as a result of asthma.	1	2	3	4	5
9. Even if the news is bad, you should be well-informed about your child's asthma.	1	2	3	4	5
10. Your physician should explain the purpose of you laboratory tests ordered for you child.	1	2	3	4	5
11. You should be given information about your child's asthma only when you ask.	1	2	3	4	5
12. It is important to know all the side effects of your child's asthma medication.	1	2	3	4	5
13. Information about asthma is as important as treatment.	1	2	3	4	5
14. When there is more than one method to treat asthma, you should be told about each one.	1	2	3	4	5

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CHAPTER 4: ASTHMA EDUCATION CLINIC ATTENDANCE AND REPEAT VISITS FOR ASTHMA EXACERBATIONS IN THE PEDIATRIC EMERGENCY DEPARTMENT

4.1 Abstract

Objective To compare the rate of repeat Emergency Department visits for children and their guardian visiting the Emergency Department for asthma between families that attend an outpatient Asthma Education Clinic with non-attendees. *Methods* The study was a retrospective cohort study of 720 children attending the Emergency Department of a pediatric emergency department. Cox proportional hazards modeling was used to compare asthma education groups. *Results* In a sample of 720 children, representing 1540 visits for asthma or hyperreactive airways disease (RAD), 144 (20%) attended an asthma education clinic. Over 80% of patients had a clinic visit within 50 days of an index ED visit. One-third of patients returned to the ED for a repeat visit related to asthma or RAD. In the entire sample, clinic attendees were found to be more likely to return to the ED for a repeat visit. For patients older than 3 years of age and with fewer than three previous visits for asthma/RAD, the time to a repeat ED visit was found to be no different in asthma clinic attendees versus non-attendees, after adjustment for known confounders. *Conclusions* Attendance at the Asthma Education Clinic does not appear to be associated with a reduced repeat ED visit rate over all patients but may be of benefit for select subpopulations of patient families attending the ED for asthma/RAD.

4.2 Introduction

In general, the count of previous Emergency Department (ED) visits for asthma in children has been shown to be an effective indicator of future ED visits for the same condition over periods of time less than a year.(1) Such crude measures of health care utilization have been important for the initial identification of heavy users of the pediatric ED and have led to studies that seek to determine the reasons for reattendance.

Weinstock (2) found that of 100 unanticipated return visits among children with asthma at Boston City Hospital, less than half (47%) were due to natural disease progression. The remaining return ED visits could be attributed to factors amenable to change: provider behaviour (22%), parental/patient anxiety (18%), and parental/patient noncompliance (13%). Spurrier, Staugas, Sawyer et al. (3) found that the background level of asthma symptoms, admission at the initial ED visit, and whether the family had a planned review visit for asthma (to review asthma management with any GP or at any ED) were the most important variables. Wasilewski, Clark, Evans, Levison et al. (4) found that repeat ED visits were associated with parents not implementing home management practices, such as following guidelines for when to bring a child to the ED, e.g., medications were given to the child but there was no improvement. Parents who did not keep medications at home were also more likely to visit the ED repeatedly. In a small, qualitative study, Goeman, Aroni, Sawyer (5) and colleagues found that in one-third of cases that reattendances were potentially preventable. The authors specifically identified asthma education as a potential solution.

All of these studies suggest that educating parents about asthma appears to be an important potential route for reducing inappropriate use of the pediatric ED. While a number of studies have attempted to evaluate the effectiveness of asthma education programs through randomized designs, the inherent difficulties of conducting such investigations, e.g., cost, typically limits the study sample size. A complementary, but little used, approach for assessing the effectiveness of asthma education programs that allows for larger sample sizes is time-to-event analysis using observational designs.

A few studies have used this methodology in different study populations. In a Canadian study considering admissions and readmissions for individuals of all ages with asthma or chronic obstructive pulmonary disease, Sin, Bell, Svenson, and Mann (6) found that follow-up visits were associated with a significant reduction in the 90-day risk of readmission. Follow-up visits were defined as a visit with a general practitioner (in 85% of cases) within a month of the index ED visit. The results for COPD and asthma were similar, but both combined and separate asthma/COPD analyses were performed. For asthma the investigators found that the relative risk for readmission after a follow-up visit was 0.75 (95% C.I. 0.67 to 0.83), after adjustment for age, sex, area of residence, and income. Consideration of whether there was a hospital admission associated with the ED visit had little effect on the results. Narrowing the sample to the 10,940 patients under the age of 19 produced similar results (RR 0.76, 95% C.I. 0.66 to 0.87).

In another Canadian study, Chen,Dales, Stewart, Johanssen et al. (7) used time-to-event analysis to examine the effect of patient age on hospital readmissions for children and young adults with asthma over the 1994 to 1997 period. They found that the incidence rate for readmission was highest in children under one year of age (25% per year in boys, 22% per year in girls). The one-year readmission rate fell to between 12% and 17% for children between one and nine years old, however, it is interesting to note that females between ten and nineteen years of age had higher readmission rates (17-21% per year) than both younger female cohorts (with the exception of those under 1 yr old) and boys of a similar age. Using 15 to 19 years olds as a reference category, the relative risk of readmission for males <1 year old and 1-4 years old were 2.36 (95% C.I.2.15-2.59) and 1.54 (95% C.I. 1.41-1.69), respectively. For females, the relative risks of readmission for children <1 year old and 1-4 years old were 1.54 (95% C.I. 1.42-1.66) and 1.15 (95% C.I.1.08-1.22), respectively.

In the only published study to look specifically at repeat ED visits, instead of readmissions, Cabana, Bruckman et al. (8) assessed the potential impact of outpatient follow-up visits with primary care physicians or pediatricians on repeat ED visits for an asthma exacerbation. Using a retrospective cohort design with a population of children aged 5 through 19 years of age, they modeled time to a repeat visit within one year using survival models while adjusting for age, gender, type of primary care provider (pediatrician vs. other), and Medicaid insurance status. A follow-up visit was defined as an appointment with a primary care provider within 30 days of the index ED visit. Repeat visits within five days were not considered to be a new event or episode of asthma for the purpose of analysis but to be an indicator of asthma severity. Interestingly, the investigators failed to find a beneficial effect of follow-up visit. Rather, follow-up visits were found to be associated with an increased hazard of repeat ED asthma visits. The association persisted after adjustment for potential confounders.

In the present analysis, repeat visits to the pediatric ED for a confirmed diagnosis of asthma were examined retrospectively. This study differs from previous studies in that the intervention of interest is an appointment with a dedicated asthma education service rather than an appointment with any general practitioner or family physician and a chart review confirmation of an asthma or hyperreactive airways disease (RAD) diagnosis.

4.3 Methods

The study is a retrospective cohort study of patients presenting in the ED with asthma. Patients were eligible to be included in the dataset if they presented in the Children's Hospital ED with symptoms associated with asthma between November, 2003 (the month the asthma education clinic began operating under the auspices of B.C. Children's Hospital) and October, 2004. Examples of terms used to describe presenting symptoms are "difficulty breathing", "shortness of breath", "asthma", "respiratory distress", "wheezing", "laboured breathing". A review of the hospital charts of all eligible patients identified those who were ultimately diagnosed as having asthma or RAD.

The inclusion criteria for the study were a diagnosis of asthma or RAD and an age of two years or older. The exclusion criteria for the study were severe co-morbidities, e.g., cancer, a permanent address outside of the Greater Vancouver Regional District, or a documented unstable family situation such as a child in foster care. Patients who met the inclusion criteria and were not explicitly excluded defined the study sample which was followed through December, 2005 by further review of the hospital chart. For each patient, all B.C. Children's Hospital ED visits resulting in a diagnosis of asthma or RAD were identified. Information collected for each patient included age, sex, primary and secondary diagnosis, whether a patient was admitted to an inpatient unit after the initial visit to the ED within the study period (the index visit), and the number of visits for asthma/RAD *prior* to the start of the study observation period. Attendance at the Asthma Education Clinic and the date of the initial clinic visit, if applicable, were obtained from a computerized clinic attendance system.

Statistical analysis was carried out using the Splus and Stata statistical packages. Descriptive cross-tabulations were produced to characterize the study sample and nonparametric techniques such as Kaplan-Meier estimation were used to describe and graph the data univariately. Ninety-five percent confidence intervals were plotted and were calculated using Greenwood's formula for standard error estimation. Univariate hypothesis testing was undertaken using both the Log-rank test and the Peto & Peto modification of the Gehan-Wilcoxon test. The Log-Rank test and the Gehan-Wilcoxon test differ in the weight they attribute to outcome differences over time, with the Gehan-Wilcoxon test giving less weight to outcome differences at later times. Since the univariate analyses do not control for known confounders, Cox proportional hazards regression was used to test each variable while controlling for the effect of other variables. The Efron method for handling ties was used. A backward stepwise model selection procedure was used with a 0.20 significance level for removal of terms from the model. Stepwise modeling was repeated with interaction terms for the variables that remained after the first stepwise selection. The time variable of interest was time between an index ED visit (initial visit to the ED within the study period) and a subsequent ED visit. The independent variable of primary interest was attendance or non-attendance at the Asthma Education Clinic offered at B.C. Children's Hospital. For the purposes of statistical analysis, patients were considered to be censored if they did not have a repeat ED visit after the index ED visit, during the study observation period (November 1, 2003 to December 30, 2005).

4.4 Results

The patient chart review for each potential ED visit for asthma or RAD led to the evaluation of a total of 1608 visits. Of the1608 visits, 68 visits were excluded, representing 58 patients. Reasons for excluding patients included: permanent residence of patient outside of the GVRD, patient in foster care, missing diagnosis or visit record, or severe comorbidity, e.g., end-stage renal disease, leukemia. Patients with a permanent residence outside of the GVRD were excluded because it was assumed that these patients would be at a significantly reduced risk for a repeat B.C. Children's Hospital ED visit. Patients in foster care were excluded because such children are often transferred from one family to another and an unstable home environment may put children at a higher risk for a repeat ED visit (as not all foster parents will be competent at managing asthma and an asthma education session cannot be assumed to transfer from one foster parent to another). Finally, patients with various comorbidities were excluded because it was judged to be possible that a compromised immune system, or some other unknown mechanism, is related to asthma exacerbations.

Of the remaining 1540 visits, 905 visits resulted in a diagnosis of asthma and a further 414 visits produced a diagnosis of hyperreactive airways disease (RAD). In total, 86% (1319/1540) of visits to the ED with symptoms associated with asthma (excluding isolated cough) at triage were diagnosed as either asthma or RAD.

The 1540 visits for asthma or RAD were distributed among a total of 720 patients, all of whom had an index visit between November 1, 2003 and October 31, 2004. The distribution of the number of visits during the study period associated with each patient is graphed in a histogram in Figure 4.1 (the x-axis is truncated as some patients have over 20 visits). Only the first repeat ED visit is considered for the purposes of this analysis. However, this figure corroborates the findings of others that asthma patients are seen repeatedly in the ED. Figure 4.2 shows the distribution of index visits, i.e., first visit during study enrolment period November 1, 2003 and October 31, 2004. Note that the index visit is not the same as the first ever visit to B.C. Children's Hospital ED for asthma/RAD. Some seasonality is apparent with a dip in ED visits for asthma/RAD in summer months. Otherwise, *index* visits are evenly spread across the study enrolment period and over half of patients have in excess of 1 ½ years of follow-up from the index visit.

Table 4.1 presents demographic data and select characteristics for the 720 patients in the sample. As expected, males are more prone to present in the ED with an asthma exacerbation or RAD (65.6% vs. 35.4% for females). Younger children are more likely to present in the ED with asthma/RAD with two year olds representing one-quarter (25.7%) of cases and three year olds accounting for one-fifth of cases (21.0%). Children four years of age and older represent over half (53.3%) of children diagnosed with asthma/RAD. While half (49.7%) of all cases were described as urgent at triage, only one-sixth of cases (16.1%) were admitted.

Table 4.2 compares the characteristics of patients whose parents were referred to the Asthma Education Clinic, and ultimately attended a clinic session, with those who did not attended a clinic session, within the study observation period. A total of 144 patients were referred along with their parents to the Asthma Education Clinic and subsequently attended the clinic, representing 20% (144/720) of the study sample. The two groups have remarkably similar age, gender, and health service delivery area distributions. Patients who are referred to the Asthma Education Clinic are more likely to be admitted (24.3% vs. 14.1%) and to be categorized as Emergent at triage (45.9% vs. 34.0%).

Figure 4.3 shows the distribution of Asthma Education Clinic visit times in relation to the study index ED visit. Previous studies (8) have used 30 days as a cut-off for inclusion of a potential participant as an individual receiving follow-up care, i.e., extended asthma education. As the figure suggests, most patient families were seen in the Asthma Education Clinic within a month of the study index ED visit (median lag 19 days; mean lag 51 days). The mean is higher because of the small number of cases with large lags between study index ED visit and Asthma Education Clinic visit. A few cases in excess of one year are not shown on the graph. A cut-off of 50 days is used for this analysis to take into account the pattern of follow-up Asthma Education Clinic visits. A 50 day cut-off includes well over 80% of patients who attended the Asthma Education Clinic in the study period.

Table 4.3 provides descriptive time-to-event statistics. One-third of patients (243/720 = 33.8%) have a repeat ED visit for asthma or RAD over the two years or less of follow-up, indicating a high proportion of censored observations. The median time to a repeat ED visit is somewhat larger than the mean time to the same endpoint (531 days vs. 478 days, respectively). An overall survival curve for the study population is shown in Figure 4.4. The time-to-event time in this graph is the time from study index ED visit for confirmed asthma/RAD to a repeat ED visit for the same diagnosis. From this curve, it is evident that over one-third of patients can be expected to return to the ED for asthma/RAD over a two year period. Univariate analyses of clinic visit, gender, age group, number of previous visits to the ED for asthma, and level of urgency at index visit are presented in Table 4.4. The hypothesis testing results suggested that Asthma Education Clinic attendance, level of urgency on triage at index visit, and number of previous visits may be related to time to repeat visit. Gender reaches borderline significance, depending on the testing procedure. Children with larger numbers of previous ED visits were more likely to have a repeat ED visit, as were younger children. Care must also be taken in interpreting the results for age, as a dichotomized age variable which separates the younger patients (2 and 3 year olds) from others is close to significant. Figure 4.5 shows the Kaplan-Meier survival curve for time to a repeat ED visit by Asthma Education Clinic attendance status. Censoring times within each group are marked as cross-hatches. This figure also suggests that Asthma Education Clinic attendees were more likely to return for a repeat visit.

The results of the Cox Proportional hazards model fitting using a backward selection procedure (with a 0.20 significance level for removal of terms) are presented in Table 4.5. Level of urgency and admission on index visit were removed from the model by the selection procedure. Asthma Education Clinic attendance, age of patient, and number of previous visits were all found to be highly significant. Gender was not found to be statistically significant. For each year of age, patients had an 11% reduction in the hazard of a repeat visit. Each prior visit to the ED was associated with an 18% increase in the hazard of a repeat visit. Attending the Asthma Education Clinic was associated a 63% increase in the hazard of a repeat visit.

Models with interaction variables were also examined. In particular, models were fit, using the same backward selection procedure used above, with interaction terms for i) clinic attendance and age of patient, ii) clinic attendance and the number of previous visits, iii) age of patient and number of previous visits. No interaction variable was left in the model after backward selection, but when forced into the model, the interaction variable between clinic attendance and patient age was the closest to achieving significance (hazard ratio 0.935, 95% C.I. 0.800-1.09). Table 4.5 shows the results of the final model with an interaction term for clinic attendance*age of patient forced into the model. Entering the interaction term inflated the hazard ratio associated with a clinic visit but does not significantly affect the hazard ratio estimates associated with other variables.

Since it was reasonable to believe that the youngest patients were most likely to have an incorrect diagnosis of asthma (9) models were run with three subsets of the sample. Specifically, the subsets examined were A) patients older than 3 years of age, B) patients who had fewer than three previous visits to the ED for asthma/RAD, and C) patients older than 3 years of age with fewer than three previous visits to the ED for asthma/RAD. The results for these subsets are presented in Table 4.6. Notably, the hazard ratio estimates for Asthma Education Clinic attendance fell in the subset analysis in comparison to the full sample analysis in Table 4.5. The hazard ratio estimates for Asthma Education Clinic attendance had confidence intervals which did not exclude 1 except in Subset B. Subset C has 281 patients, 52 of whom attended the Asthma Education Clinic. Figure 4.6 shows the survival curve for subset C comparing Asthma Education Clinic attendees vs. non-attendees. The survival curves appear to be similar and are not significantly different on log-rank and Gehan-Wilson testing.

In the last subset analysis presented here, patients who have a repeat ED visit are examined to determine whether those who attend the Asthma Education Clinic have a greater or smaller hazard of a repeat ED visit in comparison to those who don't attend the clinic. Table 4.7 shows the results of Cox Proportional Hazards modeling using a backward selection procedure on this particular subset. Most of the variables were dropped by the selection procedure. A forward selection procedure (with a 0.10

significance level) produced identical results. The hazard ratio associated with Asthma Education Clinic attendance is significant but notably smaller than the corresponding hazard ratio for the total sample. Figure 4.7 shows the survival curves for these two groups. The survival curves are significantly different on log-rank and Gehan-Wilson testing suggesting that elimination of censored observations does not produce completely different results.

4.5 Discussion

In the only published study examining time to a repeat ED visit for asthma in a pediatric population, Cabana et al. (8) found an association between follow-up visit with a GP and time to repeat ED asthma visits, i.e., follow-up was associated with an increased hazard of repeat ED visit. The unadjusted results of this study concur with their findings. However, after adjustment for confounders the results of this study deviated from those of the earlier study. Cabana et al. found that the association persisted after adjusting for potential confounders. The variables in their final model(s) were Medicaid insurance status, age < 9 years, gender, persistent asthma (a modified Heath Plan Employer Data Information Set, or HEDIS, definition), and pediatrician primary care provider versus other type of provider. The variables in the final model in this study were age, gender, number of prior ED visits for asthma, admission on index ED visit, and level of urgency at triage on index visit. One might speculate that the reason for the apparent difference in findings, after adjustment, may be related to differences in the form of the age variable or the use of different variables for persistent asthma. In this study, the number of previous visits to the ED for asthma or RAD from the charts could be considered a proxy for persistent asthma. All such visits from the chart were counted, including visits that predated the implementation of the current computerized system in 1999. Cabana et al. chose to use a modified HEDIS definition of persistent asthma which defined patients with persistent asthma as those with any hospitalization for asthma in the preceding year or any claim for inhaled corticosteriod, cromyln sodium leuktriene modifier, or methylxanthine. This study did not take medication prescribing patterns into consideration and only considered admissions for asthma exacerbation at the index visit, however, previous visit history was considered over a much longer time span.

