



Indoor tobacco legislation is associated with fewer emergency department visits for asthma exacerbation in children

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ABSTRACT

Background: During the past 3 decades, numerous cities and states have adopted laws that ban smoking in public indoor spaces. The rationale for these policies has been to protect nonsmokers from the adverse health effects of secondhand smoke.

Objective: To determine whether the implementation of indoor smoking legislation is associated with a decrease in emergency department visits for asthma in children.

Methods: This retrospective analysis used a natural experiment to estimate the impact of clean indoor air legislation on the rate of emergency department admissions for asthma exacerbation in children. Data were obtained from the Pediatric Health Information System. A Poisson regression was used for analyses and controlled for age, sex, race, payer source, seasonality, and secular trends.

Results: Asthma emergency department visits were captured from 20 hospitals in 14 different states plus the District of Columbia from July 2000 to January 2014 ($n = 335,588$). Indoor smoking legislation, pooled across all cities, was associated with a decreased rate of severe asthma exacerbation (adjusted rate ratio 0.83, 95% confidence interval 0.82–0.85, $P < .0001$).

Conclusion: Indoor tobacco legislation is associated with a decrease in emergency department visits for asthma exacerbation. Such legislation should be considered in localities that remain without this legislation to protect the respiratory health of their children.

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Introduction

During the past 3 decades, numerous cities and states have adopted laws that ban smoking in public indoor spaces, including hotels, workplaces, restaurants, and bars. The rationale for these policies is to protect nonsmokers from the numerous adverse

health effects of secondhand smoke. One population that is particularly susceptible to the adverse effects of secondhand smoke exposure is children because they typically have little or no control over their surrounding environment. Because approximately 8% of children have asthma and secondhand tobacco smoke is a known trigger for asthma exacerbation, these policies would ideally decrease asthma exacerbation; however, little is known of about the overall impact of these local and state policies on protecting children from severe asthma exacerbations.¹

Common triggers for asthma exacerbations in children include allergens (such as animal dander, pollens, molds, and pests), weather changes, upper respiratory infections, influenza, and inhaled irritants such as tobacco smoke.² National campaigns have emphasized vaccinations and hand hygiene to decrease the transmission of infectious diseases that could trigger asthma exacerbations. However, few other triggers have potential to be controlled and/or decreased by public policy, except for indoor and outdoor air quality, particularly tobacco smoke exposure. Although national campaigns have increased awareness of the adverse effects of

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smoking tobacco, children can still be adversely affected by smoke exposure in restaurants and other public spaces. Because medical expenses related to asthma exceed \$70 billion a year, the implementation of smoking bans in indoor public spaces has the potential not only to significantly decrease the incidence of asthma exacerbation in children but also to lead to an overall significant decrease in the costs associated with this disease by protecting this vulnerable population from this potent asthma trigger.³

This study assessed the association between municipal and state indoor smoking legislation and severe asthma exacerbation resulting in emergency department (ED) visits to pediatric hospitals. We hypothesized that despite variations in policy among cities and states, restricting smoking in public indoor spaces would be associated with an overall decrease in the incidence of ED visits for asthma exacerbation in children.

Methods

Study Design and Setting

This study design was a retrospective, secondary data analysis capitalizing on a natural experiment to estimate the impact of clean indoor air legislation on the rate of ED admissions for asthma exacerbation. The study sample was limited to children younger than 18 years who were treated at a pediatric hospital. Data from the 20 US children's hospitals in which a complete dataset was available were included and covered 3 years before indoor smoking legislation until 3 years after implementation of indoor smoking legislation for the region surrounding the hospital. This study was approved by our local hospital institutional review board and the de-identified data were analyzed.

Participants

Metropolitan areas were included (1) if the metropolitan area had a local children's hospital that contributes data to the Pediatric Health Information System (PHIS) and (2) if ED data were available in the PHIS for 3 years before and 3 years after indoor smoking legislation for the area surrounding the hospital. Data were not available for any metropolitan area that allowed indoor smoking in public buildings to use as "controls."

