Effect of Secondhand Smoke on Healthcare Utilization and Expenditures among Children with and without Asthma

THESIS

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Abstract

**Objective:** This study aimed to estimate the annual healthcare utilization and expenditures associated with smoke exposure inside the home and childhood asthma.

**Methods:** Healthcare utilization and expenditures data came from the 2001 and 2006 Medical Expenditure Panel Survey (MEPS). Child’s asthma diagnosis and demographic information were from MEPS as well. Secondhand smoke exposure data were determined by in-person interviews in the 2000 and 2005 National Health Interview Survey (NHIS), which used same nationally representatives as MEPS. A total of 7482 children aged 0-11 years were included in the present study. Multivariable regression models that controlling for potential confounders were used for the analysis.

**Results:** The presence of smoking inside the home was associated with an 18% increased odds of having childhood asthma (p<0.1). Among asthmatic children, smoking inside the home was associated with an increased odds of hospital stays (OR=2.18, 95% CI=1.29, 3.67). Indoor smoking was also associated with an 37% increased odds of emergency visits. The increases in expenditures for hospital stays and emergency department visits caused by childhood asthma depend on the presence of smoking inside the home. Both asthmatic and non-asthmatic children tend to spend more for hospital stays and emergency department visits because of the exposure to secondhand smoke. The increased expenditures caused by smoking inside the home among asthmatic children
were significant higher compare to non-asthmatic children. Overall, secondhand smoke exposure was associated with $50.61 in additional expenditures for health services. Childhood asthma was significantly related to higher probability of healthcare utilization and higher expenditures.

**Conclusion:** The presence of secondhand smoke exposure among children with asthma aggravated the risk of hospital stays and increased the expenditures for hospital stays and emergency visits. Reducing secondhand smoke exposure inside the home would help to reduce healthcare expenditures for children, especially asthmatic children.
This is dedicated to my family.
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Chapter 1: Introduction

1.1 Overview

Secondhand smoke is defined as “the combination of smoke emitted from the burning end of a cigarette or other tobacco products and smoke exhaled by the smoker”\(^1\). It is well-known that secondhand smoke causes adverse health outcomes both among children and adults. The 2006 Surgeon General’s report indicated that secondhand smoke can contribute to the premature death and disease among children and adults who are non-smokers\(^1\).

Although smoke-free policies are employed in many areas of the US, many Americans are still exposed to secondhand smoke in home and workplaces\(^1\). In the US, one in every three children lives with a smoker\(^2\). Many studies have established the association between secondhand smoke exposure during childhood and increased risk of adverse health outcomes, including respiratory diseases, attention deficit/hyperactivity disorder, middle ear infections, sudden infant death syndrome, dental problems and metabolic syndrome\(^3-8\).

Asthma is also linked to exposure to secondhand smoke. In the past several decades, the prevalence of asthma has increased dramatically. According to data in 2006, there were about 350 million people worldwide who were suffering from asthma\(^9\). In the US, approximately 25 million people had asthma in 2009, which had grown by 5 million
since 2000\textsuperscript{10}. Children appear to be vulnerable to asthma, as about 10% children had asthma in 2009, with boys being at higher risk compared to girls\textsuperscript{10}.

This growing prevalence of asthma will lead to an increased public health burden, especially related to healthcare expenditures. According to data from 2007, the total incremental cost of asthma to society was $56 billion, and the expenditures directly attributable to asthma were $50.1 billion\textsuperscript{11}. Patients with appropriate treatment and therapy could control their asthma, while the costs of treatment are considerable\textsuperscript{12}. However, the healthcare expenditures could be even higher among those with poor asthma control\textsuperscript{13}.

Several research studies have indicated that asthma causes a great amount of healthcare spending in the US\textsuperscript{14,15}. Additionally, some researchers have examined the relationship between childhood exposure to secondhand smoke and healthcare expenditures\textsuperscript{15-20}. However, the research concerning the association between asthma-related medical expenditures and household smoking is limited. Because of the absence of evidence, there is a need to understand such link. However, before exploring the link between asthma-related healthcare costs and secondhand smoke exposure, it is necessary to understand how secondhand smoke exposure impacts childhood asthma.

Several epidemiologic studies have indicated that secondhand smoke exposure among children is associated with prevalent asthma\textsuperscript{22-24}. However, the evidence is not sufficient to establish the causal relationship between secondhand smoke from parental smoking and childhood onset asthma\textsuperscript{25}. The epidemiologic evidence for the effect of
parental smoking on childhood asthma remains inconsistent, as there are research studies that have demonstrated non-significant results on such link.

Because the evidence about the impact of secondhand smoke on childhood asthma is insufficient, it is important to understand the association between secondhand smoke exposure and asthma-related healthcare expenses. Secondhand smoke exposure among children could predict increased asthma-related health costs, which might help to clarify the relationship between childhood asthma and secondhand smoke. Moreover, understanding the healthcare cost of childhood asthma attributable to secondhand smoke exposure would provide useful information for policymakers, as secondhand smoke is a preventable exposure.
1.2 Effect of Secondhand Smoke on Asthma

The results from studies which have investigated the effects of secondhand smoke on childhood asthma remain inconsistent, as some of the research studies suggest no association between secondhand smoke and childhood asthma \(^{26-28}\), while there are several prospective and cross-sectional studies that demonstrate a significant relationship \(^{22-24}\). The different results may be due to different methods used to examine the association or potential bias.

1.2.1 Studies Reporting a Positive Association

Among the studies that have addressed the association between secondhand smoke exposure and childhood asthma, most have been cross-sectional studies, while few have been longitudinal.

A prospective study followed 2220 males and 2056 females from birth to the age of 14 \(^{22}\). Mothers and children were recruited in Brisbane, Australia starting in 1981. Maternal smoking during pregnancy was assessed at the prenatal visit and 3 days after delivery, and postnatal smoking was measured at the 6-month and 5-year follow-up visits by questionnaire. Smoking status was classified into three levels: nonsmoking, smoking less than 20 cigarettes per day and smoking 20 or more cigarettes per day. At the child’s age of 14 years, asthma symptoms were assessed by the mother’s report. The only significant association between prenatal and postnatal maternal smoking and childhood asthma was observed among girls whose mothers were heavy smokers. Girls whose mothers consumed 20 or more cigarettes per day during pregnancy had increased odds of
developing asthma compared to those girls with non-smoking mothers. The OR for heavy smoking in the early stage of pregnancy was 1.76 (95% CI 1.16, 2.66), while that for heavy smoking in late stage of pregnancy was 1.66 (95% CI 1.14, 2.42). In addition, among mothers who smoked heavily through the first 6 months after delivery, the odds of their girls developing asthma were 1.53 times the odds among non-smoking mothers (95% CI 1.10, 2.13). The effect of maternal smoking during the prenatal period was stronger than postnatal period. No similar associations were observed among boys. The different results among boys and girls may be due to the different stage of pubertal development. The researchers assessed the outcome at participant’s age 14 years follow-up visit. By this time, most girls have completed their pubertal growth, while boys were continuing to experience growth for a longer period. The authors speculated that the disparity of lung size and hormone level may affect the prevalence of asthma among boys and girls during pubertal development period.

The association between maternal smoking during pregnancy and after delivery and asthma prevalence among children has been assessed in cross-sectional studies as well. According to Raherison and colleagues, children who have been exposed to maternal smoking in utero had a 22% higher odds of asthma compared with those whose mothers have never smoked (OR=1.22, 95% CI 1.01, 1.50). Additionally, the effect of postnatal smoking on childhood asthma was significant after adjusting for several potential confounding (OR=1.23, 95% CI 1.02, 1.47). However, this association did not appear to differ by gender in this study. Another large-scale cross-sectional study conducted in China suggested that the link between secondhand smoke and asthma is
stronger among boys rather than girls\textsuperscript{35}. These three studies have findings that contradict to each other. Therefore, the evidence for gender specific associations is not consistent, and need to be further explored.

The prospective study of Bjerg and colleagues has provided evidence of the synergism between low birth weight and prenatal smoking on childhood asthma\textsuperscript{36}. This study was based on the International Study of Asthma and Allergy in Childhood (ISSAC) questionnaire survey, in which researchers followed 3939 participants from the age of 7-8 to the age of 11-12 in northern Sweden. Prenatal smoking status was reported by mothers. Children’s asthma symptoms and physician-diagnosed asthma were reported by questionnaire. All the reported cases were clinically validated by skin-prick tests. Birth weight was self-reported as well. Low birth weight was defined as a weight less than 2500g at birth. At age 11 to 12 years, a significant association between prenatal smoking and childhood asthma was observed among adolescents with normal birth weight (RR=1.38, 95% CI 1.01, 1.76). The association was stronger among children with a low birth weight. Among children who were exposed to prenatal maternal smoking, the odds of developing asthma were 8.79 times the odds among those who were not exposed to prenatal secondhand smoke (95% CI 2.05, 42.8). In this study, the joint effect of low birth weight and prenatal smoking on asthma was not additive.