Neither study is robust enough to exclude the possibility that the other study presents a more accurate picture. Limitations in the available variables, as alluded to above, are certainly a contributing factor. Asthma is a disease characterized by well-defined airway hyperreactivity but with a multitude of potential triggers including infections (viral, upper respiratory), allergens (mites, mold, pollens, animal dander), pollutants (particulate, gaseous), irritants (scents, perfumes), cold air, and exercise. Assessment of these factors was beyond the scope of this study because recording of the potential impact of these variables in the hospital chart as triggers in a particular case was inconsistently done. Thus while both studies have the advantage of a substantial sample size for a pediatric study, as with many retrospective studies, they both suffer from less than complete information on potential confounders.

Clearly, one might hypothesize that attendance at the Asthma Education Clinic would result in a lower hazard of repeat ED visit. The fact that Asthma Education Clinic attendance resulted in an increased likelihood of repeat ED visit on univariate analysis suggests that the populations of clinic attendees and non-attendees may have been different on some variables, even though Table 4.2 suggests that clinic attendees and non-attendees were very similar on many variables. The lack of randomization may have led to unknown, uncontrolled confounders influencing the results. The fact that the increased hazard of a repeat ED visit associated with Asthma Education Clinic attendance decreased on subset analyses suggests that any or all of patient age, number of prior visits for asthma, and a higher proportion of censored cases may be contributing to the elevated hazard ratios.

Indeed, subset analyses on patient age and previous visits for asthma resulted in hazard ratios near one (Table 4.6) and similar time-to-event curves for the two education groups (Figure 4.6). A reduced sample size is unlikely to explain the disappearance of an increased hazard ratio associated with Asthma Clinic attendance (although the loss of significance for number of prior visits for asthma in Subset B might be explainable by reduced variability in the same variable). The fact that interaction terms for clinic attendance and patient age, and clinic attendance and number of previous visits, were not significant might be explained by the fact that patient age is a continuous variable in the models but the subsetting on age necessary requires selecting a cut-off age.

Taussig, Wright, Holbert (9) have demonstrated prospectively that early wheezers and young children diagnosed with asthma, i.e. one, two, and three year olds, are frequently found not to have asthma in later childhood. Thus, the lack of a difference in time to repeat ED visit in older children may, in part, be attributable to more reliable diagnosis. An Asthma Education Clinic intervention could not be expected to help parents of younger children who are wheezing because of pre-morbid, diminished respiratory system conductance, for example. If more severely ill patients were referred to the clinic, then it is not surprising that clinic attendees had a higher probability of repeat visit. However, in older children, congenitally small airways in relation to body mass would be expected to contribute less to wheezing as most children have grown in size and the probability of misdiagnosis falls. Thus, any difference in time to repeat visit would be more likely to be attributable to Asthma Education Clinic attendance. It may be that Asthma Education Clinic attendance and severity of illness had opposite effects that nearly negated each other in older children – resulting in no observed difference in time to repeat ED visit. These ideas are no more than conjectures, of course, given that, outside of the number of previous visits, longterm severity of illness was not captured as part of the dataset (the level or urgency variable is most appropriately conceptualized as capturing severity of illness for a particular visit).

It is interesting to note that while both Cabana et al and Wasilewski et al. (4) suggest that the quality, content, and structure of the follow-up visit are likely determining factors in the success of the intervention, the results of this study raise the possibility that careful selection of patients and families according to patient age may be equally important for a successful intervention. Perhaps referral of parents of two and three year olds is not worthwhile given the large proportion of children in this age group who are 'false positives' for a true diagnosis of asthma. The aforementioned issues prevent moving this hypothesis beyond speculation.

A few other study limitations are worth mentioning. The chart review for inclusion in the study sample was done only for those patients initially identified as being potential asthma cases using the descriptive terms generated at triage. It is possible, though unlikely, that an asthma or RAD patient did not exhibit any of the symptoms associated with asthma and yet was ultimately diagnosed with asthma. Such a patient would not have been captured in the study sample. This point is of particular relevance for the presenting symptom of "isolated cough". Patients were not screened for inclusion according to this symptom because of the overwhelming number of "false positives" that would have resulted. Fortunately, an isolated cough, i.e. without any wheezing or difficulty breathing, is an infrequent presenting symptom for children with asthma or RAD. Moreover, the diagnosis of children with only an isolated cough as having asthma is itself controversial.(10)

Although attendance at the Asthma Education Clinic represents a consistent, well-defined intervention compared to the 'interventions' assessed in previous studies, e.g., GP visits, no attempt was made in this study to distinguish between patients who attended the Asthma Education Clinic once or who may have attended asthma education clinics at other institutions, e.g. Surrey Memorial Hospital. Such an analysis could be interesting but was beyond the scope of the current study. It also wasn't possible to compare referred attendees with referred non-attendees. Clinic attendance was obtained from computerized system searches, and was reliable, but the referral form fill out by ED nurses was inconsistently found in the Health Record.

Finally, the exclusion criteria for this study mean that the results of this analysis should only be extrapolated to children without significant co-morbidities. Although asthma is an important concern for all patients, regardless of whether they have other serious illnesses, the small number of patients in each of the wide variety of co-morbidity categories, made it impossible to control for co-morbidities in any meaningful way.

4.6 Summary

The results of this study are thought provoking. The limits of a retrospective study design prevents a definitive statement about the potential benefits of asthma education, however, the observation that parents of children three years and older and with fewer than three previous visits for asthma or RAD have a survival curve that deviates from that of younger patients with more previous visits hints at the possibility that asthma education programs may be of benefit in certain subpopulations of ED visitors. It would clearly be interesting to use survival analysis techniques with a richer dataset as alternative trends or explanation might emerge, or to undertake a randomized study in this specific subpopulation of patients.

Table 4.1 Characteristics of Total Sample for Retrospective Cohort

Variable	**n=**	**%**
Total	720	100.0
Gender		
Male	465	65.6
Female	255	35.4
Age		
2	185	25.7
3	151	21.0
4	99	13.8
5	96	13.3
6	47	6.5
7	49	6.8
8	32	4.4
9	31	4.3
10	30	4.2
Health Service Delivery Area		
Vancouver	432	60.0
Fraser North	101	14.0
Fraser South	92	12.8
Richmond	59	8.2
Other	36	5.0
Admission		
Yes	116	16.1
No	604	83.9
Level of Urgency on Presentation at Index Visit		
Non-urgent	5	0.7
Less urgent	92	12.8
Emergent	262	36.4
Urgent	358	49.7
Resuscitation	3	0.4

Table 4.2 Characteristics of Asthma Clinic Attendees vs. Non-attendees

	Non-Attendees		Clinic Attendees	
Variable	**n=**	**%**	**n=**	**%**
Total	576	100.0	144	100.0
Gender				
Male	369	64.1	96	66.7
Female	207	35.9	48	33.3
Age				
2	147	25.5	38	26.4
3	123	21.4	28	19.4
4	71	12.3	28	19.4
5	76	13.2	20	13.9
6	42	7.3	5	3.5
7	39	6.8	10	6.9
8	24	4.2	8	5.6
9	26	5.4	5	3.5
10	28	4.5	2	1.4
Health Service Delivery Area				
Vancouver	343	60.0	89	61.8
Fraser North	81	14.1	20	13.9
Fraser South	75	13.0	17	11.8
Richmond	44	7.6	15	10.4
Other	33	5.7	3	2.1
Admission				
Yes	81	14.1	35	24.3
No	495	85.9	109	75.7
Level of Urgency at triage on Presentation at Index Visit				
Non-urgent	5	0.9	0	0.0
Less urgent	84	14.6	8	5.6
Emergent	196	34.0	66	45.9
Urgent	288	50.0	70	48.6
Resuscitation	3	0.5	0	0.0

Table 4.3 Descriptive Time-to-Event Statistics for Total Sample and Repeat Visitors

Variable		n=	%	
Total number of patients in sample		720	100.0	
Number of patients with a repeat ED visit		243	33.8	
Number of patients without a repeat ED visit		477	66.2	
Time at risk for repeat ED visit (days)				
	Total			343713
	Minimum			1
	Mean			478.0
	Median			531
	Maximum			823
For patients with a repeat ED visit:		243	100.0	
Time at risk for repeat ED visit (days)				
	Total			47844
	Minimum			1
	Mean			196.9
	Median			155
	Maximum			742

Table 4.4 Results of Univariate Hypothesis Tests for Time to Repeat ED Visit in Retrospective Cohort

	Log-rank test		Gehan-Wilcoxon test	
Variable	**Chi-square**	**p=**	**Chi-square**	**p=**
Asthma Clinic Visit	13.3	0.000	14.5	0.000
Gender	3.1	0.077	4.1	0.043
Age	12.9	0.114	13.3	0.102
Age (dichotomized: < 3, >= 3)	3.6	0.059	3.5	0.062
Number of Prior Asthma/RAD ED visits	88.5	0.000	79.6	0.000
Health Service Delivery Area	6.8	0.663	6.4	0.701
Admission	0.1	0.706	0.1	0.733
Level of Urgency at triage on Presentation at Index Visit	12.1	0.017	12.3	0.015

Table 4.5 Results of Cox Proportional Hazards Modeling on Time to Repeat ED Visit

Variable	**Hazard Ratio**	**Lower 95% C.I.**	**Upper 95% C.I.**	**p=**
Final Model for Entire Sample*				
Asthma Clinic Visit	1.63	1.23	2.17	0.001
Gender	1.23	0.94	1.61	0.140
Age	0.89	0.84	0.95	0.000
Number of Prior Visits for Asthma	1.18	1.14	1.23	0.000
Final Model for Entire Sample with Interaction Variable**				
Asthma Clinic Visit	2.12	1.09	4.10	0.027
Gender	1.23	0.93	1.61	0.144
Age	0.90	0.84	0.97	0.004
Number of Prior Visits for Asthma	1.18	1.14	1.23	0.000
Age * Asthma Clinic Visit	0.94	0.80	1.09	0.401

* backward selection procedure with 0.20 significance level for removal of terms on seven-term starting model: clinic visit, gender, age, admission index visit, number prior visits for asthma, emergent/ resuscitation vs. less urgent/non-urgent, urgent vs. less urgent/non-urgent

** forced fit of interaction term closest to significance

Table 4.6 Results of Subset Cox Proportional Hazards Modeling on Time to Repeat ED Visit

Variable	Hazard Ratio	Lower 95% C.I.	Upper 95% C.I.	p=
Final Model Subset A* (> 3 years old):				
380 patients, 116 patients with repeat ED visits				
Asthma Clinic Visit**	1.28	0.83	1.98	0.266
Age (years)	0.90	0.82	1.00	0.045
Number of prior visits for asthma	1.18	1.13	1.24	0.000
Final Model Subset B* (< 3 prior visits for asthma):				
583 patients, 164 patients with repeat ED visits				
Asthma Clinic Visit	1.53	1.07	2.18	0.020
Age (years)	0.89	0.83	0.96	0.002
Number of prior visits for asthma	1.12	0.90	1.41	0.317
Final Model Subset C* (> 3 years old and < 3 prior visits for asthma):				
281 patients, 63 patients repeat ED visits				
Asthma Clinic Visit**	0.96	0.51	1.80	0.9
Age (years)	0.90	0.78	1.03	0.112
Number of prior visits for asthma	1.35	0.96	1.90	0.081

* backward selection procedure with 0.20 significance level for removal of terms on seven-term starting model: clinic visit, gender, age, admission index visit, number prior visits for asthma, emergent/resuscitation vs. less urgent/non-urgent, urgent vs. less urgent/non-urgent

** clinic visit forced into the model

Table 4.7 Results of Cox Proportional Hazards Modeling on Time to Repeat ED Visit for Repeat ED Visitors

Variable	Hazard Ratio	Lower 95% C.I.	Upper 95% C.I.	p=
Final Model*:				
243 patients, 243 patients with repeat ED visits				
Asthma Clinic Visit	1.42	1.06	1.90	0.020
Gender	1.27	0.97	1.68	0.086

* backward selection procedure with 0.20 significance level for removal of terms on seven-term starting model: clinic visit, gender, age, admission index visit, number prior visits for asthma, emergent/resuscitation vs. less urgent/non-urgent, urgent vs. less urgent/non-urgent

Figure 4.1

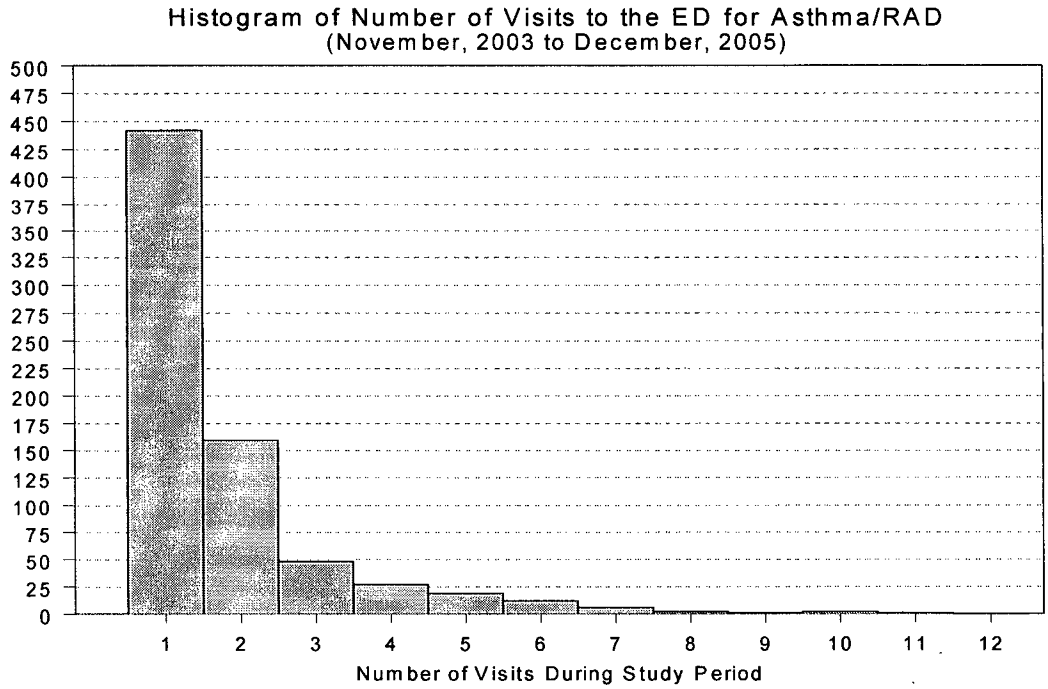


Figure 4.2

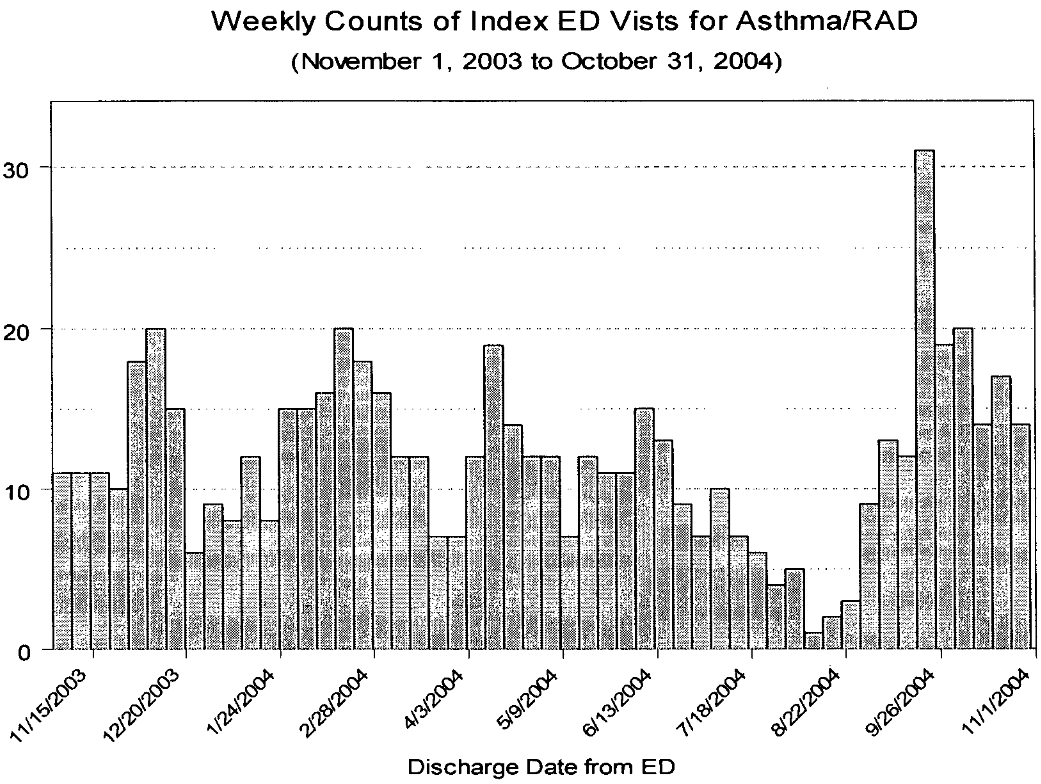


Figure 4.3

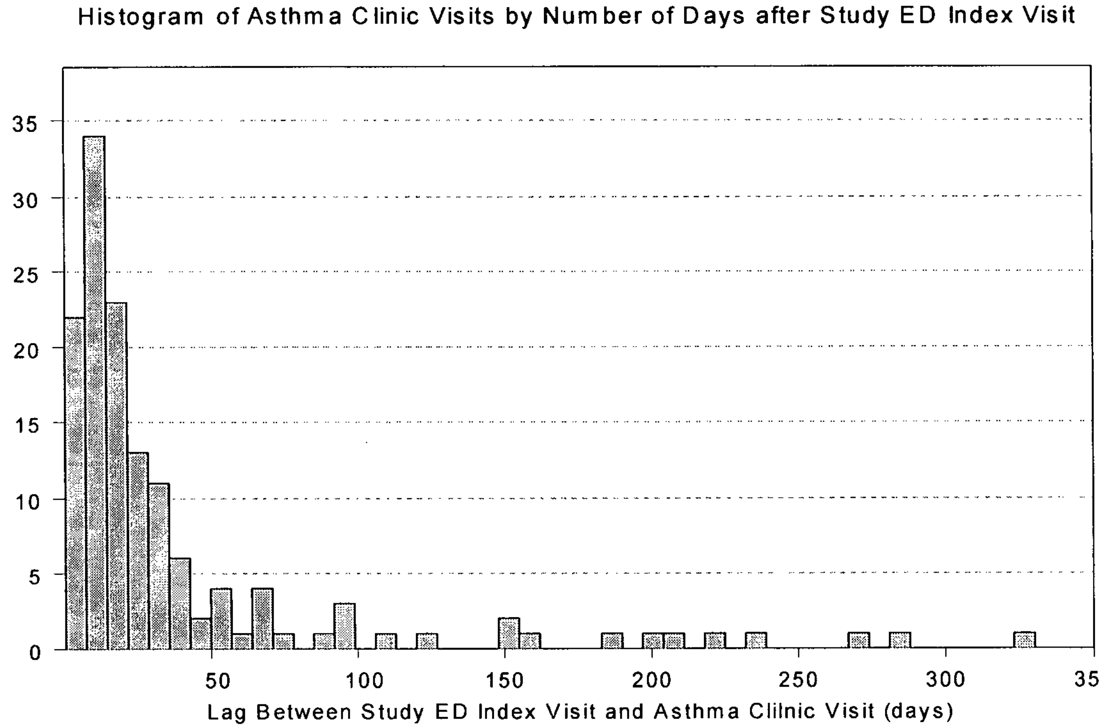


Figure 4.4 Time-to-Repeat-ED-Visit Curve for Total Sample (n=720)

