Secondhand Smoke Exposure and Adverse Asthma Events

Among Low-Income Michigan Children

by

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DEDICATION

In memory of Dr. Noreen Clark and Dr. Mary Fran Sowers, two women who taught me the value of public health with grace, rigor, and integrity.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
%	Percent
95% CI	95 percent confidence interval
ACS	American Community Survey
AIC	Akaike information criterion
Ban	Michigan Ron Davis Second Hand Smoke Ban
ED	Emergency department
ETS	Environmental tobacco smoke
FEV_1	Forced expiratory volume
FEV_{25-75}	Forced expiratory volume
ICD-9-CM	International Classification of Diseases - 9 - Clinical Modification
ICS	Inhaled corticosteroids
LCL	Lower Confidence Limit
LTC	Long-term controller medications to reduce and prevent inflammation within the airway
MDHHS	Michigan Department of Health and Human Services
n	Number
OC	Oral corticosteroid
PAMUC	Pediatric Asthma Medicaid Utilization Cohort
QIC	Quasi-likelihood information criterion
RR	Rate ratio
SABA	Short acting beta-agonists
SE	Standard Error
SES	Socioeconomic status
SHS	Secondhand smoke
Std	Standard
U.S.	United States
UCL	Upper Confidence Limit

ABSTRACT

More than eight percent of United States' children have asthma, with more than half having an asthma exacerbation annually. Minority children and those living in low income households are more likely to experience adverse asthma events and to be exposed to secondhand smoke (SHS), a potent trigger of exacerbations. State smoking bans are associated with reductions in SHS exposure and rates of cardiovascular and respiratory events. This study assesses the impact of Michigan's Dr. Ron Davis Smoke Ban on asthma exacerbations among low-income children and identifies potential effect modification by individual and area level exposures on that association.

A cohort of 98,277 children with full coverage in Michigan Medicaid programs and health care utilization consistent with a diagnosis of persistent asthma contributed 4,335,439 months to the cohort between 2007 and 2012. The 48,500 adverse asthma events (representing exacerbations) identified from administrative claims data were compared to area level estimates of neighborhood disadvantage and indicators of exposure to smoking bans.

Rates of adverse asthma events were associated with non-white race, younger age, poor asthma control in identification year and increasing neighborhood deprivation.

The ban was associated with a 17 percent reduction in asthma events (95% CI: 12-21 percent), adjusting for age group, sex, race/ethnicity, calendar month, prior poor control, prior local smoking ban, and neighborhood disadvantage. The 17 percent reduction is equivalent to 9,400 asthma events during the follow up period, which would have resulted more than $11,000,000 in emergency department charges alone. Children in prior poor control had a larger reduction in adverse asthma events after ban enactment than those with no prior evidence of poor control. Use of asthma medications exhibited similar reductions in the post-Ban period. The injury visit rate showed a smaller reduction, suggesting the reduction in asthma events was not solely due to a secular trend.

These findings support the continued enforcement of Michigan's Ban and provide evidence for the importance of environmental policy for improving asthma management in Michigan. This cohort provides a data model for other jurisdictions needing to assess or predict the impact of a smoking ban.

CHAPTER I

Introduction

The purpose of this dissertation is to further the understanding of the impact of secondhand smoke bans on asthma control among children, particularly low-income children. Specifically, this research estimates the impact of Michigan's Ron Davis Secondhand Smoke Ban (ban) on the number of times asthma control is lost among low-income children and identifiers potential effect modification by social exposures.

Nearly 7 million children in the United States (U.S.) currently have asthma[1,2]. Prevalence is higher among black children than white and among children living below the poverty level than those living above 4.5 times the poverty level[2]. Asthma results in 137,000 hospital stays, 868,000 ED visits, and 209 deaths among children in the nation each year[3,4], as well as 13.8 million missed school days[1,4]. Racial and economic disparities in rates of adverse asthma events are even greater than those for prevalence[1], due to the complex interplay of factors that increase exposure to triggers of asthma exacerbations at multiple levels[5-9], such as poor indoor[10,11] and outdoor air quality[12-16], and increased stress[5,8,17-21]. Exposure to secondhand smoke (SHS) is a well-known trigger of asthma exacerbations[22-24] and is more prevalent among low income households.

Because the use of non-smoking sections, building ventilation and air cleaners cannot eliminate SHS exposure[24], total bans on smoking are necessary to reduce SHS exposure among nonsmokers. The majority of U.S. residents living in poverty are exposed to SHS[25]. A quarter of children live with someone who actively uses tobacco, although only 7.6 percent of respondents say tobacco is used in their home[26]. Exposure in the home decreases with increasing household income; and children who are black, have public insurance, or have periods without insurance are more likely to be exposed than children lacking these characteristics. However, even children who do not live with an active smoker may be exposed to SHS by visitors or due to air flow between adjacent units and hallways in multi-family or mixed business/residential housing[27]. Children are also exposed at the homes of other caregivers or day care centers. Many schools still do not prohibit tobacco use at all times in all locations[28,29].

Implementation of jurisdictional smoking bans has been associated with SHS exposure reductions[23,30], increased smoking cessation attempts[23], and decreased cardiovascular and respiratory events[30-38]. The impact of bans on occupational SHS exposure and smoking rates has been documented, but these bans can also have potential benefits to pediatric asthma control. Smoking bans should aid children through reductions in direct SHS exposure in public places or as caregivers or neighbors quit smoking. Low income children, with higher exposure levels and less ability to mitigate that exposure, should benefit particularly from this type of policy change, leading to reduction in adverse events, of heightened importance for low income families.

A higher proportion of Michigan children are exposed to SHS at home [10.4 percent] than for those in the United States. The proportion exposed among Michigan children

diagnosed with asthma is even higher (14 percent)[39]. The Michigan Legislature passed the Dr. Ron Davis Smoke Ban, banning smoking in public places, including worksites, effective May 1, 2010[40,41]. Based on the reductions observed from bans in other jurisdictions, a reduction in adverse asthma events should result from its implementation. Many challenges to this law and its enforcement are underway; thus, an assessment of the potential impact of this ban on children's health is important to inform the enforcement. Although associations between asthma events and SHS exposure are known[31,36-38,42], questions remain about sensitive periods to SHS exposure, longevity of ban effects, and how effects of bans may differ according to predictors of poor asthma control[6,7,9,43,44]. For example, most studies that found event reductions after ban implementation[30,32-35] did not explore effect modification by economic or racial segregation.

This protocol for this study was approved by the Institutional Review Boards of the University of Michigan (#HUM00077886) and the Michigan Department of Health and Human Services (201306-01-EA).

Specific Aims and Hypotheses

Aim 1: Create a dynamic cohort of children with asthma served by the Michigan Medicaid programs, including information on demographics, asthma utilization, and area level characteristics of residential area.

Aim 2: Describe the baseline and current characteristics that predict higher numbers of adverse asthma events among children enrolled in Medicaid.

Hypothesis 2a: Children with claims history suggestive of poor asthma control during their identification year will have a higher rate of adverse events during the study period than children without this history.

Hypothesis 2b: The rate of adverse asthma events will be higher among children living in a census block group of economic deprivation than those in living in a less deprived areas.

Aim 3: Estimate the possible impact of Michigan's secondhand smoke ban on the number of adverse asthma events among low-income children.

Hypothesis 3a: Children in the cohort will have a reduced rate of adverse asthma events after the implementation of the ban compared to before the enactment period.

Hypothesis 3b: Children in the cohort will have the same rate of adverse injury events after the implementation of the ban as they had before the enactment period.

Aim 4: Identify characteristics that potentially modify the association between the ban and adverse asthma events.

Hypothesis 4a: The reduction in the rate of adverse asthma events will differ by age group.

Hypothesis 4b: The reduction in the rate of adverse asthma events will be larger among children with a claims history suggestive of poor asthma control during their identification year than those without that history.

Hypothesis 4c: The reduction in the rate of adverse asthma events will differ by racial/ethnicity group.

Hypothesis 4d: The association between the ban and rate of adverse asthma events will be weaker among children living in areas with a past local smoking ban prior to the state ban passage than among children living in areas without a prior local ban.

Hypothesis 4e: The association between the ban and the rate of adverse asthma events will be stronger among children living in census block groups with economic deprivation than among children living in other census block groups.

Background

Definitions of Asthma Control and Adverse Asthma Events

Asthma is an inflammatory disease of the airways "characterized by variable and recurring symptoms, airflow obstruction, bronchial hyper responsiveness, and an underlying inflammation[45]." Asthma cannot be cured but, for most people, can be controlled to provide an adequate quality of life, prevent loss of lung function, and reduce the risk of future asthma events. Most public health interventions focus on gaining and maintaining control of the disease, rather than on prevention of new incident cases.

Clinical asthma management begins with an assessment of clinical history and lung function to understand the current level of asthma control[45]. Asthma control is defined by current lack of functional impairment and a low risk of future events[45,46]:

> "Impairment is the assessment of the frequency and intensity of symptoms, as well as the functional limitations that the patient is experiencing now or in the past because of his or her asthma. Risk is the estimate of the likelihood of an asthma exacerbation, progressive loss of pulmonary function over time caused by asthma, or an adverse event caused by medication or even death."[46]

The Epidemiology and Natural History of Asthma: Outcomes and Treatment Regimes (TENOR) Study found that patients whose asthma was very poorly controlled (measured by lung function, symptoms and short-acting beta agonist (SABA) use over two

years) had a much higher risk of hospitalization, emergency department (ED) visits, or oral corticosteroid (OC) bursts (short course of OC to manage acute severe exacerbations[47]) compared with individuals whose control improved over two years[48]. Past loss of asthma control predicts future asthma exacerbations in other studies as well[49-51]. Although it is impractical to collect lung function testing and clinical history on a national scale, some population-based surveys collect self-reported data on the frequencies of asthma symptoms and management behaviors[52].

Control is achieved and maintained through reducing airway inflammation and preventing bronchoconstriction[53]. Pharmacologic therapy is crucial, including use of SABAs to respond to acute bronchoconstriction or prevent exercise-induced bronchospasm, and the routine use of long-term controller (LTC) medications to reduce and prevent inflammation within the airway (inhaled corticosteroids (ICS) being the first line response)[45]. The National Heart, Lung, and Blood Institute's (NHLBI) Guidelines for the Diagnosis and Treatment of Asthma recommend that health care providers monitor the use of asthma medication needed by children, the number of asthma exacerbations (including use of oral corticosteroids or number of urgent visits or hospitalizations) experienced, and objective measures of pulmonary function to assess both impairment and risk domains for the development of progressive disease.

The NHLBI's Expert Panel recommended that the goal of asthma therapy is to maintain long-term control of asthma with the least amount of medication. Therapy is approached in a stepwise manner, in which the dose and number of medications and frequency of administration are increased as necessary in response to measures of asthma symptoms or exacerbations to achieve control and decreased when possible to maintain

this control with minimum medication necessary. Therefore, asthma control is both a predictor and an outcome in understanding asthma management, which has important implications for research into interventions to improve asthma control.

However, medications cannot solely provide asthma control. Trigger avoidance is essential to asthma management, particularly to maintaining control and preventing future exacerbations. As the majority of asthma management, particularly trigger avoidance, occurs in homes, workplaces, and schools, the ability of the child with asthma to successfully obtain and maintain control over asthma is not solely under his/her control[45,54].

Distribution of Adverse Asthma Events in the United States

Asthma results in 137,000 hospital stays, 868,000 ED visits, and 209 deaths among children in the nation each year[3,4], as well as 13.8 million missed school days[1,4]. There are distinct racial disparities in the rates of adverse asthma events that are long standing. During the 2007-2009 period, black children have rates of ED visits, hospitalizations and deaths due to asthma that are 4.1, 3.0, and 7.6 times higher than respective rates for white children; 2.6, 2.0 and 4.9 times higher after adjusting for prevalence differences[52]. These disparities may be due to increased exposure to triggers of asthma exacerbations, including poor indoor air quality in homes[10,11] and outdoor air pollution[12-16], as well as increased stress[5,8,14,17-21], reduced socioeconomic status and lack of access to quality asthma care[55-59]. The disparities are thought to be due to the complex interplay of these factors across the lifespan[5-9,14,60,61].

Distribution of Adverse Asthma Events among Michigan Children

More than 260,000 Michigan children have asthma (11 percent, 95% CI: 9.3-13.1)[62]. Although the majority (74 percent, 95% CI: 69.0 - 79.6) reportedly had a routine asthma visit in the past year[39], the use of basic tools and medications for management is suboptimal. Only 44 percent of children with asthma were reported ever to have received an asthma management plan about medication use and trigger avoidance from a health care provider[63]. Less than one-third (30 percent; 95% CI: 25.0-36.0) reported using an ICS in the past quarter[63].

This lack of routine management results in adverse asthma events. More than one half of Michigan children with asthma have an exacerbation each year[63], with 18 percent going to an ED or urgent care center due to asthma (95% CI: 13.4-22.4) and 8.5 percent (95% CI: 5.5-12.9) having more than one urgent visit in the year[39]. Black children were 3.3 times as likely to have had two or more ED/urgent care visits than white children, with 19 percent (95% CI: 8.5-38.3) of black children with asthma being reported to have two or more visits in the last year (white children: 6 percent (95% CI: 3.8-8.9))[39]. Although pediatric asthma hospitalization rates dropped significantly over two decades[64], asthma is still the third leading cause of pediatric hospitalizations (14 hospitalizations per 10,000 children), after injury/poisonings and pneumonia[65], and racial disparities persist.

The one million Michigan children[66] enrolled in state-administered Medicaid programs are at an even higher risk of adverse asthma events than higher income children. More than five percent have claims evidence consistent with a diagnosis of persistent asthma each year[67]. Seventy percent of pediatric asthma deaths each year are among children enrolled in Medicaid programs[68]. Children in the Medicaid programs experienced more than one half of asthma hospitalizations in the state (1,740 of 3,354 in 2010)[69,70].

More than five percent of children in Michigan Medicaid had paid claims and encounters consistent with asthma (n=39,700) in a single year[69]. Claims data provide a mechanism to follow a child's health care utilization over time. However, use of paid claims and encounters to identify disease status will underestimate the true disease prevalence[71,72] as the estimate will not capture children who had insurance in addition to Medicaid, were not continuously enrolled during the surveillance period, or who did not submit claims for asthma care[72,73]. Regardless, claims data can provide some important information about children who had contact with the health care system for their asthma.

Even among this low-income population, racial disparities in adverse asthma events exist. In 2010, over one-quarter of children with asthma enrolled in Michigan Medicaid programs had at least one ED visit (28 percent; 95%CI: 27.3-28.4)[69]; with black children (43 percent) being 2.5 times as likely to have a visit as white children (18 percent). The ED visit prevalence was lower in rural areas (16 percent) than urban (31 percent). Although only six percent had two or more ED visits, the racial disparity was high (10 percent of black children vs. 3 percent of white) and urban children (7 percent) were three times higher than rural children (2 percent) to have multiple events[69]. Although, as with the general pediatric population, pediatric asthma hospitalization rates dropped among Michigan Medicaid enrollees between 2005 and 2010[69]; disparities by race and geography persist.

Secondhand Smoke Exposure and Asthma

In 2006, the U.S. Surgeon General concluded that secondhand smoke (SHS) exposure contributes to increased levels of morbidity and mortality due to cardiovascular and

respiratory diseases and cancer, with no risk-free level of exposure discernible. The Institute of Medicine supported the conclusion that

> "evidence is sufficient to infer a causal relationship between exposure to secondhand smoke and increased risk of coronary heart disease morbidity and mortality among both men and women[23,24]."

SHS exposure among children was determined to cause premature death and disease, as well as an increased risk for sudden infant death syndrome, acute respiratory infections, ear problems, and slowed lung growth[24].

Exposure to SHS, particularly through maternal smoking, is associated with increased asthma symptoms and exacerbations among children in the United States[42,74-77]. Increased exposure to SHS reduces forced expiratory volume (both FEV_1 and FEV_{25-75}) and other pulmonary function measures in a dose-dependent manner[42]. Children who live with a smoker also have higher numbers of respiratory-related missed school days than non-exposed children[42]. These associations tend to be stronger among younger children and reduce with increasing age.[78]

Across the world, children are involuntarily exposed to SHS at home and in public, with disparities in exposure reflecting structural, racial and economic vulnerabilities in each region[78]. Although SHS exposure among nonsmokers in the U.S. is declining (52 percent in 1999 to 40 percent in 2008 and to 25 percent in 2012), 58 million nonsmokers have SHS exposure[25,79]. Racial (47 percent of blacks vs. 22 percent of whites) and economic disparities persist (44 percent people living below poverty line). Two of five children (3-11 years) are exposed to secondhand smoke. Black children (70 percent) and children living in rental housing are more frequently exposed to secondhand smoke[79-81].

Secondhand Smoke Exposure in Michigan

Statewide cotinine studies are not available in Michigan, but self-reported data on recent SHS exposure for adults exist. In 2008, prior to passage of Michigan's smoking ban, 15 percent of adults were exposed at home, 23 percent in their car, 18 percent at work, and 43 percent in a restaurant or bar within the last seven days[82]. SHS exposure showed distinct racial disparity, with 37 percent of Black residents and 54 percent of Native American residents reporting home or car exposure, compared to 31 percent of the general adult population[83]. Prevalence was higher among adults without health coverage or routine health care provider and among adults with other co-morbidities or disability[83].

Prevalence of tobacco smoking (2007-2009) is much higher among Non-Hispanic Black (26 percent) and Native American (38 percent) adults than the general population (20 percent)[83]. Of Michigan adults who smoked tobacco in 2010, 44 percent (95% CI: 40.8-48.2) had at least one child at home[84]. More than 14 percent of Michigan children (0-18 years) with asthma are reported to be exposed to cigarette smoke at home[39]. Prevalence of exposure is higher among Black children (28 percent, 15.6-44.4) than White (9 percent, 95% CI: 6.5-12.7). Prevalence is also higher among children of respondents with lower educational attainment: 24 percent (95% CI: 13.6-39.3) of those with a high school diploma or less vs. two percent (95% CI: 1.1-4.5) of college graduates[39].

More than one half (58 percent) of Detroit children with asthma who visited a children's hospital outpatient clinic had been exposed to smokers in an enclosed area for more than 10 minutes in the past week by parental report. Although one half had been exposed to smokers in their home, nearly all (95 percent) had been exposed to smokers outside of their home. Grandparents (30 percent) and parents (30 percent) were the most

common sources of exposure; the most common locations for exposure were relative's homes (40 percent); own home (24 percent) car (15 percent), friends' homes (11 percent) and restaurants (9 percent). Children of single mothers, mothers with a high school education or less, or from low income households (less than $2,500 a month) had higher levels of exposure than comparison groups[85]. The survey results were concordant with urine cotinine testing results which indicate tobacco exposure; nearly 20 percent of these children had urine cotinine levels indicating heavy exposure to SHS. These results were very similar to those collected at the same clinic ten years prior[86]. The authors recommended public health and clinical education interventions to increase use of home and car smoking bans by parents of these children[85].

Interventions to Reduced SHS Exposure

Non-smoking sections, ventilating buildings and use of air cleaners cannot eliminate SHS exposure[24]. Smoking bans in individual homes are effective but cannot prevent exposure from other households in multifamily units[87]. Therefore, total bans on smoking of tobacco products are necessary to prevent SHS exposure among nonsmokers.

Smoking bans work to reduce smoking behavior on multiple levels[88]. The ban may change an individual's smoking behavior through individual response to the ban but may also change behavior through a neighborhood effect. As Datta describes, the neighborhood can affect smoking behavior through structural mechanisms where the neighborhood provides residents with certain constraints and opportunities for smoking or exposure. Another mechanism is contagion, where people are influenced by others in their environment and thus behavior spreads as result of local norms, experiences or

information. Lastly, an individual may be exposed to more stress in the neighborhood, which could influence the likelihood of smoking to deal with stress.