In 2008, Goodwin and colleagues used a nationally representative sample from the National Children’s Health Survey (NCHS) to address the association between household smoking and childhood asthma in the US. This study was the first to explore such link at the state-level in the US\textsuperscript{23}. A total of 102,000 subjects aged 18 years old and
younger were included in the study. Household smoking and asthma symptoms were reported by parents. There was a significant association between level of household smoking with children by state and increased rate of childhood asthma (unadjusted coefficient=0.43, 95% CI 0.04, 0.10). The association did not appear to be affected by outdoor air quality or socio-economic status.

Another important cross-sectional study was from Greece which was informative with regard to the association of secondhand smoke exposure of pregnant women and children to secondhand smoke exposure with childhood asthma. The researchers recruited 2424 preschool children aged 1-6 and evaluated the effects of pre- and postnatal secondhand smoke exposure on asthma symptoms by questionnaire. Parental smoking (OR=1.53, 95% CI 1.07, 2.35) was significantly related to childhood asthma. Maternal smoking during pregnancy was also found to be a risk factor of children’s asthma. Secondhand smoke exposure during pregnancy was positively related to asthma, which was borderline significant at $\alpha=0.1$ level (OR=1.41, 95% CI 0.98, 1.89). This study offered an important insight into the role of secondhand smoke exposure among pregnant women and children and the occurrence of asthma during childhood.

In addition to the studies described in the previous paragraphs, a meta-analysis study from Vork and colleagues examined the relationship between secondhand smoke and childhood asthma. The authors used 53 studies, including case-control and cross-sectional studies, to conduct the analysis. They found a significant relationship between secondhand smoke exposure and asthma. The summary RR for incident asthma and ever asthma in childhood due to the exposure of secondhand smoke were 1.21 (95% CI 1.08,
1.41) and 1.48 (95% CI 1.37, 1.65), respectively. The results from this study suggested a significant association between secondhand smoke and childhood asthma. Additionally, the exposure duration was considered as an important factor, which implied a causal relationship between secondhand smoke and asthma.

In summary, the evidence above suggests that prenatal and/or postnatal secondhand smoke exposure is related to an increased risk of developing childhood asthma.

1.2.2 Studies Reporting No Association

There have been studies that reported no association between secondhand smoke exposure and childhood asthma. A cross-sectional study from Fukuoka City, Japan recruited 1951 children aged 3 years. The data on prenatal maternal smoking and postnatal exposure to household smoking and asthma symptoms were collected with questionnaires. No significant association was found between both pre- and postnatal exposure and occurrence of asthma. The OR of maternal smoking during pregnancy was 1.25 (95% CI 0.78, 1.93) while the OR associated with household smoking was 1.22 (95% CI 0.87, 1.71). However, the relationship between secondhand smoke exposure after delivery and an increased risk of wheeze was observed in this study. The reason why researchers found no association between parental smoking and asthma may be due to early detection, as the subjects in the study may not be old enough to be diagnosed with asthma or have symptoms of asthma. In addition, only about 24% of eligible children in Fukuoka City were included in the analysis, which could introduce selection
bias to this study. Moreover, exposure and outcome were assessed by questionnaire rather than objective measurements, which may lead to recall bias, underreported smoking status and non-differential misclassification to attenuate the strength of target association. Additionally, the low prevalence of smoking among Japanese women may affect the result as well.

Using data from the National Health and Nutrition Examination Survey (NHANES) III (1988-1994), Mannino and colleagues examined data from 5400 US children aged 4-16 years. Household smoking status was obtained by questionnaire. The participants also completed a comprehensive physical examination, including respiratory function testing and serum cotinine (a metabolite of nicotine) concentration. Cotinine concentration reflects the exposure to secondhand smoke, which higher concentration linked to higher exposure. Approximately 11% of children had ever had asthma and 8% currently had asthma symptoms at the examination. However, no significant association between high cotinine concentration and current and ever asthma (OR=1.5 for current asthma, 95% CI 0.8, 2.7; OR=1.3 for ever asthma, 95% CI 0.8, 2.2) was found in combined age group. The significant association only existed among children aged 4-6 (OR=5.3 for current asthma, 95% CI 2.2, 12.7; OR=2.3 for ever asthma, 95% CI 1.1, 5.1). A possible explanation of such result is children at their early age have lower tolerance of secondhand smoke and those children may not be able to avoid exposure to smoke.

Kabir and colleagues focused on the effects of secondhand smoke exposure in cars on children’s respiratory health. They randomly selected 2809 children age 13-14
years old from post-primary schools in Ireland. Secondhand smoke exposure was assessed by questionnaire and respiratory function was self-reported. There was no significant association between exposure and childhood asthma, neither adjusted nor unadjusted for potential confounders (OR adjusted=1.07, 95% CI 0.81, 1.42; OR unadjusted=1.08, 95% CI 0.83, 1.41). The non-significant association may be due to subjective measurement of exposure and outcome. The smoking status and asthma prevalence might be underreported, which is a limitation of self-reported measurement compared to objective measurement. This self-reported assessment might introduce recall and non-differential misclassification bias, leading the OR toward null hypothesis.
1.3 Secondhand Smoke Exposure and Biological Mechanism for Asthma Incidence

1.3.1 Impact of Secondhand Smoke

In 2010, approximately 19.3% of US adults aged greater than 18 years were current smokers\textsuperscript{29}. Although the prevalence of smoking and tobacco use from 2004 to 2010 remained stable or showed a slight decrease trend, a large number of smokers results in a tremendous health burden either because of direct exposure to smoking or through secondhand smoke exposure.

According to the data from Center of Disease Control and Prevention, about 88 million of nonsmokers who were older than 3 years old were exposed to secondhand smoke in the US during 2007 and 2008\textsuperscript{30}. Children and youth were more likely to live with someone who smoked inside the home compared to non-smoking adults. Approximately 32 million non-smokers between 3 and 19 years old were exposed to secondhand smoke\textsuperscript{30}. One in three children and adolescents were exposed to household tobacco smoke, which was the most common way for children to be exposed to secondhand smoke\textsuperscript{2}.

Additionally, socio-economic status influences the distribution of children exposed to household tobacco smoke. Those who lived below the federal poverty level are more likely to be exposed to household secondhand smoke\textsuperscript{30}.

The association between secondhand smoke exposure and adverse health consequence can be characterized as dose-response relationship. There is no threshold at which the risk increases\textsuperscript{31}. Thus, no matter how much one was exposed to secondhand
smoke, there is an increased risk of disease or other unfavorable health conditions. Children are more vulnerable to disease, as their immune system is not well developed \(^2\).  

### 1.3.2 Possible Mechanism

One possible mechanism by which secondhand smoke induces asthma is that secondhand smoke impairs the function of detoxification of tobacco smoke \(^3\). Genotypes of glutathione S-transferases, which are important factors in the process of detoxification, can be influenced by secondhand smoke. Therefore, children with impaired glutathione S-transferases status are more vulnerable to asthma \(^3\).  

Another potential scenario is impairment of airway function. Studies show that secondhand smoke exposure among children may lead to airway narrowing and other related respiratory function \(^3\).
1.4 Medical Expenditures of Asthma among Children

There have been several studies that have estimated the economic burden of asthma in the US\textsuperscript{10,11,14}. The magnitude of healthcare cost attributable to asthma is considerable, which characterizes asthma as an important health issue.

Lozano and colleagues used National Medical Expenditure Survey (NMES) data from 1987 to examine the national healthcare costs of asthma in the US\textsuperscript{20}. They sampled 7578 children aged between 1 and 17 years with and without asthma based on the NMES database in 1987. Asthma symptoms were self-reported. The medical costs were measured by frequency and costs of medications, ambulatory visits, emergency department care, and hospitalizations for all reasons. Asthmatic children used more healthcare services and spent more money on medical services compared to children without asthma. The total medical expenditures for children with asthma ($1134 per child per year) was 2.8 times as great as the expenditures for those without asthma ($407 per child per year). This article quantified the health issue of childhood asthma by the healthcare cost and provided a general understanding that the healthcare costs of children with asthma is significantly higher than children without asthma.

Another study from Kamble and colleagues estimated the direct increase in healthcare expenditures attributable to asthma treatment in 2009\textsuperscript{38}. The data were based on the 2004 Medical Expenditure Panel Survey (MEPS), which provided a nationally representative sample of the non-institutionalized population in the US. In 2004, 39,403 individuals were included in the MEPS database, including 10,370 children (less than 18 years old) and 24,083 adults (18 years old or older). Individuals who reported asthma
symptoms were classified as asthma patients. The direct payments for healthcare were considered expenditures, and these included payments by private insurance, Medicare, Medicaid, and other sources, as well as out-of-pocket payments. The incremental direct expenditure attributable to asthma was significant among children and adults. A child with asthma would spend approximately $1,005 (p=0.002) more than a child without asthma on healthcare service every year. The annual incremental expenditure among adults was about $2,078 (p<0.0001) per person. The increased costs of asthma treatment were largely due to prescription medications and physician office visits.