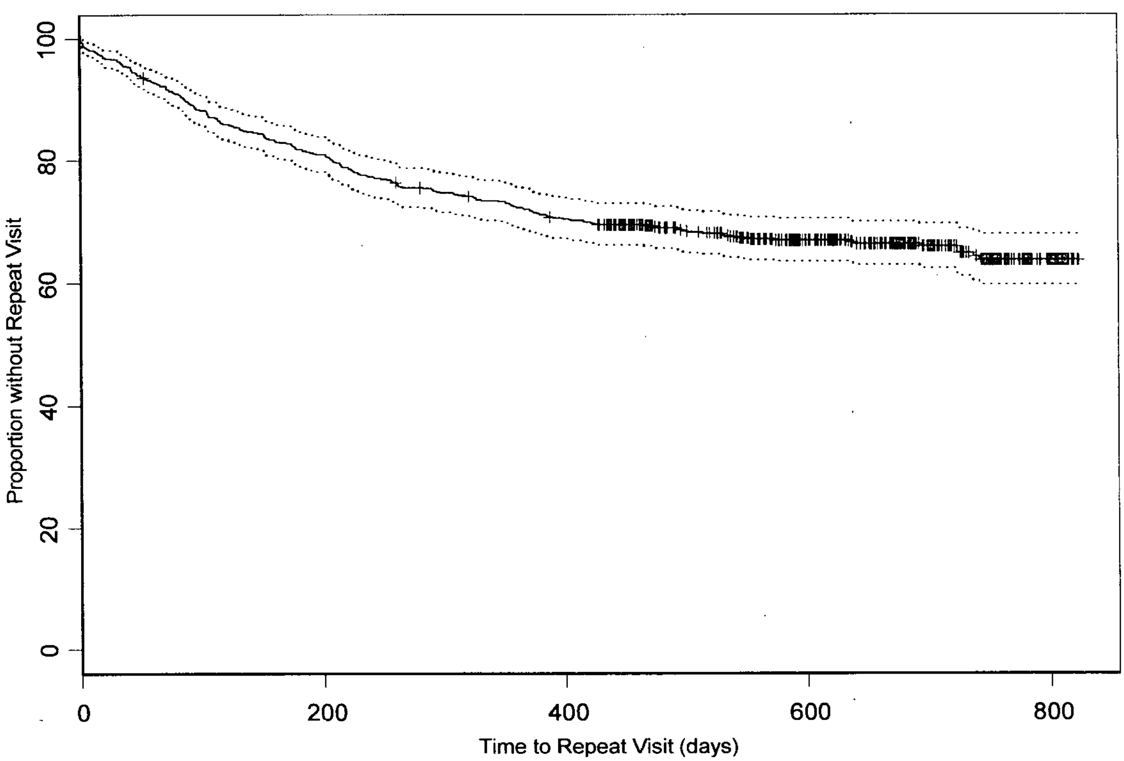


Figure 4.5 Time-to-Repeat-ED-Visit Curve (Asthma Education Clinic Attendees vs. Non-Attendees)

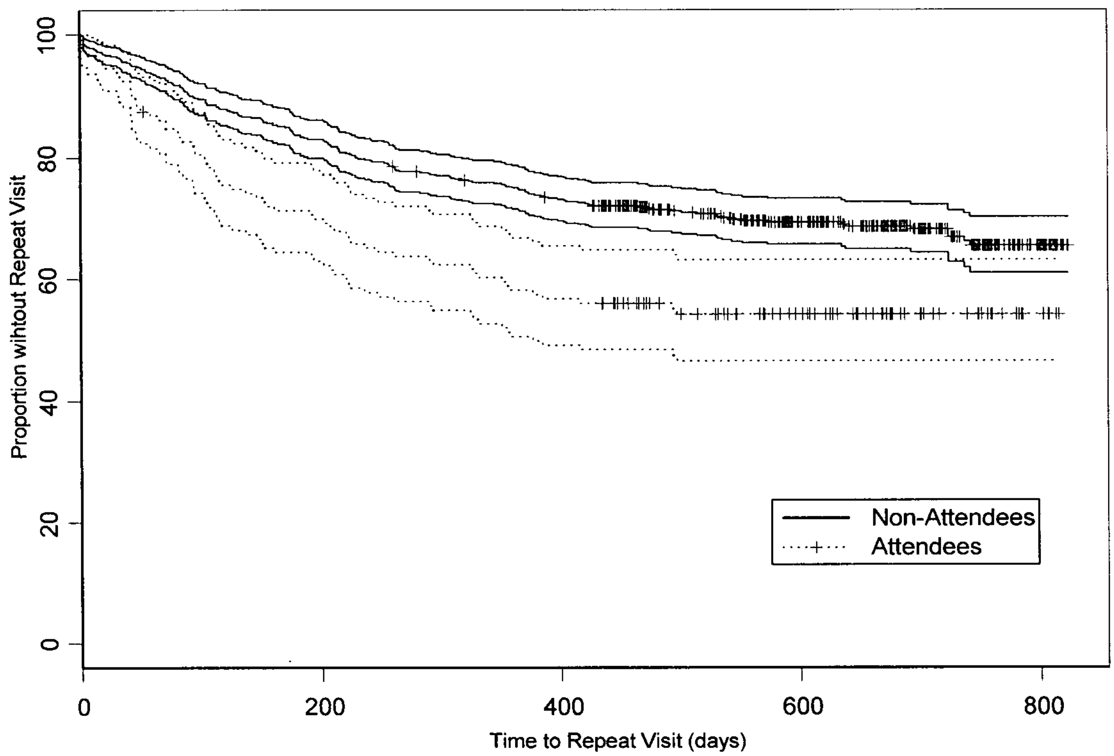


Figure 4.6 Time-to-Repeat-ED-Visit Curve for Patients > 3 Years Old and < 3 Previous Visits for Asthma (Asthma Education Clinic Attendees vs. Non-Attendees)

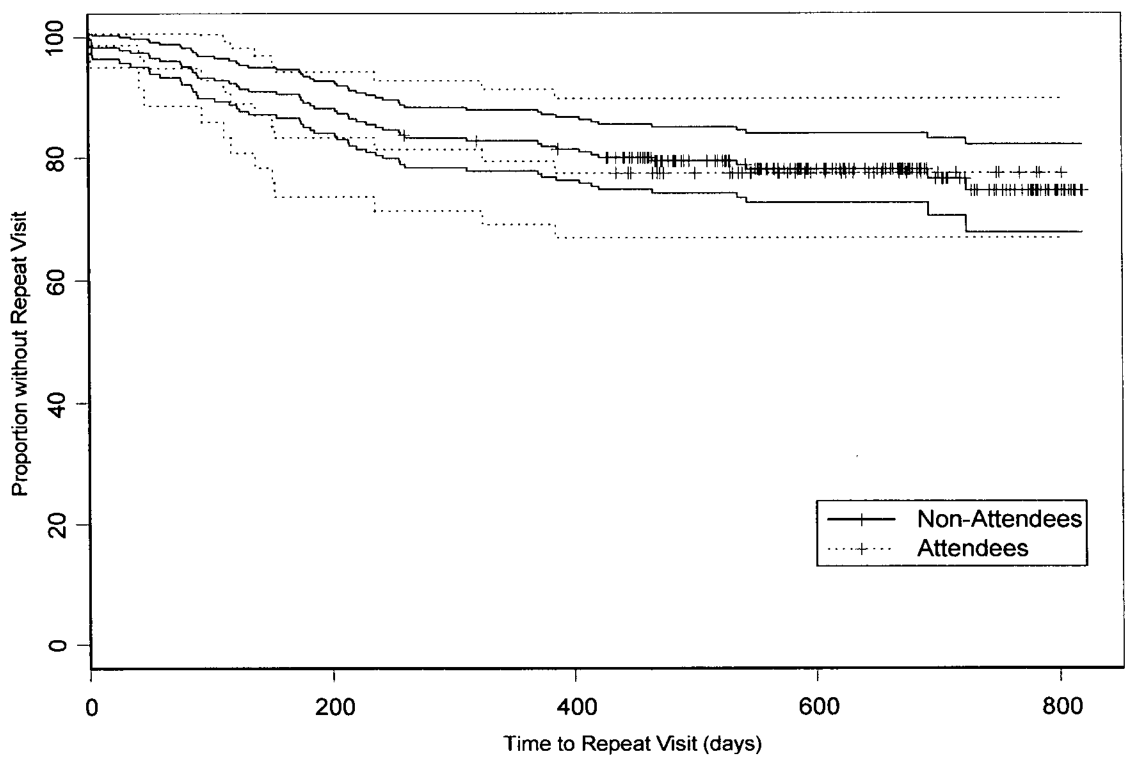
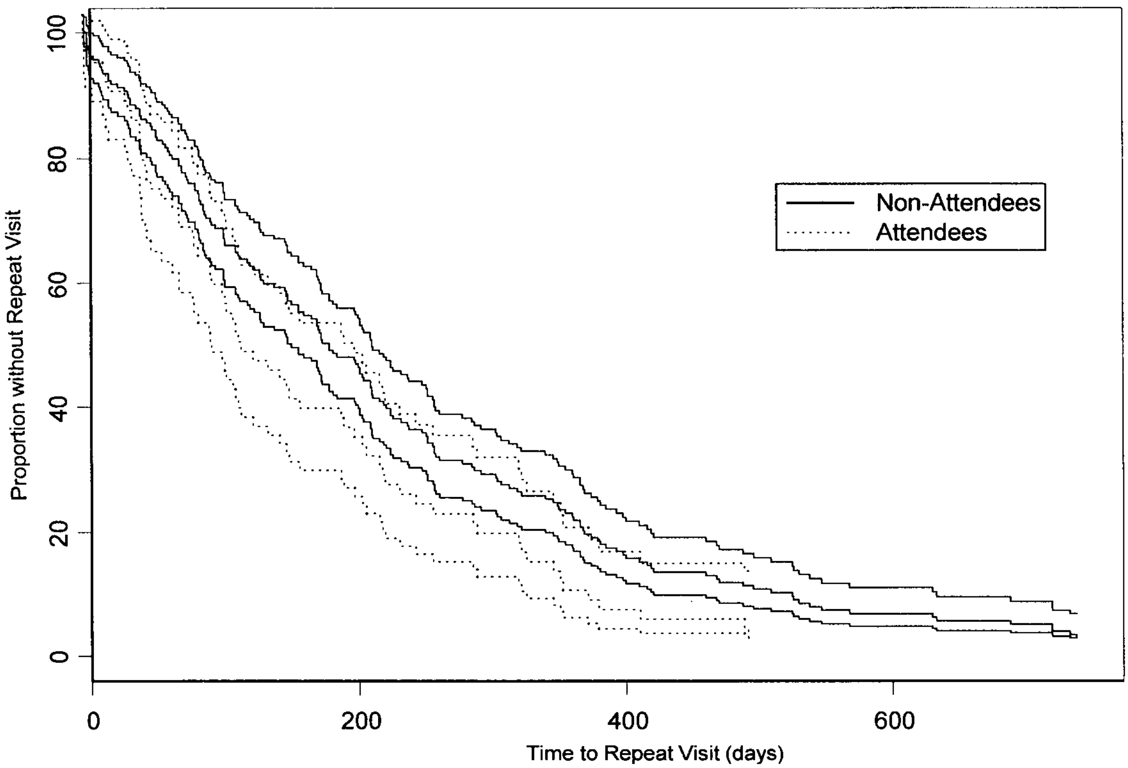


Figure 4.7 Time-to-Repeat-ED-Visit Curve for Patients with a Repeat ED Visit (Asthma Education Clinic Attendees vs. Non-Attendees)



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CHAPTER 5: PARENTAL ASTHMA KNOWLEDGE, PARENTAL CARE PREFERENCES AND REPEAT VISITS FOR ASTHMA IN THE PEDIATRIC EMERGENCY DEPARTMENT

5.1 Abstract

Objective To explore the relationship between parental care preferences and pediatric ED repeat visit rates for asthma. To assess changes in asthma knowledge after extended asthma education among parents of children who present in a pediatric ED with an asthma exacerbation. *Methods* The study was a prospective cohort study of 87 children attending the Emergency Department of an acute care pediatric hospital, with 29 children attending an Asthma Education program in a hospital-based ambulatory clinic and 59 patients receiving only basic asthma education in the ED. *Results* Asthma Knowledge Questionnaire score changes did not reach statistical significance although certain components of asthma knowledge, such as an understanding of the physiological changes that occur during an exacerbation, appear to improve after extended asthma education. Parents expressed a greater desire for information than for decision-making control but no difference emerged in ED visit rates between groups categorized by decision-making score. *Conclusions* The results of this study suggest no effect of Asthma Education Clinic attendance or parental care preferences as measured by the Asthma Autonomy Preference Index on ED utilization. ED-specific asthma knowledge questionnaires may need to be developed and tested as instruments from other settings are suboptimal for use in the ED and may, in part, explain the lack of significant findings.

5.2 Introduction

Children with asthma represent a significant proportion of attendees in the typical pediatric Emergency Department (ED), except in summer. Asthma is considered to be a manageable condition by most clinicians and for this reason parents and children who attend the pediatric ED for asthma exacerbations have been of interest to researchers and administrators alike. If asthma can be effectively controlled, what is driving the treatment-seeking behaviour of parents? A popular hypothesis is that parental knowledge about asthma may be inversely related to the likelihood of attending the ED. Assumptions of this nature underlie many of the asthma education programs that have been implemented in hospital-based clinics. However, the evaluation of such programs has produced contradictory results.

In an American study based at an inner-city hospital, Harish, Bregante, Morgan, Fann et al. (1) found that the mean number of visits to the ED was significantly lower in the treatment group in six of the first twelve months of follow-up and non-statistically lower in the remaining six months. The intervention was defined as three one-hour visits, two weeks apart, at the Pediatric Asthma Center staffed by three certified pediatric nurse practitioners, a pediatric allergist, and a social worker. The study was a randomized, controlled trial with 12 months of follow-up, with an additional 12 months of follow-up after some cross-over of controls to the treatment group at the 12 month mark (these were excluded from second year analyses). The investigators recruited 300 hundred patients aged 2 to 17 being treated for asthma in the ED of whom 129 patients (60 in treatment and 69 controls) were included in the final analysis for the first year because they met the study inclusion criteria of returning at least one questionnaire in each season during the one year of follow-up. In the second year of follow-up, the treatment group had 53 patients while the control group had 66 patients. The Center provided intensive medical and environmental control, education, close monitoring, and 24-hour availability.

The investigators note that the decrease in ED utilization by the treatment groups was statistically significant in four consecutive months in the latter part of the study year (approximately 0.1 visits/month per patient vs. 0.45 visits/month per patient). Similarly, for the last three months of the first year of follow-up the percentage of patients who visited the ED in the treatment group was statistically significantly lower than in the control group (roughly 5% vs. 22%).

In another randomized trial of 57 patients, Greineder, Loan, and Parks (2) found a significant difference in ED visits and hospitalizations for asthma between treatment and control groups. The treatment group received the full asthma outreach program (AOP) intervention while controls were only given a single asthma education class by an AOP nurse. Both groups received one-on-one education with an AOP nurse via discussion, direct demonstration, and parental skill assessment, e.g. inhaler and peak flow meter technique, but the treatment group received ongoing follow-up whereas controls were referred back to their pediatrician or family physician for follow-up.

The investigators found that the treatment group experienced a 73% reduction in ED visits compared to a 39% reduction in ED visits for the control group ($p = .0002$). A similar drop in hospitalizations for asthma (84% vs. 43%, $p = .0012$) was noted. The investigators had previously used a pre-post design study to examine the effect of an asthma outreach program on ED visits and hospital admissions and also found significant reduction in both measures (79% and 86% reduction, respectively).(3)

In contrast to the two American studies above, the investigators of a British study (4) reported that an educational intervention aimed at parents of pre-school children with asthma did not reduce morbidity, defined as parental perceptions of their child's symptoms and disability associated with asthma, or reduce health care utilization. The study was a two-centre randomized controlled trial of 200 children aged 18 months to 5 years enrolled at admission or emergency attendance. Baseline data collected via questionnaire included previous hospital admissions, pattern and severity of asthma symptoms, atopic disease, precipitating factors for wheezing, and medication on discharge. Parents were asked to fill out a second questionnaire at home after discharge to assess parental recall of educational information provided and the nature of its delivery. Follow-up information was obtained at three, six, and 12 months and consisted of general practitioner consultation frequency, hospital readmission frequency, emergency visit frequency (from general practitioner records and hospital records) and outcome measures such as child asthma symptoms and associated disability, and pediatric asthma quality of life (using questionnaires from the literature designed to measure parental perceptions of symptoms and disability in asthmatic children and quality of life, respectively), and parental knowledge of asthma (using a questionnaire developed specifically for the study).

The study authors found no statistically significant differences for readmission frequency, emergency visit frequency, or general practitioner consultation frequency between control and intervention groups during the 12 month follow-up period. Similarly, questionnaire measures for perceived symptoms and disability, quality of life, and parental knowledge showed no significant differences between the groups. The investigators note that possible reasons for the lack of an effect might include an inadequately designed intervention, lack of validation of the parental knowledge questionnaire, and the age range of the recruited children (18 months to five years).

Another negative finding was obtained by Khan, O'Meara, Stevermuer, and Henry (5) in an Australian randomized controlled trial of 266 children. The intervention in this study consisted of a telephone consultation by one of two experienced asthma educators. Both educators were registered nurses who had attended an asthma educator's course run by the Asthma Educators Association. Parents also completed an asthma control questionnaire, an asthma knowledge questionnaire, and an asthma quality of life questionnaire. Telephone counseling was conducted within 2 weeks of the return of initial questionnaires by parents and lasted an average of 13 min (range 5–44 min).

While both intervention and control groups showed significant decreases in asthma morbidity measures (doses of reliever in the past three months, days of wheezing in the past three months, asthma attacks in the past six months, ED visits in the last six months, GP visits in the last six months, and hospitalizations for asthma in the last six months) none of the measures proved to be statistically different between the two groups, initially or on follow-up.