Previous research documented the associations of passage of bans on smoking in public places and reduction in SHS exposure, smoking behavior and cardiovascular and respiratory events[32,35,89]. Exposure in public places for both patrons and workers were reduced[90,91] as was smoking behavior outside of the work place (although not all workers are affected to the same extent)[90]. The evidence on reduction in SHS in homes[92,93] and smoking prevalence in the population is mixed[94-97], however, passage of legislative smoking bans has been associated with reduction in cardiovascular[23,95,98,99] and respiratory events[35,100-103].

Expected mechanism for SHS bans and pediatric asthma control

The connection between smoking bans and reduction of occupational exposure and/or increase in cessation among adults is clear. The mechanisms of how SHS bans will benefit children may be less clear. Bans could impact children through reduction of direct exposure to SHS in public places and/or reduction of SHS exposure through reduction in smoking by caregivers or neighbors. Low income children who reside in multifamily housing or children with multiple caregivers who may have less ability to control or mitigate the environment could particularly benefit.

Research on asthma impact of past smoking bans

Scotland banned smoking in enclosed public places and workplaces effective March 2006[37]. Mackay et al. found an 18 percent per year reduction in pediatric asthma admissions to hospitals after the ban, adjusting for age group, sex, socioeconomic status, urban/rural residence, month and year. Some opponents were concerned that public bans

would increase smoking in private spaces, particularly impacting children. However, population-based surveys in Scotland found an increase in complete bans on smoking in Scottish homes after the 2006 ban[30]. The reduction in SHS exposure has continued based on a reduction in mean serum cotinine levels between 1998 and 2016[104].

Rayens et al.[38] found a reduction in ED visits for asthma after a smoke-free law was passed in a Kentucky county. After adjusting for seasonality, secular trends over time and differences in demographic subgroups, ED visits declined 22 percent, with a higher reduction among adults than in children. A smaller reduction in asthma hospitalization rates was associated with a 2002 change from a partial to full smoking ban in Delaware[31]. The rate of asthma hospitalizations among residents each quarter (three-month period) decreased five percent post-ban (2003-2004), compared to the pre-ban assessment period (1999-2002) (risk ratio: 0.95, 95% CI: 0.90-0.99; p=0.046). In comparison, quarterly rates among non-residents who were hospitalized due to asthma in Delaware increased (rate ratio: 1.62, 95% CI: 1.46- 1.86, p<0.0001). Dove et al[36] found that smoking bans were associated with lower levels of asthma symptoms among U.S. adolescents with asthma (odds ratio: 0.67 (95% CI: 0.48-0.93)) but associations with asthma attacks or ED visits for asthma were not significant (0.66 (95% CI: 0.28-1.56) and 0.55 (95% CI: 0.27-1.31), respectively) in self-reported survey data.

Been et al.[105] reviewed eleven time-series studies regarding local and national smoking bans from North America and Europe. Smoke free legislation was associated with a reduction in asthma admissions of ten percent. A Cochrane review of legislative smoking bans for reducing harms from SHS exposure[106] reviewed 77 studies from 21 countries exploring cardiovascular, respiratory and perinatal outcomes. Of the twelve studies

evaluating the impact of national smoking ban on asthma admissions, only seven reported significant reductions of twelve to 22 percent, but not all studies found a reduction in asthma utilization among children. Studies in Geneva[107], Rhode Island[108], Canada[109], and Turkey[110] found increases or no difference in rates of admissions among adults after bans enactment. Frazer et al determined that the quality of available literature was very low due to imprecision, considered the estimate around uncertain, and stated that additional research was needed.

Equity differences in ban impact

A recent review by Nanninga[111] stated that, although a number of authors found the impact of tobacco control interventions varied slightly across ethnic and SES populations, the authors did not expect that tobacco control interventions to alter inequalities in smoking, with exception of interventions on price. Nanninga's review of literature on smoke-free legislation on home-based SHS exposure among children found that specific measures of social inequity (differences in SES, place of residence, and education) increased with passage of this legislation, when studies of cotinine levels were considered.

Michigan's Dr. Ron Davis Smoking Ban

Since 1997, many local governmental jurisdictions in Michigan had passed local bans on smoking in the form of ordinances and regulations (Figure 1). However, these bans were pre-empted by the state legislature[112], forcing the need for a statewide ban. After many attempts, a state law (Public Act 188 of 2009), called the Dr. Ron Davis Smoke Ban, was passed in December 2009 banning smoking in public places as of May 1, 2010[113]. This legislation stated:

> "an individual shall not smoke in a public place or at a meeting of a public body, and a state or local governmental agency, or the person who owns, manages, or is in control of a public place shall make a reasonable effort to prohibit individuals from smoking in a public place" [113].

Cigar bars, tobacco specialty retail stores, home offices and motor vehicles were exempted from these requirements. Casinos could continue to allow smoking on the gaming floor but not in food establishments within the casino.

Although early indications are that the Dr. Ron Davis Smoking Ban is reducing SHS exposure among workers and improving air quality at monitored businesses[41], no work has been published on associations between the smoking ban and asthma outcomes among children in Michigan. Earlier literature has explored the impact of smoking bans on the general population and on children in other areas but has not explored the potential association within a statewide low-income population. In addition, limited attention has been paid to understanding how the implementation of smoking bans may differ depending on social environments. The purpose of this dissertation is to fill in some of these gaps.

Public Health Significance

Asthma is the most common chronic disease of childhood. Children living in low income households experience a disproportionately high burden of adverse asthma events. Changes in health care, housing and environmental policies can improve the ability of families of low income children living with asthma to control their disease and prevent asthma exacerbations. The impact of the Dr. Ron Davis Smoke Ban on asthma in low

income children has not been explored. Furthermore, exploration of the complex relationships between residential area characteristics and loss of asthma control among children may identify policy and intervention opportunities to enable families to better manage asthma as part of their lives. The cohort developed for this dissertation provides the ability to explore individual and area level predictors of asthma utilization that could inform programs directed at children from low income households served by the Michigan Department of Health and Human Services.

CHAPTER II

Create a dynamic cohort of children with asthma served by the Michigan Medicaid programs, including information on demographics, asthma utilization, and area level characteristics of residential area

Introduction

Asthma is one of the most common chronic conditions of childhood. More than ten percent of Michigan children currently have asthma[114], with one in five of children with asthma having had an asthma exacerbation in the past 12 months.

The Michigan Department of Health and Human Services (MDHHS) provides essential health care coverage, such as Medical Assistance or Medicaid, to Michigan residents who otherwise cannot afford it and who meet certain eligibility requirements[115]. MDHHS will approve use of Medicaid data for research purposes only if the research has potential for direct benefit to Medicaid beneficiaries. For this research, approval was obtained to use Medicaid eligibility and claims data to identify children with asthma and construct a database of health care and pharmaceutical utilization over time.

During a single year, six percent of children enrolled in Michigan Medicaid programs had asthma services utilization (hospitalization, emergency department visits, outpatient visits and asthma medications filled[116] which were consistent with having persistent

asthma[117]. About eight percent had utilization in a calendar year which provided some indication of asthma[116]. This is a substantial proportion of children in Michigan Medicaid who need clinical treatment for asthma, education services to understand routine and emergency management of asthma, access to medications and equipment to routinely treat and monitor their asthma, products to reduce the occurrence of triggers in their immediate environment (e.g., dust, cockroaches, and molds), and policies that reduce exposure to airborne exposures that trigger asthma exacerbations (e.g., SHS, particulates).

The Pediatric Asthma Medicaid Utilization Cohort (hereafter referred to as 'Cohort') combines information into a single data source that can be used to assess associations between pediatric asthma health care and pharmacy utilization, and patient, area, and residential characteristics. This information that can be used to better plan asthma programs and services, as well as assess the impact of policy changes on children's asthma care utilization. Specifically, the Cohort was set up to assess the associations between pediatric asthma utilization and characteristics of residential areas in the State of Michigan among low income children enrolled in Michigan Medicaid insurance programs. The Cohort includes children residing in the state who were enrolled in Michigan Medicaid programs between 2007 and 2012 and who had health care and pharmaceutical utilization consistent with a diagnosis of asthma. The Cohort is a detailed data set that allows for follow up of asthma events for a single child, a unique resource for the State of Michigan.

The Cohort was assembled to assess the impact of Michigan's Ron Davis Smoke Ban[118] on the number of times asthma control is lost among low-income children. The study aims also included assessing the association between exposures to area level estimates of economic deprivation and racial segregation and adverse asthma events.

The study was approved by the Institutional Review Boards of the University of Michigan (#HUM00077886) and the Michigan Department of Health and Human Services (201306-01-EA).

Methods

This prospective Cohort, the Pediatric Asthma Medicaid Utilization Cohort, includes children enrolled in Michigan Medicaid programs who had claims or encounters recorded in the Michigan Medicaid Data Warehouse[115] that were indicative of asthma. Children were considered to have asthma if, during a calendar year, they had a utilization claim or encounter for a hospitalization or emergency department visit due to asthma (primary discharge diagnosis of ICD-9-CM = 493.xx); had four or more asthma medication dispensing events[119,120]; and/or had two or more outpatient visits for asthma and two asthma medication dispensing events.

Administrative data for years 2007 to 2011 were analysed to select children meeting this definition who 1) were 18 years old or younger; 2) had continuous Medicaid enrollment (i.e., 11 or more months of enrollment during calendar year); and 3) had full Medicaid coverage with no other insurance. Full Medicaid coverage means that a child was eligible for Group 1 Medical or Group 2 Medical Services and had Full Medicaid Coverage, Healthy Kids Expansion, or Medicaid for the disabled and/or were enrolled in the Michigan Children's Special Health Care Services with asthma as their qualifying diagnosis[115].

The identification year was defined as the calendar year of the first observation that a child met the criteria above and was administratively enrolled in the Cohort. Beneficiaries who met these three criteria were assigned to their first possible identification year. Data

for all subsequent months for which children were enrolled in Michigan Medicaid and had full insurance were included in the Cohort until December 2012 or until the child turned 19 years old.

Demographic variables

Demographic variables collected from the Michigan Department of Community Health's Medicaid Data Warehouse included racial and ethnic group (defined as non-Hispanic White, non-Hispanic Black, Hispanic, or other, including both Migrant and non-Migrant populations, as reported on the benefits application), age group during each month (0-4, 5-9, 10-14, and 15-17 years) and sex. Census block group of residential address was recorded each month from the Beneficiary data files to assign area level variables.

Poor Asthma Control in the Identification Year

Children were considered to have poor asthma control during their identification year (baseline) if they had claims for one or more emergency department visits or hospitalizations due to asthma, had prescription fills for short-acting beta agonists (SABA) indicating potential overuse of the medication (thirteen or more dispensing events), or more than two prescription fills for oral corticosteroids bursts (OC).

Outcome Definitions

The count of asthma and injury outcomes described below was assigned to individual children each month during the follow up period.

An adverse asthma event is defined as claims evidence of either an inpatient hospitalization due to asthma or an emergency department (ED) visit with primary discharge diagnosis of asthma. ED visits due to asthma that result in a hospitalization due to asthma are counted only as a hospitalization due to asthma.

- Hospitalizations with primary discharge diagnosis of asthma (ICD-9-CM = 493.xx)
- Emergency Department Visits with discharge diagnosis of asthma (ICD-9-CM = 493.XX)

Hospitalizations, emergency department visits, and outpatient visits with a diagnosis of injury were counted monthly for each child, including ICD-9-CM codes falling in 800.0-909.2, 909.4, 909.9, 910.0-994.9, 995.50-995.59, or 995.80-995.85. Certain adverse effects (995.0-995.4, 995.6, 995.7, 995.89) and complications of surgical and medical care (996.0-999.9) are excluded from this definition[121-123].

Using *a priori* cut points from NHBLI's asthma treatment guidelines[124], secondary asthma outcomes were defined on a yearly basis for each child.

- Prescriptions for two or more OC bursts filled in a year
- Thirteen or more SABA prescriptions filled in a year
- Count of outpatient visits with a diagnosis for asthma (ICD-9-CM 493.xx)

Temporal variables

In the statistical analysis, indicator variables for calendar month (1-12 months) and for study month (1-72 months) were included to address seasonality of asthma events and potential age-related and secular trends not related to exposure variables.

Exposure to Smoking Bans

The MDHHS Tobacco Prevention Section tracks the passage of state and local policies, ordinances, and statutes limiting smoking or exposure to second hand smoke (**Figure 1**). Residential exposure to secondhand smoking ban or ordinance was defined by month and place of the child's residence, including a variable for statewide ban and a variable for existence of local bans and ordinances. The Dr. Ron Davis Smoke Ban on

smoking in public places, including worksites, was passed by the state legislature on December 1, 2009 and came into effect on May 1, 2010. Two residential exposure periods were defined for the pre-ban (January 1, 2007 to April 30, 2010) and post ban exposure period (May 1, 2010 to December 31, 2012). Residential exposure to local bans were defined the same way based on dates of their enactment. The earliest ban was passed in the Michigan city of Marquette in 1997. These regulations varied in scope and enforcement, but exposure was defined solely by county or city of ban and time.

Area level variables

Area level variables were calculated from the American Community Survey's (ACS) five-year estimates (2007-2011)[125] for census block group. ACS variables were obtained from the American Factfinder Download Center[126] and assigned to each child based on residential census block group recorded each month. These variables were used to calculate area level indices describing neighborhood economic disadvantage and racial segregation. These indices were assigned to each child month, based on the census block group obtained from the Beneficiary files.

The 2007-2011 ACS file included 8,142 Michigan census block groups. Children in the Cohort had at least one month of follow-up time in 6,895 census block groups (85 percent of Michigan block groups).

Racial segregation was estimated using two measures, based on the percent of the census block group population who is African American in the 2007-2011 ACS. Specifically, the dissimilarity index (proportion of African Americans who would need to move to another neighborhood to obtain complete integration) and the isolation index (probability that two individuals meeting in the neighborhood would be of the same race)[127] were used

to estimate associations of racial segregation with rates of adverse asthma events. Each formula produces a population-weighted average across all block groups in the Cohort. Each index ranges from 0 (least segregated) to 1 (most segregated). Based on a review of the literature, the isolation index would do a better job of capturing the disadvantageous circumstances in residential environments due to segregation[127].

Dissimilarity index: The evenness of racial segregation in each census block group is measured with the block group-derived dissimilarity index formula. The dissimilarity index compares the racial composition of each block group to the overall state composition and approximates the proportion of blacks who would have to move to a different block group to produce even racial distribtion across block groups. The block group-derived dissimilarity index formula is given by:

$$D = \sum_{i=1}^{n} \frac{t_i|\pi_i - \pi|}{2T\pi(1-\pi)}$$

Where:

D = index of n block groups within the state

π = proportion of black residents in the state overall

π_i= proportion of black residents in the i^{th}census block group

T = total population count of the state

T_i = the population count for the i^{th} census block group

Black isolation index: The exposure/isolation of black residents is measured using the block group-derived black isolation index. This index measures the probability that any two randomly drawn people from the same block group will be black. Using the same notation as above, the block group-derived black isolation index is given by:

$$P_x^* = \sum_{i=1}^{n} \frac{t_i}{T} \pi_i$$

The indicators were developed using the distribution of values in the census block groups represented in the Cohort, representing 85 percent of all census block groups in the State.

Neighborhood economic disadvantage[19] is an index that captures both racial and economic segregation and has been found to be associated with asthma prevalence. However, it has not been evaluated as a determinant of asthma control outcomes in a wide geographic area. The index (referred to in this dissertation as the neighborhood disadvantage index) was calculated from the average Z score for percentage of residents in the census block group who are living below poverty, unemployed, on public assistance, in female-headed households, youth, or African American. The possible range of area level poverty and racial indices was -5 to +5. This index was calculable for 3,052,717 months in the Cohort. Data were missing for one or more elements in the neighborhood Economic disadvantage index in roughly four percent (3.77 percent) of months.

Follow Up Period

Children with asthma in the Cohort were followed administratively through claims, encounters, and eligibility data in the Michigan Medicaid Data Warehouse[128] beginning in January following their identification year. Children were followed until: (a) they turned 19 years of age, (b) the December 2012 service date in claims and encounters, or (c) they were lost to follow up. Children were excluded from the denominator or numerator calculation in our analyses during times of disenrollment or loss of full Medicaid coverage, even though they were followed during the period of ineligibility.

Logistic Regression Analysis of Data from Identification Year

To explore associations within the identification year period, a logistic regression model was fit to data from the identification year period with 'being in poor asthma control' as the outcome and multiple variables representing different types of exposures plausibly related to this outcome, based on previously discussed literature, as predictors. Odds ratios and 95% confidence intervals (CI's) were computed from the regression output.

Results

During their identification year, 98,698 children met both the asthma and enrollment criteria (***Table 1***). Less than two percent of children were removed from the Cohort (1,236, 1.26 percent) because they did not have Medicaid coverage, or they resided outside of the state of Michigan during the follow up period. The final Cohort of 97,548 children with asthma contributed 4,335,349 child-months of observations, including 1,163,287 months in the identification year and 3,172,152 months to the follow up period.

Fifty-nine percent of children were male, 43 percent were 0-4 years old; and nine percent were 15-17 years old (***Table 1***) during their identification year. The Cohort was significantly younger than all children in Michigan where 31 percent of children were under five years of age in 2012[125]. More than half of children (51 percent) were reported to be Non-Hispanic White and 38 percent were reported as Non-Hispanic Black in the Medicaid files. Black children were overrepresented in the Cohort, compared to the state's population (16 percent)[125]. Nearly one third (32 percent) of children resided in Wayne County, including the city of Detroit, for at least one month in their identification year.

Nearly half of the children (49 percent) in the Cohort had claims evidence of poor asthma control in their identification year (***Table 1***). Based on the most severe evidence of loss of asthma control, one-third of children in their identification year had an asthma hospitalization (five percent) or emergency department visit (28 percent), eleven percent had filled two or more OC prescriptions (used to treat acute asthma exacerbations) without any claim for hospitalization or emergency department visit, and four percent had filled thirteen or more SABA prescriptions (considered 'over use') to relieve bronchoconstriction in a year without claims for other poor control events. Young children (0-4 year olds) were more frequently found to be in poor control (62 percent) and to have at least one hospitalization (61 percent). However, a higher proportion of pre-teens and adolescents (14 percent of 10-14 year olds and 16 percent of 15-19 years olds) had loss of asthma control due solely to SABA over use than younger children (data not shown).

More than one half of Cohort children were living in census block groups with an existing local smoking ban during their identification year. One-third of children in the sample were enrolled in the first year of the Cohort (2007), with decreasing enrollment until 2011, when 14 percent of the sample enrolled (***Table 1***).

Counts of hospitalizations and emergency department visits with a primary discharge diagnosis of asthma (ICD-9-CM = 493.xx) were tracked each month. During the identification year, there were 39,422 emergency department visits (0.40 visits per child per year 339 visits per 10,000 child months) and 5,680 inpatient stays (0.06 stays per child per year or 49 stays per 10,000 child months) due to asthma. More than one half of children had more than one oral corticosteroid fills (range 0-24 fills in a year for 0.88 fills per child per year for a total of 86,242 fills or 741 fills per 10,000 child months). Children

filled an average of 2.75 SABA prescriptions per child (range 0-30), for a total of 268,551 fills in identification year (or 2,308 fills/10,000 child months).

During the years after identification period or the follow up period (2008-2012), the Cohort contains 3,172,152 child-months. On average, children had 44 months of enrollment throughout the follow up period. The proportion of follow up months in each year varied across the follow up period from eleven percent of total follow up months in 2008 to 27 percent in 2012 (***Table 2***).

Despite including new children each year, the Cohort aged over the follow up period, with 16 percent of children being in the 0-4 year age group in the last month of their enrollment in year 2012 (***Table 1***). The racial make-up of the Cohort, evidence of poor control at identification year, exposure to local ban, and distribution of identification year Cohort did not change significantly during the follow up period (***Table 1***).

Using all months in the Cohort, monthly rates of adverse asthma events fluctuated seasonally each year (***Figure 2***), ranging from a minimum of 0.38 adverse events to a maximum of 2.05 events, with a mean monthly rate of 0.88. During follow up, there were 5,166 inpatient stays and 43,352 emergency department stays due to asthma (i.e., primary diagnosis of asthma (ICD-9-CM 493.xx)), for a total of 48,518 adverse asthma events.