Data Sources and Variables

The PHIS contains inpatient, ED, ambulatory surgery, and observation data from 44 not-for-profit tertiary care pediatric hospitals in the United States. These hospitals are affiliated with the Children's Hospital Association (Overland Park, Kansas), which serves as the data repository for these secondary data. Data quality and reliability are assured through a joint effort between the Children's Hospital Association and participating hospitals. The data warehouse function for the PHIS database is managed by Truven Health Analytics (Ann Arbor, Michigan). For external benchmarking, participating hospitals provide discharge and encounter data, including demographics, diagnoses, and procedures. Data are de-identified at the time of data submission, and data are subjected to a number of reliability and validity checks before being included in the database. It has been estimated that this database captures approximately 15% of all pediatric admissions across the country.^{4–6}

We obtained data for all ED visits by children younger than 18 years with a primary discharge diagnosis of asthma (*International Classification of Diseases, Ninth Revision* code 493) using the PHIS. Date of discharge, admit age in years, sex, race, payer source, and cost of visit also were downloaded from the PHIS database.

The remaining data were retrieved from publicly available records. Dates of indoor smoking legislation for each metropolitan area were determined from the Americans for Nonsmokers' Rights

website and Wikipedia and then confirmed on local and regional websites.^{7,8} Population estimates (<18 years of age) for each metropolitan statistical area (MSA) for each included year were obtained from the US Census Bureau and used as the denominators in rate calculations.⁹

Measurements

Dependent variable and outcome measurement

The primary outcome measurement was the rate of ED visits for asthma each day. The number of ED admissions for asthma was counted for each day. Because asthma exacerbations were counted rather than individuals, individual children might have been included in the analyses more than once. Rates were calculated by dividing the number of ED admissions for each day by the pediatric population of the MSA for the respective year.

Independent variables, covariates, and adjusters

Independent variables were as follows. A dummy variable was coded to test the impact of legislation, with 0 indicating an event before legislation in the region surrounding the hospital and 1 indicating an event after legislation in the same region. To account for seasonal variation in asthma exacerbation, first- and second-order harmonics were included in the model, as performed in a related type of analysis.¹⁰ To control for secular linear time trends in asthma, a variable was created that assigned a unique number from 1 to 163 for each month from January 2000 through July 2013. Results were unchanged when the linear time trend was replaced with separate indicator variables for each month in the data. Sex, black race, payer source (Medicaid vs all others), and admit age were included in the adjusted model.

Statistical Analysis

Poisson regression with negative binomial distribution to account for over-dispersion was used to model the rate of ED visits for asthma exacerbation for combined and local data and results are presented as rate ratios (RRs). Records with missing covariates were retained in the final model. Our policy measurements, which changed from 0 to 1 at the time of the smoking legislation, might have been capturing merely temporal variations in ED rates. To mitigate this concern, we conducted a falsification test in which we assigned an arbitrary date of January 1, 2007 for our policy variable in all locations. We expected to find no statistically significant policy effect in this placebo test. All analyses were conducted using SAS 9.3 (SAS Institute, Pacific Grove, California).

Results

For the cities that contribute to the PHIS database, indoor tobacco legislation was implemented from January 1, 1990 (Norfolk, Virginia) through June 4, 2012 (Birmingham, Alabama). Almost half the included municipalities (19 of 43) implemented indoor tobacco legislation from 2006 through 2008. At the time we accessed the data (second quarter of 2014), 20 of the 44 hospitals that participate in the PHIS had data available for 3 years before implementation of indoor smoking legislation and 3 years after implementation. These 20 hospitals were located in 14 different states plus the District of Columbia. In total, 335,588 ED visits for asthma were captured from these hospitals from July 2000 through January 2014. Included hospitals, the relevant MSA, the estimated population (children <18 years old) for the MSA at the time of the smoke-free ordinance, and the dates of implementation of the smoking ordinance are presented in [Table 1](#).

The impact of indoor tobacco legislation in each metropolitan area varied. A statistically significant decrease was found in 4 urban regions and ranged from 5% to 15% in adjusted analyses (secular trends, seasonality, male sex, Medicaid status, black race, and age).