Several non-randomized studies aimed at evaluating asthma education programs have also been done. In an Australian study of 158 families, Liu and Feekery (6) sought to evaluate an asthma education program through a quasi-randomized controlled trial with assessments before intervention and at one, six, and 12 months after intervention. The interventions consisted of either face-to-face education sessions or education through home-based video. The face-to-face sessions comprised two 40-minute sessions. Parents first participated in a small group session followed by an individual session. The home-based video intervention consisted of two videotapes being mailed to families. The investigators found that education positively impacted parental asthma knowledge with the difference between control and education groups being significant at one and 12 months follow-up. Assessment consisted of administration of a questionnaire which measured parental asthma knowledge, attitudes and beliefs, parents' locus of control and the occurrence as well as severity of child asthma symptoms, e.g., frequency of wheezing/coughing, medications use, night waking etc., and consequences of such symptoms, i.e., school days missed, ER visits, hospitalizations. Although no significant group difference was found for parental anxiety at six and 12 months, the children's asthma severity and morbidity was found to be significantly lower in the face-to-face education group than in the control group at 12 months.

In a Dutch study, Mesters, van Nunen, Crebolder, and Meertens (7) used a two-group pretest-posttest design to evaluate the effect of an asthma education protocol used by general practitioners on medical care consumption including emergency visits to GPs, specialists, and hospital admissions. To be included in the study, children had to be no older than four years of age and had to have been diagnosed with asthma within the past six months. Using analysis of covariance, the investigators concluded that the number of emergency visits to a GP and the number of emergency contacts with a GP were significantly lower in the treatment group post-intervention.

A German study (8) sought to evaluate two versions of an asthma training program for children and their parents. Eighty-one patients from hospital outpatient clinics were divided into two intervention groups (five-day asthma training program with monthly follow-up, and five-day training program with no monthly follow-up) and a control group. Evaluation consisted of before and after comparison of the results of standardized tests administered to the children for measuring health locus of control, anxiety, and self-management ability. Shorter questionnaires were given to parents and doctors. Relevant medical outcome data was also obtained. The investigators report that children who received training were more aware of prophylactic measures and implemented these measures earlier. In particular, knowledge of emergency measures such as intervention peak-flow score was significantly better at one year. However, the implementation of emergency measures, although significant at six months, was not significant at one year. The authors did not find outcomes such as schools days missed and lung-function to be significantly different at one year. They concluded that while the intervention is effective an improving knowledge about attack prevention and emergency measures (at six months), early perception of warning signs, importance of adherence to medication regimen, and prophylactic treatment before exercise, it did not result in long-term compliance (defined as the implementation of emergency measures at one year).

The conflicting results between studies for the effectiveness of asthma education programs at reducing ED visits is striking. One may conjecture that differences in results are attributable to factors such as differences in populations, interventions, and follow-up. Alternatively, there may be other unmeasured factors, such as the autonomy of parents, that influence ED visits. This study examines the potential influence of parental information-seeking and decision-making preferences, as measured by the Asthma Autonomy Preference Index (9), on ED visit rates, and of asthma education asthma education on parental asthma knowledge.

5.3 Methods

The study was a prospective cohort study of children diagnosed in the B.C. Children's Hospital ED with asthma or hyperreactive airways disease (RAD). The enrolment of patients was done on site weekday evenings and weekends (peak ED visitation times) during the period July 1, 2005 to October 31, 2005. Patients were allocated in a nonrandomized fashion to the two arms of the study: basic asthma education (usual care with possible brief asthma education by ED nurses) or extended asthma education (basic education plus follow-up asthma education in the Asthma Education Clinic). Basic asthma education was not always provided as the load on the ED dictated the amount of time available to ED nurses for asthma education. Recruitment and asthma knowledge assessment occurred after emergency care has been provided (e.g., three Ventolins® over an hour) but prior to anti-inflammatory drug treatment (e.g. dexamethasone) and basic asthma education. Patients admitted from the ED to the General Paediatric unit or other ward for an overnight stay/short-stay observation were approached before leaving the ED.

Patients were eligible to be included in the study if they were two years of age or older, were resident in the Greater Vancouver Regional District, had no serious comorbidities, and the parents/guardians were capable of understanding and speaking English. Patients who were previously seen in the ED for an asthma exacerbation were enrolled if they did not receive extended asthma education through the Asthma Education Clinic or elsewhere and they had not seen their primary care physician about asthma in the past year. Patients who presented in the ED with asthma symptoms but who were ultimately diagnosed with RAD rather than asthma, and who had no previous diagnosis of asthma and fewer than two visits for RAD, were not included in the study. Some patients were excluded from the analysis if the follow-up extended asthma education session did not occur within the four month follow-up period (these were rare and usually a result of scheduling conflicts which delayed the education session).

A baseline questionnaire was administered in the ED that consisted of questions regarding patient characteristics, home environment, usual physical activity, general history of respiratory infections, and family history of asthma. An Asthma Autonomy Preference Index (to measure parental information-seeking and decision-making preferences) (9) and an Asthma Knowledge Questionnaire (10) were also administered. In situations where it was difficult to administer the entire baseline questionnaire in the ED, only the Asthma Knowledge Questionnaire and Asthma Autonomy Preference Index were administered and the remaining portions of the baseline questionnaire were administered by phone a few days after the ED visit. Follow-up data collection occurred after parents and children had been seen by an asthma education nurse (for those referred for extended asthma education in the Asthma Education Clinic) or received basic asthma education from an emergency nurse (for those not referred). The follow-up questionnaire assessed parental knowledge of asthma using the Asthma Knowledge Questionnaire but also include basic questions about asthma-related health care use such as ED visits. Chart/computer review and was be done at Children's Hospital to identify any additional visits or admissions.

The data collection procedure and questionnaire administration was pilot tested in a sample of ten patients. The pilot provided an opportunity to refine the enrolment process to minimize interference with care providers and to ensure that parents/guardians had no difficulty responding to items on the questionnaires. No specific data analysis was done with the pilot data because of the small sample size.

Statistical analysis was done using the Splus statistical package. Descriptive tabulations were produced to characterize the study sample. Univariate hypothesis testing was done using Chi-square and ANOVA. Bivariate testing was done using the ties-corrected Kruskal-Wallis' nonparametric test. The outcome variables of interest included the number of ED visits during follow-up and Asthma Knowledge Questionnaire scores. The independent variables of primary interest were attendance or non-attendance at the extended asthma education program and asthma care preference scores as measured by the Asthma Autonomy Preference Index. The two groups of care preferences measured by the index were information-seeking preferences and decision-making preferences.

5.4 Results

Patient enrolment in the study resulted in an initial sample of 87 patients, with 30 patients in the extended asthma education arm and 57 patients in the basic asthma education arm. Baseline questionnaire data was collected for all 87 patients, however, 10 patients were lost to follow-up (two in the extended education arm and eight in the basic education arm), resulting in fewer observations for the follow-up questionnaire (n = 28 and 49 in extended asthma education and basic asthma education arms, respectively).

Table 5.1 presents the baseline demographic characteristics of the 77 patients with both baseline and follow-up information and the 10 patients who were lost to follow-up. The two groups were similar along most characteristics. Patients lost to follow-up were more likely to have parents/guardians with lower levels of education, and less full-time employment. There are two unknowns for parental education status and employment status because of a couple of children accompanied by foster parents.

Tables 5.2 through 5.5 provide baseline descriptive information on the study sample. Table 5.2 shows medical care usage for both arms of the study while Table 5.3 describes the patient and family medical history for the same groups. Both mean and median values are presented in Table 5.2 to emphasize the skewed nature of the visit data. While some families have visited other hospital EDs the majority of reported ED visits were at B.C. Children's Hospital. The mean and median values do not suggest that there is a difference between the two groups in terms of past medical care utilization. Patients referred to the asthma education were more likely to have been born prematurely, to have been previously diagnosed with asthma, and to have other family members diagnosed with asthma or atopic disease (eczema or allergic rhinitis) at any time.

Table 5.4 shows the environmental variables for the same groups. Very few children had had allergy testing done, presumably because of the relatively young age of the study sample. Triggers for asthma or RAD symptoms were obtained using a multiple response format. The most common reported triggers were infections, dust, cold air/weather changes, and pollens. Children referred to the asthma education clinic tended to have more infection-triggered exacerbations. Other known triggers such as exercise and aspirin may not have been represented in the sample because of the relatively young age of patients. As expected, relatively few homes had an air conditioner and the most common type of heating was electric baseboard heating. Few families in either study arm had a humidifier or vaporizer in their child's bedroom. Family homes also tended to have substantial amounts of carpeting, including the child's bedroom, and few families had purchased mite-proof covers for their child's mattress. Many children had stuffed toys but not all children played with them regularly.

Table 5.5 describes asthma symptoms variables for the study sample. Although asthma management variables were originally designed to be part of the data collection process, the reliability of the medication use data was deemed to be low. Parents and guardians frequently had significant difficulty remembering medication names. For this reason, medication use data was excluded from analysis. Reported symptoms for asthma over a typical week were surprisingly low and did not suggest a difference between groups. Also notable was the low number of parents/guardians reporting that an action plan had been established with their family physician or pediatrician, possibly reflecting time pressures in family practice.

Table 5.6 presents Asthma Knowledge Questionnaire results at baseline and follow-up. Simple inspection suggests that the proportion of respondents correctly answering the true/false questions tended to increase in both basic and extended education groups. For questions 5, 7, 9, and 16 the increase in proportions appeared to be larger for those receiving extended education through the Asthma Education Clinic than it was for the basic education group. The first three questions pertain to physiological changes that occur during an asthma attack, and the consequences of these changes, while the last question related to the value of prophylactic administration of asthma medications. Chi-square tests for differences between the four proportions (baseline basic, baseline extended, follow-up basic, follow-up extended) did not result in any statistically significant findings. Similarly, one-way analysis of variance on the mean total scores (bottom of Table 5.6) for the four groups did not produce a significant finding.

Table 5.7 presents Asthma Autonomy Preference Index scores. Total scores are the averaged total score of individual response items. Information-seeking-preference item responses generally scored high and indicate that parents/guardians wanted as much information as possible. Mean scores for decision-making-preference items generally reflected a lower preference for autonomy compared to a desire for information. Just as importantly, scores were characterized by greater variability suggesting that parents differed more on the importance of autonomy in making decisions about the care of their child in relation to his or her asthma. This was particularly apparent for the item "You should decide how frequently your child needs a checkup for his/her asthma.". Although no differences were found between groups on statistical testing of item means, the high scores do suggest that parents/guardians would have been very receptive to an asthma education intervention.

Finally, Table 5.8 shows the annualized ED visit rates according to asthma education group, Asthma Knowledge Questionnaire score group (above and below/equal to median score), and decision-making-preference score group as determined from the Asthma Autonomy Preference Index (above and below/equal to median decision-making preference score). The ties-corrected Kruskal-Wallis test did not produce significant results and casual inspection does not suggestion that there are differences in ED visit rates. It should be noted that the numbers within cells are small as a result of cross-tabulation by multiple variables.

5.5 Discussion

The results of the study suggest that targeted asthma education does not have a dramatic impact on parental asthma knowledge levels or on subsequent ED visit rates, or that parental decision-making preferences have an impact on ED visit rates. However, the relatively small sample size, especially for the intervention group, may have precluded finding statistically significant results. The power calculations that were done as part of the original study protocol (See Table 5.9) assumed a higher repeat ED visit rate than was found to be the case for this population (See Chapter 4). The assumption was legitimate in light of the findings of previous studies, i.e. 32% of children are repeat visitors in a six month period (16), and the fact that a longer length of follow-up was originally intended. With standard values for Type I and Type II error, the minimum number of subjects in each arm was determined to be approximately 60 subjects. The number in each arm was lower for repeated observations, i.e. multiple follow-up points, but this study was restricted to one follow-up interview when it became clear that the questionnaire item responses were clustering and it was deemed unlikely that significant findings would result.

Other investigators have noted a parallel movement in outcome measures in intervention and control groups. Thus, interventions subsequent to interaction with ED staff may have to have a sizeable effect in order for them to be detected. For example, Khan, O'Meara, Stevermuer, and Henry (5) suggested that the large reductions in ED visits observed in both groups may be the result of good asthma management practices by ED staff that made it difficult to demonstrate an effect of a subsequent intervention. They acknowledge that it is also possible that the large improvement in both groups represented a seasonal effect and that this might have swamped any possible positive effects. In this study, seasonal factors are unlikely to explain the negative findings because enrolment was in later summer and follow-up occurred over the fall and into winter (when visits for asthma usually increase).

Another factor which cannot be ignored is that the Asthma Knowledge Questionnaire used in the study, while tested for validity and reliability (10), had three characteristics that may have made it difficult to detect a differences in this study. First, the questionnaire was validated in adults with and without asthma rather than with parents of children with asthma. For the purposes of this study, the questionnaire was adapted with wording changes to ask questions about the parent/guardian's child rather than about the parent/guardian. An inherent assumption was that the wording changes would not make a large difference to the validity or reliability of the questionnaire.

Second, testing of the discriminatory ability of the questionnaire was done using individuals with asthma and individuals without asthma (10). Individuals without asthma consistently scored low on some questions, as might be expected given that they have no personal experience with asthma. In this study, all parents had children with asthma and one of the aims of the study was to detect differences in knowledge levels before and after an educational intervention. It may be that the baseline knowledge level of parents who have children with asthma, as measured by the questionnaire, was sufficiently high that an effect on knowledge levels substantive enough to be detected was improbable.

In addition, an integral assumption to an assessment of any asthma education program is that parental knowledge of asthma is measurable and related to parental ability to manage their child's asthma. A number of questionnaires have been developed in the past to assess parental asthma knowledge, however, almost all were constructed before inflammation was emphasized as a key element in causal pathways for asthma exacerbations (11). Ho, Bender, Gavin, O'Connor et al. assessed the psychometric properties of an Asthma Knowledge Questionnaire they constructed with a multidisciplinary panel with some adaptation from previously published questionnaires. They found their questionnaire to be valid but of only adequate internal consistency reliability. They suggest that asthma knowledge may need to be conceptualized as multidimensional and that future questionnaire development efforts should explore whether knowledge is better assessed through answers to real-life scenarios and with more sensitive questions types i.e. multiple choice instead of true/false questions.

In an attempt to address these concerns, consideration was given in the design phase of this study to using more a sophisticated instrument for measuring asthma knowledge. In particular, the questionnaires designed and tested by Adams, Brestan, Ruggiero et al. (12) were carefully examined. However, it was determined that the characteristics that likely made these questionnaires more reliable, i.e. multiple choice format, also made them difficult to administer in an ED setting and/or over the telephone. These questionnaires have been successfully used in a clinic setting for which they were presumably designed.

Mirroring Asthma Knowledge Questionnaire issues, the Asthma Autonomy Preference Index produced high mean scores on many items. There may have been a ceiling effect that significantly reduced the ability of the instrument to pick up differences in parental information-seeking and decision-making preferences in the sample. The authors who developed this scale did not report problems in this regard (9) but the results in this study suggest that a more sensitive instrument is necessary.

While an acknowledged weakness of this study is the choice of instruments for the measurement of asthma knowledge and parental care preferences, given the realities of conducting ED-based studies, the choice of knowledge questionnaire was arguably one of practical necessity. It is clear, however, that more reliable and sensitive questionnaires that are easy to administer in an ED setting are needed in order for this kind of study to succeed.

Another possible reason for a failure to find any significant differences may be related to the nature of the population in Vancouver as a whole. Harish, Bregante, Morgan, Fann et al. (1) note in their study in New York City that the prevalence of asthma in the Bronx had been shown to be twice the US national average. Similarly, asthma hospitalizations and mortality rates from asthma were five-fold higher. The other study to find positive findings (2) was similarly based in a predominately urban area of a major U.S. city (Boston). Prevalence rates for asthma in British Columbia have been estimated in the past to be as low as 2-4% in British Columbia with an increasing geographic gradient moving east to the Maritimes (where prevalence was estimated at 7-8%).(13) Although the study by Dales, Raizenne, El-Saadany et al. which produced this Canadian prevalence data did not specifically examine Vancouver there is little reason to believe that Vancouver has prevalence rates in excess of the Canadian national average. In assessing the impact of an asthma education program, high baseline prevalence rates, with a presumably consequential high ED visit rates, are likely to contribute to the ability to detect an effect of any interventions. The positive results of the American inner-city studies may be valid but difficult to replicate in areas where asthma prevalence is not as high.

Portions of the baseline questionnaire also suffered from item response problems that were not picked up during pilot testing. Of the four questions that asked about frequency of symptoms in a typical week, only the question related to daytime wheezing resulted in affirmative answers. The reasons for the low numbers are unclear but may be related to one or more of the following: the intermittent nature of asthma, the difficulty in recollecting this type of information, or the difficulty in averaging count estimates over long periods of time. With such low numbers it was impossible to distinguish between the two groups in terms of symptom history.

Although differences between the study arms were not apparent, it was notable that home environment variables on the baseline questionnaire frequently appeared as opportunities for improvement in both arms of the study. It would not take much effort, or be a large investment, to obtain a humidifier for the child's bedroom or to encourage them to play with toys other than stuffed toys. Home carpeting and upholstered furniture may present a bigger challenge as the cost of removing carpeting in homes and replacing it with tile or wood and the cost of replacing upholstered furniture may be prohibitive for some families. However, in the context of chronically ill children, it may be possible to convince parents that larger investments are also worthwhile.

5.6 Summary

The lack of statistically significant findings fails to lend support for the effectiveness for the asthma education programs. The overall sample size, and the size of the intervention group in particular, may explain the lack of significant differences in light of the original power calculations. However, it should be noted that the scores for particular items on the Asthma Knowledge Questionnaire relating to the physiological changes occurring during an asthma attack, and the consequences of such changes, show greater improvement (although nonsignificant on chi-square testing) than other scores and it may be that asthma education is particularly effective at imparting an understanding in this particular domain. Scores for other questionnaire items were high leading to an observed ceiling effect. This was likely because most parents of children with asthma already have some basic knowledge about asthma. Further research should be directed at using questionnaires specifically designed for asthma knowledge assessment in individuals already having some knowledge of asthma but who may benefit from further education. The reliability and validity of such questionnaires in the specific context of the ED, where overly complicated questionnaires cannot practicably be administered, is an important consideration that may affect the interpretation of results.