The demographic and socioeconomic characteristics of residential areas where Cohort children lived are described in ***Table 3***. During the identification year, children tended to reside in census block groups where 31 percent of the residents were of Black race only, 20 percent of households were headed by women living with their own children, four percent of families living in poverty, seven percent of households on public assistance, ten percent of residents were unemployed, and 26 percent of the population was under 18

years of age. Mean neighborhood characteristics were similar in the follow-up period. A number of these variables were heavily skewed.

Quartiles and deciles of these index variables were created based on the Cohort's state-wide distribution (***Table 4***). The distribution of poverty or racial segregation did not differ between the identification year and the entire Cohort period. About one half of the Cohort child months were spent residing in the most impoverished census block groups in Michigan. Similarly, about 40 percent of months were spent in the most isolated census block groups and the most dissimilar census block groups.

A logistic regression model was fit to data from the identification year period with 'being in poor asthma control' as the outcome and multiple variables representing different types of exposures plausibly related to this outcome, based on previously discussed literature, as predictors (***Table 5***). Children 0-4 years old were 2.29 times (95% CI: 2.26-2.32) as likely to be in poor control during a month in their identification year than adolescents (15-17 years), controlling for sex and racial group. Black children were 2.11 times (95% CI: 2.10-2.13) as likely as non-Hispanic White children to be in poor control during a month in their identification year, controlling for age group and sex.

For every unit increase in disadvantage of census block group of residence, the odds of being in poor control during the identification year were 1.13 times as likely (95% CI: 1.12-1.14), holding age group, race/ethnicity and sex of child constant (Table 5). After controlling for poverty, age and sex, non-Hispanic Black children were still 1.9 times (95% CI: 1.89-1.92) as likely to be in poor control during their identification year as non-Hispanic White children. Hispanic children were 1.25 times as likely as non-Hispanic White children

(95% CI: 1.23-1.27) to be in poor control during their identification year, holding age, sex and residential poverty constant.

Discussion

Investment in the Health Data Warehouse by the Michigan Department of Health and Human Services enabled the development of the Pediatric Asthma Medicaid Cohort, a unique, statewide, population-based Cohort with 4,335,349 person-months of observation. The large sample size and stability of participation over time guarantees adequate power to examine the research questions that motivated its formation, as low-income children in this Cohort experienced 93,620 adverse asthma events (emergency department visits and hospitalizations) over the observation period.

Associations calculated from Cohort data were consistent with others reported in the literature. For example, younger children (0-4 years) had higher rates of adverse events than older children during their identification year. The consistency in associations with expectations, based on other populations, provides some support for the validity of this Cohort. Racial disparity was also evident, even among a low-income Cohort and controlling for area level poverty. The characteristics associated with poor control in the identification year are expected to be predictors of higher numbers of adverse asthma events among Cohort children during the follow-up period.

This Cohort also makes use of available information about both state-wide smoking ban and local ordinances and bans put into place over time in different Michigan cities and counties. The availability of geocoded information on census block group of monthly residence allows more flexibility for assigning many area level characteristics. In most

Cohort months, children resided in areas with higher levels of neighborhood disadvantage, racial isolation, and racial dissimilarity. While past work explored associations between area level exposures and health outcomes within a metropolitan region, this Cohort expands this type of analysis to the level of variation found across an entire state.

The detailed information on enrollment and insurance status in this Cohort provides the ability to understand the impact of continuous coverage on future asthma events. The availability of monthly indicators of census block group of residence could be leveraged to assess other area exposures, such as medical shortage areas or other data sets regarding health care access.

Figure 1: History of Secondhand Smoke Laws in Michigan

County/City*	Type of Law*	Passed*	2000 Population*	2010 Pop**
City of Marquette	Ordinance	7/28/97	19,661	21,355
Ingham County	Regulation	2/12/02	278,592	280,895
Washtenaw County	Regulation	11/20/02	314,847	344,791
Genesee County	Regulation	11/25/03	443,883	425,790
Chippewa County	Regulation	7/12/04	38,780	38,520
Otsego County	Regulation	12/14/04	24,665	24,164
Emmet County	Regulation	2/10/05	33,580	32,694
Wayne County (excl. Detroit)	Ordinance	3/17/05	1,086,715	1,106,807
Antrim County	Regulation	4/14/05	24,422	23,580
City of Detroit	Ordinance	7/20/05	911,402	713,777
Marquette County	Regulation	8/02/05	65,634	67,077
Midland County	Regulation	1/17/06	84,034	83,629
Saginaw County	Regulation	2/21/06	208,356	200,169
Mackinac County	Regulation	7/06	11,331	11,113
Schoolcraft County	Regulation	7/06	8,819	8,485
Alger County	Regulation	7/06	9,662	9,601
Luce County	Regulation	7/06	6,789	6,631
City of Grand Rapids	Ordinance	10/17/06	195,601	188,040
Berrien County	Regulation	3/1/07	162,453	156,813
Lenawee County	Regulation	3/14/07	102,033	99,892
St. Clair County	Regulation	3/21/07	171,426	163,040

Traverse City	Ordinance	5/7/07	14,532	14,674
Ottawa County	Regulation	8/28/07	238,314	263,801
Calhoun County	Regulation	6/07/07	137,991	136,146
Houghton County	Regulation	3/13/07	36,016	36,628
Ontonagon County	Regulation	8/21/07	7,363	6,780
Muskegon County	Regulation	8/11/09	173,344	172,188
Benzie County	Regulation	7/21/09	25,998	17,525
Leelanau County	Regulation	8/1/09	21,119	21,708

Sources: * Shamo, F. Personal Communication. Michigan Department of Community Health, Division of Chronic Disease and Injury Control, Tobacco Section. ** American Factfinder Community Facts. 2010 Demographic Profile queried from DP-1 - Profile of General Population and Housing Characteristics: 2010. (http://factfinder2.census.gov/faces/nav/jsf/pages/community_facts.xhtml#none) Accessed 03/10/13.

Table 1: Demographic and Utilization Characteristics of Pediatric Asthma Medicaid Utilization Cohort, Identification Year and Final Year, 2007-2011 and 2012, State of Michigan

Characteristics		Identification Year Children (Percent)	2012 Year Children (Percent)	p-value Chi-square
Children		97,548	70,745	
Sex	Female	40,220 (41.23)	28,785 (40.69)	0.91
	Male	57,328 (58.77)	41,960 (59.31)	
Racial Group	Non-Hispanic White	50,038 (51.30)	35,486 (50.16)	0.99
	Non-Hispanic Black	37,075 (38.01)	27,261 (38.53)	
	Hispanic	5,091 (5.22)	3,834 (5.42)	
	Other	5,344 (5.48)	4,164 (5.89)	
Age Group	0-4 years	41,921 (42.97)	11,029 (15.59)	<0.0001
	5-9 years	27,327 (28.01)	26,114 (36.91)	
	10-14 years	19,888 (20.39)	20,412 (28.85)	
	15-18 years	8,412 (8.62)	13,190 (18.64)	
Poor Control Measure*	Any Poor Control Evidence	47,606 (48.80)	35,723 (50.5)	0.73
	≥1 Inpatient Stays	5,110 (5.24)		
	≥1 Emergency Dept Visits	27,974 (28.28)		
	≥2 Oral Corticosteroid Fills	10,844 (11.12)		
	≥7 Short-acting Beta Agonists	3,678 (3.77)		
Exposure to Local Ban	No	44,026 (45.13)	32,404 (45.8)	0.89
	Yes	53,522 (54.87)	38,341 (54.2)	
Identification Year	2007	33,196 (33.93)	20,840 (29.46)	0.83
	2008	16,822 (17.19)	11,662 (16.48)	
	2009	16,940 (17.28)	12,392 (17.52)	
	2010	16,955 (17.19)	13,406 (18.95)	
	2011	14,173 (14.40)	12,445 (17.59)	

Figure 2: Monthly Mean of Asthma Hospitalization and Emergency Department Event Rates, Pediatric Asthma Medicaid Utilization Cohort, 2007-2012, State of Michigan

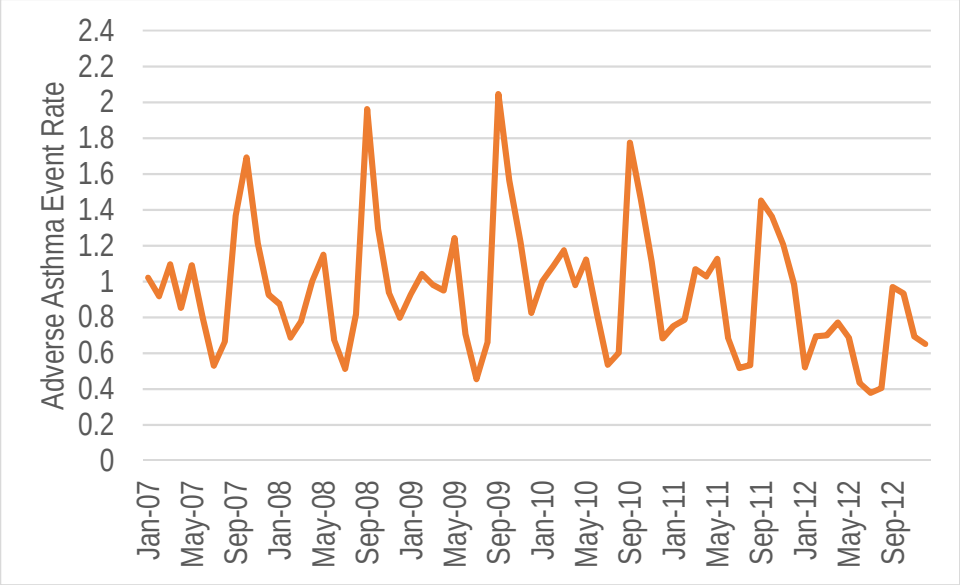


Table 2: Yearly Distribution of Months of Cohort Enrollment in Pediatric Asthma Medicaid Utilization Cohort, Identification Year and Follow Up Period, 2007-2012, State of Michigan

	Member Months Per Data Year						
Identification Year	2007	2008	2009	2010	2011	2012	Total
2007	395,096	362,169	324,455	300,633	274,906	253,082	1,910,341
2008		200,011	184,313	168,593	154,268	141,844	849,029
2009			199,709	185,815	165,789	151,198	702,511
2010				200,568	184,411	164,827	549,806
2011					167,903	155,849	323,752
Total	395,096	562,180	708,477	855,609	947,277	866,800	4,335,439
Follow Up		362,169	508,768	655,041	779,374	866,800	3,172,152
Percent of all Follow Up		11%	16%	21%	25%	27%	

Table 3: Area Level Demographic and Economic Characteristics of Census Blocks, Pediatric Asthma Medicaid Utilization Cohort, Identification Year and Follow Up Period, 2007-2012, State of Michigan

Percent of Block Group Population	Period	Mean	Standard Deviation	Interquartile Range	Skewness
Black Sole Race	Identification	30.98	37.63	66.37	0.84
	Follow-Up	31.23	37.53	66.32	0.83
White Sole Race	Identification	61.71	37.00	71.62	-0.60
	Follow-Up	61.49	36.88	71.35	-0.59
Hispanic	Identification	6.34	12.58	6.37	3.78
	Follow-Up	6.38	12.55	6.41	3.75
Female Headed Households with Own Children	Identification	19.75	16.94	22.68	1.09
	Follow-Up	19.90	16.89	22.81	1.08
Families Living in Poverty	Identification	4.42	7.99	5.63	3.21
	Follow-Up	4.31	7.72	5.57	3.21
On Public Assistance	Identification	6.84	7.70	8.28	2.09
	Follow-Up	6.79	7.62	8.18	2.08
Residents Unemployed	Identification	10.49	6.61	7.92	1.33
	Follow-Up	10.51	6.57	7.90	1.26
Youth	Identification	26.40	9.14	11.44	0.32
	Follow-Up	26.42	9.10	11.42	0.33
Neighborhood Disadvantage Index	Identification	0.45	0.89	1.18	1.13
	Follow-Up	0.45	0.88	1.17	1.13
Isolation Index	Identification	3.2E-05	4.1E-05	5.4E-05	1.39
	Follow-Up	3.3E-05	4.2E-05	5.5E-05	1.36
Dissimilarity Index	Identification	0.00013	0.00013	0.00013	1.64
	Follow-Up	0.00013	0.00013	0.00013	1.61

Table 4: Count and Percent of Cohort Months by Quartile of Area Level Neighborhood Disadvantage, and Racial Segregation, Pediatric Asthma Medicaid Utilization Cohort, 2007-2012, State of Michigan

		Total Months	Percent	Identification Year Months	Percent
Neighborhood Disadvantage Quartile					
	1	589,763	14	159,808	14
	2	638,083	15	172,576	15
	3	1,047,192	24	278,406	24
	4	2,060,401	48	552,497	47
		4,335,439		1,163,287	
Isolation Index Quartile					
	1	160,949	4	42,659	4
	2	1,398,566	32	380,122	33
	3	920,330	21	247,997	21
	4	1,855,594	43	492,509	42
		4,335,439		1,163,287	
Dissimilarity Index Quartile					
	1	1,007,103	23	268,389	23
	2	717,646	17	192,562	17
	3	908,672	21	245,682	21
	4	1,702,018	39	456,654	39
		4,335,439		1,163,287	

Table 5: Odds Ratios and 95% Confidence Intervals (CI) from Logistic Regression for Being in Poor Asthma Control During Identification Year, Pediatric Asthma Medicaid Utilization Cohort, 2007-2011, State of Michigan

Model/variable		Odds Ratio	95% CI
Demographic Model			
Sex	Female vs Male	0.94	0.93-0.95
Age Group	0-4 vs 15-19 years	2.29	2.26-2.32
	5-9 vs 15-19 years	1.04	1.03-1.06
	10-14 vs 15-19 years	0.84	0.83-0.85
Race	Black vs White	2.11	2.10-2.13
	Hispanic vs White	1.31	1.29-1.33
	Other Group vs White	1.17	1.15-1.19
Neighborhood Disadvantage Model			
Neighborhood Disadvantage		1.13	1.12-1.14
Sex	Female vs Male	0.94	0.93-0.94
Age Group	0-4 vs 15-19 years	2.28	2.25-2.32
	5-9 vs 15-19 years	1.05	1.03-1.06
	10-14 vs 15-19 years	0.83	0.82-0.85
Race	Black vs White	1.91	1.89-1.92
	Hispanic vs White	1.25	1.23-1.27
	Other Group vs White	1.12	1.10-1.14

CHAPTER III

Describe the baseline and current characteristics that predict higher numbers of adverse asthma events among children enrolled in Medicaid.

Introduction

Although recognized for hundreds of years, the relationship between place and well-being has recently received more attention in the United States. Asthma, given the sensitivity of its expression to environmental and social exposures, provides an important lens for understanding the relationship between health and place[7,19,129]. The impact of social and environmental exposure on incidence of asthma is also hypothesized to occur prenatally and to cross generational boundaries, illustrating the importance of place for both current and future health[130]. An important source of disparities in these exposures and resulting outcomes in the United States (U.S.) is expected to be the economic and racial segregation generated by institutional discrimination[7].

Much of the work exploring the impact of place on asthma has been conducted using asthma incidence or prevalence as the outcome. *Neighborhood disadvantage*[19], characterized by presence of community-level stressors such as poverty, unemployment or underemployment, limited social capital or social cohesion, substandard housing, and high

crime/violence exposure rates, has been shown to be associated with asthma prevalence across metropolitan areas[19,130]. However, multi-level approaches to study the impact of area level exposures on asthma control have not been widely applied[131,132]. Economic and racial segregation impacts an individual's income and resources, as well as creating and maintaining area differences in access to primary care and exposures to social stressors and poor air quality. In addition, theses aspects of place may "mutually reinforce" individual level choices[133]. Through these mechanisms, area disadvantages will reduce the ability of people with asthma to manage their disease, resulting in differential rates of adverse events. Understanding the impact of area variables on outcomes, while controlling for individual level characteristics, could provide crucial information for shaping policies related to health care, environmental, housing, transportation, and school programs. This information is necessary for an implementation of a 'health in all policies' approach[134].

This study assessed the association between area level estimates of economic deprivation on the number of times of adverse asthma events occurred among children living in low income households. Specific hypotheses included:

- Children with claims history suggestive of poor asthma control during their identification year will have a higher rate of adverse events during the study period than children without this history.
- Children living in a census block group characterized by more neighborhood disadvantage will have higher rates of adverse asthma events than those in living in an area of less economic disadvantage area.

This study was approved by the Institutional Review Boards of the University of Michigan (#HUM00077886) and the Michigan Department of Health and Human Services (201306-01-EA).

Methods

A cohort of children enrolled in Michigan Medicaid programs with persistent asthma was identified using enrollment and claims data in the Michigan Medicaid Data Warehouse. Children were selected to be followed in the Cohort if they were 2-18 years with continuous Medicaid enrollment (i.e., 11 or more months of enrollment), had full Medicaid coverage with no other insurance, and had health care or pharmaceutical utilization consistent with a diagnosis of asthma during a baseline year between 2007 and 2011. Children were considered to have persistent asthma if they had a utilization claim or encounter for a hospitalization or emergency department visit due to asthma; had four or more asthma medication dispensing events; and/or had two or more outpatient visits associated with asthma and two asthma medication dispensing events during their identification year (see Chapter Two for more detail). Children with asthma were followed until December 2012 service date in claims, they turned 19 years old, or they were lost to follow up, regardless of continuity of enrollment. Children were excluded from the denominator or numerator during times of disenrollment or loss of full Medicaid coverage, but their data were included in the cohort when they later returned to eligibility.

Demographic variables collected from the MDHHS Medicaid Data Warehouse included racial and ethnic group (defined as non-Hispanic White, non-Hispanic Black, Hispanic, or other), age group each month (0-4, 5-9, 10-14, and 15-19 years) and sex (male

or female). Children were considered to have poor asthma control during their identification year (baseline) if they had claims for one or more emergency department visits or hospitalizations due to asthma, had prescription fills for short acting beta agonists (SABA) indicating potential overuse of the medication (thirteen or more dispensing events), or more than two prescription fills for oral corticosteroids bursts (OC) in their identification year (see Chapter two for more detail). An indicator variable for month of study (1 to 72) was included in these analyses to address potential age-related and secular trends not related to exposure variables. An indicator variable for calendar month (1 to 12) was included in these analyses to address seasonality of asthma events each year.

Monthly block group of residence from the Beneficiary file was used to assign area level variables based on 2007-2012 American Community Survey data. A neighborhood disadvantage index representing neighborhood economic disadvantage[19] was used to capture both racial and economic segregation (see Chapter two for more detail). The possible range of area level poverty index was -5 to +5. The index was calculated from the average Z score for percentage of residents in the census block group who are living below poverty, unemployed, on public assistance, in female-headed households, youth, or African American. Counts of hospitalizations and emergency department visits with a primary discharge diagnosis of asthma (ICD-9-CM = 493.xx) were tracked each month.

Poisson Regression

Associations between exposures and counts of adverse asthma events in the follow up period were assessed using generalized estimating equations with a Poisson distribution. A repeated subjects statement was used to address the autocorrelation of measurements for each child across months. Correlation of individual months for each

child was addressed using a compound symmetry matrix in each model. Goodness of fit for Generalized Estimating Equations was assessed using the quasi-likelihood information criterion (QIC). Variables were added to the model the beta coefficient for the main effect of interest for the model changed by more than 20 percent, regardless of the p-value for the variable. Statistical analyses were run using SAS version 9.4 (SAS Institute Inc, Cary, NC).

Covariates included in all models included demographics of participants (sex, racial/ethnic group) as well as time varying demographics and exposures, such as age group and month of study (to handle seasonality of asthma events and potential age-related and secular trends not related to exposure variables).