Table 1

Pediatric Health Information System Hospitals and Dates of Implementation of Indoor Smoking Legislation for the Surrounding Area

Hospital name	Metropolitan statistical area	Legislation date	Population ^a
Akron Children's Hospital	Akron, Ohio	12/7/2006	163,798
Children's Healthcare of Atlanta	Atlanta, Sandy Springs, and Marietta, Georgia	7/1/2005	1,294,408
Lurie Children's Hospital of Chicago	Chicago, Illinois (excluding Naperville and Joliet)	1/1/2008	2,032,829
Cincinnati Children's Hospital Medical Center	Cincinnati and Middleton, Ohio, Kentucky, and Indiana	12/7/2006	533,094
Nationwide Children's Hospital	Columbus, Ohio	12/7/2006	435,127
Driscoll Children's Hospital	Corpus Christi, Texas	4/14/2009	110,499
Children's Medical Center	Dallas, Plano, and Irving, Texas	4/10/2009	1,213,665
Children's Hospital Colorado	Denver, Aurora, and Broomfield, Colorado	7/1/2006	614,596
Cook Children's Health Care System	Fort Worth and Arlington, Texas	1/1/2008	578,061
Children's Mercy Hospitals and Clinics	Kansas City, Missouri and Kansas	6/21/2008	513,593
Le Bonheur Children's Medical Center	Memphis, Tennessee, Mississippi, and Arkansas	7/1/2007	353,678
Children's Hospital of Wisconsin	Milwaukee, Waukesha, West Allis, Wisconsin	7/5/2010	382,504
Children's Hospitals and Clinics of Minnesota	Minneapolis, St Paul, and Bloomington, Minnesota and Wisconsin	10/1/2007	813,548
Children's Hospital	New Orleans, Metairie, and Kenner, Louisiana	1/1/2007	239,471
Children's Hospital & Medical Center	Omaha and Council Bluffs, Nebraska and Iowa	6/1/2009	222,402
Children's Hospital of Pittsburgh of UPMC	Pittsburgh, Pennsylvania	9/11/2008	482,492
Seattle Children's Hospital	Seattle, Bellevue, and Everett, Washington	12/8/2005	734,777
St Louis Children's Hospital	St Louis, Missouri and Illinois	1/2/2011	661,831
All Children's Hospital Johns Hopkins Medicine	Tampa, St Petersburg, and Clearwater, Florida	7/1/2003	565,739
Children's National Medical Center	Washington, DC, Arlington and Alexandria, Virginia, Maryland and West Virginia	1/1/2007	1,300,697

^aPopulation younger than 18 years at the time of indoor tobacco legislation implementation.

However, 2 cities had a statistically significant increase rate in ED visits for asthma in children despite indoor tobacco legislation (adjusted RRs 1.14 and 1.44). These results are presented in Table 2.

In the pooled results, indoor smoking legislation was associated with a 17% decrease in childhood ED visits for asthma exacerbation from 3 years before law implementation through 3 years after law implementation after controlling for secular trends, seasonality, male sex, Medicaid status, black race, and age (adjusted RR 0.83, 95% confidence interval [CI] 0.82–0.85, $P < .001$). An appreciable and increasing rate decrease also was seen after only 1 year after law implementation (adjusted RR 0.92, 95% CI 0.90–0.94, $P < .001$) and 2 years after law implementation (adjusted RR 0.87, 95% CI 0.85–0.88, $P < .001$). These results are presented in Table 3.

Results for our falsification test are presented in Table 4. We found no statistically significant relation between our placebo

policy measurement and ED visits in all but the 2-year estimation; however, for the 2-year estimation, the RR estimates approached 1 (adjusted RR 0.96, 95% CI 0.94–0.98, $P < .0001$). Lack of meaningful effects in the falsification test increase our confidence that we are capturing true policy effects in our baseline models.

Discussion

The objective of our analysis was to examine the impact of indoor smoking legislation in the United States on pediatric asthma exacerbations that lead to ED visits. After considering 3-year pre- and post-legislation data pooled across 20 geographic locations, we found that indoor smoking legislation was associated with a 17% decrease in the incidence of severe asthma ED visits. Significant decreases also occurred within 1- and 2-year time windows. The absolute degree of decrease varied across metropolitan areas.