Table 5.1 Demographic Characteristics of Patient Sample for Prospective Cohort (Complete Follow-up vs. Loss-to-Follow-up)

	Complete Follow-up			Loss to Follow-up		
Variable	**n=**	**% or mean**	**S.D.**	**n=**	**% or mean**	**S.D.**
Total	77	100.0		10	100.0	
Patient Gender						
Male	52	67.5		7	66.7	
Female	25	32.5		3	33.3	
Patient Age	77	4.9	1.4	10	6.2	1.7
Mother's Age	75	27.5	4.2	10	24.5	3.1
Father's Age	75	30.5	5.3	10	28.9	4.2
Mother's Education						
Elementary	5	6.5		7	70.0	
High school	58	75.3		2	20.0	
College/University	12	15.6		1	10.0	
Unknown	2	2.6		0	0.0	
Father's Education						
Elementary	12	15.6		6	60.0	
High school	47	61.0		2	20.0	
College/University	16	20.8		2	20.0	
Unknown	2	2.6		0	0.0	
Mother's Employment status						
Employed FT	35	45.5		4	40.0	
Employed PT	12	15.6		0	0.0	
Unemployed	26	33.8		6	60.0	
Student	2	2.6		0	0.0	
Unknown	2	2.6		0	0.0	
Father's Employment status						
Employed FT	72	93.5		4	40.0	
Employed PT	0	0.0		3	30.0	
Unemployed	3	3.9		3	30.0	
Student	0	0.0		0	0.0	
Unknown	2	2.6		0	0.0	

Table 5.2 Medical Care Utilization related to Asthma at Baseline for Prospective Cohort

	Basic Education					Extended Education				
Variable	**n=**	**Mean**	**S.D.**	**Median**	**Range**	**n=**	**Mean**	**S.D.**	**Median**	**Range**
Visits to any ED in past year	49	1.3	0.6	0	0-7	28	1.4	0.4	0	0-5
Visits to Children's ED in past year	49	1.1	0.6	0	0-7	28	1.2	0.4	0	0-5
Hospitalizations any hospital past year	49	0.3	0.3	0	0-2	28	0.3	0.3	0	0-1
Hospitalization Children's past year	49	0.1	0.2	0	0-1	28	0.2	0.2	0	0-1
GP/pediatrician visits past year	49	1.9	0.7	0	0-9	28	2.1	0.9	0	0-7

Table 5.3 Patient and Family Medical History at Baseline for Prospective Cohort

	Basic Education		Extended Education	
Variable	**n=**	**%**	**n=**	**%**
Total	49	100.0	28	100.0
Premature birth	24	49.0	20	71.4
More than 4 respiratory tract infections	8	16.3	4	14.3
Previously diagnosed with asthma	26	53.1	22	78.6
Other family members with asthma	8	16.3	17	60.7
Other family members with eczema	5	10.2	8	28.6
Other family members with allergic rhinitis	5	10.2	7	25.0

Table 5.4 Environmental Triggers and Home Environment Characteristics at Baseline for Prospective Cohort

Variable		Basic Education n=	Basic Education %	Extended Education n=	Extended Education %
Total		49	100.0	28	100.0
Child has had allergy testing		4	8.2	2	7.1
Triggers:	Infections	19	38.8	19	67.9
	Dust	10	20.4	4	14.3
	Weather changes/cold air	14	28.6	13	46.4
	Pollens	7	14.3	3	10.7
	Molds	5	10.2	1	3.6
Air conditioner in home		3	6.1	0	0.0
Dehumidifier in home		4	8.2	0	0.0
Electric baseboard heating		45	91.8	27	96.4
Forced air heating		4	8.2	1	3.6
Gas heating		0	0.0	0	0.0
Mostly hardwood/tile flooring		6	12.2	3	10.7
Mostly carpet flooring		6	12.2	5	17.9
Half and half		37	75.5	20	71.4
Upholstered furniture in house		43	87.8	25	89.3
Pets in the house		5	10.2	3	10.7
Humidifer/vaporizer in child's bedroom		5	10.2	1	3.6
Hardwood/tile in child's bedroom		3	6.1	2	7.1
Carpet in child's bedroom		46	93.9	26	92.9
Wool bedding on child's bed		0	0.0	0	0.0
Down/feather bedding on child's bed		3	6.1	0	0.0
Washable bedding on child's bed		46	93.9	28	100.0
Mite-proof cover on child's mattress		7	14.3	5	17.9
Child has stuffed toys and plays with them		22	44.9	15	53.6

Table 5.5 Asthma Symptoms at Baseline for Prospective Cohort

Variable		Basic Education n=	Basic Education %	Extended Education n=	Extended Education %
Total		49	100.0	28	100.0
Number of times coughing during daytime in a week:	0	47	95.9	27	96.4
	1	1	2.0	1	3.6
	2	1	2.0	0	0.0
	3	1	2.0	0	0.0
Number of times out of breath in daytime in a week:	0	49	100.0	28	100.0
	1	0	0.0	0	0.0
	2	0	0.0	0	0.0
	3	0	0.0	0	0.0
Number of times wheezing in daytime in a week:	0	44	89.8	23	82.1
	1	4	8.2	3	10.7
	2	1	2.0	1	3.6
	3	0	0.0	1	3.6
Number of time chest tightness in daytime in a week:	0	49	100.0	27	96.4
	1	0	0.0	1	3.6
	2	0	0.0	0	0.0
	3	0	0.0	0	0.0
Child stopped playing/exercising because of asthma symptoms		6	12.2	3	10.7
Child has missed school because of asthma symptoms (age >= 6)		3	37.5 (n = 8)	3	60.0 (n=5)
GP/pediatrician has establish action plan		5	10.2	3	10.7
Peak flow meter used at home		0	0.0	0	0.0

Table 5.6 Asthma Knowledge Questionnaire Scores at Baseline and Follow-up for the Prospective Cohort

Question	Baseline % Correct*		Follow-up % Correct*	
	Basic Education	Extended Education	Basic Education	Extended Education
	n=57	n=30	n=49	n=28
1 Left untreated, asthma will eventually go away.	100	100	100	100
2 Asthma is a nervous or psychological illness	84.2	86.7	89.8	85.7
3 Asthma is a breathing problem that may be triggered by strong emotions	78.9	83.3	81.6	85.7
During an asthma attack....				
4 ...the muscles around the airtubes tighten and the tubes become narrow	73.7	76.7	77.6	85.7
5 ...more mucus is produced in the airtubes	68.4	66.7	71.4	89.3
6 ...the lining of the airtubes becomes swollen	87.7	90.0	87.8	92.9
7 ...the changes in the airtubes make it difficult to get air out of the lungs	64.9	70.0	73.5	92.9
8 ...the airtubes collapse	94.7	96.7	95.9	96.4
9 ...the changes in the airtubes make it difficult to get air into the lungs	73.7	73.3	75.5	89.3
10 Medications return the airtubes to normal and no permanent damage usually occurs	77.2	70.0	79.6	85.7
11 Your child can become addicted to asthma medications if he/she uses them all the time	89.5	86.7	89.8	92.9
12 Asthma medications do not work as well if your child uses them all the time	91.2	86.7	89.8	96.4
13 Although it can not be cured, asthma can usually be controlled by taking the correct medication	100	100	100	100
14 Side-effects are less likely with inhaled medication than with tablets because inhaled medication is not absorbed into the body	61.4	66.7	65.3	75.0
15 Syrups and tablets work about as quickly as inhaled medications	94.7	83.3	87.8	82.1
16 If your child get a cold or flu, you should increase his/her asthma medications	52.6	56.7	55.1	78.6
17 A doctor is best able to measure how bad asthma is by listening to the chest with a stethoscope	73.7	70.0	77.6	78.6
18 Measuring the amount of air in the lungs with a peak flow meter or spirometer is the most accurate way of measuring how bad asthma is	84.2	80.0	79.6	92.9
19 Most asthma deaths could have been prevented	96.5	93.3	95.9	100.0
20 If a person has died from an asthma attack, it usually means that the attack must have begun so quickly that there was not time to start treatment	94.7	86.7	95.9	96.4
21 Your child may have fewer asthma attacks if you can identify and avoid things that trigger them	100	100	100	100
22 When asthma is well controlled by medication it is not triggered so easily	84.2	90.0	87.8	92.9
When your child is going to be exposed to something that triggers his or her asthma...				
23 ..your child should take medication just before exposure	84.2	86.7	81.6	89.3
24 ..you should wait until your child develops symptoms before giving medication	98.2	90.0	91.8	92.9
25 Regular exercise such as swimming can cure asthma	80.7	90.0	85.7	96.4
26 Exercise can help keep your child fit and well and better able to cope with asthma	87.7	90.0	87.8	96.4
27 Your child exercising until he/she becomes breathless can damage the heart and/or lungs	78.9	83.3	81.6	89.3
28 Your child should not exercise if exercise brings on even the occasional attack	94.7	96.7	89.8	100.0
29 Some medications taken 10 minutes before exercising, can stop your child getting asthma when he/she exercises	80.7	86.7	83.7	89.3
30 Some medications can be used during exercise if your child gets asthma	87.7	83.3	85.7	92.9
31 Only a doctor can call an ambulance for your child.	100	100	100	100
Mean Total Score**	26.2	26.7	27.3	27.2
S.D.	1.91	1.90	1.30	1.59

* Chi-square tests on individual questionnaire items nonsignificant.

** ANOVA on mean scores nonsignificant.

Table 5.7 Asthma Autonomy Preference Index Scores at Baseline for the Prospective Cohort

Question	Basic Education (n= 49) Likert Score Mean	S.D.	Extended Education (n=28) Likert Score Mean	S.D.
Decision-making Preference*				
1. The important medical decisions about your child's asthma should be made by your physician, not you.	4.6	0.2	4.2	0.3
2. You should go along with your physician's advice even if you disagree with it.	4.7	0.2	4.3	0.3
3. If your child is hospitalized for asthma, you should not be making decisions about your child's care.	4.7	0.2	4.5	0.3
4. You should feel free to make decisions about everyday problems with your child's asthma.	0.5	0.3	0.6	0.3
5. If your child was sick and if his/her asthma became worse you would want your physician to take greater control.	3.5	0.5	3.6	0.6
6. You should decide how frequently you need a check-up for your child's asthma.	2.4	0.6	2.2	0.7
Total Decision-Making Score (out of 30)	24.6	1.0	23.8	1.2
Information-seeking Preference**				
7. If your child was sick and if his/her asthma worse, you should be told more and more about your asthma.	5.0	0.0	5.0	0.0
8. You should understand what is happening inside your child's body as a result of asthma.	5.0	0.0	5.0	0.0
9. Even if the news is bad, you should be well-informed about your child's asthma.	5.0	0.0	5.0	0.0
10. Your physician should explain the purpose of you laboratory tests ordered for you child.	4.4	0.2	4.2	0.4
11. You should be given information about your child's asthma only when you ask.	4.8	0.2	4.7	0.3
12. It is important to know all the side effects of your child's asthma medication.	5.0	0.0	5.0	0.0
13. Information about asthma is as important as treatment.	3.8	0.4	3.6	0.5
14. When there is more than one method to treat asthma, you should be told about each one.	4.0	0.3	3.8	0.4
Total Information-Seeking Score (out of 40)	37.0	0.7	36.3	0.9

* Decision-making preference items: Rated on a Likert scale with 1 for 'Strongly Agree' to 5 for 'Strongly Disagree'. ** Information-seeking preference items: Rated on a Likert scale with 1 for 'Strongly Disagree' to 5 for 'Strongly Agree'.

Table 5.8 Annualized ED Visit Rate per Patient by Education Arm, Decision-making Preference group, and Asthma Knowledge Questionaire Score group

Asthma Knowledge Score	Decision-making Preference Score	Basic Education			Extended Education		
		n=	Mean	S.D.	n=	Mean	S.D.
<= median	<= median	13	0.8	0.5	7	1.2	0.6
	> median	12	1.0	0.6	6	1.0	0.5
>= median	<= median	12	1.2	0.6	7	0.8	0.4
	> median	12	1.0	0.5	6	1.0	0.5

Results of Kruskal-Wallis ties-corrected tests on ranked ED visit counts nonsignificant.

Table 5.9 Power Calculations from the Original Study Protocol

	Type I Error	Type II Error	ED Repeat Visit rate 1	ED Repeat Visit Rate 2	Rho	Number of Follow-ups	Sample Size per arm
Non-longitudinal analysis*							
	0.05	0.1	0.85	0.65	n.a.	n.a.	59
	0.05	0.1	0.80	0.60	n.a.	n.a.	66
Longitudinal analysis**							
	0.05	0.1	0.85	0.65	0.5	2	40
	0.05	0.1	0.80	0.60	0.5	2	35
	0.05	0.1	0.85	0.65	0.8	2	52
	0.05	0.1	0.80	0.60	0.8	2	46

* formula for power calculations from Kahn and Sempos (14)

** formula for power calculations from Diggle, Heagerty,Liang, Zeger (15)

5.7 References

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CHAPTER 6: PARTICULATE MATTER POLLUTION ELEVATION AND VISITS FOR ASTHMA EXACERBATIONS IN THE PEDIATRIC EMERGENCY DEPARTMENT

6.1 Abstract

Objective To test for a possible relationship between particulate matter (PM) pollution concentrations during the Burns Bog fire of September, 2005 and B.C. Children's Hospital ED visit counts for asthma/hyperreactive airways disease and to quantify any such relationship. *Methods* The study was a time series study of 221 confirmed visits for asthma or hyperreactive airways disease by children and their parents to an urban pediatric ED between August 1, 2005 and October, 31, 2005. Poisson regression modeling was done to assess the effect of $PM_{2.5}$ and PM_{10}, independently, while adjusting for temperature and precipitation. PM concentrations were averages of readings at multiple monitoring stations. Models were tested with and without moving-averaged PM concentration exposures. A sensitivity analysis was performed with models of interest to assess the impact of adjusting downward the spike in ED visits for asthma. *Results* PM_{10} was determined to be significantly associated with pediatric ED visits for asthma during the two-week period encompassing the occurrence of the Burns Bog Fire (IRR 1.16, 95% C.I. 1.07-1.25). $PM_{2.5}$ was similarly associated with ED visits (IRR 1.07, 95% 1.02-1.12). *Conclusions* An association between very high PM levels and pediatric visits for asthma is possible. However, potential confounders, such as exposure to triggers, could also explain the results and the one week lag between peak exposure and peak ED visit count remains unexplained.

6.2 Introduction

A potential link between particulate matter (PM) pollution concentrations and hospital ED visits for asthma exacerbations has been a source of debate. Although a number of studies have reported associations, they tend to be weak associations.

In a study examining pediatric ED visits for asthma in relation to PM and gaseous pollutants, Norris, YoungPong, Koenig, Larson, et al. (1) found significant positive associations for PM_{10}, dry light scattering data, and carbon monoxide with ED visits for asthma. The authors counted ED visits for a period of 15 months to each of six inner city Seattle-area hospital EDs, including one tertiary care pediatric center that accounted for the majority of cases. PM_{10} and dry light scattering data (which measures fine PM < 1 μM) was collected for the same period from three monitoring sites in north, central, and south Seattle. Levels for pollutants measured at multiple sites were averaged for use in the analyses. Using a semi-parametric Poisson regression model, the investigators found that PM_{10} was positively associated with ED visits (R.R. 1.14 for an interquartile range increase, C.I. 1.05-1.23). For dry light scattering, the positive association was a slightly stronger (R.R. 1.15. C.I. 1.08-1.23). In an earlier Seattle-based study, Schwartz, Slater, Larson, Pierson et al. (2) found that daily counts of ED visits for asthma in individuals aged 65 or younger were significantly associated with PM_{10} exposure on the previous day. A mean PM_{10} value across four days was found to be an even better predictor (R.R. 1.12, 95% C.I. 1.04 to 1.20).

A California study examined ED visits in relation to elevated PM concentrations associated with forest fires in 1987.(3) Although the study did not focus solely on children, the investigators found that significantly more patients were treated for asthma than would be expected (observed-to-expected ratio 1.4) during the two-and-a-half week period of the forest fires. Ambient PM_{10} or total suspended particulate concentrations were measured at six monitoring stations in four counties and PM concentrations were found to have dramatically risen in Siskiyou County, an area where visibility had been reduced to 10% of normal for several days. Onset of the fires occurred on a Saturday and a peak in ED visits for respiratory-related conditions was observed eight days later.

A more recent California study examined the health effects of forest fire smoke resulting from wildfire near Hoopa Valley National Indian Reservation in 1999.(4) The study was a community survey of adult residents, with oversampling of individuals previously treated for asthma, chronic obstructive pulmonary disease, other lung diseases, and coronary artery disease, at the reservation medical center. Ambient PM_{10} concentrations were measured on the reservation and for 15 days concentrations exceeded national standards for air quality. The investigators found that medical visits for respiratory problems increased by 52% (417 to 634 visits) from 1998 to 1999 and that weekly PM_{10} concentrations were substantially higher in 1999 than in 1998. A positive correlation between the weekly number of patients presenting to the facility with respiratory illnesses and PM_{10} concentrations was found using Pearson's correlation coefficient ($r = 0.74$ in 1999, and $r = 0.63$ in 1998). Interestingly, for individuals who ran portable HEPA filters in their home, increased duration of use was significantly associated with decreased odds of reporting worsening respiratory symptoms (OR = 0.54). No comment was made by the authors on HEPA filter use in relation to presentation to medical facilities.

Two Spanish studies have also examined the hypothetical link between pollutants and ED visits for asthma. Tenías, Ballester, and Rivera (5) explored the association of gaseous pollutants and black smoke with ED visits for asthma in individuals older than 14 years of age at a single hospital in the city of Valencia. The investigators collected data for a three-year period but focused their analysis on one year. They found a positive and significant association between ambient NO_2 and O_2 concentrations and ED visits but the associations for SO_2 and black smoke with ED visits were not statistically significant. However, on analysis of the entire three-year series, a significant positive association emerged for PM in cold months (R.R. 1.049 for an increase of 10 $\mu g/m^3$, 95% CI 1.008 to1.093). As with almost all air pollution studies, the relative risk, although significant, was small.

In an earlier Spanish study, in the city of Barcelona, Castellsague, Sunyer, Saez, and Anto (6) also examined ED visits for asthma in individuals older than 14 years of age from a register of hospital emergency visits covering the four largest hospitals and 80%

of asthma ED visits for Barcelona. The city's air quality monitoring network provided daily 24-hour averaged SO_2 and black smoke levels and one hour maximum values of NO_2 and O_3. The investigators found small but significant positive associations for particulates and NO_2 with ED visits due to asthma after adjustment for temperature, humidity, and time trends. No significant associations were found for SO_2 or O_3. In contrast to the Tenías, Ballester, and Rivera study black smoke showed the strongest association in summer. Asthma visits increased by 11 percent for a 25 $\mu g/m^3$ increase in the level of black smoke in this season.

Both Spanish studies are limited by their use of black smoke as a proxy for inhalable particulate concentrations; more sophisticated measures, like PM_{10}, were not available at the time of the studies. The British smoke filter technique measures light reflected by all sampled particles (non-size-selective sampling) and uses standard curves to estimate airborne concentrations from the result. Since the combustion of different compounds, e.g. wood, gasoline, produces a variety of particle sizes, the degree of correlation between black smoke and size-specific PM concentrations is variable.

In this Chapter, the potential association between $PM_{2.5}$ and PM_{10} levels with ED visits to a pediatric ED is explored. Distinguishing this analysis from earlier investigations is the occurrence of a fire in a major population centre in British Columbia during the period under study. This produced elevated PM concentrations and casual observation suggested a possible increase in ED visits for asthma in children.