Results

During the follow up period (2008-2012), children were enrolled with full Medicaid coverage for 3,172,152 child months. The number of months varied during the five years of follow up from eleven percent of months in 2008 to 27 percent of months in 2012 (***Table 6***). The demographic distribution of children in the identification year and follow up period was similar for sex and race (***Table 6***) but differed by age group. The mean neighborhood disadvantage index was similar in the identification year and follow up period.

There were 5,166 inpatient stays (44 events per 10,000 child months or 523 events per 10,000 cohort members) and 43,352 emergency department visits due to asthma (373 events per 10,000 child months or 4,392 events per 10,000 cohort members) during the follow up period, for a total of 48,518 adverse events. Children filled 464,584 prescriptions for SABAs in the follow up period or 4.7 SABA prescriptions per child. Children also filled 123,560 OC prescriptions or 1.25 OC prescriptions per child.

Distribution of Exposure Variables

Figure 3 and ***Figure 4*** provides the box plots describing the distribution of months for area level measures making up the neighborhood disadvantage, racial isolation and racial dissimilarity indices, including the percent of block group residents who are of black race, under 18 years, receiving public assistance, were unemployed, and living below the federal poverty line, and the percent of households in the block group led by a single female living with her own children. The distribution of months by census block group's neighborhood disadvantage index, racial isolation index, and racial dissimilarity index are also provided. Based on the distribution of months in the entire cohort period (identification year and follow up period), during an average month, Cohort children resided in a census block group where 31 percent of residents reported their race as Black (***Figure 3***). The distribution was heavily skewed with the first 25 percent of months being in block groups with less than one percent of Black residents. The median block group had ten percent Black population, and the third quartile block group had 67 percent Black population. The Racial Isolation Index and Dissimilarity Index based on these data were heavily skewed (***Figure 3***). The Isolation Index ranged from 0 to 0.000207 with a mean of 0.00003302 and median of 0.000012, meaning the probability of a black person meeting another black person in a median census block group is less than one percent. The Dissimilarity Index ranged from 9.23 e-09 to 0.000728 with a mean of 0.000133 and a median of 0.000082. The distribution of neighborhood disadvantage index was more normally distributed with a median of 0.24, mean of 0.45, standard deviation of 0.88, and range from -1.32 to 5.1.

The neighborhood disadvantage, racial isolation and dissimilarity measures were originally developed based on the variation in metropolitan statistical area at a census tract level. Adaption of these indices to a state level using census block groups resulted in very skewed distribution for the measures of racial isolation and dissimilarity, which were unable to be used in Poisson modelling, even after log transformation. Because the neighborhood disadvantage index was less skewed at a statewide distribution and was potentially directly related to the implementation of the SHS ban, it was retained for further analysis as a predictor of adverse asthma events.

Rates of Adverse Asthma Events over Time by Exposure

Adverse asthma rates peaked seasonally, with rates being highest in the early/mid fall, reducing to a low in February, then peaking again in March or April. Rates are the lowest in the summer. The size of the seasonal peaks reduced over time. ***Figure 5*** provides monthly rates of adverse events in the follow up period by age group, race-ethnic group, poor asthma control status during identification year, and by neighborhood disadvantage.

The adverse asthma event rate among children 0-4 years tended to be higher than for children of other age groups (***Figure 5***). The mean monthly rate per 10,000 child months for children 0-4 years was 0.019 (range: 0.008-0.047) vs 0.014 (range: 0.006-0.046), 0.013 (range: 0.007-0.036) and 0.013 (range: 0.007-0.030) for older age groups. The monthly rates of adverse events were higher earlier in the follow up period than later, with higher seasonal peaks.

The monthly adverse asthma rates differed by racial group (***Figure 5***), with Black children having the highest rates and largest peaks (geometric monthly mean = 0.024, range = 0.013-0.070), followed by children of other races (geometric monthly mean =

0.017, range = 0.007-0.040). The rates were lowest among White children (geometric monthly mean =0.008, range = 0.003-0.019). The monthly rates of adverse events were higher earlier in the follow up period than later, with higher seasonal peaks. However, these bivariate comparisons do not adjust for aging of the cohort.

Children who were in poor asthma control during their identification year had higher adverse asthma rates each month (geometric monthly mean = 0.024, range = 0.011-0.071) than children without claims evidence of poor asthma control in their identification year (geometric mean = 0.006; range = 0.003-0.015) (***Figure 5***). Both groups of children experienced seasonal peaks. The monthly rates of adverse events were higher earlier in the follow up period than later, with higher seasonal peaks. However, these bivariate comparisons do not adjust for aging of the cohort.

The neighborhood disadvantage index was divided into two groups, including months of residence in areas with the highest neighborhood disadvantage quartile and all other months. During the months children resided in the highest poverty quartile areas, they had higher adverse asthma rates (geometric mean = 0.019; range = 0.009-0.054) than when residing in areas with lower level of poverty (geometric mean = 0.011; range= 0.005-0.028) (***Figure 5***). Seasonal peaks in adverse asthma events were evident for both geographic groups. Like the comparisons between children with and without poor asthma control, the monthly rates of adverse events were higher earlier in the follow up period than later, with higher seasonal peaks. However, these bivariate comparisons do not adjust for aging of the cohort.

Poisson Models: Age Group and Racial/Ethnic Groups

The rate of inpatient and emergency department visits due to asthma ("adverse events") in the follow-up period was 149.13 (95% Confidence Interval: 146-152) per 10,000 children (QIC: 3,746,757). The addition of a categorical variable for racial and ethnic groups did not improve fit over the null model (QIC: 3,763,960), but the terms for Black non-Hispanic, Hispanic, and Other non-Hispanic children were significant in comparison with White non-Hispanic children. Multiple parameters representing age were assessed for inclusion in regression models. The age group terms (rate ratios of 1.68 and 1.20 for 0-4 and 5-9 vs 15-18 years old, respectively) were significant, and the addition of the categorial age group term did not improve fit over the null model (QIC: 3,749,532 and 3,746,757, respectively) (Table 7). However, the categorical term provided better fit than the continuous age variable. Addition of age squared or interaction terms for age did not improve model fit. The addition of calendar month did not improve fit of the model.

Based on QIC (3,767,060), the addition of race, age group, and sex did not significantly improve the fit of the model (***Table 7***) but were included in the analysis as these variables are known to be related to asthma control and the terms were significant in the model. However, interaction terms for race by age and for sex by age improved model fit (QIC: 373,340) and were significant in the model. Age- and sex-specific rates for Black children were higher than rates for White children, as expected from the literature. Differences in seasonality were consistent with hospitalization patterns in Michigan, where rates are higher in the spring and fall and lower in the summer months.

Poor Asthma Control at During Identification Year

Nearly one-half (49 percent) of the follow up months (1,557,293) were contributed by children who were in poor control during their identification year (baseline) (***Table 8***).

Adding the poor control variable to the null model did not improve fit (QIC: 3,773,810), although poor control was significant in the model ($p<0.0001$) and had a large effect size (OR 4.09; 95% CI:3.93-4.25). The addition of the poor control variable to the demographically adjusted model greatly improved fit (QIC: 369,076). After controlling for age, race/ethnicity, sex, demographic interactions, and calendar month, the adverse asthma event rate among children in poor control at baseline was 3.39 times (95% CI 3.26-3.53) the rate of children with no evidence of baseline poor control (***Table 8***).

Census Block Group Neighborhood Disadvantage

There were 8,142 Michigan census block groups represented in the 2007-2011 ACS file. Cohort members resided in 6,895 census block groups for at least one month of the follow-up period. The neighborhood disadvantage index was calculable for 3,052,717 months (missing data for one or more elements in 3.77 of months). The mean and median neighborhood disadvantage score were 0.45 and 0.24 (IQR: 1.17, range 6.43, minimum = -1.32 and maximum = 5).

The addition of neighborhood disadvantage index as a continuous variable dramatically improved the fit of the null model (QIC = 366,371) (***Table 9*** neighborhood disadvantage model). Although the inclusion of calendar month with the crude poverty model improved model fit, the coefficient for poverty was unchanged and time was therefore not included in future models due to computational difficulties. The inclusion of simple demographics in the crude model increased the fit (QIC = 357,909) and altered the coefficient on the main effect variable as well (***Table 9***). The inclusion of interaction terms for age, race and sex did not improve model fit or change the coefficient for poverty. In the simple demographic model, each unit increase in the Neighborhood Disadvantage Index

was associated with an increase in the adverse asthma event rate of seven percent (95% CI: 1.05-1.09), controlling for age, race and sex. ***Figure 6*** displays the increase in mean adverse event rate by decile of neighborhood disadvantage index, which illustrates the increase in adverse asthma events with increasing disadvantage.

To examine effect modification by identification year asthma control status on the association between neighborhood disadvantage index and asthma rates, this model was run for each strata of Poor Asthma Control status (***Table 10***). The rate ratio per unit increase of area neighborhood disadvantage index did not differ between the two strata of identification year asthma control (rate ratio of 1.06 versus 1.05, respectively).

Discussion

As found in previous literature, rates of adverse asthma events vary by race, age group and sex. Rates were highest among 0-4 year old children. Black children had rates of adverse asthma events two to three times those of White children of the same age and sex. Hispanic children had rates 10-50 percent higher than those of White children of same age and sex. The variation in adverse asthma event rates by calendar month was consistent with Michigan's seasonal pattern for asthma hospitalization in the general population.

Children with evidence of poor asthma control during their identification year had adverse asthma event rates that were 3.4 times those of the 35 percent of children who did not have evidence of poor control, after controlling for age, race and sex differences. This is consistent with other literature, such as the TENOR study[135-137], that found patients whose asthma was very poorly controlled (measured by lung function, symptoms and SABA use over two years) had a much higher risk of hospitalization, ED visits, or OC bursts compared

with individuals whose control improved over two years[48]. Past loss of asthma control predicts future asthma exacerbations in other studies as well[49-51].

Associations between area level exposures and adverse event rates were less clear. After controlling for age, race and sex, the area level measure of neighborhood disadvantage was still significantly associated with increases in adverse asthma event rates in this low-income cohort. This finding is consistent with the relationship seen in studies of asthma prevalence in metropolitan areas[19,20,57,58,129,130,132]. The use of the measure in a low-income cohort at a state level is unique in the literature. That an association can be seen with poverty in a low-income cohort implies there is actionable variation in the access to health-related resources and exposure to asthma triggers among children enrolled in Michigan Medicaid Programs. Additional analyses of this cohort data could further elucidate characteristics of geographic areas that present more challenges for children living with asthma, to develop new policy and interventions to reduce those challenges and improve asthma control.

This study had many strengths. The large sample size provided adequate power to examine the potential associations, with the ability to stratify by other variables of interest. The availability of latitude and longitude for monthly residence in the Medicaid beneficiary files allowed flexibility for assigning many area level characteristics and accommodating changes in residence and in exposure assignment. Detailed information on enrollment and insurance status provides some ability to understand the importance of continuity of enrollment and benefits on future asthma events. Finally, this work offers new insights on a geographic scale, since past work exploring the relationship between area exposures and

asthma outcomes was undertaken within a metropolitan region, not at the level of variation found across an entire state.

A limitation of this study is that it is representative of a cohort of children in low income houses only and cannot provide information about the experience of children in Michigan who had different insurance status. Furthermore, although children in this study resided in 85 percent of the Michigan census block groups, this study cannot describe the entire range of area level economic diversity in Michigan.

The use of claims data is, at best, an incomplete way to assess receipt of services, let alone asthma management behavior. Potential risk factors for asthma exacerbation leading to adverse asthma events, such as presence of viral infection, exposure to pets, smoking, or other personal exposures, are not captured by claims and encounters. Since these data were collected for administrative purposes, potential misclassification of variables such as racial status and residence is possible. This misclassification may reduce the power of the analyses to detect differences across variable categories.

Although claims data provide a mechanism to follow a child's health care utilization over time, use of paid claims to identify disease status will underestimate the true disease prevalence[71,72], as the estimate will not capture children who had insurance in addition to Medicaid, were not continuously enrolled during the surveillance period, or who did not submit claims for asthma care[72,73]. This method of identifying children with potential asthma will miss children with asthma who are enrolled in Michigan Medicaid programs but who did not have a billed claim for asthma services meeting the criteria above. Regardless, claims data can provide some information about children who had contact with the health care system for their asthma.

Use of health care claims to capture adverse asthma events and represent severe exacerbations may underestimate the frequency of some of these events, since claims cannot represent loss of asthma control that did not result in a hospitalization or ED visit. Misclassification may also occur in the other direction, as ED events may be due to prescription refills for lost medication or lack of primary care access for medication refill. Asthma events may also be misidentified as other respiratory claims. Lastly, the fully adjusted claims data cannot capture events that were not billed for or claims that Medicaid refused to pay. However, most of these limitations are expected to be nondifferential in their impact.

A difficulty inherent to research into asthma control, and illustrated by this cohort, is the need to define both eligibility (or exposure) and outcome using similar measures. In this study, asthma events and medication utilization are used as part of the asthma criteria for enrollment into the cohort, as part of the definition of poor asthma control in the enrollee's identification year, and as an outcome in the follow up period. This could introduce bias, as children with less well controlled asthma will be more likely to be enrolled in the cohort and will be more likely to have adverse asthma events in the future. Therefore, the cohort would be less likely to be able to assess the impact of smoking ban on asthma events. However, the identification criteria for this study included children who did not have an emergency department visit or hospitalization (i.e., the use of four or more asthma medications filled in a year or having two medications filled and two outpatient visits). These children could be considered successful in their use of routine asthma management to control their disease. One half of children (51.2 percent) did not have any evidence of poor asthma control during their identification year.

The use of area-level variables for analyses have some drawbacks as well. Many authors have discussed the limitations of using census tracts as indicators of neighborhood characteristics as they are arbitrary in shape and size and vary in ability to capture the concepts of segregation and how that concept relates to health resources and behaviors[138-140]. The area level variables used in this study may not represent the area exposures that children and families exist in. Furthermore, these data cannot capture experiences where children play, go to school/day care or receive health care. An area level variable also is not informed by individual behaviors or exposures specific to individual and family behavior. However, these are the only data available for measuring these concepts for the entire state of Michigan and our ability to link them to geo-coded addresses was a strength.

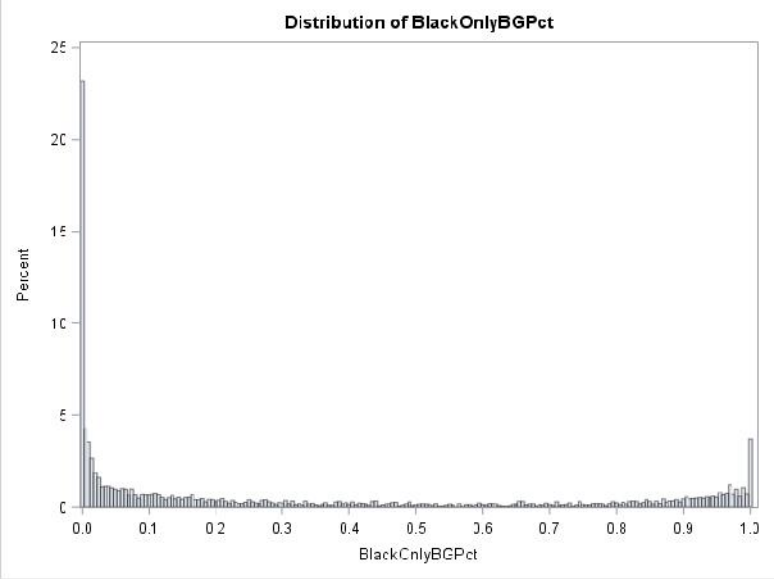
Further work addressing the skewed distribution of the racial isolation and dissimilarity variables would be needed before the variables can be useful in a state level analysis. Further work could be undertaken, for example, recalculating these variables within a metropolitan statistical area or city regional area, the conditions under which the indices were designed.

Table 6: Characteristics of Pediatric Medicaid Asthma Utilization Cohort Members during Identification Year and Follow Up Period, 2007-2011, 2008-2012, State of Michigan

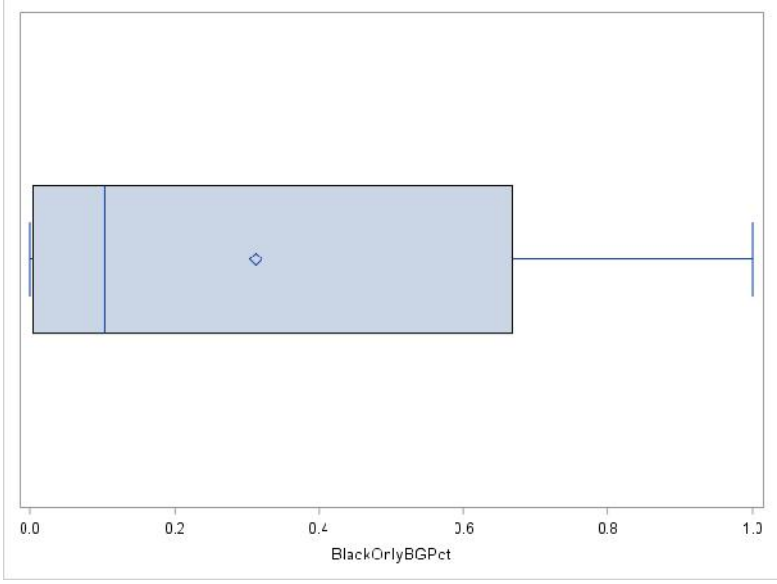
Characteristics	Identification Year (2007-2011) N=97,548		Follow Up Period (2008-2012) N= 96,766		χ- square
	No.	%	No.	%	p-value
Sex					
Female	40,220	41.23	39,921	41.26	0.99
Male	57,328	58.77	56,845	58.74	
Racial Group					
Non-Hispanic White	50,038	51.3	49,476	51.13	0.99
Non-Hispanic Black	37,075	38.01	36,885	38.12	
Hispanic	5,091	5.22	5,071	5.24	
Other	5,344	5.48	5,334	5.51	
Age Group					
0-4 years	41,921	42.97	15,097	15.6	<0.0001
5-9 years	27,327	28.01	32,220	33.3	
10-14 years	19,888	20.39	25,407	26.26	
15-18 years	8,412	8.62	24,042	24.85	
Any Poor Control Evidence	47,606	48.80	47,283	48.86	
Total Months			3,172,152		
Neighborhood Disadvantage Index					
Mean (SD) for all months	0.45	0.89	0.45	0.88	
Identification Year					
2007	33,196	33.93	32,862	33.96	0.99
2008	16,822	17.19	16,671	17.23	
2009	16,940	17.28	16,691	17.25	
2010	16,955	17.19	16,660	17.22	
2011	14,173	14.40	13,882	14.35	

Figure 3: Distribution of Block Group Area Demographic Characteristics, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

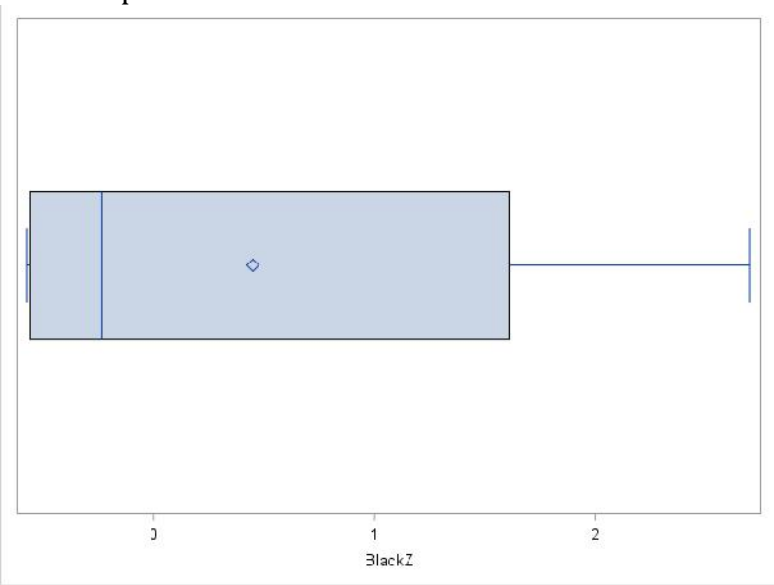
3A: Histogram Distribution of Percent of Block Group Residents of Black Race, Follow Up Months



