



Reduction in emergency department visits for children's asthma, ear infections, and respiratory infections after the introduction of state smoke-free legislation

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ABSTRACT

Despite the benefits of smoke-free legislation on adult health, little is known about its impact on children's health. We examined the effects of tobacco control policies on the rate of emergency department (ED) visits for childhood asthma ($N = 128,807$), ear infections ($N = 288,697$), and respiratory infections ($N = 410,686$) using outpatient ED visit data in Massachusetts (2001–2010), New Hampshire (2001–2009), and Vermont (2002–2010). We used negative binomial regression models to analyze the effect of state and local smoke-free legislation on ED visits for each health condition, controlling for cigarette taxes and health care reform legislation. We found no changes in the overall rate of ED visits for asthma, ear infections, and upper respiratory infections after the implementation of state or local smoke-free legislation or cigarette tax increases. However, an interaction with children's age revealed that among 10–17-year-olds state smoke-free legislation was associated with a 12% reduction in ED visits for asthma (adjusted incidence rate ratios (aIRR) 0.88; 95% CI 0.83, 0.95), an 8% reduction for ear infections (0.92; 0.88, 0.97), and a 9% reduction for upper respiratory infections (0.91; 0.87, 0.95). We found an overall 8% reduction in ED visits for lower respiratory infections after the implementation of state smoke-free legislation (0.92; 0.87, 0.96). The implementation of health care reform in Massachusetts was also associated with a 6–9% reduction in all children's ED visits for ear and upper respiratory infections. Our results suggest that state smoke-free legislation and health care reform may be effective interventions to improve children's health by reducing ED visits for asthma, ear infections, and respiratory infections.

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1. Introduction

The global expansion of smoke-free legislation has improved population health with reductions in hospital admissions for coronary events and heart disease (Callinan et al., 2010; Tan and Glantz, 2012). Although more recent evidence suggests that these benefits may also extend to respiratory diseases, including asthma, the majority of research has focused on adults (Tan and Glantz, 2012). Despite decreases in second-hand smoke over the past decade in the US, children continue to have higher levels of exposure than adults (Homa et al., 2015). Children's principal source of exposure occurs in the home, particularly for young children (US Department of Health and Human Services, 2006). While one third of US children live with at least one smoker, half of

children from low-income households live with two or more smokers (King et al., 2009).

The US Surgeon General (US Department of Health and Human Services, 2006) and other systematic reviews (Tinuoye et al., 2013; Jones et al., 2011; Burke et al., 2012; Jones et al., 2012) have concluded that parental smoking increases children's risk for prevalent and incident asthma and wheeze, middle ear disease (including acute and chronic ear infections), and lower respiratory illnesses. However, only a few studies have examined the impact of smoke-free legislation on children's health. Two longitudinal studies, in Scotland and England, have shown reductions in hospital admissions for childhood asthma after country-wide bans on smoking in public places (Mackay et al., 2010; Millett et al., 2013). Other studies have found decreases in hospital admissions or emergency department (ED) visits for asthma after the introduction of state or local smoke-free legislation among all ages together, (Naiman et al., 2010; Herman and Walsh, 2011) adults and children separately, (Rayens et al., 2008; Landers, 2014) or an effect among adults and not children (Shetty et al., 2011). However, methodological limitations include the lack of a control group, (Mackay et al., 2010;

Abbreviations: ED, emergency department; IRR, incidence rate ratios.

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Millett et al., 2013; Herman and Walsh, 2011; Rayens et al., 2008) not accounting for other tobacco control policies, (Mackay et al., 2010; Millett et al., 2013; Naiman et al., 2010; Herman and Walsh, 2011; Rayens et al., 2008) or not distinguishing state from local policies (Herman and Walsh, 2011; Shetty et al., 2011). More recent studies have found reductions in hospitalizations for children's respiratory tract infections, primarily attributed to decreases in lower respiratory infections, after the introduction of country-wide smoke-free legislation (Been et al., 2015; Lee et al., 2016). Despite plausible mechanisms, (US Department of Health and Human Services, 2006) we are not aware of any studies that have examined the effects of secondhand smoke exposure on children's hospital admissions or ED visits for ear infections.

Tobacco control programs often take a multi-pronged approach, (World Health Organization, 2003) highlighting the importance of considering the impact of multiple policies rather than examining them in isolation. Cigarette taxes have been very effective at improving population health by reducing the uptake of smoking and encouraging smokers to either quit or reduce tobacco consumption (Chaloupka et al., 2012). In 2006, Massachusetts enacted health care reform legislation, which included a provision for Medicaid recipients to gain access to low-cost or free tobacco cessation medications and counseling and widespread promotional efforts to increase provider and patient awareness (Commonwealth of Massachusetts; Massachusetts Department of Public Health Tobacco Cessation and Prevention Program). Land and colleagues found that in the 30 months post-implementation, nearly 40% of Medicaid smokers used the benefit and smoking decreased approximately 26% (Land et al., 2010a). Medicaid recipients who utilized the benefits were also less likely to have inpatient hospital claims for coronary events and heart disease post-implementation compared to pre-implementation (Land et al., 2010b). However, studies in Massachusetts have not evaluated potential downstream effects of these policies on children's health.