6.2.1 The Burns Bog

The Burns Bog is a 3,000 hectare raised bog ecosystem that exists as a two-layered peat deposit, an upper acrotelm layer and a lower catotelm layer, with widespread, surface peat-forming *Sphagnum* moss communities. The peat deposit is produced by the partial decomposition of *Sphagnum* along with other plant debris. Peat accumulates because the rate of biomass production is greater than the rate of decomposition in continuously wet, oxygen-deprived conditions. The lower catotelm layer is permanently saturated with water as part of an underlying water table, and is called a water mound. The upper acrotelm layer displays seasonal variation in water saturation such that in the winter months the upper limit of the water table is at the bog surface and in non-drought summer months the upper limit of the water table is at the lower margin of the acrotelm.

The Bog has been used for industrial purposes, such as peat and gravel extraction, over the past century and more recently for agricultural purposes such as cranberry farming. In the year 2000, the provincial government commissioned a review aimed at determining the factors crucial to preserving the Burns Bog. (7). The review found that the movement and distribution of water in the bog, i.e. its hydrology, is determined by the water mound, fluctuating water levels in the upper porous acrotelm layer of the bog that is about 50 cm deep, and a system of manmade ditches. The extensive network of ditches was built to create drier conditions for peat farming, agricultural, and recreational use. However, the system of ditches has lowered the water table in the acrotelm layer such that it is 30 cm lower than it was in the 1930s. The lowered water table accelerates the rate of decomposition of peat in the acrotelm, and has resulted in drying of the acrotelm and even parts of the catotelm. This drying process increases the risk of fire. Although fire has historically been a natural part of the Burns Bog ecosystem, it has had little long-term effect on its viability. In the present context of a drier Bog, fire, along with drought, constitute the two-system wide disturbances that have the potential to threaten the existence of the Bog. The authors of the review concluded that the acrotelm zone is vital to the continued existence of the water mound and *Sphagnum* mosses and that the ditches that drain the core of the Bog had to be blocked for the Bog to survive. (7)

6.2.2 The Burns Bog Fire, September, 2005

In September, 2005, a fire arose in the Burns Bog, potentially a result of human activity. Although the fire posed no threat to communities, i.e. a non-interface fire, the air quality in the greater Vancouver area was affected due to smoke, fine particulates and fumes.(8)

A 'bog fire timeline', reconstructed from British Columbia newspaper reports, suggests that:

- the fire began in the afternoon of Sunday, September 11th, 2005 (9)
- the fire affected air quality in the Greater Vancouver Regional District (GVRD) for four days, and authorities issued an air quality advisory, although the air quality appeared to vary depending on location in the GVRD (10)
- air quality improved by Thursday, September 15th or Friday, September 16th as the GVRD lifted its air quality advisory (11) (12)
- the fire was contained by Saturday, September 17th by the 100 firefighters and support personnel working at the site, although pockets of smoke were still visible by helicopter (13)
- air quality was declared to be good on Saturday, September 17th (14)
- firefighting moved from suppression to "mop-up" by September 21st as a thermal scanning device indicated that there were only 10 hot spots in the 200-hectare burn site, none of which were smoking (15)

A monthly water balance analysis performed in the Bog has demonstrated that there is typically a water deficit in the Bog from April to September (7), thus it seems likely that the Bog was at its most susceptible when the fire occurred. It is not known how the PM pollution emanating from the Burns Bog fire compared to other PM pollution, e.g. diesel exhaust, in terms of chemical composition. The fact that for the first few days, smoke was visible over the GVRD suggests that some of the pollution was of small diameter, but does not exclude the possibility of larger PM.

6.3 Methods

Visits to the ED of B.C. Children's Hospital for asthma or hyperreactive airways disease (RAD) during the period August 1, 2005 to October 31, 2005 were determined via a combination of computer searching and chart review. As a final diagnosis for ED visits is not recorded in the computer system, a list of potential ED visits for asthma exacerbations was constructed using common and less common Emergency Department presenting symptoms, e.g., "wheezing", "shortness of breath", "respiratory distress", stated "asthma". Patient charts were reviewed using this list to differentiate cases that were ultimately diagnosed as asthma exacerbation or RAD from conditions which may present with similar symptoms at triage, e.g., bronchiolitis, croup, pneumonia. A similar review was performed for the same August to October period for each of the six preceding years to provide a historical 'baseline' ED visit count data for comparison.

PM pollution data were obtained from 11 monitoring stations for $PM_{2.5}$ and 13 monitoring stations for PM_{10} that are part of the Greater Vancouver District's (GVRD) air quality monitoring network. Daily temperature and precipitation data were obtained from Environment Canada.

Statistical analysis was done using the Stata statistical software package. Descriptive graphs of ED visit counts and PM levels were plotted using the Splus statistical package and the Excel spreadsheet software. Comparisons between 1999-2004 and 2005 were done by averaging values across the first six years. Before averaging, years were aligned by matching the first weekend in August across all panels to control for the 'day of week' effect on ED visits. PM levels, expressed as $\mu g/m^3$, were averaged across all stations, except Abbotsford, Chilliwack and Hope, to create $PM_{2.5}$ level and PM_{10} level variables for analysis. For five days, readings at the Airport monitoring station were unavailable. Averages were calculated excluding this station for these five days. Contingency tables were constructed to describe the mean and variance of ED visit counts stratified by one week and two week periods. Continuous predictor variables were assessed for correlation via a correlation matrix.

Poisson and zero-inflated Poisson regressions were performed with the ED visit count data using unadjusted PM measures and 3-day and 7-day moving-averaged PM data. These moving averages were calculated on the particulate matter pollution data by averaging the PM concentration on a given day with the concentrations for the previous two and six days, respectively. Single pollutant models were fit with each of $PM_{2.5}$ and PM_{10} separately. PM data was parameterized into two-week periods i.e. piecewise linear models were constructed. Model fit was assessed using Poisson post-estimation methods, i.e. goodness-of-fit tests such as the Pearson statistic and the deviance statistic. The Vuong statistic was used to assess the appropriateness of a zero-inflated Poisson regression in comparison to a straightforward Poisson regression. Minimum daily temperature and precipitation indicator variables were entered as possible covariates in both of these models. Incidence-rate ratios and 95% confidence intervals were calculated from regression coefficients. Sensitivity analyses were performed with the final models varying the number of ED visits on the day of peak ED visits for asthma, downward.

6.4 Results

Figure 6.1 shows the daily distribution of confirmed diagnoses of asthma or RAD in the ED at B.C. Children's Hospital for 2005. A total of 345 ED visits in 2005 were reviewed resulting in 221 ED visits for asthma or RAD. Notably there is a spike in asthma/RAD visits on September 20^{th} with 13 confirmed cases. A few other days have visit counts near seasonal maximums. Figure 6.2 contrasts the 2005 ED visit experience with the average of the 1999 to 2004 counts. It is apparent that the usual trend is a low visit rate in August, with one or two cases per day being the norm, but then increasing numbers in September. The normal maximum number of cases seen in the three month span is eight or nine visits. Although the 2005 series exhibits greater variability than the 1999-2004 average, as would be expected, the ED visit counts are generally similar to previous years. The exception is the peak on September 20^{th} which has no comparable peak in the prior six years. Figure 6.3 shows the distribution of visit counts overall. This skewed distribution could be described by a Poisson distribution.

Figure 6.4 and 6.5 depict PM pollution data for the August 1st to October 31st, 2005, period. Graphed are the daily $PM_{2.5}$ and PM_{10} levels at the numerous monitoring stations around the Greater Vancouver Regional District. A spike in PM concentrations associated with the fire is easily distinguishable although it is difficult to identify individual monitoring stations. The peak PM levels appear to occur on September 13th, seven days before the peak ED visit count in Figure 6.2. The important points to derive from the graphs are: 1) PM levels were fairly consistent across monitoring stations during the time period in question, 2) there was a spike in both $PM_{2.5}$ and PM_{10} levels associated with the Burns Bog fire, 3) the Abbotsford, Chilliwack, and Hope monitoring stations, distinguishable as thicker lines on the graphs, did not record PM levels as high as that of other monitoring stations during Burns Bog Fire, as might be expected given the greater distance of these locations from Delta. It is also interesting that the Kitsilano monitoring station (diamond-shaped data point markers) recorded higher $PM_{2.5}$ levels earlier in September. The reasons for these atypical readings are unclear although the GVRD is known to have variable wind patterns.

Table 6.1 shows the mean and percentiles for ED visit counts, PM pollution, temperature, and precipitation for the three month period in 2005. It is interesting that ED visit count and PM data all had median values below the mean, while the temperature data did not. Table 6.2 shows the mean number of ED visits by one-week and two-week period. It is mostly the case that as the mean number of ED visits increased as the variance also increased (except week 11). Thus, Poisson regression was deemed to be a viable approach for analysis.

Table 6.3 shows the bivariate correlation matrix for exposure variables. It is not surprising that the temperature variables were correlated or that PM variables were correlated. Separate models for $PM_{2.5}$ and PM_{10} were deemed to be desirable. Following the approach of other investigators, minimum temperature was entered as the temperature variable into models because, in autumn, it is a cold, dry weather day which normally triggers asthma exacerbations in some children.

Using Poisson regression, models were fitted beginning with either daily $PM_{2.5}$ or daily PM_{10} variables and entering minimum temperature and precipitation as covariates.

However, assessments of goodness of fit by deviance statistic and Pearson statistic were significant suggesting that it was necessary to reject the hypothesis that the data were Poisson distributed. To find an acceptably fitted model, the analyses for both $PM_{2.5}$ and PM_{10} were repeated with PM data parameterized by week, i.e. 13 variables with each representing a week of daily PM data. The weekly model produced the best fit according to goodness of fit statistics but models with $PM_{2.5}$ and PM_{10} parameterized by two-week period, i.e. 6 variables with each representing a two-week period of daily PM data, were selected as they produced acceptable fit (see bottom of Table 6.4 for goodness of fit statistics) and smaller confidence intervals. Nonsignificant goodness of fit statistics implied that it was acceptable to assume a Poisson distribution.

Although the overall models had acceptable goodness of fit, models that did not use moving-averages for PM exposure did not produce significant results. Three-day moving average and 7-day moving average PM models were therefore fitted to assess significance of the six PM variables. Table 6.4 and Table 6.5 present the results of modeling using Poisson regression and zero-inflated Poisson regression. The Vuong statistic (bottom of Table 6.5) was significant for both $PM_{2.5}$ and PM_{10} models suggesting that zero-inflated models were more appropriate than straightforward Poisson regression because of the 16 days with no ED visits. The incidence-rate ratio (IRR) for the 'PM weeks 7 & 8' variable (a time span which more than covered the days of the Burns Bog Fire) was significant for the PM_{10} analysis (I.R.R. 1.18, 95% C.I. 1.09-1.28) as it was for the $PM_{2.5}$ analysis (I.R.R. 1.07, 95% C.I. 1.02-1.12). These results suggest that during weeks 7 & 8, a unit increase in $\mu g/m^3$ resulted in an 18% and 7% increased probability for PM_{10} and $PM_{2.5}$, respectively, of a visit to the ED for asthma or hyperreactive airways disease in comparison to week 13. Apparent significant 'protective' effects of $PM_{2.5}$ pollution in the early weeks in the straightforward Poisson regression model (Table 6.4) disappeared on application of zero-inflated Poisson regression (Table 6.5).

Finally Table 6.6 presents the results of sensitivity analyses done for both PM_{10} and $PM_{2.5}$. Of interest was whether downward adjustment of the peak asthma ED visit count, i.e., lowering the number of visits on September 20th, 2005, would result in a loss of significance for the 'PM week 7 & 8' variable in either analysis. IRR estimates were lowered more for PM_{10} than for $PM_{2.5}$. The IRR estimates approached loss of statistical significance for PM_{10} only when the ED visit count was lowered to one visit. IRR estimates in the $PM_{2.5}$ analysis already had confidence intervals close to one, and these did not go lower with the manipulation of September 20th ED visit counts.

6.5 Discussion

The results were based on a single institution-study of ED visits by children for asthma and RAD. The potential for parents to take their children to other hospitals exists, and it becomes more likely for families that live greater distances from B.C. Children's Hospital in central Vancouver. Several techniques were used to attempt to mitigate this factor. For example, PM concentration readings from Hope, Chilliwack, and Abbotsford were excluded from the Poisson regressions because the proportion of parents bringing their children to B.C. Children's Hospital from this area is relatively small (they are more likely to go to Matsqui-Sumas-Abbotsford Hospital in Abbotsford). However, B.C. Children's Hospital is the only acute care pediatric institution in the Greater Vancouver Regional District and it is likely that parents living within a reasonable proximity to the hospital (Burnaby, Richmond, Surrey, city of Vancouver) will bypass local, adult or general care institutions in favour of a specialized, pediatric hospital. Indeed, Norris, YoungPong, Koenig et al. (1) noted in their six institution study of visits to EDs in inner city Seattle, the majority of cases came from a single children's hospital specializing in diagnoses for childhood diseases. Moreover, the average number of visits for exacerbations in this study was comparable to that found by Norris, YoungPong, Koenig et al. and as were the maximum number of number of visits for exacerbations in a day (excluding the 2005 peak visit count).

As Castellsague, Sunyer, Saez, and Anto (6) have noted, ED visit counts for asthma that are restricted to one season may facilitate interpretation of the effect of air pollutant because the sources, composition, and levels of air pollutants vary among seasons. In addition, visits to the ED are characterized by seasonal periodicity. (16) As such, the covariate adjustment in this analysis may have benefited from restriction to one season. However, it is also the case that the season during which this study took place was late summer/early autumn and viral infections are known to increase during this season. Comparison with previous years mitigates some of this concern, however, one cannot exclude the possibility of viral infections with increased infectivity in 2005 in comparison to earlier years. Some have suggested that the increase in pediatric ED visits is associated with school opening which exposes children to a greater number of other children.(17) The seasonality in ED visits for asthma in individuals under 30 years of age compared to those older than 30 years of age may support this argument.(18) To facilitate the interpretation of results in light of this possibility, the collection of historical ED visit count data for the corresponding periods in the previous six years was done to provide a 'baseline' comparison.

The stronger association of PM_{10} with ED visit counts, compared to $PM_{2.5}$, is a little surprising given that some researchers have suggested that smaller diameter, and perhaps even ultrafine particles (< 1 μM diameter), are more likely to be factors in the development of asthma. However, triggers for an exacerbation are not necessarily the same as factors that promote disease expression. It is also true that other researchers have suggested that PM electrostatic charge may be a more important physicochemical determinant of the effect of PM on respiratory health than other characteristics like diameter.(19) It is unknown how charge varied with PM size in pollution generated by the Burns Bog Fire.

The sensitivity analysis resulted in larger movements in IRR estimates for the 'PM week 7 & 8' variable in the PM_{10} analysis than in $PM_{2.5}$ analysis. The reasons for this differential effect are not entirely clear although the fact that PM_{10} concentrations were almost 50% higher than $PM_{2.5}$ concentrations suggests that the IRR estimates for PM_{10} may have been more sensitive to ED visit counts. The fact that IRR estimates for the 'week 7 & 8' variable for both PM measures did not lose significance on manipulation of September 20th ED visit count suggests that one cannot entirely discount the possibility that the spike in ED visits on September 20th is not the primary factor behind significant results. It is possible that ED visits in general were higher during the two-week period and triggered by factors not included or controlled for in the study.

The fact that IRRs did not exceed one for other two-week periods in the study may suggest that normal PM concentrations for the GVRD are not high enough to show a correlation with ED visits for asthma. Other factors, such as cold weather, minimum temperature, humidity/precipitation, and wind patterns may play a more dominant role on days when PM concentrations are near norms for the GVRD (although these factors did reach significance in the model in this study some of them have been found to be significant in other studies).

It must not be forgotten that it was necessary to introduce a moving average measure of PM in order to achieve significant results. The implication is that the model assumes that some time, i.e. days, must pass for the impact on ED visits to occur. Other investigators have found a lag between PM concentration elevation during fires and ED visits (3) but the reasons for the lag are unclear and it is therefore possible that the association between spike in PM concentrations and ED visits is spurious.

There are many other potential confounders in an asthma study. As with most single institution ED visit-air pollution studies, the small number of daily counts prevents the analysis of subsets of data such as by patient age. Thus no assertions can be made about the effect of PM concentrations on children of different ages or by important characteristics, e.g., whether their exacerbations were associated with a viral illness or whether the child was atopic.

The short length of the time series precluded the use of some statistical techniques that are often used the literature. Although there is still considerable controversy over which methods are most appropriate for particular situations, it could arguably have been informative to model with two or three different techniques and compare results. Positive findings using multiple methods would be more convincing than positive findings using one statistical technique alone. A longer time period would also allow for better adjustment for potential confounders.

Despite these caveats, the IRR estimates for the two-week period spanning the fire are high enough to merit consideration. The IRR estimate for the PM_{10} analysis, in particular, is higher than the ratios typically found in air pollution/ED visit studies. It would seem wise for the GVRD to maintain its policy of issuing air quality warnings during such events when PM concentrations are high.

6.6 Summary

The association of PM_{10} and $PM_{2.5}$ with ED visits for asthma was significant in the seventh and eight weeks of the study period. This may suggest an effect of PM on asthma exacerbation but a lag of one week between peak exposure and peak ED visits remains unexplained. The Burns Bog fire represents an unusual event but one that is relevant to the province of British Columbia where a significant proportion of the province is fire-prone in early autumn.