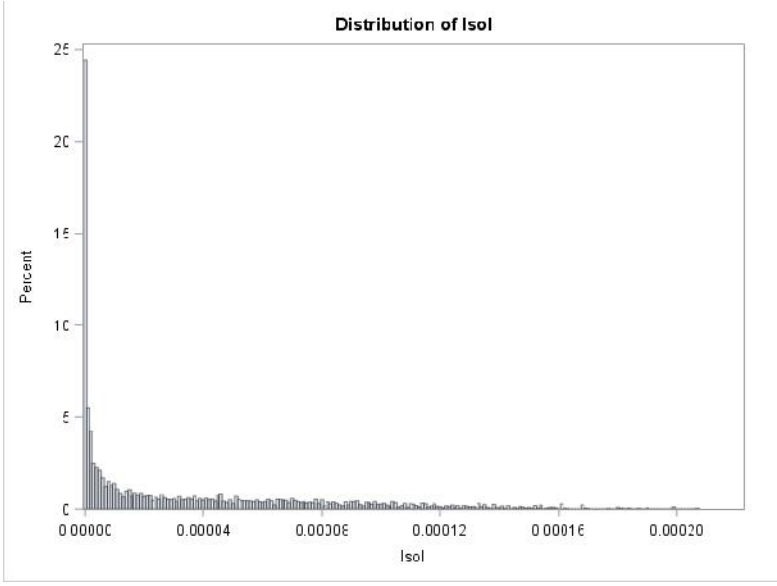
3B: Box Plot Distribution of Percent of Block Group Residents of Black Race, Follow Up Months



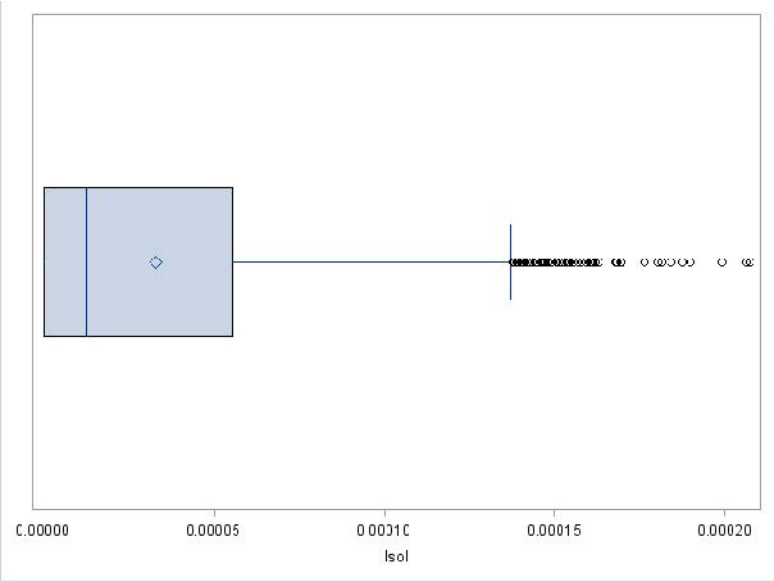
3C: Box Plot Distribution of Z Scores for Percent of Block Group Residents of Black Race, Follow Up Months



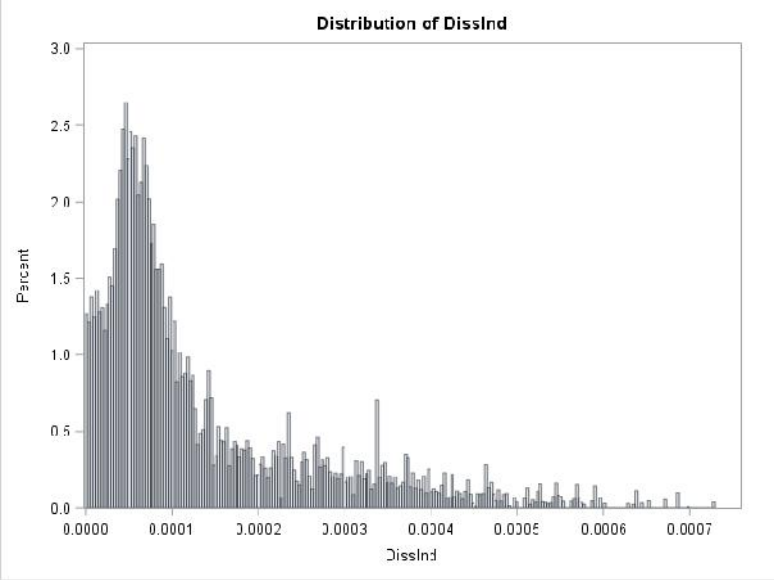
3D: Histogram Distribution of Racial Isolation Index, Follow Up Months



3E: Box Plot Distribution of Racial Isolation Index, Follow Up Months



3F: Histogram Distribution of Racial Dissimilarity Index, Follow Up Months



3G: Box Plot Distribution of Racial Dissimilarity Index, Follow Up Months

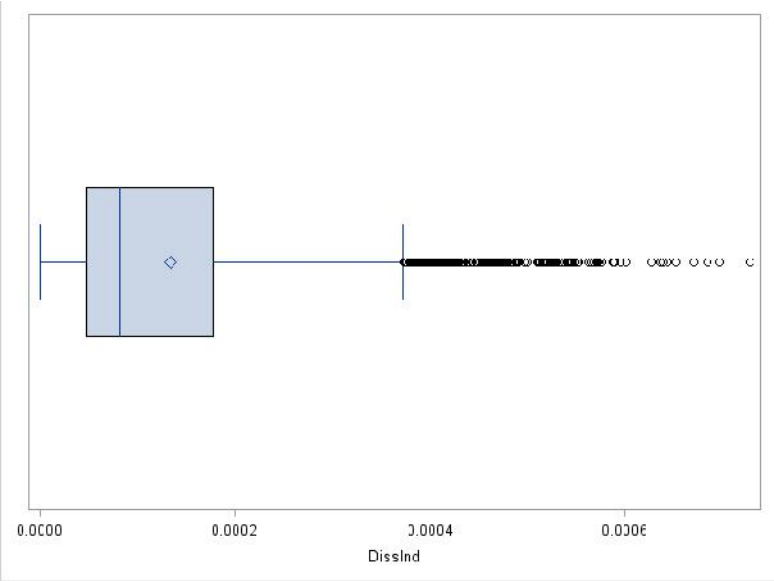
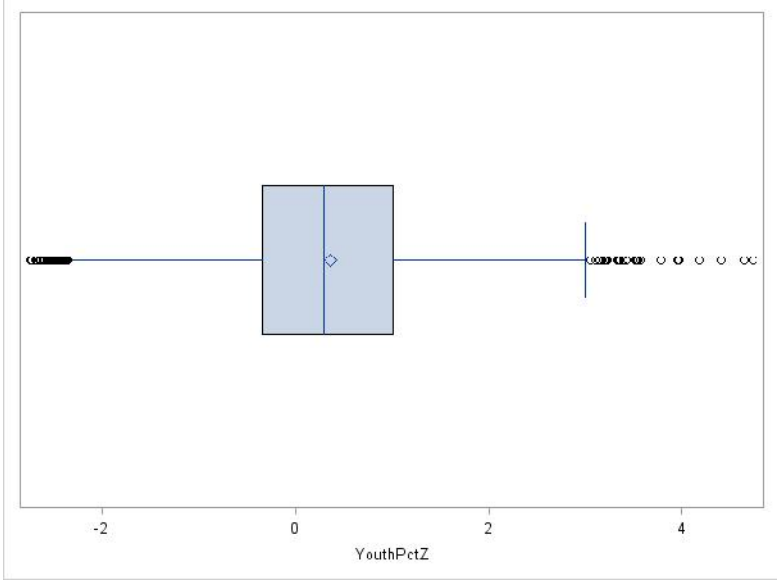
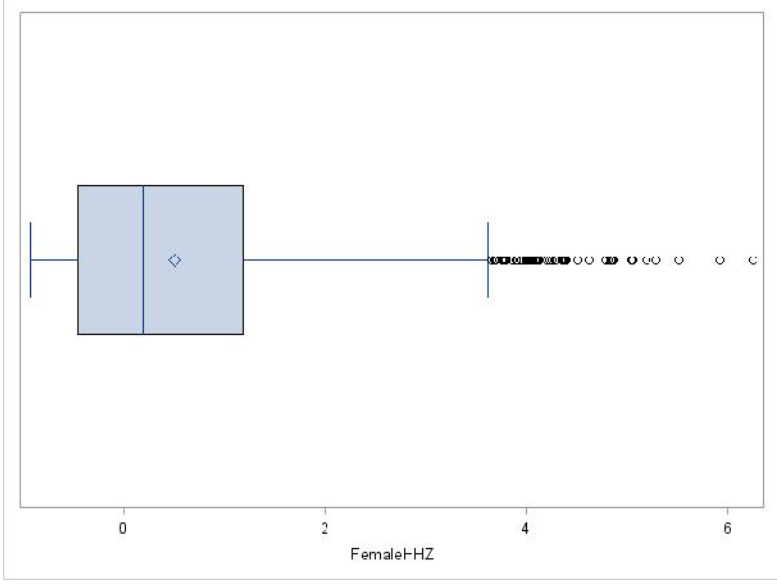


Figure 4: Distribution of Block Group Selected Variables Related to Neighborhood Disadvantage, Pediatric Asthma Medicaid Utilization, 2008-2012 Follow Up Period, State of Michigan

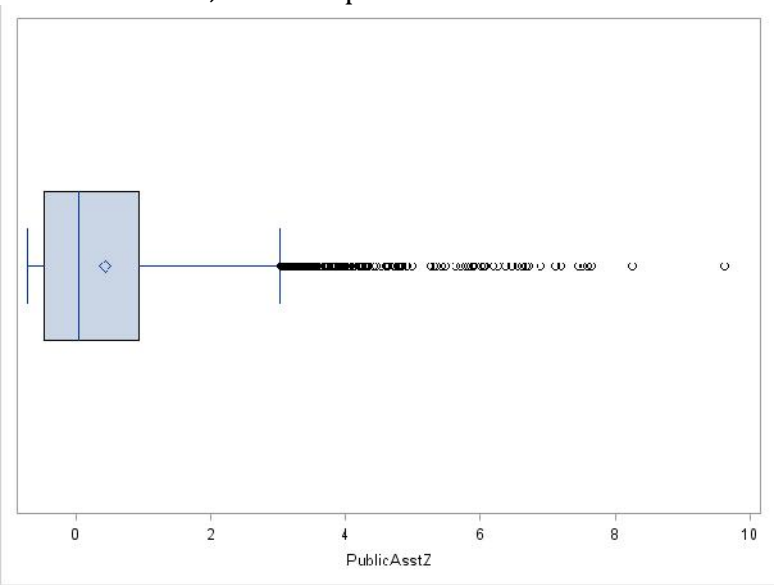
4A: Box Plot Distribution of Z Score of Block Group Residents Under Age 18 Years, Follow Up Months



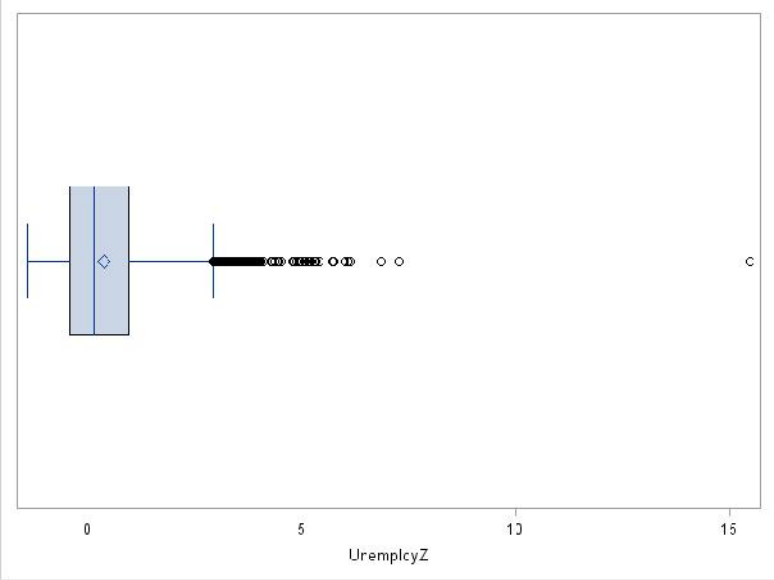
4B: Box Plot Distribution of Z Scores for Percent of Households Headed by Single Female with Own Children, Follow Up Months



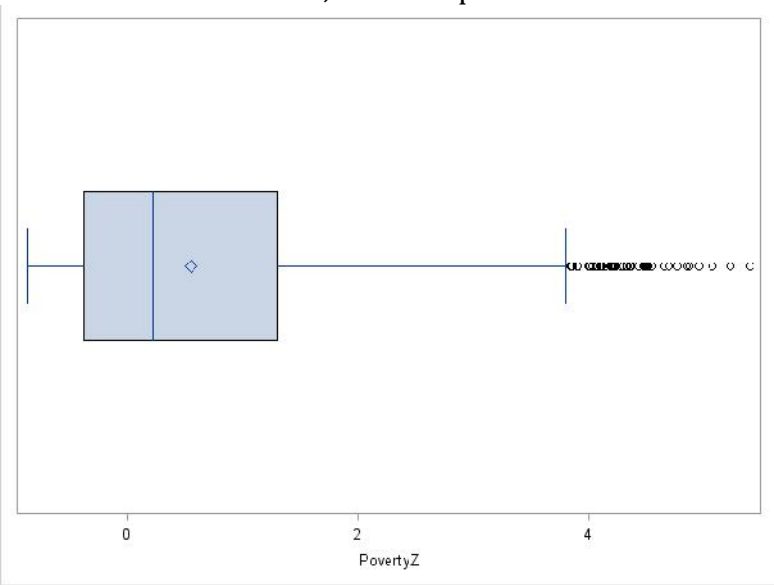
4C: Box Plot Distribution of Z Scores for Percent of Residents Receiving Public Assistance in Last 12 Months, Follow Up Months



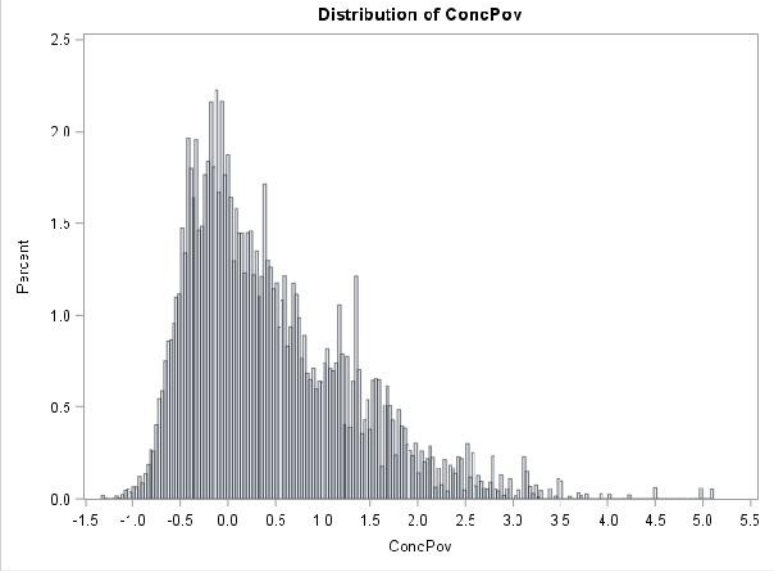
4D: Box Plot Distribution of Z Scores for Percent of Residents Unemployed in Last 12 Months, Follow Up Months



4E: Box Plot Distribution of Z Scores for Percent of Residents Living Below Federal Poverty Level in Last 12 Months, Follow Up Months



4F: Histogram Distribution of Block Group Neighborhood Disadvantage Index, Follow Up Months