In general, children and adults with asthma are experiencing increased healthcare expenditures compared to those without asthma. It is necessary for patients with asthma to use asthma control treatments in order to assure a high quality of life and to prevent higher medical costs. As asthma is a chronic disease, from the long-term perspective, patients with a high level of control would incur reduced health burden compared to those without asthma control treatment\textsuperscript{39}. 


1.5 Medical Expenditures for Children Living with Smokers

According to previous research, children living with smokers may have an increased risk of adverse health outcomes and incur a higher economic burden compared to those who are not living with smokers. This relationship is not clear though, as several studies have given modest or non-significant results. Thus, further research is needed to understand the long-term association between secondhand smoke exposure and healthcare expenditures.

Florence and colleagues estimated healthcare costs attributable to secondhand smoke exposure in 2007. They used data from the 1998 National Health Interview Survey (NHIS) and the 1999 to 2000 and 2000 to 2003 rounds of MEPS to analyze the health expenditure related to household smoking. The study included 36,420 children aged 12 years and under. The household smoking status was assessed by self-reported questionnaires. The results of the analysis suggested that children’s exposure to household smoking is negatively related to any health expense in the year, and those values were significant at p=0.05 (1999/2000 MEPS coefficient=-0.39, 2000/2004 MEPS coefficient=-0.102). Interestingly, the expense on respiratory diseases was positively related to the presence of smokers in household, based on the data of 2000 to 2004 rounds of MEPS (coefficient=0.82, p≤0.05). Although the result of this study was unclear on the relationship between secondhand smoke and expenditure, the overall healthcare expenses attributable to household smoking was considerable, which ranged from $640 to $860 million in 2003 dollars.
Hill and Liang estimated the respiratory healthcare expenditures for young children exposed to household secondhand smoke. The study was based on two MEPS panels which had started in 1999 and 2000. A total of 2759 children aged 0-4 were included in the study. Household smoking was assessed by self-reported questionnaires, with smoking status grouped into three categories: smoking inside the home, smoking outside the home, and no smoker in the household. The healthcare expenditures consisted of payments due to hospital stays, emergency department use, and prescription drug related to respiratory conditions. About $117 additional respiratory care expenditures were attributable to children’s exposure of indoor secondhand smoke (p <0.05). Additionally, exposure to indoor secondhand smoke was associated with a 3.1% increase in hospital stays and 4.8% increase of emergency department visits (p<0.05). There was no association between outdoor smoking and increased healthcare cost (difference in healthcare cost=$7, p>0.05). This study provided evidence that secondhand smoke exposure was related to a higher healthcare cost of children, especially for children who had been exposed to secondhand smoke inside the house.

Because no relevant research study had addressed the association between secondhand smoke exposure among children and its healthcare costs in the low income households, Levy and colleagues conducted a research to investigate such a link. The study used the data from MEPS and sampled children from birth to age 11 years. As the subjects of interest were children from low income household, researchers included only children who had been enrolled in Medicaid. A total of 16,154 children were included in the study. Children were classified as being exposed to secondhand smoke if there was at
least one smoker in the household according to the self-report questionnaires. The economic covariates were assessed by the annual expenditures paid for Medicaid. After adjusting for relevant covariates, there was no significant difference (difference = $149, 95% CI -$68, $427) in healthcare payments between children who were living with and without smokers in general. The estimate of annual healthcare payments among children living with smokers on average was $10 higher on emergency department expenditures compared to those living with non-smokers (95% CI $3, $18). The emergency visit-related payments were the only type of expenditure that reminded significant after adjusting for confounders. This study suggests that the presence of smoking in household was only slightly associated with increased healthcare expenditures in children. Further research is needed to clarify this relationship.

In addition to finding an association between maternal smoking and children’s respiratory health, a mother’s smoking status has been related to increased healthcare expenses. Stoddard and Gray examined the association between maternal smoking and medical care costs for childhood respiratory illness based on 1987 NMES in 1997. They included 2624 children under age 5 years, and the healthcare expenses were collected from the administrative record of NMES. In the adjusted analysis, maternal smoking was significantly related to increased expenses on children’s respiratory treatments. On average, the expenditures among children whose mothers smoked were $120 per year higher than the expenditures among those children whose mothers were non-smokers (P<0.05). For children aged 2 and younger, among those whose mothers
smoked the healthcare expenditures were $175 per year higher compared to others (P<0.05).

Overall, the previous evidence may not be sufficient to suggest that secondhand exposure among children is associated with increased healthcare expenditures. Long-term prospective studies are needed to better address the impact of secondhand smoke on economic burden among children is needed in the future.
1.6 Healthcare Cost among Children with Asthma and Secondhand Smoke

The research focused on the association between asthma-related medical expenditures and household smoking is limited. To my knowledge, only one study has compared the asthma-related health resource use among children living with and without smokers\(^9\). The researchers collected data from 1470 parents who had children aged 1 through 11 years from two randomized trials that evaluated self-help smoking cessation interventions, and motivational adjuncts at Group Health Cooperative of Puget Sound. The smoking conditions of parents were self-reported. Additionally, the use of health service of children was assessed from the Group Health Cooperative’s database. After statistical analysis, the results showed that there was no difference in the total primary care use, or emergency room visits, asthma-related therapy, or inpatient stays between children of smokers and children of non-smokers. For asthma-related prescriptions, 17.2% of children with non-smoking parents used such health service versus 16.7% of children of smokers. Although the results of this study were not significant, there was one noteworthy point in the article: smoking parents were less likely to utilize preventive health service for their children compared to non-smoking parents. It is important to examine whether the access of healthcare service for children biased the associations of interest.

Because of the absence of studies demonstrating such a link between secondhand smoke exposure and asthma-related healthcare expenditure among children, it is important to perform additional studies.
1.7 Statement of Problem

There is a substantial body of work indicating that maternal smoking during pregnancy and during the early years of childhood has a causal association with asthma. However, the research that has addressed the association between asthma-related healthcare expenditures and secondhand smoke exposure during childhood is limited. There was only one study has examined such link and no association was found\(^\text{19}\). This study included a small sample size from a single-site health maintenance organization. They found that asthmatic children’s healthcare expenditures were not significantly related secondhand smoke exposure. No national representative sample has been used to analyze this association.

Given the increasing trend of asthma prevalence among children, the substantial impact of secondhand smoke, and the unclear influence of secondhand smoke on childhood asthma, understanding the effect of secondhand smoke exposure on childhood by estimating asthma-related healthcare utilization and expenditures is needed. It is possible that children who are exposed to secondhand smoke are at increased risk of poor health, which would lead a great amount of healthcare expenditures compare to those children who were never exposed to secondhand smoke. Therefore, it is valuable to understand the availability to release the economic health burden for children with asthma, for secondhand smoke is a preventive exposure.
1.8 Objectives

The objectives of this study were to: 1) estimate the prevalence of asthma and the odds of having childhood asthma by secondhand smoke exposure; 2) estimate the odds of having annual healthcare utilization among children with and without asthma and with and without secondhand smoke exposure; 3) estimate annual expenditures of health services among children with and without asthma and with and without secondhand smoke exposure.

In the current study, samples were drawn from the respondents of nationally representative Medical Expenditure Panel Survey (MEPS) and National Health Interview Survey (NHIS).
Chapter 2: Methods

2.1 Data Sources

In the current study, the sample consisted of children aged from 0 to 11 years old who were included in Panel 6, 2001 and Panel 11, 2006 of the MEPS Household Component. The MEPS is a national survey designed to collect information related to healthcare expenditures among the civilian, non-institutionalized household population in the US, which funded by the Agency for Healthcare Research and Quality (AHRQ).

Each year, the sample of the MEPS Household Component is drawn from the households that responded to the NHIS in the previous year. Typically, the MEPS sampling frame is taken from respondents in two of the first three quarters of data collection for the NHIS. The fourth quarter is usually excluded because of the late collection time. The sampling frame for NHIS is representatives of US households and non-institutionalized group quarters such as college dormitories. Unlike the NHIS, MEPS excludes individuals living in dormitories. The sample design of NHIS is a complex probability sampling plan which involves clustering, stratification, oversampling and multistage sampling. Basically, the MEPS sample design follows the NHIS. According to the sampling plan of the MEPS and NHIS, the 2000 and 2005 NHIS data were linked to the 2001 Panel 6 and 2006 Panel 11 MEPS respectively.
Both the MEPS and NHIS employ a personal household interview for the data collection. The MEPS uses an overlapping and ongoing panel design to collect data. The sampled households are interviewed five times during a two-year period\textsuperscript{40}. In addition, an annual self-administered questionnaire was introduced to the MEPS since 2000. The response rate of the first interview of Panel 6 and Panel 11 was about 81.1\% and 76.1\%, respectively\textsuperscript{41,42}. The overall response rate of households completed five interviews over the two-year period was about 64.0\% for Panel 6 and 55.4\% for Panel 11 \textsuperscript{43,44}. To ensure the completeness of data, the MEPS imputed the expenditure data for public use \textsuperscript{41-44}.