Table 6.1 Distributional Characteristics of ED visit counts and Potential Predictors for August 1, 2005 to October 31st, 2005

Variable	n=	Mean	S.D.	Minimum	Percentile 25	Percentile 50	Percentile 75	Maximum
ED visit count	92	2.4	2.2	0	1	2	4	13
$PM_{2.5}$ (micrograms/m^3)	92	6.52	4.06	1.53	4.10	5.55	7.45	31.07
PM_{10} (micrograms/m^3)	92	14.88	5.72	6.30	11.60	13.57	16.74	40.86
Mean Temperature (°C)	92	15.0	3.6	7.30	11.95	15.15	18.12	21.20
Min Temperature (°C)	92	11.1	3.2	2.90	8.63	11.15	14.08	17.00
Maximum Temperature (°C)	92	18.9	4.3	9.70	15.30	19.20	22.20	27.20
Precipitation (mm/day)	92	2.58	6.07	0.00	0.00	0.00	0.85	39.20

Table 6.2 Mean ED visits by One-week Period and Two-week Period

Time Period	ED Visits n=	ED Visits Mean	ED Visits S.D.
Total Period	92	2.4	2.2
Week 1 (Aug 1 - Aug 7)	7	1.0	1.0
Week 2 (Aug 8 - Aug 14)	7	0.6	0.5
Week 3 (Aug 15 - Aug 21)	7	0.7	0.8
Week 4 (Aug 22 - Aug 28)	7	1.4	1.3
Week 5 (Aug 29 - Sep 4)	7	0.9	1.2
Week 6 (Sep 5 - Sep 11)	7	1.1	1.4
Week 7 (Sep 12 - Sep 18)	7	4.4	1.7
Week 8 (Sep 19 - Sep 25)	7	5.7	3.5
Week 9 (Sep 26 - Oct 2)	7	2.9	2.2
Week 10 (Oct 3 - Oct 9)	7	3.6	1.9
Week 11 (Oct 10 - Oct 16)	7	4.0	1.0
Week 12 (Oct 17 - Oct 23)	7	1.9	0.7
Week 13 (Oct 24 - Oct 30)	7	2.7	1.7
Week 1 & 2 (Aug 1 - Aug 14)	14	0.8	0.8
Week 3 & 4 (Aug 15 - Aug 28)	14	1.1	1.1
Week 5 & 6 (Aug 29 - Sep 11)	14	1.0	1.2
Week 7 & 8 (Sep 12 - Sep 25)	14	5.1	2.8
Week 9 & 10 (Sep 26 - Oct 9)	14	3.2	2.0
Week 11 & 12 (Oct 10 - Oct 23)	14	2.9	1.4

Table 6.3 Bivariate Correlation Matrix for Exposure Variables for August 1, 2005 to October 31st, 2005

	Max. Temp	**Min. Temp.**	**Mean Temp.**	**Precipitation**	**$PM_{2.5}$**	**PM_{10}**
Max. Temp	1.00	0.81	0.97	-0.37	0.40	0.50
Min. Temp.	0.81	1.00	0.94	-0.12	0.27	0.31
Mean Temp.	0.97	0.94	1.00	-0.28	0.36	0.44
Precipitation	-0.37	-0.12	-0.28	1.00	-0.29	-0.38
$PM_{2.5}$	0.40	0.27	0.36	-0.29	1.00	0.92
PM_{10}	0.50	0.31	0.44	-0.38	0.92	1.00

Table 6.4 Results of Poisson Regression on ED Visit Count for August 1, 2005 to October 31st, 2005

	I.R.R.	**S.E.**	**Lower 95% C.I.**	**Upper 95% C.I.**
PM_{10} Model (7-day Moving Avg.)*				
Variable				
PM_{10} Weeks 1&2	0.20	0.13	0.05	0.70
PM_{10} Weeks 3&4	0.54	0.19	0.27	1.07
PM_{10} Weeks 5&6	0.49	0.16	0.26	0.92
PM_{10} Weeks 7&8	1.18	0.05	1.09	1.28
PM_{10} Weeks 9&10	1.07	0.07	0.94	1.22
PM_{10} Weeks 11&12	1.06	0.07	0.92	1.21
Minimum Temperature	1.00	0.03	0.94	1.07
Total Precipitation	1.01	0.01	0.99	1.04
$PM_{2.5}$ Model (7-day Moving Avg.)**				
Variable				
$PM_{2.5}$ Weeks 1&2	0.86	0.06	0.75	0.98
$PM_{2.5}$ Weeks 3&4	0.93	0.04	0.86	1.01
$PM_{2.5}$ Weeks 5&6	0.86	0.06	0.75	0.98
$PM_{2.5}$ Weeks 7&8	1.08	0.03	1.03	1.13
$PM_{2.5}$ Weeks 9&10	1.02	0.06	0.92	1.14
$PM_{2.5}$ Weeks 11&12	1.02	0.06	0.91	1.14
Minimum Temperature	0.95	0.03	0.89	1.01
Total Precipitation	1.02	0.01	1.00	1.01

* Goodness of fit chi-square: deviance (p = .07), Pearson (p =.19)
** Goodness of fit chi-square: deviance (p = .05), Pearson (p =.07)

Table 6.5 Results of Zero-inflated Poisson Regression on ED Visit Count for August 1, 2005 to October 31st, 2005

	I.R.R.	S.E.	Lower 95% C.I.	Upper 95% C.I.
PM_{10} Model (7-day Moving Avg.)*				
Variable				
PM_{10} Weeks 1&2	0.33	0.20	0.10	1.07
PM_{10} Weeks 3&4	0.64	0.21	0.33	1.23
PM_{10} Weeks 5&6	0.79	0.24	0.43	1.44
PM_{10} Weeks 7&8	1.16	0.05	1.07	1.25
PM_{10} Weeks 9&10	1.04	0.07	0.92	1.18
PM_{10} Weeks 11&12	1.02	0.07	0.89	1.17
Minimum Temperature	1.02	0.03	0.96	1.09
Total Precipitation	1.01	0.01	0.99	1.03
$PM_{2.5}$ Model (7-day Moving Avg.)**				
Variable				
$PM_{2.5}$ Weeks 1&2	0.92	0.06	0.81	1.05
$PM_{2.5}$ Weeks 3&4	0.97	0.04	0.90	1.04
$PM_{2.5}$ Weeks 5&6	0.97	0.07	0.84	1.11
$PM_{2.5}$ Weeks 7&8	1.07	0.03	1.02	1.12
$PM_{2.5}$ Weeks 9&10	1.00	0.05	0.90	1.12
$PM_{2.5}$ Weeks 11&12	1.00	0.06	0.89	1.11
Minimum Temperature	0.95	0.03	0.89	1.01
Total Precipitation	1.02	0.01	1.00	1.04

* Vuong test of zero-inflated Poisson vs. Poisson z = 4.83 p = 0.0000
** Vuong test of zero-inflated Poisson vs. Poisson z = 4.91 p = 0.0000

Table 6.6 Sensitivity Analyses on ED Visit Count for September 20th, 2005

		I.R.R.	S.E.	Lower 95% C.I.	Upper 95% C.I.
PM_{10} Model (7-day Moving Avg.)					
Peak ED Visit Count	Variable				
13	PM_{10} Weeks 7&8	1.16	0.05	1.07	1.25
9	PM_{10} Weeks 7&8	1.14	0.05	1.05	1.23
5	PM_{10} Weeks 7&8	1.12	0.05	1.03	1.21
1	PM_{10} Weeks 7&8	1.10	0.05	1.01	1.19
$PM_{2.5}$ Model (7-day Moving Avg.)					
Peak ED Visit Count	Variable				
13	$PM_{2.5}$ Weeks 7&8	1.07	0.03	1.02	1.12
9	$PM_{2.5}$ Weeks 7&8	1.07	0.02	1.02	1.12
5	$PM_{2.5}$ Weeks 7&8	1.07	0.02	1.02	1.11
1	$PM_{2.5}$ Weeks 7&8	1.06	0.02	1.02	1.11

Figure 6.1

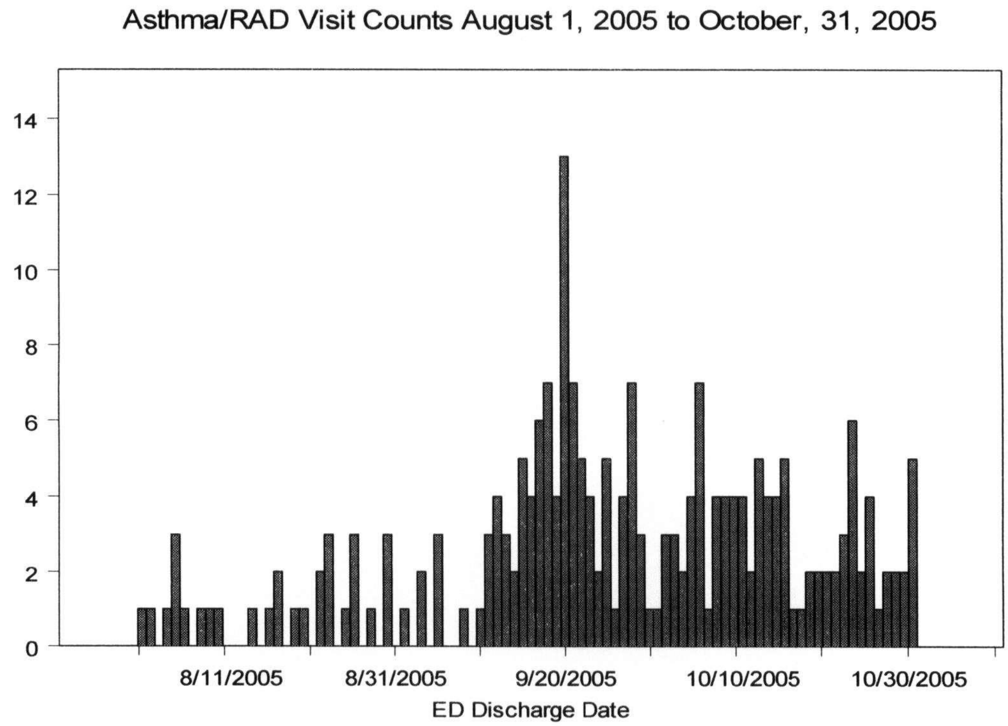


Figure 6.2 ED Visit Counts for Asthma/RAD, Aug to Oct (1999-2004 vs. 2005)

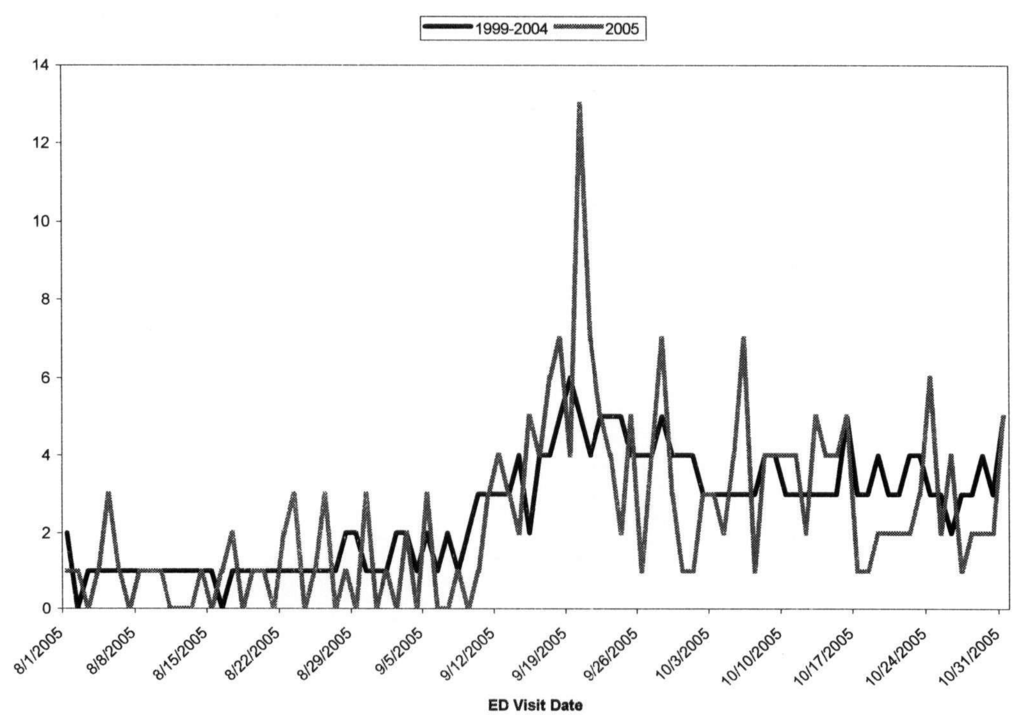


Figure 6.3 Distribution of Daily ED Visits (August 1, 2005 to October 31, 2005)

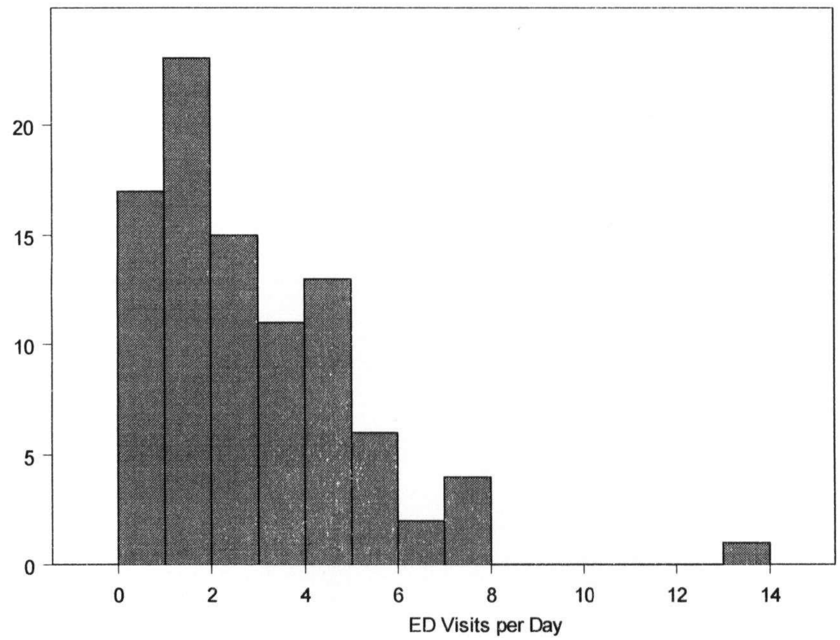


Figure 6.4 Individual Station $PM_{2.5}$ Concentrations (August 1, 2005 to October 31, 2005)

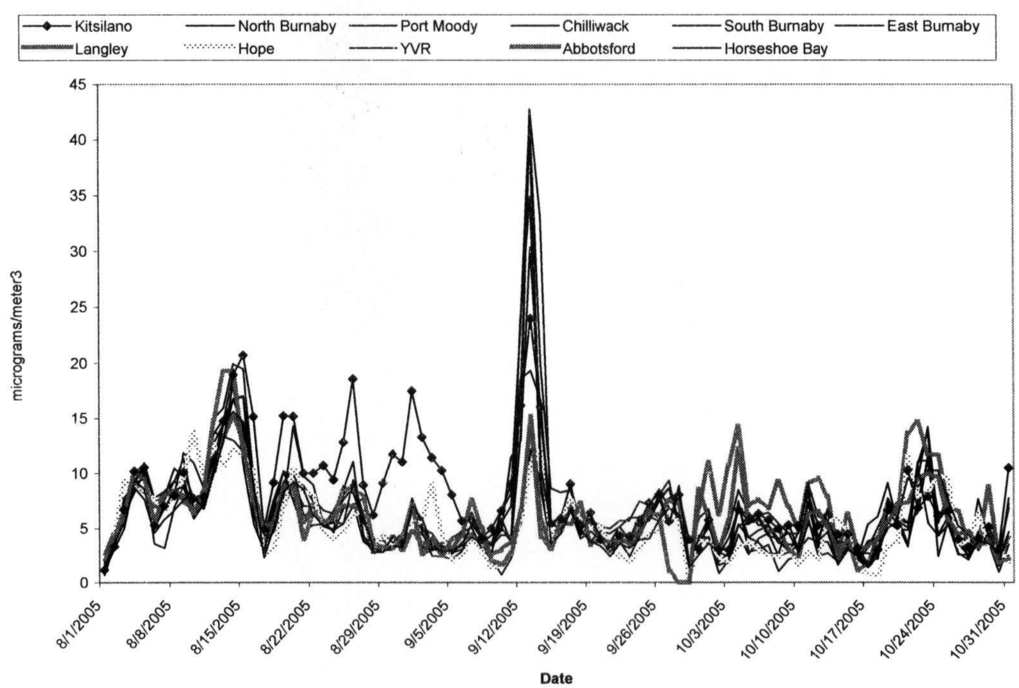
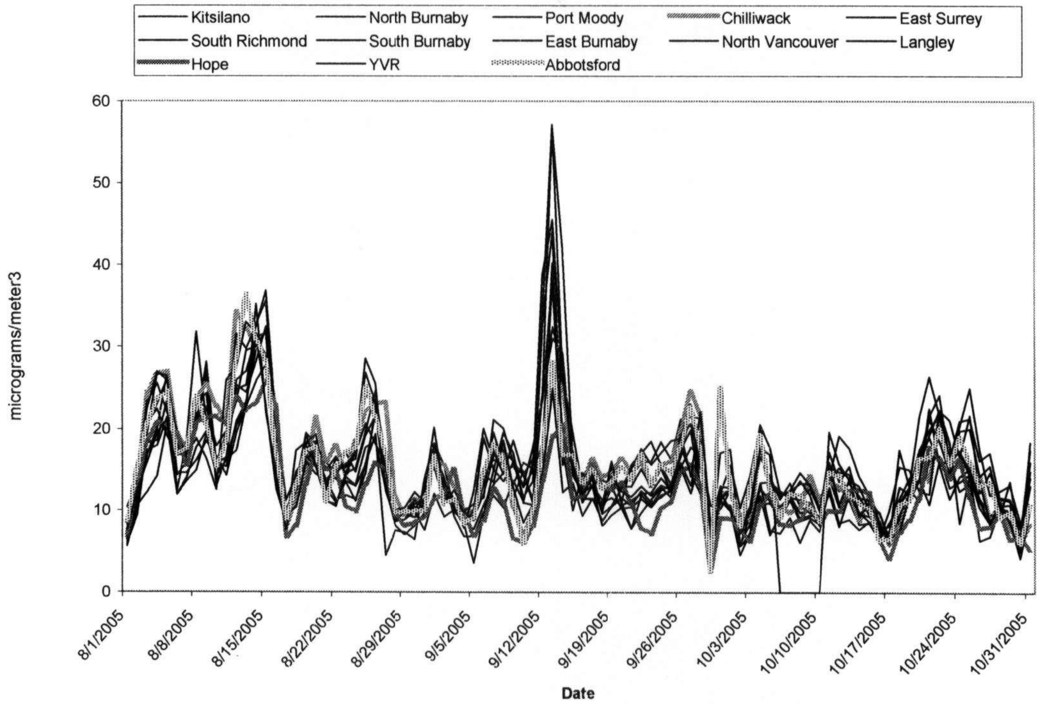


Figure 6.5 Individual Station PM_{10} Concentrations (August 1, 2005 to October 31, 2005)



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CHAPTER 7: CONCLUDING REMARKS

7.1 Findings and Implications

The results of the research undertaken for this dissertation have produced a mixture of positive and negative findings. The retrospective study examining the impact of Asthma Education Clinic attendance on repeat ED visits described in Chapter 4 did not find an overall positive influence of Asthma Education Clinic attendance on time to a repeat ED visit. Rather, clinic attendees were more likely to visit the ED again. Given that the study was a non-randomized, observational study, it may be that ED personnel were astute in selecting patients/parents who were more likely to experience further problems and referred them for further asthma education. The observed difference in time to repeat ED visit might therefore be attributable mostly to differences in unmeasured variables that contributed to a referral decision.

However, further analysis gave rise to the possibility, albeit speculative, that parents of younger and older children may be characterized by different repeat ED visit patterns in the context of an asthma education intervention. In particular, a previous landmark study (1), notable because it followed a cohort of children from birth and included baseline laboratory tests such IgE concentration measurement and pulmonary function tests, suggested that older children are less prone to misdiagnosis due to a lower prevalence of wheezing that can be attributed to congenitally small airway passages relative to body mass. Thus, an asthma education program for older children might be more effective (assuming an asthma education program which sees a high proportion of parents of the young children who do not actually have asthma but are diagnosed with asthma is an inefficient use of resources). The fact that no difference in time to repeat ED visit was observed in older patients whereas a difference was observed in younger patients lends some support to this idea.