4G: Box Plot of Block Group Neighborhood Disadvantage Index, Follow Up Months

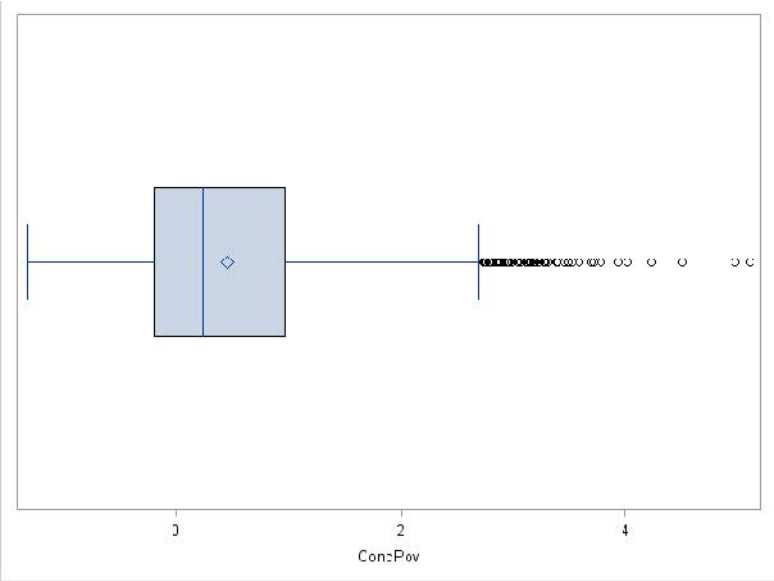
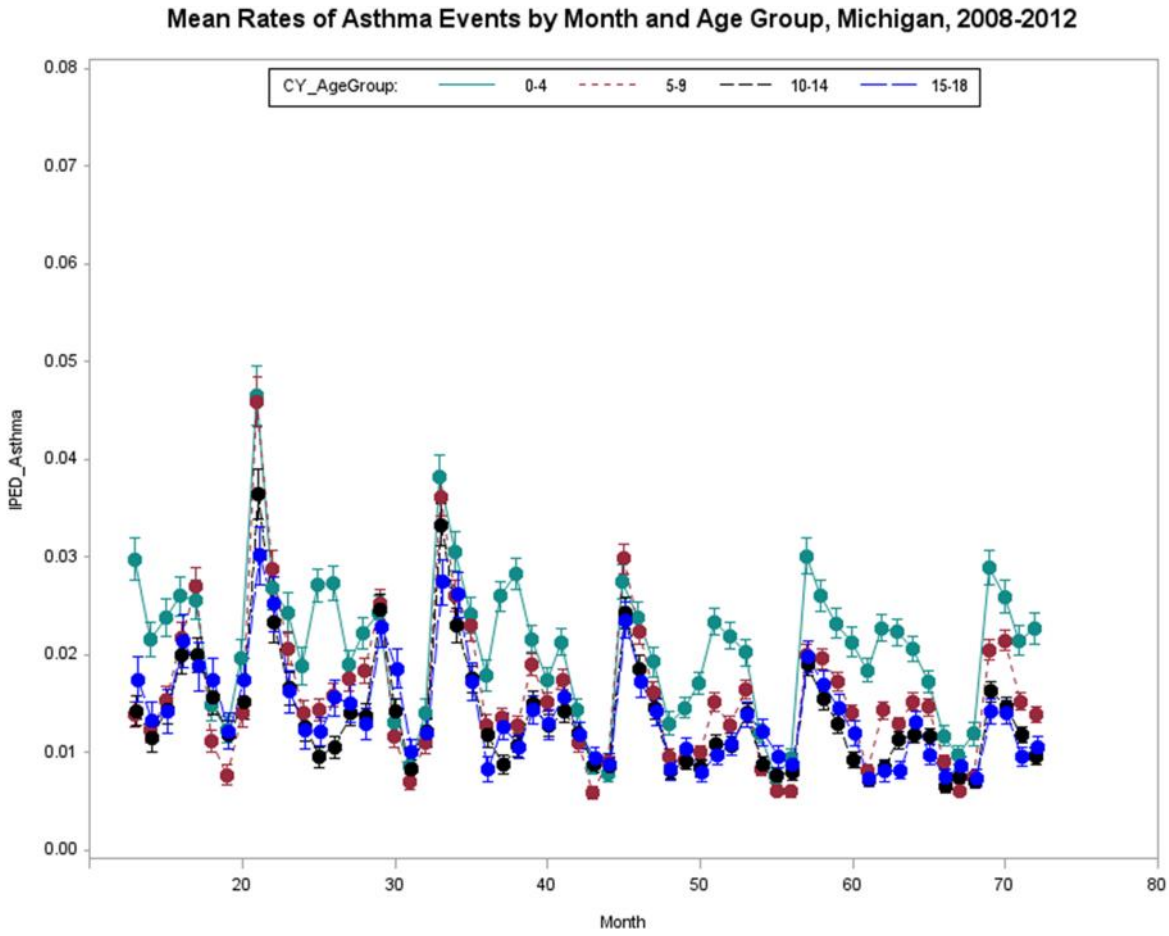
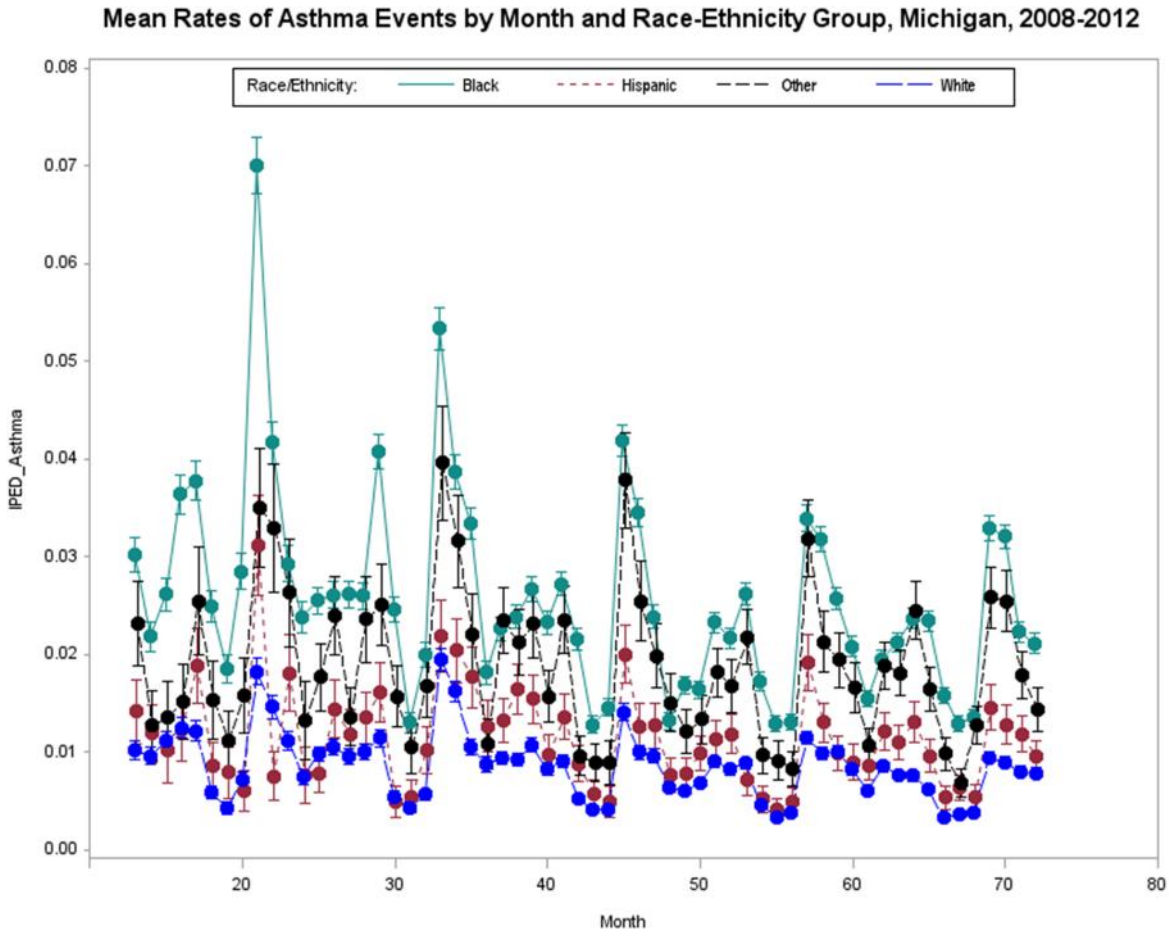


Figure 5: Asthma Adverse Event Rates per 10,000 Children by Month, Age Group, Racial/Ethnic Group, Poor Control, and Neighborhood Disadvantage with Standard Error Bars, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

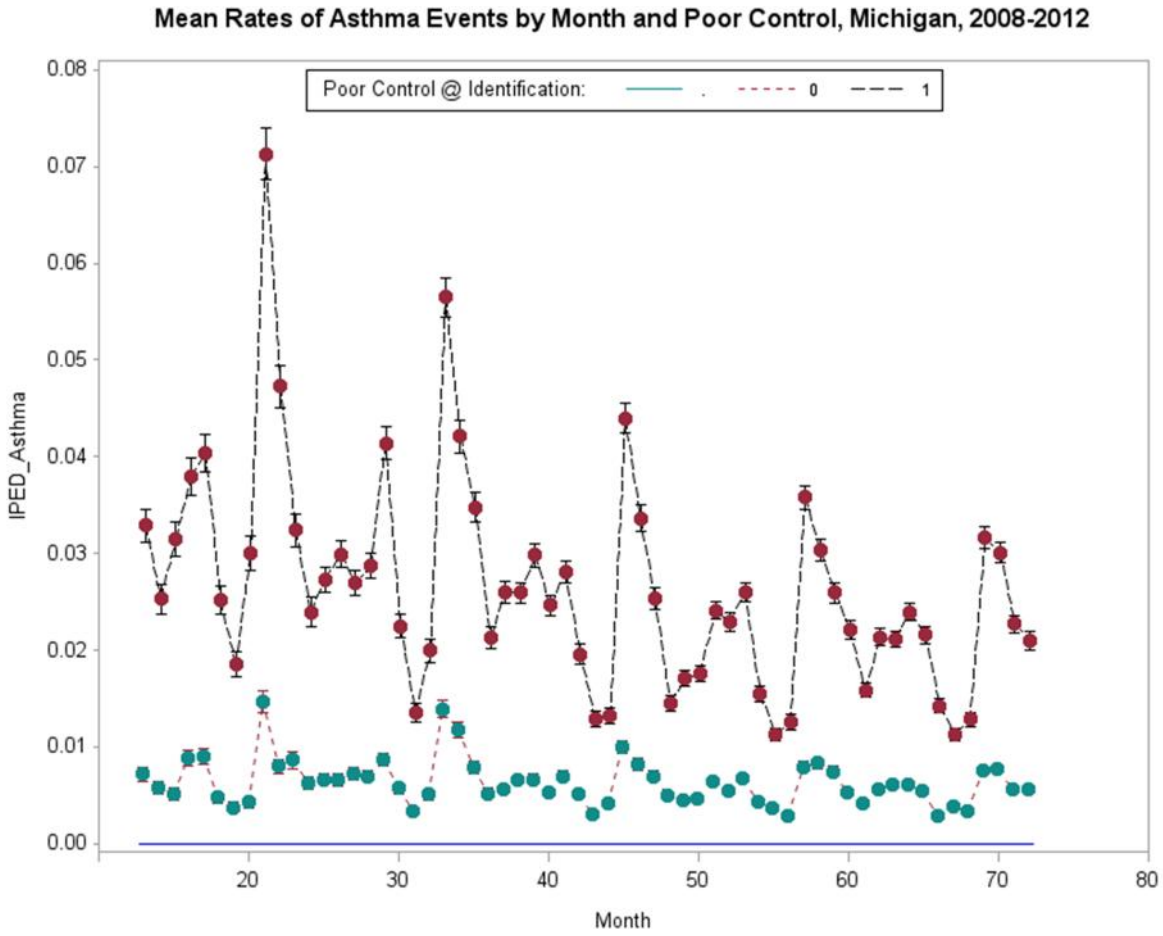
5A: By Age Group



5B: By Race/Ethnicity Group



5C: By Identification Year Poor Control Status



5D: By Neighborhood Disadvantage Index (4th Quartile vs all other quartiles)

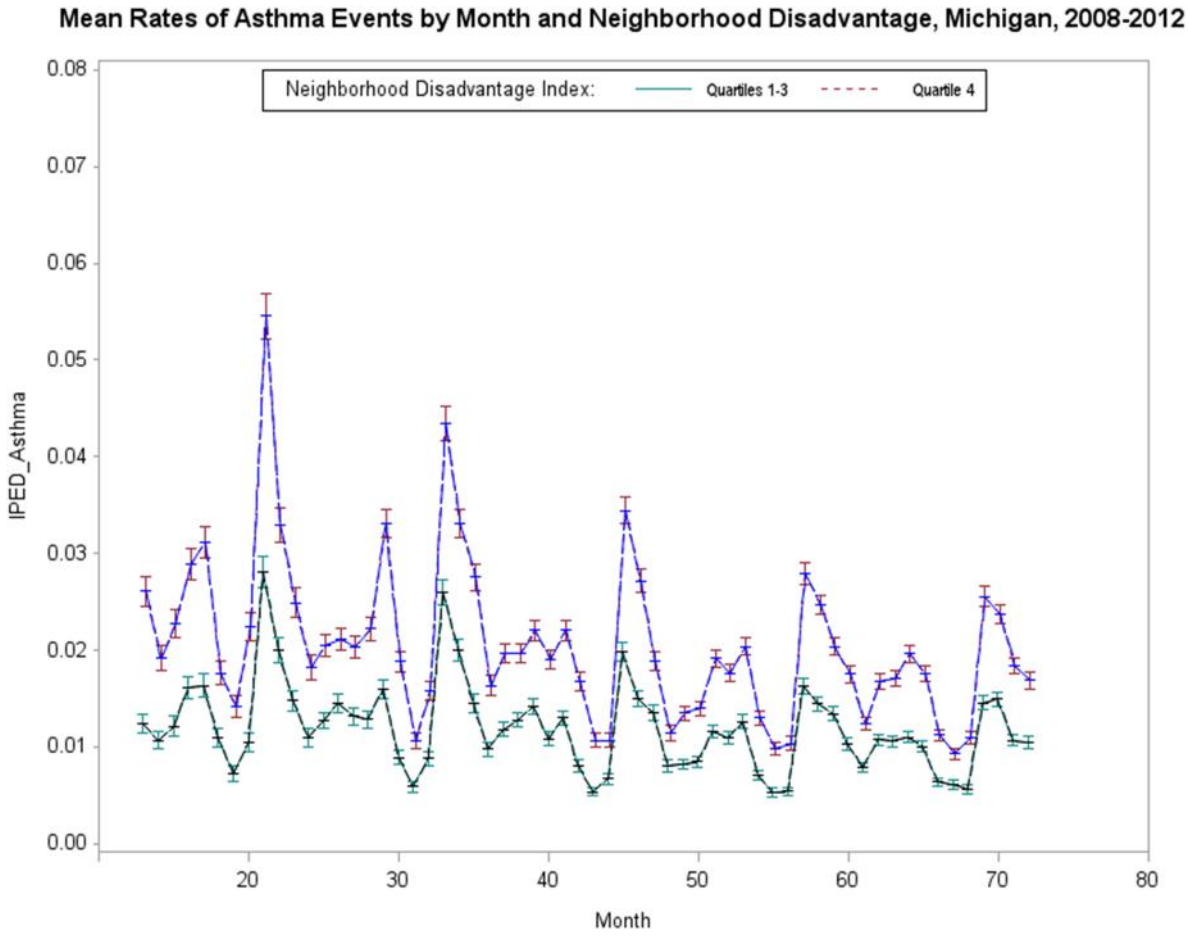


Table 7: Rate Ratios (RR) and 95% Confidence Intervals (CI) from Poisson Regression for Adverse Asthma Events with Racial/Ethnic Group, Sex and Age Group, Asthma Medicaid Cohort, 2008-2012 Follow Up Period, State of Michigan

Model/variable		RR (Rate/10,000)	95% CI
Race, Sex, and Age (1)			
Intercept		78.24	75.70, 80.87
Race	Black	2.96	2.84, 3.08
	Hispanic	1.32	1.21, 1.44
	Other	2.04	1.85, 2.25
Sex		0.98	0.96, 1.00
Age Group	0-4 years	1.40	1.37, 1.44
	5-9 years	1.01	0.99, 1.04
	10-14 years	0.86	0.84, 0.88
Temporal Adjusted Model (2)			
Intercept		74.69	72.20, 77.26
Race	Black	2.94	2.83, 3.06
	Hispanic	1.32	1.14, 1.44
	Other	2.06	1.86, 2.27
Sex		0.97	0.95, 0.99
Age Group	0-4 years	1.42	1.03, 1.46
	5-9 years	1.02	1.00, 1.05
	10-14 years	0.86	0.83, 0.88
Month	Jan	0.91	0.88, 0.94
	Feb	0.97	0.94, 1.00
	Mar	1.08	1.04, 1.11
	Apr	1.09	1.06, 1.13
	May	1.22	1.19, 1.26
	Jun	0.76	0.73, 0.79
	Jul	0.55	0.52, 0.57
	Aug	0.67	0.64, 0.70
	Sep	1.84	1.79, 1.89
	Oct	1.49	1.45, 1.53
	Nov	1.17	1.14, 1.21
Full Interaction Model (3)			
Intercept		75.65	73.08, 78.32
Race	Black	2.87	2.74, 2.99
	Hispanic	1.35	1.23, 1.49
	Other	1.95	1.74, 2.19
Sex		1.00	0.98, 1.02
Age Group	0-4 years	1.40	1.34, 1.47
	5-9 years	0.92	0.88, 0.96
	10-14 years	0.85	0.81, 0.89

Black	0-4 years	1.03	0.97, 1.09
	5-9 years	1.15	1.09, 1.21
	10-14 years	1.01	0.95, 1.07
Hispanic	0-4 years	0.83	0.73, 0.94
	5-9 years	1.12	0.99, 1.26
	10-14 years	1.10	0.96, 1.28
Other	0-4 years	1.05	0.92, 1.20
	5-9 years	1.20	1.05, 1.36
	10-14 years	1.02	0.88, 1.18
Female	0-4 years	0.95	0.92, 0.97
	5-9 years	0.94	0.91, 0.96
	10-14 years	0.97	0.95, 1.00
Month	Jan	0.91	0.88, 0.94
	Feb	0.97	0.85, 1.00
	Mar	1.08	1.04, 1.11
	Apr	1.09	1.06, 1.13
	May	1.22	1.19, 1.26
	Jun	0.76	0.73, 0.79
	Jul	0.55	0.94, 0.57
	Aug	0.67	0.64, 0.70
	Sep	1.84	1.79, 1.89
	Oct	1.49	1.45, 1.53
	Nov	1.17	1.14, 1.21

1. QIC = 3,767,059 2. QIC = 3,774,292 3. QIC = 3,775,770

Table 8: Rate Ratios (RR) and 95% Confidence Intervals (CIs) from Poisson Regression for Adverse Asthma Events with Poor Asthma Control in Identification Year, Controlling for Race/Ethnicity, Age Group, Sex, and Calendar Month, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

Model/variable		RR (Rate/10,000)	95% CI
Crude Model (1)			
Intercept		57.98	56.07, 59.94
Poor Control		4.09	3.93, 4.25
Demographically Adjusted Model (2)			
Intercept		27.50	35.81, 38.99
Poor Control		3.39	3.26, 3.53
Race/Ethnic	Black	2.39	2.29, 2.49
	Hispanic	1.25	1.14, 1.38
	Other	1.86	1.66, 2.08
Sex	Female	1.00	0.98, 1.02
Age Group	0-4 years	1.23	1.18, 1.29
	5-9 years	0.91	0.87, 0.95
	10-14 years	0.91	0.87, 0.96
Black	0-4 years	1.03	0.97, 1.09
	5-9 years	1.11	1.05, 1.17
	10-14 years	1.00	0.94, 1.06
Hispanic	0-4 years	0.84	0.75, 0.95
	5-9 years	1.12	0.99, 1.26
	10-14 years	1.09	0.94, 1.26
Other	0-4 years	1.04	0.91, 1.19
	5-9 years	1.18	1.03, 1.34
	10-14 years	1.01	0.87, 1.16
Female	0-4 years	0.95	0.92, 0.97
	5-9 years	0.94	0.91, 0.96
	10-14 years	0.98	0.95, 1.01
Month	Jan	0.91	0.88, 0.95
	Feb	0.97	0.94, 1.01
	Mar	1.08	1.05, 1.12
	Apr	1.09	1.06, 1.13
	May	1.23	1.19, 1.26
	Jun	0.76	0.73, 0.79
	Jul	0.55	0.53, 0.57
	Aug	0.67	0.64, 0.69
	Sep	1.83	1.78, 1.88
	Oct	1.48	1.44, 1.53
	Nov	1.17	1.13, 1.20

1. QIC = 3,772,666 2. QIC =3,795,443

Table 9: Rate Ratios (RR) and 95% Confidence Intervals (CIs) from Poisson Regression for Adverse Asthma Events with Neighborhood Disadvantage Index, Adjusted by Racial/Ethnic Group, Sex, Age Group and Interaction Terms, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

Model/variable		RR (Rate/10,000)	95% CI
Crude Area Disadvantage Model (1)			
Intercept		135.44	132.60, 138.36
Neighborhood Disadvantage Index		1.21	1.19, 1.24
Demographic Adjusted Model (2)			
Intercept		78.45	75.85, 81.14
Neighborhood Disadvantage Index		1.07	1.05, 1.09
Race	Black	2.79	2.67, 2.91
	Hispanic	1.28	1.17, 1.40
	Other	2.01	1.82, 2.22
Sex	Female	0.98	0.96, 1.00
Age Group	0-4 years	1.40	1.36, 1.43
	5-9 years	1.01	0.99, 1.04
	10-14 years	0.86	0.84, 0.89

1. QIC = 366,371, 2. QIC = 357,909

Figure 6: Mean Rate per 10,000 Child Months and 95% Confidence Intervals (CI) of Adverse Asthma Events by Decile of Neighborhood Disadvantage Index, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

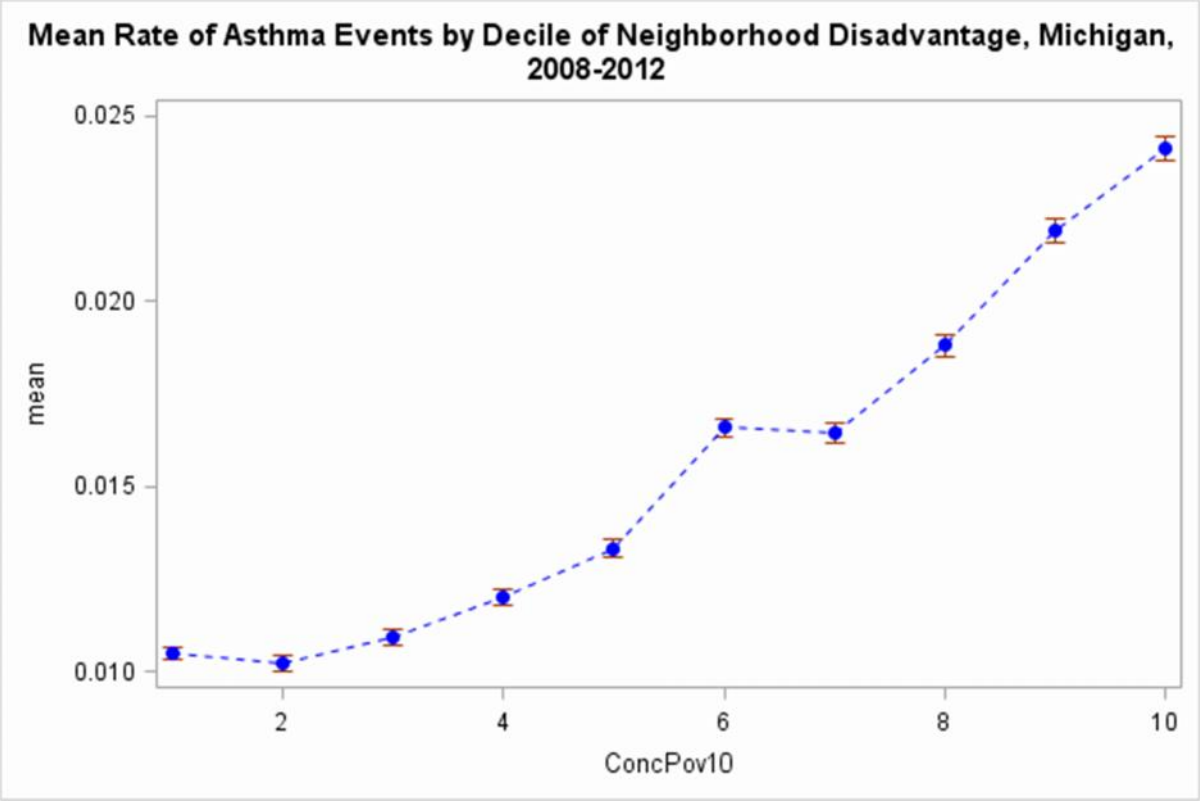


Table 10: Rate Ratios (RR) and 95% Confidence Intervals (CI) for Adverse Asthma Events Association with Neighborhood Disadvantage Index, Stratified by Identification Year Asthma Control Status, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

		No Poor Control at Identification		Poor Control at Identification	
Variable		RR (Rate/10,000)	95% CI	RR (Rate/10,000)	95% CI
Intercept		41.08	38.98, 43.30	133.79	128.28, 139.54
Neighborhood Disadvantage Index		1.06	1.03, 1.10	1.05	1.03, 1.07
Race	Black	2.30	2.14, 2.48	2.34	2.22, 2.46
	Hispanic	1.38	1.18, 1.60	1.14	1.03, 1.27
	Other	1.21	1.04, 1.40	2.13	1.90, 2.38
Sex		0.99	0.96, 1.02	0.98	0.96, 1.00
Age Group	0-4 years	1.22	1.15, 1.29	1.23	1.20, 1.27
	5-9 years	0.99	0.94, 1.03	0.97	0.95, 1.00
	10-14 years	0.90	0.86, 0.95	0.93	0.90, 0.96

CHAPTER IV

Estimate the possible impact of Michigan's secondhand smoke ban on the number of adverse asthma events among low-income children

Introduction

Racial and economic disparities in rates of adverse asthma events exist[141], due to the complex interplay of factors that increase exposure to triggers of asthma exacerbations[5-9], including poor indoor[10,11] and outdoor air quality[12-16]. Exposure to secondhand smoke (SHS) is a well-known trigger of asthma exacerbations among children[22-24,142].