These results overall support the importance of widespread restriction of smoking in public places on the respiratory health of children. States and metropolitan areas that have yet to implement such protective laws should consider new ordinances to protect the respiratory health of their children. As of January 2014, 10 states remained with no general statewide ban on indoor smoking: Alabama, Alaska, Kentucky, Mississippi, Missouri, Oklahoma, South Carolina, Texas, West Virginia, and Wyoming. In addition, Oklahoma remains the only state in which state law prohibits local governments from regulating smoking more strictly than the state. Most major metropolitan areas have implemented indoor smoking bans despite the lack of a statewide ban, and Oklahoma is the only state without any legislated smoking bans.^{7,8}

Table 2

Rate of Pediatric Emergency Department Visits for Asthma Exacerbation 3 Years After Implementation of Indoor Tobacco Legislation

MSA	Adjusted RR ^a	95% CI
1	0.91 ^b	0.86–0.96
2	0.95 ^b	0.91–0.99
3	0.87 ^b	0.82–0.92
4	0.85 ^b	0.79–0.92
5	1.04	0.96–1.12
6	0.99	0.91–1.08
7	1.03	0.98–1.08
8	1.09	1.00–1.18
9	1.01	0.96–1.07
10	0.94	0.87–1.01
11	0.96	0.90–1.02
12	1.03	0.98–1.09
13	1.02	0.96–1.09
14	1.01	0.95–1.06
15	0.97	0.86–1.09
16	1.07	1.01–1.15
17	0.93	0.83–1.03
18	1.05	0.98–1.12
19	1.14 ^b	1.05–1.24
20	1.44 ^b	1.33–1.57

Abbreviations: CI, confidence interval; MSA, metropolitan statistical area; RR, rate ratio.

^aAdjusted for secular trends, seasonality, sex, race, payer source, and admit age.^b $P < .05$.**Table 3**

Rate of Pediatric Emergency Department Visits for Asthma Exacerbation After Implementation of Indoor Tobacco Legislation

MSA	Adjusted RR ^a	95% CI
Pooled (all MSAs) 3 y pre-post	0.83 ^b	0.82–0.85
Pooled (all MSAs) 2 y pre-post	0.87 ^b	0.85–0.88
Pooled (all MSAs) 1 y pre-post	0.92 ^b	0.90–0.94

Abbreviations: CI, confidence interval; MSA, metropolitan statistical area; RR, rate ratio.

^aAdjusted for secular trends, seasonality, sex, race, payer source, and admit age.^b $P < .001$.

Table 4
Falsification Tests

MSA	Adjusted RR ^a	95% CI	P value
Pooled (all MSAs) 3 y pre-post	1.01	1.00–1.03	.09
Pooled (all MSAs) 2 y pre-post	0.96	0.94–0.98	<.0001
Pooled (all MSAs) 1 y pre-post	0.97	0.92–1.02	.23

Abbreviations: CI, confidence interval; MSA, metropolitan statistical area; RR, rate ratio.

^aAdjusted for secular trends, seasonality, sex, race, payer source, and admit age.

The results of this study are corroborated by similar findings from previous studies on national and regional levels. Rayens et al¹⁰ reported a very similar 18% (95% CI 4–29) decrease in childhood ED visits for asthma in Lexington, Fayette County, Kentucky after implementation of indoor smoking legislation. Their study also found a 24% (95% CI 16–31) decrease in adults, with a total decrease across all ages of 22% (95% CI 14–29). Another study in 2010 by Mackay et al¹¹ reported an 18.2% (95% CI 14.7–21.8) decrease in hospital admissions for asthma in Scotland in preschool and school-age children after analyzing more than 21,000 hospital admissions for asthma over a 9-year period. The publication of the latter study was followed by a letter to the editor of the journal, which also described a 30.7% (95% CI 22.8–38.6) decrease in asthma admissions in the Lombardy region of Italy after analyzing more than 15,000 asthma admissions.¹² Millett et al¹³ described a 9% (95% CI 7–11) decrease in pediatric asthma admissions after smoke-free legislation in England in 2007. These results collectively support the findings of this study and the positive impact of indoor tobacco legislation on pediatric asthma.