The MEPS Household Component provides data on demographics, health conditions, use and cost of healthcare and certain health behaviors from a representative national sample. Information about a person’s asthma diagnosis and health service uses and expenses was collected by the MEPS by face-to-face interview. Although MEPS collected information on personal smoking behavior in the self-administered questionnaire, the NHIS data were used to obtain the adult’s smoking behavior inside the home, and to accomplish the measurement of household smoking status in the MEPS. In the 1998, 2000 and 2005 NHIS, participants were asked whether or not people smoked inside the household. Although NHIS collected household smoking status in 1998, the information about people’s asthma diagnosis was not available in the 1999 MEPS data. To gather the complete information on both household smoke exposure and childhood asthma, the 1998 NHIS and the 1999 MEPS were excluded from the present study.
The current study focused on children who were age 11 years and younger, because they are more likely to spend time with their family so they may have higher risks of being exposed to household secondhand smoke, while at the same time, they are less likely to be current smokers\textsuperscript{1}. In total, 7482 children were included in the study. All the analyses were weighted to reflect the association of interest on the U.S. population level in 2001 and 2006.
2.2 Outcome Variables

The primary outcome of this study was childhood asthma, as the first objective was to estimate the odds of having asthma by household smoking status. During the interview, a knowledgeable family member was selected and asked whether or not the child/children in the household has/have asthma diagnosis/diagnoses.

The secondary outcomes were annual utilization and healthcare expenditures. Uses of and expenditures due to hospital stays, emergency department visits, ambulatory visits, prescription medications and total healthcare expenditures were derived from the MEPS data.

In the MEPS data, the annual healthcare utilization and expenditure data were constructed based on the information collected from the household interviews and the medical providers to reflect the health services use and expenditures a person paid in the previous year. As a dataset that validates and supplements the Household Component data, the Medical Provider Component collects the utilization and expenditure data from the medical providers of the MEPS sample. In the Household Component, the sampled adult was asked about how many times he/she visited the hospital and used health services, and how much they paid for those health services during the previous year. Respondents to the Household Component were also asked information about their medical providers. In the Medical Provider Component, the medical providers are asked about the total visits, payments and the sources of the payments for a specific sampled subject in the Household Component. The total expenditures were defined as a sum of payments from all sources, including one’s out-of-pocket payments and payments paid by
insurance or other third party payers. People may report their out-of-pocket payments accurately, because those payments are usually showed on the bills. However, they may not always know about their insurance reimbursement rate, which is available to the medical providers. Therefore, to accurately estimate the total expenditures of a subject, the data collected from medical providers were used primarily, which means the Medical Provider Component data were used if complete; otherwise, the Household Component data were used. In the current study, the costs and uses of health services reflect the annual average of 2001 and 2006. The data on hospital stays, emergency department visits, the use of prescription medications and the total healthcare expenditures were directly available in the MEPS. The costs and frequencies ambulatory visits were calculated by combining the information of office-based visits and outpatient visits.

The expenditures were inflated to 2010 dollars according to the instruction suggested by AHRQ.
2.3 Independent Variables

For the analyses of healthcare utilization and expenditure, the independent variables of interest were childhood asthma and secondhand smoke exposure.

Childhood asthma was defined by the asthma diagnosis which was recorded by interviewers. During the survey interview, a knowledgeable adult was randomly selected to provide information of the child/children in the household. He/she was asked whether or not the child/children has/have asthma diagnosis/diagnoses.

Exposure to secondhand smoke was measured by family member’s reporting of household smoking status. In the self-administered questionnaire of the Household Component, respondents were asked whether or not they smoked. In the NHIS, there was information on smoking inside the home. One adult per family was randomly sampled to complete this detailed question. In the 2000 NHIS Cancer Module, the selected person was asked how many days anyone smoked inside the home during the past week. In 2005, NHIS asked the sampled adult about whether or not the residents of the household smoked inside home. Reporting smoking behavior inside the home is a sensitive assessment of secondhand smoke exposure, especially for young children, as they tend to spend a considerable amount of time at home which increases the risk of exposure to tobacco smoke \(^1\). Additionally, given the fact that there is no threshold for the risk of exposure to secondhand smoke, anyone smoked inside the home may cause a child to be exposed to tobacco smoke \(^31\). Furthermore, parental report of exposure has been validated in previous studies \(^47\). Therefore, in the present study, the exposure of secondhand smoke was defined as children who lived in households in which anyone
smoked inside the home during the survey cycle. Children who were not exposed to any smoke inside the home were defined as the reference group. In the dataset which linked the NHIS to the MEPS, among adults who answered the question about smoking inside home behavior in NHIS about 0.7% refused to answer that question and 0.2% of them reported “don’t know”, and 3.7% of sampled adults had interviewers labeled “not ascertained” on their smoking behavior. Moreover, approximately 8.1% of adults in NHIS data failed to link to MEPS. Based on the document of linked file, the unlinked cases may be newborns, newly in-scope persons and those who answered to the NHIS but were unable or refused to response to the MEPS. Those adults whose smoking status failed to link to the MEPS or showed non-applicable/ not ascertained were defined as missing. This resulted in 24% of sampled children not having the information on their family members’ smoking behaviors. The inflated percentage of missing values was largely caused by the failure of linking the information from NHIS to the MEPS data, given the family-based assessment of exposure to secondhand smoke inside the home. Because the data were mostly missing by the failure of linking the two surveys, it was less likely that the missing values are due to the unwillingness of answering the smoking questions.

Although the smoking data were missed at random, to control for the possibility of non-random missing, the smoking missing data were kept in the analyses. Thus, smoking status was divided into three categories to reflect exposure to smoking inside the home: (1) no adult smoked inside the home, (2) any adult smoked inside the home, (3) smoking status missing.
To control the potential confounders, the multivariable models adjusted for characteristics of the child, insurance type of the child, family characteristics and survey year. Characteristics included age, race, gender, census region and urban or rural area where the child lives. Insurance type was categorized as private insurance, public insurance and uninsured. Family characteristics included the family income as a percentage of the federal poverty line, the number of residents in the household, parental asthma history and the highest education level of parents. Survey year was included in the model to adjust for the variability caused by pooling two years of survey data.
2.4 Data Analyses

Multivariable models were used for the statistical analyses. The types of multivariable model depended on the outcome. To estimate the odds of having childhood asthma by household smoke exposure logistic regression models were used. The annual healthcare utilization among children with and without asthma and with and without secondhand smoke was estimated by logistic regression models. To estimate annual expenditures of health services two part models were used, controlling potential confounders. Moreover, the effects of childhood asthma and secondhand smoke exposure on predicted expenditures were examined by linear regression models.

First, the characteristics of study populations were assessed by household smoking status. The different distributions of the characteristics among children who were exposed to secondhand smoke in the household and children who had missing values on household smoking status were compared to the reference group. The reference group consisted of children living with no adult smoked inside the home. Bivariate logistic regression models were used to examine the differences.

Next, multivariable logistic regression models were used to estimate the odds of having childhood asthma. The primary independent variable was the exposure of smoking inside the home. Odds ratios (ORs) were calculated to demonstrate the differences in the odds of having childhood asthma among children exposed versus those did not exposed to secondhand smoke. Confidence Intervals (CI) for ORs were calculated using the lower and upper limits of 95% confidence intervals. Child’s age, race, gender, census region and urban or rural area they live, insurance status, and their family’s
poverty level, the number of residents present in the home, parental asthma history, the highest education level of parents and the survey year were considered as potential confounders.

Logistic regression models were used to examine the effect of childhood asthma and secondhand smoke exposure on the having any uses on health services. Children’s use of certain health services were treated as binary variables. Secondhand smoke exposure and asthma diagnosis were considered as primary independent variables. The interaction of household smoking status and asthma diagnosis was included in the model if significant at 0.05 level. The OR and 95% CIs were calculated to demonstrate the effects of childhood asthma and secondhand smoke exposure on children having any use associated with certain health services. These logistic regression models were adjusted for potential confounders, as indicated above.

The average expenses of health services were calculated to reflect the annual expenditures. Healthcare expenditures data tend to cluster at zero for a large number of children. Thus, data were not normally distributed. To model these data including the expenditures on hospital stays, emergency department visits, ambulatory visits, purchase of prescription medications and total annual expenditures, two-part models were employed. In the first part, a logistic regression model was fit to estimate the probability of any expenses. In the second part, a gamma model with log link was used to predict the expenditures among children with any expenses. Each type of predicted annual expenditure was calculated by multiplying the estimated probability of any expense to the estimated expenditures among children with expenses. Sampled children were divided
into several groups to reflect their asthma diagnosis and the exposure to smoking inside the home. Those reported annual expenditures and their 95% CIs were corresponding to the defined groups. To assess the effect of childhood asthma and secondhand smoke exposure on healthcare expenditures, linear regression models were used. The annual adjusted healthcare expenditures obtained from the two-part models were considered as outcome variables. The regression models contained secondhand smoke exposure and asthma diagnosis, as well as the interaction between asthma and secondhand smoke exposure. The differences in estimated expenditures by asthma diagnosis and secondhand smoke exposure were assessed.