Although the proportion of nonsmokers exposed to SHS in the United States (U. S.) dropped between 1999-2000 and 2011-2012 from 50 percent to 25 percent, exposure disparities remained[80], with 40 percent of U.S. residents living in poverty reporting SHS exposure[25,80]. Two in five young children were exposed to SHS, with home being the primary exposure source[80]. Home exposure decreased with increasing income; children who were Black, had public insurance, or had periods without insurance were more likely to be exposed to SHS than children lacking these characteristics. Children who do not live with an active smoker may be exposed by visitors, exposed due to air flow between adjacent units and hallways in multi-family or mixed business/residential housing[27], or

exposed at the homes of other caregivers[28,29]. In Michigan, during the time period around enactment of the Dr. Ron Davis Smoking Ban (ban), 44 percent of adults who smoke (40.8-48.2) had at least one child living in the household[83]. One in ten Michigan children with a diagnosis of asthma reported SHS exposure at home, with prevalence being higher among households with lower educational attainment[143].

Because non-smoking sections, building ventilation systems, and use of air cleaners cannot eliminate SHS exposure[24], total smoking bans are necessary to protect nonsmokers from exposure. Jurisdictional smoking bans have been associated with SHS exposure reductions[23,30], increased smoking cessation attempts[23], and decreased cardiovascular and respiratory events[30-38,105,144-146]. SHS bans should aid children through reductions in direct exposure in public places or because household members, caregivers or neighbors quit smoking. Low income children, with higher exposure and fewer resources to mitigate exposure, could particularly benefit from policy changes reducing SHS. The literature regarding differences in implementation of smoking bans by social environments is limited. Although associations between asthma events and SHS exposure are known[31,36-38,42], questions remain about sensitive periods of exposure, longevity of effects, and interaction between effects of smoking bans and predictors of poor control[6,7,9,43,44].

The ban, which eliminates smoking in public places and worksites, became effective May 1, 2010[40,41]. Based on impacts observed from bans in other jurisdictions, a reduction in adverse asthma events in the population could result from its implementation. An assessment of the potential impact of this ban on children's health is important as this law and its enforcement have been challenged. Early indications are that Michigan's ban is reducing SHS exposure among workers, improving air quality at monitored businesses, and

reducing asthma hospitalization rates among adults[41,145]. No work regarding associations between the ban and asthma outcomes in Michigan children has been published.

The purpose of this study is to estimate the possible impact of Michigan's Dr. Ron Davis Secondhand Smoke Ban on the number of adverse asthma events among a cohort of low-income children in the state. Children in this cohort are expected to have a reduced rate of adverse asthma events during the period after the implementation of the ban compared to the period before implementation. In comparison, rates of injury events are not expected to be associated with the periods before and after ban implementation.

The reduction in asthma rates is expected to be higher among children with greater potential for SHS exposure, including younger children, Black children, those whose asthma has been in poor control in the past, and children living in areas of neighborhood disadvantage. The reduction associated with the ban is not expected to be as strong in geographic areas which had a prior local smoking ban in effect.

This study was approved by the Institutional Review Boards of the University of Michigan (#HUM00077886) and the Michigan Department of Health and Human Services (MDHHS) (201306-01-EA).

Methods

A dynamic cohort of children with persistent asthma, the Pediatric Asthma Medicaid Utilization Cohort (hereafter referred to as 'Cohort'), was identified using enrollment, encounter, and claims data from Michigan Medicaid programs[147], as described in Chapter Two.

Counts of hospitalizations and emergency department (ED) visits due to asthma were tracked each month in the follow up period for each child. Counts of prescriptions filled for short acting beta-agonists (SABAs), oral corticosteroid (OC) bursts, and long-term controller medications (LTC), such as inhaled corticosteroids, were summed on an annual basis as a secondary set of asthma outcomes. Counts of outpatient and inpatient visits for injury were also tracked as a control condition that could be affected by secular changes, such as hospital policy and economic forces, but would not be expected to change in response to the ban's implementation.

Since 1997, many local governmental jurisdictions in Michigan passed local smoking bans in the form of ordinances and regulations. These bans were pre-empted by the state legislature[112], forcing the need for a statewide ban. Michigan Public Act 188 of 2009, passed in December 2009, banned smoking in public places as of May 1, 2010[113]. For this analysis, dates and jurisdictions of enactment of state and local smoking bans and ordinances were obtained from the MDHHS Tobacco Prevention Section (***Figure 1***). An area indicator of residential exposure to a smoking ban or ordinance was defined by ban coverage in the place of the child's residence each month during the Cohort period, including variables for statewide ban and for existence of local bans and ordnances. The ban is characterized dichotomously for this analysis as the period before its effective date or pre-effective data (January 1, 2007 to April 30, 2010) and post-effective date (May 1, 2010 to December 31, 2012).

Additional covariates related to asthma events included individual racial/ethnicity group, sex, age in years, and census block group of residence obtained from the beneficiary information from the MDHHS Medicaid Data Warehouse. An indicator for past poor asthma

control was defined as any ED and hospitalizations due to asthma, overuse of SABA (as measured by 13 or prescriptions fills), and/or more than two fills for OC bursts in the identification year. A calendar month indicator variable (January =1, February =2, etc.) was defined for each month of Cohort enrollment to control for seasonality of asthma events.

An area level measure of neighborhood disadvantage, based on the 2007-2011 American Community Survey (ACS) data, was assigned to monthly census block group of residence reported in the Michigan Medicaid Data Warehouse. This neighborhood disadvantage index[19], capturing both racial and economic segregation and was found associated with asthma prevalence in the metropolitan Chicago area[19]. The index was calculated from the average Z score for percentage of residents in the census block group who were living below poverty, unemployed, on public assistance, in female-headed households, youth, or African American, based on 2007-2011 ACS data (for detail, see Chapter 2).

Poisson regression was used to explore the association between demographic and exposure variables and adverse asthma events with an individual offset of the log of person months in the Cohort. Over dispersion (variance greater than mean, excessive zeros) was checked using Akaike information criterion[148-151] by comparing the goodness of fit of a model that did not account for over-dispersion versus that of a model that did account for it. Autocorrelation in the outcome due to repeated measures (data from individual months) for each child was addressed by using a compound symmetry matrix as correlation matrix in each model. Differences between nested Poisson regression models were assessed using the quasi-likelihood information criterion (QIC) with smaller QIC denoting better explanatory power. Variables were added to a model if the coefficient for the main effect of

the model changed by more than 20 percent, regardless of the p-value for the variable. Statistical data analyses were computed using SAS version 9.4 (SAS Institute Inc, Cary, NC).

Results

As described in Lyon-Callo et al[147], 97,548 children were enrolled during their identification year in 2007-2011. 96,766 children remained enrolled in the follow up period during 2008-2012 (***Table 11***), contributing 3,172,152 months. The frequency distributions of sex, racial/ethnic group, and poor asthma control during identification year were very similar between these periods, although the Cohort aged predictably, with more than one half of children being age 10 years or older during their last month in the Cohort. The percent of months of residential exposure to prior local smoking ban was consistent between the two periods, as was mean area neighborhood disadvantage index. The relative months of Ban exposure were very different by identification year (74 percent were pre-ban passage) and follow up period (35 percent were pre-ban passage) (***Table 11***).

Adverse asthma events were rare in the follow up period; 99 percent of child-months (3,130,459) did not have an inpatient or ED visit for asthma, with most of the remaining months having single events (35,727 months). The mean number of adverse asthma events during the follow up period ranged from 0.01 to 0.05 events for children, with younger age groups tending to have larger number of events per month (***Figure 5***). The rate of ED and inpatient stays due to asthma was 149.13 events per 10,000 child months (events/10,000 child months) during the follow up period (95% Confidence Interval (95% CI: 146.33-152.01).

Most months in the Cohort follow up period (65 percent) occurred after the ban was effective (***Table 11***). Children resided in areas where a local ordinance or ban had been passed for one half of the months in the follow up period.

The rate of adverse events decreased by 26 percent (95% CI: 24-28) in the period after the ban was enacted than compared to before (***Table 12***). This was a decrease from 181.99 events/10,000 child months to 134.36 events/10,000 child months. Model fit improved with the addition of age, age-squared, sex, racial/ethnic group and calendar month variables from a QIC of 378,153 to 368,768 (Model 2 in ***Table 12***). Poor asthma control during identification year (poor control), residence area with a prior ban (prior ban), and area neighborhood disadvantage index (poverty) variables were all significant in a model including multiple demographic variables, which was also the best fitting model (QIC = 354,942) (Model 7 in ***Table 12***). This model suggests a 25 percent reduction (95% CI: 23-27) in adverse asthma event rate during the post-ban period, adjusting for other covariates. Although sex and prior ban indicator were not significant in all models, these variables were retained as they improved model fit.

Most interaction terms were not significant when added to Model 7, including interaction terms for age by sex, race by ban, sex by ban or terms for study month and year (data not shown). The interaction of ban and prior ban indicators was not significant in the model (data not shown).

The interaction term of poor asthma control in identification year and Ban status was significant in the full model (rate ratio (RR) = 0.88; 95% CI: 0.82-0.83) with demographics and area level variables (Model 8 in ***Table 12***). The ban rate ratio was changed by 11 percent with the addition of the interaction term, from an RR of 0.75 (95%

CI: 0.73-0.77) to 0.83 (95% CI: 0.79-0.88) with the term. Children in poor control had asthma event rates during the pre-ban period 3.70 times that of those who were not in poor control during the pre-ban period (95% CI: 3.51-3.91), controlling for other variables in the model including ban exposure period. The effect of poor control on event rate was reduced by twelve percent after ban enactment (95% CI: 0.82-0.93). However, this model, including ban, age, age squared, sex, race/ethnicity, prior ban, poor asthma control, area poverty and interaction between ban and poor control, did not have the best fit (QIC = 356,466 vs 354,924 originally).

After the enactment of the ban, children in the cohort contributed 2,076,557 months. Applying the adverse asthma rate during the pre-ban period and the post-ban period, to this number of months and taking the difference, we estimate that the enactment of the Dr. Ron Davis Smoking Ban in Michigan prevented 9,400 events among this cohort of children with asthma. Based on median charge for emergency departments nationally during this time period ($1,233)[152], the ban may be associated with more than $11,000,000 reduction in ED charges. This is a crude estimate of charges, not payments, and does not take into account other savings such as those realized when children with better asthma control miss fewer days of school, and their parents miss less work.

Stratified Models

Stratified models were run to assess differences in ban ratio by age group and by race/ethnicity and by identification year control status (***Table 13***). The reduction in asthma events during the ban period compared to before ban enactment was consistent in size and statistical significance in the younger three age groups (0-4, 5-9, and 10-14 years

groups) but not significant in the 15-19 years group (ban period RR: 0.99 (95% CI: 0.87-1.13)).

The ban term was significant in models stratified by race/ethnicity group for black children (non-Hispanic Black RR: 0.86 (95% CI: 0.80-0.93)) and non-Hispanic White children (non-Hispanic White RR: 0.80 (95% CI: 0.73-0.87)). The ban terms in the other two stratified models had a similar effect size to the White and Black specific strata, but the ban terms were not statistically significant in these two models (Hispanic RR: 0.86 (95% CI: 0.68-1.08); Other RR: 0.80 (95% CI: 0.62-1.03)).

Asthma rates among children who were in poor control during their identification year dropped 27 percent after the ban enactment (RR: 0.73 (95% CI: 0.71-0.75)). In comparison, children who had no evidence of poor control who exhibited a 17 percent reduction (RR: 0.83 (95% CI: 0.79-0.88)). The stratum specific odds ratios were no different for categories of neighborhood disadvantage (quartiles 1 to 3 vs quartile 4).

Secondary Asthma Outcomes

The associations between the ban and additional asthma outcomes were also explored. Before the enactment, children in the Cohort filled 1,234 SABA, 983 OC, and 2,775 LTC prescriptions per 10,000 Cohort members. Fill rates for SABA, OC, and LTC medications were lower in the post-Ban period by 16 percent, eleven percent and 21 percent respectively (***Table 14***). Unlike the association with adverse asthma events, fill rates for Black children were lower than those for White children in this Cohort, particularly for LTC, controlling for Ban and other demographic variables (***Table 14***). The reduction in long term control medication use after the enactment of the Smoking Ban could be associated with the ability of children to use less routine control medication for

routine care as they have less exposure to secondhand smoke. As secondhand smoke exposure is associated with inflammatory response, children whose exposure to secondhand smoke is removed would theoretically need less inhaled corticosteroid or other routine asthma medication as that inflammation is reduced.

Injury Outcomes

Children in this Cohort had 334 visits/10,000 members for injuries to outpatient, ED or inpatient settings during the follow up period (crude model not shown). Although ban was significantly associated with decreases in injury rate in all models (***Table 15*** as example model), the point estimates for the decrease after Ban enactment were just four percent or less, regardless of covariates included in the model.

Discussion

The passage of the Dr. Ron Davis Smoke Ban in Michigan was associated with a large and significant reduction in asthma ED visits and hospitalizations among a Cohort of low income children served by the state's Medicaid programs. The 26 percent reduction in adverse asthma events seen in the crude model was attenuated to 17 percent, after adjustment for demographics, seasonality, asthma control, and neighborhood disadvantage, but remained significant.

The adjusted effect size was similar in magnitude to associations found in other states and countries. Meta-analyses of studies of smoking bans and asthma hospitalizations put the estimate at an eleven percent reduction[105,144,153] in pediatric populations in the U.S. and Europe. Similarly, Rando-Matos et. al[146] found a consistent pattern of reduction in asthma hospital admissions after passage of second hand smoking bans. Significant

decreases of between five to 31 percent of admissions for asthma were described in 13 of the 17 papers examining the impact of smoking bans on asthma hospitalizations, and the pooled RR from all these papers was 0.85 [0.79-0.91] for hospital admissions after enactment of bans[146]. The present study of low income children found a somewhat larger reduction, which could be expected due to children in low income Michigan households having higher SHS exposure in the pre-ban period.

Two papers also explored the effect of prior local ban on the impact of later statewide bans in the U.S. and Canada. Herman et. al[35] found that communities with a prior county-level restaurant smoking ban did not see an impact on asthma hospitalization rates from the state level ban or of additional county-level smoking bans. Landers[154] similarly found no additional reduction in pediatric asthma hospitalization rates for a state ban over the impact of a previous county level ban, looking at counties across the United States. Naiman's study[102] in Toronto, Canada assessed the impact of a complicated phased ban, implemented in various settings in multiple stages. In a 2017 study of respiratory admissions among adults, the asthma discharges decreased by 33 percent (95% CI 32–34) during the period after a ban affecting restaurant settings (effective in June 2001), but not after a ban on smoking in public places (enacted in October 1999) or a ban on smoking in bars, casinos and similar facilities that started in June 2004. These researchers did not find any reductions of respiratory hospital admission rates in control cities or for control conditions. The lack of significant interaction between prior local bans and Michigan's Dr. Ron Davis Secondhand Smoking Ban in the final models of our analysis is inconsistent with these prior findings, however, the pre-emption of local bans and ordinances by the State

Legislature may have reduced the effect of these bans on SHS exposure for children. In addition, the prior local bans in Michigan were variable in scope and enforcement.

Many studies looking at the impact of secondhand smoking bans on asthma care utilization rely on a pre-post design for ecological level data, presenting difficulties in interpreting changes in rates of outcomes. The use of a control condition, such as appendicitis, is used in some studies to separate the impact of a smoking ban from that of other policies or secular impact on discharge rates. Naiman et al's[102] study of respiratory and cardiovascular hospital admissions in the Toronto area used both geographic controls and a set of gastrointestinal control conditions (acute cholecystitis, bowel obstruction and appendicitis) to provide comparison for any changes seen in asthma hospitalization rates. Landers[154] found a statistically significant effect of county bans on child asthma discharges but no significant relationship with appendicitis discharges and smoking bans. This study of asthma outcomes among low income children in Michigan similarly had a control condition, injury, which was significantly associated with the ban period, possibly due to randomness or residual confounding with age, but the effect size was very small.

A few studies also explored interactions by age group, racial/ethnic group, geographic or socioeconomic status. Interaction among demographic factors is expected as asthma hospitalization and emergency department visit rates vary by these demographic factors. This study of children living in low income households in Michigan did not find any effect modification of racial/ethnic group, age group, or area level poverty index on the association between ban and asthma outcomes. Other authors did not find variation in the impact of secondhand smoking bans by these demographics either[37]. In contrast to this current study, Marchese et. al[145] study found asthma hospitalization rates among Michigan

adults decreased by eight percent after the enactment of Michigan's public smoking ban, and observed a slightly greater annual decrease in hospitalization rates among White adults (10 percent) versus Black adults (7 percent). This is counter to the finding of no interaction between race and ban in this low income pediatric Cohort.

A unique contribution of this study is the exploration of the impact of prior asthma control. As hypothesized, the association between adverse asthma events and ban period was stronger among children who had been in poor asthma control when they were identified to be part of this cohort than children without claims evidence of poor control. This study also provides a unique contribution in assessing if area level poverty alters the association with ban at all. While area level poverty was associated with asthma rates, the association between asthma events and ban period did not differ according to the neighborhood disadvantage index of the child's residence area.