To our knowledge, only 1 study has been published that failed to find that indoor tobacco legislation had an impact on asthma exacerbation in children. In 2013, Gaudreau et al¹⁴ analyzed discharge data from the Prince Edward Island Discharge Abstract Database, a validated Canadian database that captures all admissions of Prince Edward Island with Provincial Health Numbers. Although a decrease in acute myocardial infarction after the ban was seen, the Prince Edward Island legislation was not found to decrease pediatric or adult asthma admissions (odds ratio 1.48, 95% CI 0.90–2.41). However, the Prince Edward Island tobacco legislation was unique from legislation implemented in Scotland, England, and most US cities in that the original 2003 ban still allowed smoking in bars and restaurants in designated smoking rooms.¹⁵ It has been shown that separate smoking areas with or without separate ventilation do not protect nonsmokers from secondhand smoke.^{16,17} Presumably, restaurants are a major source of secondhand tobacco exposure in children outside the home environment; therefore, the Canadian legislation in its 2003 form might have been inadequate to protect children (or adults) with asthma.

These data identified 2 cities in which ED visits for asthma in children increased despite legislation. One metropolitan area was struck with a natural disaster near the time of implementation of indoor tobacco legislation. As such, any short-term benefit of the legislation in this city was likely blunted by several environmental and social factors. The increase in ED visits for asthma seen at the other identified city was likely an artifact caused by the implementation of a marketing campaign across the respective metropolitan area advertising a new asthma center and a known effort on the part of the institution to increase access to and quality of asthma care at the time of law implementation. This likely influenced families with a child with asthma to transfer care to this institution (personal communication with local asthma center).

The strength of this study is the innovative approach used to understand the impact of public health legislation. Because of the many variables that affect asthma exacerbations, accessing large amounts of data is essential to have appropriate power to

determine whether indoor smoking legislation is significantly associated with a lower rate of asthma ED admissions. This is exemplified by the inability to determine significance in the small, individual MSA datasets. The collaborative approach that many pediatric hospitals have taken by pooling their billing data into 1 unified data warehouse has proved to be an effective strategy to make observations that would otherwise not be feasible.

These findings should be interpreted with full knowledge of the study's limitations. First, this study was designed to determine association, not causation, and therefore should be interpreted as such. A randomized controlled trial designed to determine causation is not feasible because of the ethical implications of knowingly subjecting children to secondhand smoke. Therefore, epidemiologic studies are an essential method to determining the impact of indoor tobacco legislation. Second, this study attempted to associate a decrease in asthma exacerbation with implementation of several unique, regional legislations. Because no national indoor smoking legislation exists, a comparison of unique legislations was necessary and exemplified by the fact that no difference in rates existed before and after indoor tobacco legislation, with several of the smaller datasets obtained from 1 regional hospital within each MSA. This limitation also is likely to have a minimal influence in the findings because the major source of variability in each policy was the inclusion or exclusion of bars, casinos, and/or other age-restricted environments, which are unlikely to have a significant impact on children. Third, because all pediatric hospitals who contribute data to PHIS are in metropolitan areas that have passed indoor smoking legislation, we did not have control locations. We attempted to address this concern by using historical comparisons and changing time windows. We also included a falsification test to address concerns about temporal trends in asthma ED visits. In addition, each hospital included was a nonprofit tertiary care pediatric hospital in an urban area; therefore, the results might not be generalizable to all areas of the country. Third, because each pediatric hospital that participates in the PHIS has unique billing and coding systems, institutional variability in these data might exist; however, we also believe this to be a minor limitation because the PHIS system is supported by a robust data quality program.

In summary, these multiregional data show a significant decrease in ED visits from asthma in children associated with the implementation of indoor tobacco legislation. Because government taxes are typically a significant contributor to fund the cost of children's health care, action should be considered in localities that remain without indoor tobacco legislation to protect children of the state and to allow redistribution of the significant dollars spent on ED visits for asthma in these children.

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