All the statistical analyses were weighted using personal weights given by the MEPS. The statistics were estimated with Stata 12.0 (Stata Corporation, College Station, TX).
Chapter 3: Results

3.1 Characteristics of the Study Population

There were 7,849 children aged 0-11 years enrolled in Panel 6, 2001 and Panel 11, 2006 MEPS. They are the representative of the child population in the U.S. About 0.2% of them did not have information on asthma diagnosis, and approximately 4.5% of them had non-positive weights. Therefore, 7,482 children were included in the present study.

Among the sampled children, about 61.4% were not exposed to adult smoking inside the home, 14% were exposed to secondhand smoke inside the home, and 24.6% did not have complete information on smoking status (Table 1). Among children with complete information on smoking status, approximately 31.5% lived with at least one smoker in the household, and about 18.4% were exposed to secondhand smoke inside their homes during the previous year.

Exposure to secondhand smoke differed by race and ethnicity. Among children who were exposed to the household secondhand smoke, about 74.3% were white, 20.5% were black and 5.2% of them were other races. Among children who did not have secondhand smoke exposure, 78.7% were white, 14.3% were black and 7.0% were other races. Black children were more likely to be exposed to household tobacco smoke compared to White and other races. Hispanic children were at a lower risk of exposure compared to non-Hispanic children. Among children exposed to secondhand smoke,
about 11.1% of them were Hispanic, while among those did not have the exposure, 20.2% were Hispanic children.

In addition, children exposed to household tobacco smoke were more likely to be enrolled in public insurance or be uninsured rather than being enrolled in private insurance. Among children without the exposure, 5.6% were uninsured, 26.2% enrolled in public insurance program; for children with the exposure, about 8.8% and 30.7% were uninsured and had the public insurance, respectively.

Secondhand smoke exposure appeared to have a lower prevalence in the Western US compare to other areas. Based on the household smoke exposure status, among children had such exposure, 12.1% were from the in the West, 18.2% were from the Northeast, 28.9% were from the Midwest, and 40.8% were from the South. The proportion of children from the West appeared to be higher among children without the exposure. Interestingly, among those who exposed to smoking inside the home, children lived in rural area shared a greater proportion. About 15.8% of children who did not expose to secondhand smoke were from rural area and about 84.2% of them were from urban area. The percentage of children from rural area increased to 23.7% among those exposed children. Smoking inside the home was more prevalent in rural areas compared to urban areas.

Smoking inside the home behavior was more likely to occur in the family with low parental education level and low income level. For the sample with household smoke exposure information, about 24.8% of children whose parents had education levels less than high school, about 49.7% of children had parents with high school diploma as the
highest education level, while 11.3% of children’s parents achieved a Bachelor’s degree or higher. In contrast, among children did not expose to secondhand smoke, about 47.8% of children’s parents had high school diploma or lower, and 35.1% of children have parents with bachelor’s degree and higher. Children exposed to secondhand smoke were more likely to live in the families with low income. About 28.8% of children whose family lived under the federal poverty level, among children with the exposure; in contrast, among children without the exposure, 16.3% of them lived under the poverty line. Moreover, children exposed to secondhand smoke were less likely to live at or above 200% poverty. About 62.6% of exposed children lived at or above 200% poverty, while 43.2% of unexposed children whose families lived at this level.

Secondhand smoke exposure did not vary with child’s age, gender, parental asthma history and the number of residents present in the household.
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No Adult Smoked Inside the home</th>
<th>Smoking Status Missing</th>
<th>Any Adult Smoked Inside The Home</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean)</td>
<td>5.5</td>
<td>5.5</td>
<td>5.6</td>
<td>0.12</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50.9%</td>
<td>52.6%</td>
<td>49.6%</td>
<td>0.45</td>
</tr>
<tr>
<td>Female</td>
<td>49.1%</td>
<td>47.4%</td>
<td>50.4%</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>White</td>
<td>78.7%</td>
<td>75.2%</td>
<td>74.3%</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>14.3%</td>
<td>15.3%</td>
<td>20.5%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>7.0%</td>
<td>9.5%</td>
<td>5.2%</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Non-Hispanic</td>
<td>79.8%</td>
<td>75.9%</td>
<td>88.9%</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>20.2%</td>
<td>24.1%</td>
<td>11.1%</td>
<td></td>
</tr>
<tr>
<td>Insurance type</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Uninsured</td>
<td>5.6%</td>
<td>7.8%</td>
<td>8.8%</td>
<td></td>
</tr>
<tr>
<td>Public Insurance</td>
<td>26.2%</td>
<td>44.0%</td>
<td>30.7%</td>
<td></td>
</tr>
<tr>
<td>Private Insurance</td>
<td>68.2%</td>
<td>48.2%</td>
<td>60.5%</td>
<td></td>
</tr>
<tr>
<td>Census Region</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Northeast</td>
<td>16.9%</td>
<td>14.6%</td>
<td>18.2%</td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>21.3%</td>
<td>20.1%</td>
<td>28.9%</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>36.0%</td>
<td>35.6%</td>
<td>40.8%</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>25.8%</td>
<td>29.7%</td>
<td>12.1%</td>
<td></td>
</tr>
<tr>
<td>Urban/Rural Area</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Urban</td>
<td>84.2%</td>
<td>84.4%</td>
<td>76.3%</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>15.8%</td>
<td>15.6%</td>
<td>23.7%</td>
<td></td>
</tr>
<tr>
<td>Parental Asthma History</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Asthma</td>
<td>12.4%</td>
<td>10.6%</td>
<td>13.6%</td>
<td>0.42</td>
</tr>
<tr>
<td>Without Asthma</td>
<td>87.6%</td>
<td>89.4%</td>
<td>86.4%</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Characteristics of the Study Population by Secondhand Smoke Exposure
Table 1. Characteristics of the Study Population by Secondhand Smoke Exposure

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No Adult Smoked Inside the home</th>
<th>Smoking Status Missing</th>
<th>Any Adult Smoked Inside The Home</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest Parent Education level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than High School Diploma</td>
<td>12.4%</td>
<td>16.7%</td>
<td>24.8%</td>
<td></td>
</tr>
<tr>
<td>High School Diploma</td>
<td>35.4%</td>
<td>40.6%</td>
<td>49.7%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Bachelor's Degree and Higher</td>
<td>35.1%</td>
<td>26.8%</td>
<td>11.3%</td>
<td></td>
</tr>
<tr>
<td>Other Degree</td>
<td>17.1%</td>
<td>15.9%</td>
<td>14.2%</td>
<td></td>
</tr>
<tr>
<td>Percentage of Federal Poverty Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 100%</td>
<td>16.3%</td>
<td>19.5%</td>
<td>28.4%</td>
<td></td>
</tr>
<tr>
<td>100%-199%</td>
<td>21.1%</td>
<td>23.2%</td>
<td>28.4%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>&gt;=200%</td>
<td>62.6%</td>
<td>57.3%</td>
<td>43.2%</td>
<td></td>
</tr>
<tr>
<td>Residents Present in the Household (mean)</td>
<td></td>
<td></td>
<td></td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>1.48</td>
<td>1.68</td>
<td>1.49</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>61.40%</td>
<td>24.60%</td>
<td>14.00%</td>
<td></td>
</tr>
</tbody>
</table>

Note: The null hypothesis of test statistic was that characteristic among children exposed to secondhand smoke was not different from the characteristic among children without secondhand smoke exposure. All the values interpreted in the table were weighted.
3.2 Prevalence of Childhood Asthma