In conclusion, Michigan's Dr. Ron Davis Smoking Ban was associated with a reduction in the adverse asthma event rates in this low-income pediatric cohort by 17 percent, controlling for confounders. Children who had been in poor control at baseline experienced more benefit from the ban enactment. Rates of medication utilization for asthma dropped in the follow up period, although the effect size was smaller than for hospitalization stays and emergency department visits. The rate of injury visits was only slightly reduced during this time, suggesting the larger reduction in asthma events is likely not due to a secular trend or Cohort aging.

This study documents the importance of maintaining policies to protect children from exposure to secondhand smoke, particularly those children whose asthma is in poor control. The continued disparity in adverse asthma events and long-term controller

medication use among Black and Hispanic children compared to White children among this low-income population with full insurance indicates more work is needed to improve asthma management in subpopulations, including improvements in environmental factors related to asthma exacerbations.

Table 11: Characteristics of Pediatric Medicaid Asthma Utilization Cohort Members during Identification Year and Follow Up Period, 2007-2011, 2008-2012, State of Michigan

Characteristics		Identification Year (2007-2011) N=97,548		Follow Up Period (2008-2012) N= 96,766	
		No.	%	No.	%
Sex					
Female		40,220	41.23	39,921	41.26
Male		57,328	58.77	56,845	58.74
Racial Group					
Non-Hispanic White		50,038	51.3	49,476	51.13
Non-Hispanic Black		37,075	38.01	36,885	38.12
Hispanic		5,091	5.22	5,071	5.24
Other		5,344	5.48	5,334	5.51
Age Group					
0-4 years		41,921	42.97	15,097	15.6
5-9 years		27,327	28.01	32,220	33.3
10-14 years		19,888	20.39	25,407	26.26
15-18 years		8,412	8.62	24,042	24.85
Any Poor Control Evidence		47,606	48.8	47,283	48.86
Total Months				3,172,152	
Months Exposure to Local Ban					
No		527,615	45.36	1,439,614	45.38
Yes		635,672	54.64	1,732,538	54.62
Months Exposure to State Ban					
No		861,417	74.05	1,095,595	34.54
Yes		301,870	25.95	2,076,557	65.46
Neighborhood Disadvantage Index					
Mean (SD) for all months		0.45	0.89	0.45	0.88
Identification Year					
	2007	33,196	33.93	32,862	33.96
	2008	16,822	17.19	16,671	17.23
	2009	16,940	17.28	16,691	17.25
	2010	16,955	17.19	16,660	17.22
	2011	14,173	14.4	13,882	14.35

Table 12: Rate Ratios and 95% Confidence Intervals (CI) from Poisson Regression for Smoking Ban and Emergency Department and Inpatient Stays Due to Asthma, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

	Rate per 10,000 Children and Rate Ratios with 95% Confidence Intervals							
	Model 1	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Intercept Rate	181.99	196.38	184.48	71.68	176.75	182.19	70.14	65.79
Ban	0.74 0.72-0.76	0.80 0.78,0.82	0.78 0.76,0.80	0.75 0.73,0.77	0.78 0.76,0.80	0.78 0.76,0.80	0.75 0.73,0.77	0.83 0.79,0.88
Age (years)		0.87 0.85,0.88	0.87 0.86,0.89	0.91 0.90,0.93	0.87 0.86,0.89	0.88 0.86,0.89	0.91 0.90,0.93	0.92 0.90,0.93
Age Squared		1.01 1.00,1.01	1.00 1.00,1.01	1.00 1.00,1.00	1.00 1.00,1.01	1.00 1.00,1.01	1.00 1.00,1.00	1.00 1.00,1.00
Female		0.98 0.96,1.00	0.98 0.96,1.00	0.98 0.96,1.00	0.97 0.96,0.99	0.97 0.95,0.99	0.98 0.96,1.00	0.98 0.96,1.00
Black		2.94 2.83,3.06	2.93 2.81,3.04	2.39 2.30,2.49	2.82 2.71,2.94	2.77 2.65,2.89	2.27 2.18,2.37	2.27 2.18,2.38
Hispanic		1.32 1.21,1.43	1.32 1.21,1.44	1.22 1.12,1.33	1.31 1.20,1.43	1.28 1.17,1.40	1.19 1.09,1.30	1.19 1.09,1.30
Other		2.02 1.83,2.23	2.05 1.86,2.26	1.96 1.78,2.16	2.01 1.82,2.22	2.03 1.84,2.24	1.93 1.75,2.13	1.93 1.75,2.13
Poor Asthma Control				3.47 3.33,3.62			3.44 3.30,3.58	3.70 3.51,3.91
Local Ban					1.11 1.06,1.15		1.04 1.00,1.08	1.04 1.00,1.08
Neighborhood Disadvantage						1.06 1.04,1.08	1.04 1.02,1.06	1.04 1.02,1.06
Ban*Poor Control								0.88 0.82,0.93
Jan.			0.89 0.86,0.93	0.89 0.86,0.92	0.89 0.86,0.93	0.89 0.86,0.92	0.89 0.86,0.92	0.89 0.86,0.92
Feb.			0.95 0.92,0.98	0.94 0.91,0.98	0.95 0.92,0.98	0.95 0.91,0.98	0.94 0.91,0.97	0.94 0.91,0.97
March			1.05 1.02,1.09	1.05 1.01,1.08	1.05 1.02,1.09	1.05 1.02,1.09	1.04 1.01,1.08	1.04 1.01,1.08
April			1.06 1.03,1.10	1.06 1.02,1.09	1.06 1.03,1.10	1.07 1.03,1.10	1.06 1.03,1.10	1.06 1.03,1.09
May			1.25 1.21,1.29	1.25 1.22,1.29	1.25 1.21,1.29	1.25 1.21,1.29	1.26 1.22,1.30	1.26 1.22,1.30
June			0.78 0.75,0.81	0.78 0.75,0.81	0.78 0.75,0.81	0.77 0.74,0.80	0.78 0.75,0.81	0.78 0.75,0.81
July			0.56 0.53,0.58	0.56 0.54,0.59	0.56 0.53,0.58	0.56 0.53,0.58	0.56 0.54,0.59	0.56 0.54,0.59

Aug.			0.68 0.65,0.71	0.68 0.65,0.71	0.68 0.65,0.71	0.68 0.65,0.71	0.68 0.65,0.71	0.68 0.65,0.71
Sept.			1.85 1.80,1.90	1.85 1.80,1.90	1.85 1.80,1.90	1.86 1.81,1.91	1.86 1.81,1.91	1.86 1.81,1.91
Oct.			1.50 1.45,1.54	1.50 1.46,1.54	1.50 1.45,1.54	1.50 1.46,1.55	1.50 1.46,1.55	1.50 1.46,1.55
Nov.			1.18 1.14,1.21	1.18 1.14,1.22	1.18 1.14,1.21	1.18 1.14,1.22	1.18 1.14,1.22	1.18 1.14,1.22
QIC	378,153	367,559	368,768	364,148	368,633	359,744	354,942	356,446

Table 13: Rate Ratios and 95% Confidence Intervals (CI) for Poisson Regression Stratified by Race/Ethnicity, Age Group, Identification Year Poor Asthma Control, or Quartile of Neighborhood Disadvantage, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

	Rate Ratio (95% CI)	
Race/Ethnicity Strata (1)		
Black, Non-Hispanic	0.86	0.80-0.93
White, Non-Hispanic	0.80	0.73-0.87
Hispanic (2)	0.86	0.68-1.08
Other, Non-Hispanic (2)	0.80	0.62-1.03
Age Group Strata (1)		
0-4 years (2)	0.79	0.70-0.89
5-9 years (2)	0.73	0.67-0.80
10-14 years (2)	0.76	0.69-0.84
15-18 years	0.99	0.87-1.13
Poor Control Strata (3)		
Poor Control at Identification (4)	0.73	0.71-0.75
No Poor Control	0.83	0.79-0.88
Neighborhood Disadvantage Strata (5)		
Highest Quartile	0.82	0.76-0.88
Lowest Three Quartiles (4)	0.86	0.79-0.92

1. Adjusted for calendar year age, age-squared, sex, racial-ethnic group, calendar month, prior smoking ban, Neighborhood Disadvantage Index, poor control during identification year, and poor control*ban interaction term.

2. Poor Control*Ban interaction terms are statistically insignificant in this stratum.

3. Adjusted for calendar year age, age-squared, sex, racial-ethnic group, calendar month, prior smoking ban, and Neighborhood Disadvantage Index.

4. Prior Ban term is statistically insignificant in this stratum.

5. Adjusted for calendar year age, age-squared, sex, racial-ethnic group, calendar month, prior smoking ban, poor control during identification year, and poor control*ban interaction term.

Table 14: Rate Ratios (RR) and 95% Confidence Intervals (CI) from Poisson Regression for Asthma Medication Prescription Fills by Exposure to Smoking Ban and Demographics, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

		Short Acting Beta Agonists		Oral Corticosteroids		Long Term Controllers	
Parameter		RR (Rate)	95% CI	RR (Rate)	95% CI	RR (Rate)	95% CI
Intercept		1,234	1199, 1271	983	949, 1019	2,775	2681, 2873
Ban		0.84	0.83, 0.84	0.89	0.87, 0.90	0.79	0.79, 0.80
Race	Black	0.97	0.95, 0.98	0.92	0.90, 0.94	0.58	0.57, 0.60
	Hispanic	0.90	0.87, 0.93	0.94	0.90, 0.99	0.68	0.64, 0.71
	Other	1.16	1.12, 1.20	1.25	1.19, 1.31	0.96	0.92, 1.00
Age		1.06	1.05, 1.07	0.88	0.87, 0.88	1.08	1.07, 1.09
Age Squared		1.00	1.00, 1.00	1.00	1.00, 1.00	0.99	0.99, 0.99
Sex		0.99	0.98, 0.99	0.98	0.97, 0.99	0.99	0.97, 1.00
Prior Ban		1.04	1.03, 1.06	1.03	1.01, 1.06	0.95	0.93, 0.97

Table 15: Rate Ratios (RR) and 95% Confidence Intervals (CI) from Poisson Regression for Injury Visits by Exposure to Statewide Smoking Ban and Demographics, Pediatric Asthma Medicaid Utilization Cohort, 2008-2012 Follow Up Period, State of Michigan

Parameter		RR	95% CI
Intercept (Rate per 10,000 children)		387	358, 418
Statewide Smoking Ban		0.96	0.94, 0.98
Race	Black	0.65	0.64, 0.67
	Hispanic	0.71	0.68, 0.75
	Other	0.84	0.80, 0.88
Age in Years		0.96	0.95, 0.97
Age Squared		1.00	1.00, 1.00
Sex	Female	0.93	0.92, 0.94

CHAPTER V

Discussion

Overall Summary of Research and Findings

This dissertation explores the impact of demographic, temporal, and area level factors on adverse asthma events among children who reside in low income households. Understanding these factors can inform policy and interventions to reduce pediatric asthma exacerbations by expanding access to care or reducing exposure to asthma triggers in the environments where children live, learn and play. Even among a low-income cohort of children with full insurance, asthma disparities are, in part, associated with area level variables. The impact of policy changes, such as Michigan's Dr. Ron Davis Smoke Ban, can significantly impact experiences with adverse asthma events among Michigan children, particularly those children most at risk for asthma attacks.

Aim 1

The first aim of this work was to create a dynamic cohort of children with asthma served by the Michigan Medicaid programs, including information on demographics,

asthma health care and pharmaceutical utilization, and area level characteristics of residential address. The Pediatric Asthma Medicaid Utilization Cohort is a statewide, population-based cohort with 4,335,349 person-months of observation between 2007 and 2012. The low-income children in this cohort experienced 93,620 adverse asthma events (emergency department visits and hospitalizations), which represents a significant target for reduction in the future, as well as power for statistical analysis. Children in this study resided for at least one month in more than 85 percent of the census block groups in the state, which provides variation in neighborhood disadvantage, racial isolation, and racial dissimilarity indices for analyses. Nearly one half of children had claims evidence of being in poor asthma control during their identification year. Compared to all children in the State of Michigan, children in the Cohort were younger during their identification year and Black children were overrepresented in the Cohort. During their identification year, children had 39,422 emergency department visits and 5,680 inpatient stays. More than one half of children filled an OC prescription. Cohort members filled an average of 2.75 SABA prescriptions during their identification year.

The odds of being in poor asthma control (defined as having had an asthma hospitalization, an emergency department visit for asthma, used two or more OC prescriptions, or used thirteen or more SABAs in a year) increased by increasing unit of neighborhood disadvantage, controlling for race and age during their identification year. Preschool aged children (0-4 years) had 2.29 times (95% CI: 2.26-2.32) the odds of being in poor control during a month in their identification year the odds of adolescents (15-17 years), controlling for sex and race/ethnicity group. The odds of being in poor control

among of Black children was 2.11 times (95% CI: 2.10-2.13) the odds of White children, controlling for age group and sex.

Racial isolation and dissimilarity indices were calculated for each month of a child's enrollment in the Cohort. Forty percent of months in the Cohort period were spent in the highest quartile of isolation or dissimilarity. These indices were used in health analyses using data from census tracts within a metropolitan statistical area or city. This cohort extends the use of those indices, as well as the neighborhood disadvantage index, to census block group across an entire state geography. Although the neighborhood disadvantage index was used in models, the racial isolation and dissimilarity indices were too skewed for use in the Poisson regression modelling technique, despite efforts at transformation.

The detailed information on enrollment and insurance status in this Cohort provides the ability to understand the impact of continuous coverage on future asthma events. The availability of a monthly address indicator could also be leveraged to explore the acute impact of residential mobility on asthma events, as well as associations with other area level factors, such as residence in medical shortage areas or other data related to health care access.

Aim 2

Aim Two describes the characteristics of the cohort which predict higher adverse asthma rates among children enrolled in the Michigan Medicaid programs during the cohort follow up period. Children who were in poor control during their identification year or who resided in areas of higher neighborhood disadvantage had higher rates of adverse asthma events than their counterparts. Children in poor control during their identification

year had 3.39 times as high asthma rates as children without evidence of poor control. In the follow up period, children experienced a seven percent increase in adverse asthma rates for every unit increase in the area's neighborhood disadvantage index.

Although associations between area level exposures and adverse event rates were less clear, the significant association between neighborhood disadvantage index and increases asthma rates in this low-income cohort is consistent with the relationship seen in studies of asthma prevalence in metropolitan areas[19,20,57,58,129,130,132]. The use of the measure in a low-income cohort at a state level is unique in the literature. That an association can be seen with neighborhood disadvantage in a low-income cohort implies that there is variation in the access to health-related resources and exposure to asthma triggers among children enrolled in Michigan Medicaid Programs. Additional use of this type of cohort data could further elucidate the type of geographic areas that present more challenges for children living with asthma, to develop new policy and interventions to reduce those challenges and improve asthma control.

Aim 3 and 4

Aims three and four estimate the potential impact of Michigan's Dr. Ron Davis Smoke Ban on the number of adverse asthma events among low income children. As hypothesized, adverse asthma rates were lower after ban enactment than before. The unadjusted rate of adverse asthma events was 23 percent lower in the post-ban period than the pre-ban period. After controlling for prior ban, past prior asthma control, and demographic variables, the ban was still associated with a 17 percent reduction in the adverse asthma rates in the follow up period.

The study had hypothesized that younger children, black children, and children living in more disadvantaged areas would experience a larger reduction in asthma events after the Ban, but there were no differences in these strata. However, children who were in poor asthma control during their identification year had a 27 percent reduction in asthma event rates after the ban enactment, whereas children without evidence of poor control during their identification year had a 17 percent reduction in asthma event rates.

The rate of injury visits was not expected to change in association with the ban. Although there was a statistically significant reduction in this rate, this reduction was a relatively small effect (four percent). The size of this reduction suggests that reduction in asthma rates associated with the ban was not solely due to a secular trend or aging of the cohort. The smaller reduction in injury visits could be related to residual confounding due to aging of the cohort or could be due to changes in coding of injury visits, particularly the increasing use of e-codes in billing of emergency department visits.

This study provides evidence supporting the importance of maintaining policies to protect children from exposure to secondhand smoke, particularly those children whose asthma was in poor control. The association with being in poor control during identification year provides potential opportunity for targeting enhanced education or case management for children. The continued disparity in adverse asthma events and long-term controller medication use among Black and Hispanic children compared to White children among this low-income population of children with full insurance indicates more work is needed to improve asthma management in subpopulations. This disparity persists despite large reductions in asthma hospitalization and ED visits over time.

In conclusion, Michigan's Dr. Ron Davis Smoking Ban was associated with a reduced rate of adverse asthma events among low income cohort of children with asthma. Children who had been in poor control at baseline experienced more benefit from the ban enactment. Rates of medication utilization for asthma also dropped in the follow up period, although not as strongly. The rate of injury visits was not substantially reduced during this time, indicating that this reduction in adverse asthma events was not due to a secular trend or aging of the Cohort. The use of Medicaid claims data to assess these associations provides a model for other states who are considering adopting such a ban or need to assess a ban's impact.

Strengths and Limitations

This Cohort has many strengths. The large sample size guarantees adequate power to examine the motivating research questions that led to its formation. The availability of geocoded information on census block group of monthly residence allows more flexibility for assigning many area level characteristics and could be used to assess the effect of changes in residence on various outcomes. Detailed information on enrollment and insurance status provides the ability to understand the impact of continuous coverage on future asthma events. Past work has explored the associations between area level exposures and health outcomes within a metropolitan region, but this Cohort expands the use of these techniques to the level of variation found across an entire state. The cohort could be leveraged to assess other area exposures, such as medical shortage areas or other data sets regarding health care access.

There are many limitations however. The use of administrative claims may underestimate asthma prevalence and can only represent low-income children enrolled in Michigan Medicaid programs for whom Medicaid paid for claims for asthma services. These data cannot represent asthma exacerbations for which children did not seek care. Furthermore, these data do not contain information about potential risk factors for asthma exacerbation in the environment or in patient's lifestyle. There are also limitations to the use of census block groups as indicators of neighborhood characteristics as they are arbitrary in shape and size, and vary in ability to capture the concepts of segregation and how that concept relates to health resources and behaviors [127,155,156]. The use of area variables assumes that children are exposed to the conditions within this area. In addition, the geographic definition for prior ban and neighborhood disadvantage assume that children's exposures can be defined by county or census block group geography, whereas people do not limit their asthma management behavior by geopolitical boundaries.

These limitations are expected to result in non-differential misclassification. The large sample size allowed for the power to detection of an association at the state despite misclassification.

Future Directions

There is additional work that could be undertaken with this existing Cohort data set to further understand the predictors of asthma events among low income children. The racial isolation and dissimilarity indices could be recalculated and run within metropolitan statistical areas. The impact of residential mobility within this data set, either laterally within a bracket of neighborhood disadvantage or between different types of areas.

Analyses could also be undertaken to assess whether the SHS ban had differential impact in different geographic areas of the state.

Additional work could be conducted to estimate the cost savings in reduction in number of inpatient and outpatient visits and reduction in number of medications filled, as well as estimating reduction in indirect costs as children and caregivers do not miss as many days of school or work due to reduction in asthma exacerbations.

Data could be added to the current Cohort data set to understand the impact of primary care or specialty provider shortage areas or housing or business characteristics of the area where children live. Given the Michigan Department of Health and Human Services (MDHHS) responsibilities for health care insurance policy, emergency housing assistance, foster care, and other programs information on potential health benefits to housing stability could be important to inform improvements. It would also be possible to add more information about these children's asthma control, including severity of asthma hospitalization (length of stay), asthma mortality, and impact of comorbid conditions. Additional control conditions, such as appendicitis, could also be added to the data set. Adding additional years to the Cohort could be used to examine longevity of the ban effect in the population, data could be added up to the conversion to ICD-10-CM in October 2014. The generalizability of these findings to other populations in Michigan could be assessed if similar administrative cohorts could be developed for other insured populations.

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