The study results are at least consistent with prospective studies that suggest age is an important variable in asthma diagnosis. Surprisingly, to date, very few studies have attempted to critically examine the role of age. Some studies have opted to include only older children, e.g., greater than five years of age. However, there are still sizeable proportions of three and four year old wheezers who do develop asthma. Simple exclusion may not be sufficient for producing results that are generalizable to the population of patients seen in the ED.

The prospective study described in Chapter 5 suggests that sizeable proportions of the population of parents visiting pediatric EDs could benefit from advice on how to change their home environment to minimize the risk of triggering asthma attacks. In particular, variables pertaining to the child's bedroom environment were identified as areas for intervention in both arms of the study. A humidifier in the child's bedroom, for example, does not represent a large investment for most families although it may be for lower-income families. Encouraging children to play with toys other than stuffed toys is a low or no-cost intervention. The cost of a mite-proof mattress cover is minimal. More expensive preventive measures, such as reducing the amount of carpeting and upholstered furniture in the home were also identified but present a bigger challenge for implementation given cost of replacing the offending material and replacing it with alternatives.

The small sample size prevented any definitive statement about the effectiveness of Asthma Education Clinic attendance and item response clustering on both the Asthma Knowledge Questionnaire and the Asthma Autonomy Preference Index, (reported in Chapter 5) precluded a meaningful statement about the impact of asthma knowledge and parental information-seeking and decision-making preferences on ED visit rates. The clustering of item responses, observable as a ceiling effect for most questionnaire items, suggests that the questionnaires, although previously tested for validity and reliability in clinic settings (2)(3), may not translate well to the pediatric ED environment. Having said this, specific Asthma Knowledge Questionnaire items that related to physiological changes as a result of asthma and the prophylactic use of corticosteroids did appear to show improvement after asthma clinic attendance.

Reflection on the results of the two asthma education studies (Chapters 4 and 5) suggests that there may be separate processes involved in the acquisition of asthma management skills. Although some aspects of parental asthma knowledge may increase as a result of asthma clinic attendance, the fact that subsequent resulting behavioural change is harder to demonstrate suggests that the acquisition of knowledge and changes in behaviour may be precipitated by different enabling and reinforcing factors. This dichotomy is consistent with Bandura's social learning theory.

It may be that the location of the asthma education clinic on site at B.C. Children's Hospital is counterproductive as it might make parents more comfortable with the idea of B.C. Children's hospital as primary care provider. Perhaps a better enabler would involve funding family practitioners to provide asthma education. The advantage of this approach is that the doctor-patient relationship is reinforced, education can be personalized by the care provider who should have the best understanding of the family context of all potential care providers, and the opportunity for continuity of care exists.

Given that primary care practitioners are not available in the evenings or early morning when parents often have the greatest need for assistance, asthma education through family physicians cannot be the only solution. Managing ED load therefore because an issue of resource management. Perhaps a redistribution of resources should be considered such that a drop-in evening asthma clinic could be implemented during peak asthma seasons. The costs to the institution associated with asthma exacerbations would not be eliminated, but they could be lowered given that the primary driver of costs in the ED is labour and that clinics are typically less expensive to operate than the ED.

Seasonal particulate matter pollution concentrations have been explored in relation to hospital admissions or ED visits but only a few studies have been able to address the question of ED visits in the context of sizeable spikes in PM pollution concentrations. Previous studies (4)(5) have considered the potential effect on the general population rather than on pediatric populations. Thus, Chapter 7 presents a unique contribution because it focuses on pediatric ED visits in the context of a spike in PM concentrations due to a large biomass fire in an urban environment.

The positive findings concur with those of earlier adult studies in that a modest, but observable increase in I.R.R. was observed during the spike in PM concentrations. These findings suggest that the conflicting results from pollution studies that do not examine hospital admissions or ED visits in the context of large spikes in PM concentrations may suffer from insufficient variation in PM concentrations. In multi-pollutant models with only seasonal variation in PM concentrations, significant associations could easily be masked by the effect of other variables.

Overall, the set of studies in this dissertation have demonstrated the usefulness of focusing on ED visits as a measure of health care utilization and, to some degree, as a proxy for respiratory morbidity. Emergency-based personnel are understandably wary of research studies because the demands of providing care make active participation in research difficult and in the pediatric context it presents additional challenges for care provider-parent interaction. However, the success achieved in approaching and enrolling parent/patients into the prospective study in Chapter 5 provides strong evidence that ED-based asthma studies are possible.

Most asthma patients and their parents are asked to stay in the ED for extended periods of time. Thus, there is ample time for an investigator to approach parents and children about participation in a study. Providing emergency care has already been provided and the child has shown signs of stabilizing, almost all parents are receptive to participation in a study because 1) visits to the ED take up a significant amount of their time, and 2) visits to the ED can be alarming events that parents would understandably rather not experience. In fact, the experience of this investigator suggests that many parents weary of spending hours in the ED and find it refreshing to have a new “visitor”. The sample size issues encountered in Chapter 5 are not a reflection of the enrolment success rate but rather an overestimate of the number of verifiable asthma cases that could be anticipated in a given time frame.

The research techniques may also be applicable to populations of children with other chronic conditions who present in the ED. However, asthma stands out to some degree because of the relatively large numbers of cases that pass through the ED. For less common acute events, prospective studies may need to be multi-centre trials to enroll sufficient numbers in a reasonable amount of time.

7.2 Limitations

Several issues that span across all three studies stand out as caveats for the interpretation of results. Perhaps of primary significance for a pediatric asthma study is the difficulty in differentiating between bronchiolitis and asthma in young children. Pulmonary inflammatory viruses are a cause of bronchiolitis but are considered to be a trigger for asthma (ignoring the debate over lower respiratory tract infections early in life and later diagnosis of asthma). Indeed, as Wolf (6) has noted, clinically both conditions appear the same, characterized by hyperinflation, prolonged exhalation, and wheezing. Bronchiolitis does not respond well to bronchodilators or corticosteroids and the timing of the wheeze is later in bronchiolitis than in asthma. However, in the context of the limited observation time typical in the ED a response to corticosteroids cannot be determined. Moreover, assessing the timing of the wheeze is generally clinically difficult. Mitigating this issue to some degree is the fact that in the PM pollution analysis in Chapter 6 the study window was earlier than the seasonal increase in respiratory infections. For Chapters 4 and 5, there was little reason to believe that asthma clinic attendees versus non-attendees would be differentially susceptible to viral infections. Thus, it was assumed that the effect of some bronchiolitis cases appearing in an asthma cohort could reasonably be assumed to affect both groups equally. Age, as complicating factor, emerged on later analysis.

Another issue is that the single institution nature of the studies simplified data extraction but one cannot discount the possibility that parents may choose to take their children to other EDs. Although Norris, YoungPong, Koenig, Larson et al. (7) found, in their multi-centre air pollution study, that the vast majority of asthma cases in children came from the single pediatric acute care institution in their study, a small proportion of parents do take their children to general hospital EDs. Presumably, the further a family lives from B.C. Children's Hospital the more likely they will turn to a local, general hospital ED. In Chapters 4 and 5, it was assumed that the probability of a visit by an individual child/family was the same under the assumption that they did not change residence over the two years of follow-up (ethics approval was not obtained to examine changes in residence). In Chapter 6, PM pollution concentration data from outlying areas of the Greater Vancouver Regional District were excluded from averaged pollutant exposure variables in light of the fact that few children in the sample came from areas like Abbotsford and Chilliwack.

Measurement issues were also factor in one of the studies. In Chapter 5, the measurement of asthma knowledge and parental care preferences was limited by the questionnaires that were used. The clustering of responses, observable as a ceiling effect for most questionnaire items, may reflect the overly simple nature of the questionnaires. Although previously validated, the questionnaires were unable to discriminate between parents to any significant degree. This may have been related to the differences in the validation population and the population in the study in Chapter 5, i.e., adults who knew nothing about asthma vs. parents of children with asthma – such parents are likely to know more about asthma then the general public. Whatever the reason, the lack of variation hindered the ultimate analysis and made finding positive results an unlikely outcome.

It must also be acknowledged that while the asthma education clinic is comprehensive in its coverage of key areas of knowledge for asthma management, it is possible that more extensive personalization of the educational message is necessary. One hour on an occasional basis is a long period of time in comparison to most family practice or ED encounters; however, in the context of a complex disease management, it may still be an inadequate amount of time. Longer sessions may permit asthma nurse educators to really understand the family and social context in which the children live and tailor the educational message such that realistic goals can be set.

In Chapter 6, data for some variables measured in other air pollution studies were not collected. While PM concentrations, temperature, and precipitation were ascertained, the possible contributory or confounding effects of gaseous pollutants such as SO_2, NO_2, and ozone were not captured. While previous studies have produced mixed results regarding the importance of these pollutants, it must be acknowledged that the study would have been stronger with evidence to suggest that these other pollutants either contributed or didn't contribute to the observed increase in ED visits for asthma.

Some issues were more difficult to address and must simply be acknowledged as limitations that may affect the interpretation and generalizability of the results. First, is that much of the background material in support of the studies, e.g., ED utilization studies, was based on American data. In many U.S. cities, especially in inner cities, the ED is viewed as the primary care provider.(8)(9) Socioeconomic reasons are likely a major driver behind this observation as many Americans are uninsured. These individuals would have to pay out-of-pocket to visit a family physician but under U.S. federal law they are must be seen in the E.D. It is possible that even the underinsured represent some proportion of ED visits as inadequate insurance plans, i.e. plans with high co-payments, may prompt some insured individuals to seek care in the ED. While socioeconomic issues are also relevant in a Canadian context, the disparities in socioeconomic status are generally not nearly as great as in the U.S. and there is universal coverage for primary care in Canada.

Recent Institute of Medicine reports on the state of emergency care (10) and pediatric emergency care (11) in the U.S. paint a bleak picture. They state that demand for emergency care grew by 26% between 1993 and 2003 but that over the same period, the number of EDs declined by 425. This has contributed to ED crowding such that patients back up in the ED because they can not get admitted to inpatient beds and are often held in the ED until an inpatient bed becomes available. Another indicator of overcrowding in EDs is that in 2003, ambulances were diverted 501,000 times across the U.S.

The authors of these reports point to multiple reasons for current situation in the U.S. including the fragmentation of Emergency Service delivery in the U.S. since 1981 when the federal government ended direct funding and transferred responsibility to individual states. However, they do note that certain types of illnesses, particularly asthma and diabetes, become exacerbated and result in ED visits and hospital admissions when children have ongoing healthcare needs that go unmet. They cite data from the National Health Interview Survey of the mid1990s as evidence that children from poor and near poor households are three times as likely as non-poor children to have unmet healthcare needs. Similarly, uninsured children were three times as likely as insured children to have unmet healthcare needs.

A report by the Canadian Institute for Health Information in 2005 (12) suggests that while an economic gradient may exist for ED utilization in Canada it is appears to be nowhere near as dramatic as the gradient that exists in the U.S. Using data from the National Ambulatory Care Reporting System, the authors found that, in Canada, those in the lowest income group were more likely to have visited the ED for their most recent treatment than those in the highest income group (18% vs. 13%). While these data pertain to all age groups, and not just children, they suggest that the population of ED visitors do differ between Canada and the U.S. in some respects. Unless U.S. studies separate analyses according to insurance status, the results of some studies may not be comparable to the Canadian experience.

In the specific context of an asthma education program, if economic factors are the driving force behind a decision to use the ED for a child's asthma exacerbation in a significant proportion of the population of attendees, as might be the case in American inner cities, then an asthma education program in Canada may not have much of an effect. On the other hand, if education and awareness levels are primary determinants, as might be the case in more affluent neighbourhoods in the U.S., it may be the case that dramatic increases in parental asthma knowledge levels are possible. Thus conflicting results from previous studies might be explainable, in part, by the dramatic difference in socioeconomic conditions from region to region in the U.S.

A related economic issue that may have confounded results is the cost of the medications themselves. Corticosteroids are on average an order of magnitude more expensive than adrenergic agonists. In British Columbia, the Fair Pharmacare program provides prescription medication coverage to the very poor i.e. those below certain income levels, however, the working poor (low pay and without employer health benefits) must typically use their own resources to purchase prescription medications. It could very well be that this group is overrepresented among ED users and that the cost of medications outweighs any potential effect of asthma knowledge improvement.

Finally, the failure to find an overall positive impact of the asthma education clinic in this dissertation may reflect the fact that the success of an intervention program depends to some degree on homogeneity of attitudes and beliefs in the target population. An education program attempts to influence behaviour but behaviour is also influenced by preexisting attitudes and beliefs. Vancouver is characterized by a diverse population, with significant ethnic populations from countries and regions as dissimilar as China, South Asia, Romania, and Iran. Some of these countries and regions have there own medical traditions, i.e. Chinese medicine and Ayurvedic medicine, while other countries have significant populations with cultural or religious beliefs that can affect health care seeking behaviour. For example, a Muslim woman from Iran or South Asia may be averse to seeking medical care for herself or for her female children from a male physician. Language barriers are also a significant issue in Vancouver, especially among Chinese immigrants and to some degree among South Asian immigrants. Although an attempt was made in the prospective study in Chapter 5 to exclude families in which parents/guardians did not understand and speak English well, such exclusion criteria were impossible to implement for the retrospective analysis in Chapter 4. No attempt was made to assess cultural or religious beliefs or attitudes in relation to health care preferences as it was beyond the scope of the studies in this dissertation.

7.3 Future Research

Suggestions for future research arising from this dissertation are based in part on the findings but also on the experience of conducting research – a process that proved to be very informative.

To date, asthma education studies have been implemented with little consideration given to the differences between younger and older children. Rarely do exclusion criteria become more onerous than excluding children who are below a minimum cut-off age, e.g., five years of age, and even rarer are age-stratified analyses or tests for interaction. The former limits the generalizability of studies and the latter may overlook significant effect of age on results. As mentioned earlier, it may be that the difficulty of an asthma diagnosis in younger children accounts for some of the observed differences by age. Improved diagnostic techniques could alleviate this issue. Nitric oxide measurements, as an indicator of airway inflammation (13), may provide a noninvasive way to assist in differentiating between early wheezers due to pre-morbid diminished airway conductance from early wheezers due to inflammatory processes. Thus, the promise of nitric oxide measurements is important not only for patient care but also for the reliability of measures in pediatric asthma epidemiology and health services research.

The lack of asthma knowledge questionnaires that work well in the ED environment, or over the telephone post-visit, is a notable gap in the literature. Although an attempt was made to use modified versions of questionnaires previously tested for validity and reliability in clinic environments, they did not translate well to the ED because of response clustering. A questionnaire by Adams et al. (14), and validated in a clinic setting, had been identified as an instrument less likely to suffer from response clustering. A multiple choice format was felt to be superior to a true/false format questionnaire. Unfortunately, this questionnaire was too cumbersome to use in the ED and over the phone. Thus, there is a clear need for asthma knowledge questionnaires that balance the data quality requirement for a study with the feasibility of implementation in an ED setting and the asthma education field would be well-served by further developments in this area.

Finally, while there have now been a few studies, in addition to the one presented in this dissertation, that have pointed to the possible effect of PM concentrations on pediatric ED visits (7) or general ED visits for asthma (4), the missing link in this study is clearly an explanation for the observed lag between the spikes in PM concentrations and pediatric ED visits for asthma. There are two avenues of research that could provide further insight. First, biological models that approximate the human experience of an asthma exacerbation in animal models could take basic science research in asthma beyond isolated cell research.(15) It is at the tissue and airway level that bronchoconstriction is observed and animal models might allow testing for both immediate and delayed effects of PM pollution. Second, follow-up with parents and patients around the time of the spike in ED visits to ask them about their reasons for seeking ED care on that particular day and whether they put off seeking care until they felt their child's condition was not going to resolve might reveal whether the lag is a result of the parental decision-making process. Unfortunately for the PM pollution study presented in this dissertation, the amount of time that has passed makes recall bias a serious issue but follow-up interviews are an item that should be considered should similar findings be found in other studies.

7.4 Conclusions

Recurrent respiratory problems are among the most common conditions afflicting children and children with asthma form a significant proportion of this group, even if a substantial proportion of early wheezers diagnosed with asthma are only transient wheezers. With the numerous studies on asthma in children from an epidemiologic and health services research perspective, it is surprising how relatively few focus on the use of Emergency Services. The reasons may include: the inadequate quality of health records for emergency visits, the perceived difficulties in recruiting in the ED, the ethics approval process for a study in pediatric environment with a primary mandate to provide emergency care, and perhaps even disinterest on the part of some care providers in the ED in research.

The series of studies that form this dissertation have demonstrated that ED-based studies can be carried out using a variety of study designs and with the aim of addressing an assortment of questions. Given the significance of children with asthma, or at least wheezing, for ED utilization and as an indicator of unmet healthcare needs, these studies should be encouragement for continued research into the factors that affect use of the ED by the parents of this particular population of children.

Evidence in this dissertation suggests part of the unmet healthcare need consists of inadequate asthma knowledge levels among parents, especially with regard to the home environment, and that the Asthma Education Clinic is addressing part of this unmet healthcare need even if it is difficult to demonstrate impact using proxies such as time to a repeat ED visit. However, knowledge is only part the equation and exploration of other barriers to a parent effectively managing their child's asthma, in the context of the ED, are needed. PM pollution may be one such factor, as suggested by the research presented here and previous studies, but it is only one trigger in a very long list of potential asthma triggers. Researchers can contribute to the betterment of care from children with asthma by viewing this list as an opportunity to be tackled one item at a time.

7.5 References

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Appendix

The University of British Columbia
Office of Research Services and Administration
Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	NUMBER
Sheps, S.B.	Health Care/Epidemiology	B05-0035

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT
UBC Campus ,
CO-INVESTIGATORS:
Joseph, Jay, Health Care/Epidemiology; Kissoon, Niranjan, Health Care/Epidemiology; MacNab, Ying, Health Care/Epidemiology
SPONSORING AGENCIES
Michael Smith Foundation for Health Research
TITLE:
Factors Affecting Emergency Visits for Asthma in the Pediatric Emergency Department

APPROVAL DATE	TERM (YEARS)	AMENDMENT:	AMENDMENT APPROVED:
05-04-12 (yr/mo/day)	1	May 19, 2006, Contact letter / Consent form / New title / Research method	JUN 26 2006

CERTIFICATION:

The request for continuing review of an amendment to the above-named project has been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approved on behalf of the Behavioural Research Ethics Board
by one of the following:
Dr. Peter Suedfeld, Chair,
Dr. Susan Rowley, Associate Chair
Dr. Jim Rupert, Associate Chair
Dr. Arminee Kazanjian, Associate Chair

This Certificate of Approval is valid for the above term provided there is no change in the experimental procedures