The estimated prevalence of childhood asthma was 10.0%, among the U.S. children who were under age 12 years (Table 2). There were disparities in the prevalence of childhood asthma among certain demographic groups. The prevalence of childhood asthma among boys was 11.8%, which was 3.6% higher than the prevalence among girls. The prevalence of asthma was higher among black children compared to children of other races. About 14.9% of black children had childhood asthma, while about 8.9% of white children and 10.8% of children in other races had asthma. The prevalence of asthma appeared to be lower among Hispanic children, the prevalence was about 8.0% among Hispanic children compare to 10.4% among non-Hispanic children. Children with asthma tended to have more access to health insurance, with 95% of them enrolled in public or private insurance. About 12.1% of children who were enrolled in public insurance and 9.3% of children who had private insurance had asthma. Among those who did not have any insurance plan, the prevalence of asthma was about 7.4%. Childhood asthma had a higher prevalence in the Northeast and South compare to West and Midwest. In the South, the prevalence of asthma was about 11.5%, whereas in the Northeast, the prevalence was 10.9%. In the Midwest and West, the prevalence estimates were 7.7% and 9.2%, respectively, which were lower than the overall average prevalence of asthma. Asthma appeared to be more common in urban areas than in rural areas. The prevalence was 10.1% in urban areas, and 8.9% in rural areas. Asthma was associated with parental asthma history; among children with parental asthma history the prevalence was about 24.8% which was 3 times the prevalence among children without parental asthma history. Low
parental education and family income were associated with increased prevalence of asthma. Among children whose parents had a high school degree or less education, the prevalence of asthma was about 10.8%, while among children whose parents achieved a Bachelor’s degree or higher, the prevalence was about 9.1%. In addition, among children who lived under the poverty level, about 12.2% had childhood asthma; while among children lived between 100% and 199% of the poverty line, the prevalence was around 10.2%, and for children lived at 200% or above the poverty line, the prevalence decreased to 9.2%.
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Prevalence of Asthma</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>11.8%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Female</td>
<td>8.2%</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>8.9%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Black</td>
<td>14.9%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>10.8%</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
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<td></td>
</tr>
<tr>
<td>Non-Hispanic</td>
<td>10.4%</td>
<td>0.02</td>
</tr>
<tr>
<td>Hispanic</td>
<td>8.0%</td>
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</tr>
<tr>
<td>Insurance Type</td>
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</tr>
<tr>
<td>Uninsured</td>
<td>7.4%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Public Insurance</td>
<td>12.1%</td>
<td></td>
</tr>
<tr>
<td>Private Insurance</td>
<td>9.3%</td>
<td></td>
</tr>
<tr>
<td>Census Region</td>
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<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>10.9%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Midwest</td>
<td>7.7%</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>11.5%</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>9.2%</td>
<td></td>
</tr>
<tr>
<td>Urban/Rural Area</td>
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<td></td>
</tr>
<tr>
<td>Urban</td>
<td>10.1%</td>
<td>0.59</td>
</tr>
<tr>
<td>Rural</td>
<td>8.9%</td>
<td></td>
</tr>
<tr>
<td>Parental Asthma History</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With Asthma</td>
<td>24.8%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Without Asthma</td>
<td>7.8%</td>
<td></td>
</tr>
<tr>
<td>Highest Education Level of Parents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than High School Diploma</td>
<td>10.6%</td>
<td>0.01</td>
</tr>
<tr>
<td>High School Diploma</td>
<td>10.9%</td>
<td></td>
</tr>
<tr>
<td>Bachelor's Degree and Higher</td>
<td>9.1%</td>
<td></td>
</tr>
<tr>
<td>Other Degree</td>
<td>9.1%</td>
<td></td>
</tr>
<tr>
<td>Percentage of Federal Poverty Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 100%</td>
<td>12.2%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>100%-199%</td>
<td>10.2%</td>
<td></td>
</tr>
<tr>
<td>&gt;=200%</td>
<td>9.2%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10.0%</td>
<td></td>
</tr>
</tbody>
</table>

Note: The null hypothesis of test statistics was the prevalence of asthma did not vary by the distribution of each characteristic; all the values interpreted in the table were weighted.

Table 2. Prevalence of Asthma by Characteristics
Table 3 presents the prevalence of asthma by secondhand smoke exposure inside the home. Asthma prevalence was higher among children who were exposed to secondhand smoke inside the home. Approximately 10.8% of children who were exposed to secondhand smoke had asthma, while among children with no exposure to household smoke, the prevalence of asthma was about 9.5%. Exposure to household smoke was associated with an increased odds of having asthma (OR=1.18, 95% CI=0.97, 1.43). This increase was significant at $\alpha=0.1$ level. The prevalence of asthma among children with missing smoke exposure was not different from the prevalence among children who had no exposure to household tobacco smoke (p-value=0.148).

<table>
<thead>
<tr>
<th>Smoking Status</th>
<th>Prevalence of Asthma</th>
<th>OR(95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Adult Smoked Inside the Home</td>
<td>9.5%</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Smoking Status Missing</td>
<td>10.5%</td>
<td>1.10 (0.96, 1.27)</td>
<td>0.15</td>
</tr>
<tr>
<td>Any Adult Smoked Inside The Home</td>
<td>10.8%</td>
<td>1.18 (0.97, 1.43)</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Note: The ORs were adjusted for child’s age, race, gender, census region and urban or rural area they live, the number of residents present in the home, and the survey year. The prevalence of asthma was weighted.

Table 3. Prevalence and Odds Ratios of Asthma by Secondhand Smoke Exposure
3.3 Healthcare Utilization

In the multivariable regression analyses of healthcare utilization, the interaction between asthma and secondhand smoke exposure and the main effects of those two exposures were assessed, while adjusting for potential confounders. A positive interaction between secondhand smoke exposure and asthma was found when analyzing the use of inpatient services ($p = 0.03$). When asthmatic children were exposed to secondhand smoke inside the home, the odds of having hospital stays increased dramatically (Table 4). Among children without asthma, the odds of having hospital stays increased slightly because of exposure to secondhand smoke. The apparent effect of secondhand smoke exposure was not significant at 0.05 level (OR=$1.10$, 95% CI=$0.84$, 1.49). In contrast, among children with asthma, the effect of smoking inside the home became significant on increasing the odds of having a hospital stay. Among asthmatic children, the odds of having hospital stays among children exposed to household tobacco smoke were 2.18 times the odds among those who were not exposed (OR=$2.18$, 95% CI=$1.29$, 3.67).

There was no significant interaction between presence of smoking inside the home and childhood asthma observed in the utilization of emergency department visits, ambulatory visits and prescription medications. In Tables 5 and 6, the main effects of childhood asthma and secondhand smoke exposure on those healthcare utilizations were assessed, respectively.
### Table 4. Adjusted Odds Ratios of Secondhand Smoke Exposure for Hospital Stays by Childhood Asthma

<table>
<thead>
<tr>
<th>Groups</th>
<th>OR (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Among Non-asthmatic Children</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Adult Smoked Inside the Home (Reference)</td>
<td>1.00</td>
<td>---</td>
</tr>
<tr>
<td>Any Adult Smoked Inside the Home</td>
<td>1.10 (0.84, 1.49)</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Among Asthmatic Children</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Adult Smoked Inside the Home (Reference)</td>
<td>1.00</td>
<td>---</td>
</tr>
<tr>
<td>Any Adult Smoked Inside the Home</td>
<td>2.18 * (1.29, 3.67)</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Note: The odds ratios were adjusted for child’s age, race, gender, census region and urban or rural area they live, insurance status, and their family’s poverty level, the number of residents present in the home, parental asthma history, the highest education level of parents and the survey year.

*p-value of test statistic <0.05
Table 5 presents the adjusted effect of having asthma on use of health care services. Childhood asthma was positively associated with the use of healthcare services. Having asthma was associated with 66% increased odds of having emergency department visits (OR=1.66, 95%CI=1.43, 1.93). The odds of having ambulatory visits among asthmatic children were 1.69 times the odds among children without asthma (OR=1.69, 95%CI=1.25, 2.29). A significant increase in the use of prescription medications was observed among children with asthma. The odds of using prescription medications among children with asthma were 4.36 times the odds of use among children without asthma (OR= 4.36, 95%CI=3.72, 5.77).

<table>
<thead>
<tr>
<th></th>
<th>Non-asthmatic Children (Reference group)</th>
<th>Asthmatic Children</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Department Visits</td>
<td>1.00</td>
<td>1.66 (1.43, 1.93)*</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Ambulatory Visits</td>
<td>1.00</td>
<td>1.69 (1.25, 2.29) *</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Prescription Medications</td>
<td>1.00</td>
<td>4.36 (3.72, 5.77) *</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>6,707</td>
<td>775</td>
<td></td>
</tr>
</tbody>
</table>

Note: The odds ratios were adjusted for secondhand smoke exposure, child’s age, race, gender, census region and urban or rural area they live, insurance status, and their family’s poverty level, the number of residents present in the home, parental asthma history, the highest education level of parents and the survey year.

*p-value of test statistic<0.05

Table 5. Adjusted Odds Ratios for Utilization of Health Services by Asthma Diagnosis
The results of healthcare utilization by household smoke exposure suggests that adult smoking inside the home was associated with an increased odds of having emergency department visits and using prescription medications (Table 6). Exposure to secondhand smoke exposure was associated with 37% increase in the odds of having emergency department visits (OR=1.37, 95%CI=1.24, 1.51). This estimate suggests the odds of using emergency department visits were higher among children who exposed to secondhand smoke inside the home. There was an apparent increase in uses of prescription medications among children exposed to secondhand smoke inside the home, which indicate the utilization of prescription medications was higher among children exposed to secondhand smoke, but the estimate was not statistically significant (OR=1.12, 95%CI=0.85, 1.47). The difference in the odds of having ambulatory visits among children exposed to household smoke compare to children who did not have such exposure was also not statistically significant. There was no difference in use of healthcare utilization between children who were not exposed to smoking inside the home and children who did not have complete household smoking information.
<table>
<thead>
<tr>
<th></th>
<th>No Adult Smoked Inside (Reference group)</th>
<th>Any Adult Smoked Inside</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Department Visits</td>
<td>1.00</td>
<td>1.37 (1.24, 1.51) *</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Ambulatory Visits</td>
<td>1.00</td>
<td>0.86 (0.64, 1.14)</td>
<td>0.28</td>
</tr>
<tr>
<td>Prescription Medications</td>
<td>1.00</td>
<td>1.12 (0.85, 1.47)</td>
<td>0.43</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>4,638</td>
<td>1,048</td>
<td></td>
</tr>
</tbody>
</table>

Note: The odds ratios were adjusted for childhood asthma, child’s age, race, gender, census region and urban or rural area they live, insurance status, and their family’s poverty level, the number of residents present in the home, parental asthma history, the highest education level of parents and the survey year. *p-value of test statistic <0.05

Table 6. Adjusted Odds Ratios for Utilization of Health Services by Secondhand Smoke Exposure
3.4 Healthcare Expenditures

Based on the two-part models and regression model analyzing the interaction between childhood asthma and secondhand smoke exposure, the main effects, childhood asthma and secondhand smoke exposure, and the effect of their interaction on estimated healthcare expenditures were examined, adjusting for potential confounders. For the predicted expenditures for hospital stays and emergency department visits, the interaction was statistically significant. Table 7 presents these two types of estimated expenditures for an average child with and without asthma, by secondhand smoke exposure. The point estimates suggest that secondhand smoke exposure was associated with higher expenditures for hospital stays and emergency department visits. This effect was more significant among children with asthma.

In general, the average estimated expenditure on hospital stay for a child without asthma and secondhand smoke exposure was about $230.10 (95%CI= $219.87, $240.33) and the expenditure for a non-asthmatic child with secondhand smoke exposure was about $306.58 (95%CI= $283.67, $329.48). In the analyses, we found that among children without asthma, exposure to household tobacco smoke was associated with an additional $76.48 in annual expenditure of hospital stays for each child, and such difference was statistically significant (95%CI= $53.95, $99.01). Among children with asthma, the increase in hospital stay expenditures associated with secondhand smoke exposure was much higher. About $959.90 additional expenditures for hospital stays per year for an asthmatic child was due to secondhand smoke exposure (95%CI= $859.68, $1060.12). For a child with asthma, the estimated average expenditure for hospital stays was about
$727.17 if he/she had no exposure to secondhand smoke inside the home (95%CI= $667.44, $786.90), and the expenditure increased to $1687.07 if a child exposed to such exposure (95%CI= $1584.29, $1789.85).

For a child without asthma, the additional estimated expenditure for emergency department visits caused by exposed to secondhand smoke inside the home was about $9.33 per year (95%CI= $5.86, $12.80). The increased emergency department expenditure caused by such exposure for an asthmatic child was higher compare to non-asthmatic child. The estimated additional expenditure was $27.83 (95% CI=$15.50, $40.17). Among non-asthmatic children, the cost of emergency department visits was about $76.85 per person per year, if one was not exposed to secondhand smoke inside the home (95% CI=$75.39, $78.32). When the child without asthma was exposed to secondhand smoke, the cost of emergency department visits increased to $86.18 (95% CI=$82.80, $89.56). For a child with asthma, the expense for emergency department visits increased from $206.40 (95%CI= $195.21, $217.60) to $234.24 (95% CI= $223.35, $245.12) among those exposed to secondhand smoke.

The expenditures for ambulatory visits, prescription medications and total healthcare expenditures were higher among asthmatic children compare to non-asthmatic children. However, such difference did not depend on exposure to secondhand smoke. The analysis of estimated expenditures for ambulatory visits, prescription medications and total healthcare expenditures by childhood asthma and secondhand smoke exposure are presented in Table 8 and Table 9, respectively.
Table 8 suggests that having asthma was associated with significantly higher predicted expenditures in ambulatory visits, prescription medications and total healthcare expenditure. The additional annual expenditures due to asthma were about $165.87 (95% CI= $147.98, $183.75) for ambulatory visits and $396.06 (95% CI=$373.84, $418.28) for prescription medications. For a child without asthma, the estimated healthcare expenditures were $1032.13 per year (95% CI= $1021.35, $1042.90); for an asthmatic child, the total expenditures increased to $ 2401.96 (95% CI = $2337.52, $2466.40). A total of $1369.84 additional expenditures were found to be associated with childhood asthma (95% CI= $1311.10, $1428.57).

In Table 9, the presence of smoking in the home was significantly associated with an increase in the annual total healthcare expenditures. Children exposed to secondhand smoke exposure spent an additional $50.61 on medical care every year (95%CI=$19.47, $81.74). There was no relationship between the presence of smoking in the home and prescription medication expenditures. A decrease in the expenditures for ambulatory visits associated with household smoke exposure was observed.

No significant difference in expenditures was found among children with incomplete household smoking information compare to those who did not expose to secondhand smoke inside the home.
### Table 7: Estimated Annual Expenditures for Hospital Stays and Emergency Department Visits by Childhood Asthma and Secondhand Smoke Exposure

<table>
<thead>
<tr>
<th></th>
<th>Non-asthmatic Children</th>
<th>Asthmatic Children</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Adult Smoked Inside</td>
<td>Any Adult Smoked</td>
</tr>
<tr>
<td></td>
<td>the Home (95% CI)</td>
<td>the Home (95% CI)</td>
</tr>
<tr>
<td>Hospital Stays</td>
<td>$ 230.10 (219.87, 240.33)</td>
<td>$ 306.58 (283.67, 329.48)</td>
</tr>
<tr>
<td>Emergency Department</td>
<td>$ 76.85 (75.39, 78.32)</td>
<td>$ 86.18 (82.80, 89.56)</td>
</tr>
<tr>
<td>Visits</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The estimated expenditures were adjusted for child’s age, race, gender, census region and urban or rural area they live, insurance status, and their family’s poverty level, the number of residents present in the home, parental asthma history, the highest education level of parents and the survey year. The effect of secondhand smoke exposure was the estimate of the difference in estimated expenditures for children observed to be exposed to secondhand smoke exposure compare to those who did not exposed to the exposure.

*p-value of test statistic <0.05
<table>
<thead>
<tr>
<th></th>
<th>Non-asthmatic Children</th>
<th>Asthmatic Children</th>
<th>Effect of Childhood Asthma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulatory Visits</td>
<td>$374.24 (356.36, 392.13)</td>
<td>$540.11 (508.73, 571.48)</td>
<td>+$165.87* (147.98, 183.75)</td>
</tr>
<tr>
<td>Prescription Medications</td>
<td>$104.87 (102.69, 107.06)</td>
<td>$500.93 (477.96, 523.90)</td>
<td>+$396.06* (373.84, 418.28)</td>
</tr>
<tr>
<td>Total Expenditures</td>
<td>$1032.13 (1021.35, 1042.90)</td>
<td>$2401.96 (2337.52, 2466.40)</td>
<td>+$1369.84* (1311.10, 1428.57)</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>6,707</td>
<td>775</td>
<td></td>
</tr>
</tbody>
</table>

Note: The odds ratios were adjusted child’s age, race, gender, census region and urban or rural area they live, insurance status, secondhand smoke exposure, and their family’s poverty level, the number of residents present in the home, parental asthma history, the highest education level of parents and the survey year.

*p-value of test statistic < 0.05

Table 8. Estimated Annual Expenditures for Ambulatory Visits, Prescription Medications and Total Expenditures by Childhood Asthma
Note: The odds ratios were adjusted for child’s age, race, gender, census region and urban or rural area they live, insurance status, childhood asthma, and their family’s poverty level, the number of residents present in the home, parental asthma history, the highest education level of parents and the survey year.

*p-value of test statistic <0.05

Table 9. Estimated Annual Expenditures for Ambulatory Visits, Prescription Medications and Total Expenditures by Secondhand Smoke Exposure

<table>
<thead>
<tr>
<th></th>
<th>No Adult Smoked Inside</th>
<th>Any Adult Smoked Inside</th>
<th>Effect of Secondhand Smoke Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulatory Visits</td>
<td>$412.46</td>
<td>$294.014</td>
<td>-$118.45 (-128.93,-107.97)</td>
</tr>
<tr>
<td></td>
<td>(392.70, 432.23)</td>
<td>(281.28, 306.75)</td>
<td></td>
</tr>
<tr>
<td>Prescription Medications</td>
<td>$143.63</td>
<td>$142.97</td>
<td>-$0.66 (-9.76, 8.45)</td>
</tr>
<tr>
<td></td>
<td>(138.56, 148.68)</td>
<td>(136.21, 149.72)</td>
<td></td>
</tr>
<tr>
<td>Total Expenditures</td>
<td>$1156.302 (1138.58, 1174.03)</td>
<td>$1206.91 (1178.33, 1235.49)</td>
<td>+$50.61 (19.47, 81.74)</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>4,638</td>
<td>1,048</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 4: Discussion

To our knowledge, this is first study to examine the effect of secondhand smoke exposure on healthcare utilization and expenditures among asthmatic children, using a nationally representative data set.

First, we found an increased prevalence of asthma among children who exposed to secondhand smoke inside the home. The presence of smoking inside the home was associated with 18% increase in the odds of having childhood asthma. Our finding is consistent with previous studies.\(^{22-24}\)

Second, the utilization of some certain types of health service was associated with childhood asthma and secondhand smoke exposure. In general, asthmatic children were more likely to use the health services. The presence of smoking inside home appeared to intensify this situation. The result suggested that among asthmatic children, secondhand smoke exposure was associated with more than doubling the odds of hospitalization. While among the children without asthma, the impact of secondhand smoke exposure was not statistically significant. This finding supports the idea that the presence of smoke inside the home may exacerbate children’s asthma symptoms. In the other words, if children have asthma, their exposure to secondhand smoke may dramatically raise their risks of hospital stay. After controlling for child’s asthma diagnosis, exposure to secondhand smoke inside the home increased the odds of having emergency department
visits by 37%. We also observed that children exposed to secondhand smoke inside the home had higher odds of having expenses on prescription medications. However, this factor was not strong enough to be statistically significant.

The findings that secondhand smoke exposure raised children’s health utilization on hospitalization and emergency department visits confirmed the results conducted by Hill et al. who reported that the presence of smoking in the home was related to about 36% of the hospitalizations and 18% of emergency department visits among young children \(^{18}\). Additionally, in Hill’s study, they indicated that smoking inside the home was not associated with increased prescription medications as well. Their estimations of prescription medications between children who exposed and did not exposed to secondhand smoke were similar.

Finally, we found that healthcare expenditures were more costly among children with asthma, and the presence of smoking inside the home aggravated the increased expenditures for hospital stays and emergency department visits among asthmatic children. A great economic burden was observed among asthmatic children, which is consistent to the previous reports \(^{11,14}\). Moreover, the presence of smoking inside the home was associated with higher expenditures for hospital stays and emergency department visits. The increased expenditures caused by smoking inside the home among asthmatic children were significant higher compare to non-asthmatic children. For a child with asthma, the increased annual expenditure for hospital stays attributed to secondhand smoke exposure was about $883.42 higher compare to a non-asthmatic child. A similar trend was observed for the expenditures for emergency department visits. Secondhand
smoke caused the costs of healthcare for a non-asthmatic child to increase by $9.33, while for an asthmatic children about $27.83 increase were caused by secondhand smoke. The amounts of our estimates of expenditures for hospitalization and emergency department visits are consistent with the previous studies, which validate the accuracy of these estimations\textsuperscript{15,18}. These findings suggest that secondhand smoke exposure may aggravate children’s health expenditures and their health conditions, especially among asthmatic children.

After adjusting for childhood asthma, exposure to secondhand smoke inside the home raised the total healthcare expenditures by $50.61 per year. The expenditures for prescription medications stayed the same by the household smoking status. Previous estimates for the effect of secondhand smoke exposure on annual healthcare expenditures consisted of mixed results. Using MEPS data, a recent study by Levy and colleagues found that there was no association between secondhand smoke exposure and total health expenditures among Medicaid children, including total expenses and prescription costs\textsuperscript{15}. Although the results were not statistically significant, they observed an increasing trend for total expenses, which was found significant in the current study. In the Florence et al. study, using 2000 to 2003 MEPS data and the file linked to the NHIS, they found that exposure to household smoking was associated with lower total expenditures among children aged 12 years and under\textsuperscript{17}. The authors explained that their negative finding might be due to smoker parent’s lower orientation toward preventive healthcare. Thus, children who lived with smokers may have less access of healthcare and healthcare
related expense. This explanation appears to be plausible for our study. We found that children exposed to secondhand smoke were less likely to have ambulatory visits.

Our results about observing lower odds of ambulatory visits and expense on ambulatory services among children exposed to secondhand smoke can be further explained in several ways. First, these results were consistent with previous reports. In Hill and Liang’s study, they also detected that children who were exposed to smoking inside the home used less ambulatory services, although this difference was not significant \(^1^8\). In addition, other studies found that environmental tobacco exposure was not necessarily associated with more uses of outpatient consultations as well \(^1^9,^4^8\).

Second, adult smokers may have less sense of using preventive health services \(^1^7,^1^9,^4^9\). A Dutch birth-cohort study found that mothers who smoke tend to underutilize health services when their children had mild respiratory problem. However, for the severe respiratory diseases, being a smoker did not affect the behavior of seeking for healthcare \(^5^0\). Thus, parents who smoke may be less likely to seek preventive services such as outpatient and office-based consultations for children when the conditions have not developed into serious cases. It also explains our findings that children exposed to secondhand smoke had higher utilization and expenditures for hospital stays and emergency department visits. Finally, given that children exposed to smoking inside the home were less likely to have ambulatory visits, they tend to spend less money on ambulatory visits as well.

The lower estimates on expenditures for ambulatory visits led to relatively lower estimates on total expenditures, as ambulatory expenditures accounted for a considerable
amount of total expenditures. As indicated above, we found that the presence of smoking in the household was associated with a $50.61 increase in the total expenditures per child per year, which is lower than the estimates in some previous studies. In Stoddard and Gray’s study, maternal smoking was associated with an additional $120 in respiratory expenditures per child age 0-5 in 1995 dollars, which inflated to 2010 dollars would be $183.54 \textsuperscript{20}. The data for this study were derived from the 1987 National Medical Expenditures Survey (NMES) data. Besides the current study has lower ambulatory expenditures, the differences between their results and ours might be due to the changes in healthcare policies. The implementation of State Children’s Health Insurance Program ensured more children enrolled in the public insurance, which may lead to a decrease of the annual healthcare expenditures among children \textsuperscript{51}. Hadley et al. found that among children who were public insurance enrollees the health services was less costly compare to children who enrolled private insurance \textsuperscript{51}. Moreover, Stoddard’s study focused on the change in respiratory expenditures, which is closely related to tobacco smoke exposures. Only analyzing expenditures for respiratory conditions would enhance the impact of such exposure. Therefore, the estimated increase in respiratory expenditures caused by presence of smoking inside the home tends to be higher than the increase in the average total expenditures. Another study conducted by Hill et al. indicated that smoking inside the home was associated with an additional $135.06 annual expenditure on respiratory conditions per child, in 2010 dollars \textsuperscript{18}. In addition to the strong relationship between secondhand smoke exposure and respiratory expenditures mentioned above, the different age groups may account for the reason that they get a higher estimate. As Hill and Liang
suggested, children aged under 5 appear to spend most of their time at home, therefore, they tend to have the higher level of exposure compared to older children.

This study contains several limitations. First, exposure to secondhand smoke was reported by a family member. If that selected respondent under reported the presence of smoking inside the home, the effect of this exposure to the healthcare utilization and expenditures may be underestimated. However, we have indicated that self-reported smoking behavior is a valid proxy to measure the exposure to secondhand smoke. Second, the interview question that asks about the presence of smoking inside the home in the 2005 NHIS was different from the one in the 2000 NHIS. In 2000, the NHIS asked how many days anyone smoked inside the home during the past week. However, in 2005, they asked whether or not the residents of the household smoked inside home. It is possible that someone other than the household residents smoked inside the house and has been reported to the NHIS in 2000. Fortunately, if anyone smoked less than one day per week inside the household, the NHIS defined this condition as nobody smoked inside the home, which avoided the overestimation of exposure level. Finally, there might be some unmeasured confounders exist in the relationship among exposure to secondhand smoke, childhood asthma and healthcare utilization and expenditures. For example, parents who smoke may feel reluctant to bring their children to see a doctor, especially for asthma-related symptoms; under report their smoking behavior or children’s uses of healthcare because of feeling guilty; or reduce their smoking behavior to alleviate the asthma symptoms of their children. In addition, we did not measure the geographic variance in healthcare expenditures, the distribution of health resources and price of
health services. Because of the uneven distribution of those factors, a selection bias might exist in the study. Based on our study, children who exposed to secondhand smoke were more likely to live in the Midwest and South of the US. While, according to AHRQ, individuals who live in those areas have a lower accessibility of care, because lower quantities of medical cares and less physicians provided in those regions\textsuperscript{54-55}. It may lead those individuals have less spending on health care\textsuperscript{54-55}. The existence of unmeasured factors and potential selection bias may decrease the estimated impact of secondhand smoke in the current study.
Chapter 5: Conclusion

In conclusion, the present study found that children exposed to secondhand smoke were associated with higher healthcare utilization and expenditures. The adverse impact of secondhand smoke appeared to be more serious among asthmatic children. Therefore, to reduce smoking behavior may help children to improve their health and reduce the healthcare expenditures. To better address the association between secondhand smoke and healthcare uses among asthmatic children, the future study should measure the exposure to secondhand smoke directly, and control for the discrepancies on the attitudes of seeking for doctors between smoking and non-smoking parents and the disparities of accessing health services.
References


9. Barman S. Global burden of asthma. *Chest*. 2006;130:4S-12S