To address these limitations in the literature, we conducted a quasi-experimental study to examine the effects of state and local smoke-free legislation on the rate of ED visits for childhood asthma, ear infections, and respiratory infections in Massachusetts, New Hampshire, and Vermont, controlling for cigarette taxes and health care reform legislation.

2. Methods

The Massachusetts Center for Health Information and Analysis, (Massachusetts Division of Health Care Finance and Policy) New Hampshire Department of Health and Human Services, (New Hampshire Department of Health and Human Services) and Green Mountain Care Board (Vermont Department of Banking, Insurance, Securities and Health Care Administration) collect patient-level data on all ED visits as required by law. In Massachusetts, 74 acute care hospitals report data. We obtained the ED database from January 1, 2001 through September 30, 2010, which captured all ED visits in Massachusetts' acute care hospitals and satellite emergency facilities that did not result in admission to an inpatient or outpatient observation stay. In New Hampshire, all 26 acute care hospitals report data. We obtained the restricted inpatient and outpatient hospital discharge files from January 1, 2001 through December 31, 2009. In Vermont, all 14 acute care hospitals report data. We obtained the restricted hospital discharge files for ED visits, which were extracted from the inpatient and outpatient data files, from January 1, 2002 through December 31, 2010. As inpatient and outpatient visits account for approximately 2% of all visits in New Hampshire and 3% in Vermont, both types were included.

The Boston College Institutional Review Board reviewed this study and considered it exempt; each participating state also approved the protocol.

We limited the analyses to children age 0–17 years who presented to the ED in each state. All three states used the International Classification of Diseases ninth revision, clinical modification (ICD-9-CM) to code diagnoses associated with hospital utilization (National Center for

Health Statistics, Centers for Disease Control and Prevention). We identified all ED visits with a principal diagnosis of: asthma as code 493; ear infections as codes 381 and 382 (including nonsuppurative and suppurative otitis media and Eustachian tube disorders); acute lower respiratory infections as codes 466, 480–488, including bronchitis, pneumonia, and influenza; and acute upper respiratory infections as codes 460–465. For each patient contact, we extracted the month/year of visit, age (0–4, 5–9, 10–17 years), sex (female, male), and zip code (linked to municipality of residence). Data on race was not consistently collected across states. We also created a health insurance indicator because of increasing rates of children covered by public insurance over the study period (Racine et al., 2014). We calculated the fraction of visits covered by Medicaid versus commercial insurance at the state-age-year level for accidents (codes 800–999), as patients are unlikely to be turned away based on their ability to pay.

2.1. Policy measures

Table 1 presents the date that smoke-free legislation, cigarette tax changes, and health care reform legislation came into effect in Massachusetts, New Hampshire, and Vermont. Using the month/year of each child's ED visit, we identified whether the visit occurred before or after each policy came into effect and the current cigarette tax.

2.2. Smoke-free legislation

We obtained the effective dates of 100% smoke-free legislation for workplaces and restaurants for each state and municipality from the American Nonsmokers' Rights Foundation (American Nonsmokers' Rights Foundation). In Massachusetts, restaurants and workplaces became 100% smoke-free in July 2004. Prior to state-wide implementation, 94/351 municipalities had 100% smoke-free restaurant policies and 65/351 had 100% smoke-free workplace policies (American Nonsmokers' Rights Foundation). Since 108 municipalities had either restaurant or workplace policies (51 had both), we coded exposure to any local smoke-free policy. In New Hampshire, restaurants became

Table 1

Dates that cigarette taxes, smoke-free legislation, and health care reform legislation came into effect in Massachusetts, New Hampshire and Vermont.

	Massachusetts	New Hampshire	Vermont
2001	Tax \$0.76	Tax \$0.52	Tax \$0.44
2002	Tax \$0.76	Tax \$0.52	Tax \$0.44
2003	Tax \$1.51 (7/25/02)	Tax \$0.52	Tax \$0.93 (7/1/02)
2004	Tax \$1.51 7/5/04: Smoke-free workplaces, restaurants	Tax \$0.52	Tax \$1.19 (7/1/03)
2005	Tax \$1.51	Tax \$0.52	Tax \$1.19 9/1/05: Smoke-free restaurants
2006	Tax \$1.51 07/1/06: Medicaid recipients receive low-cost tobacco cessation therapies as part of Health Care Reform	Tax \$0.80 (7/1/05)	Tax \$1.19
2007	Tax \$1.51	Tax \$0.80 9/17/07: Smoke-free restaurants	Tax \$1.79 (7/1/06)
2008	Tax \$1.51	Tax \$1.08 (7/1/07)	Tax \$1.79
2009	Tax \$2.51 (7/1/08)	Tax \$1.33 (10/1/08)	Tax \$1.99 (7/1/08) 7/1/09: Smoke-free workplaces
2010	Tax \$2.51	Tax \$1.78 (7/1/09)	Tax \$2.24 (7/1/09)

100% smoke-free in late September 2007. None of the municipalities were smoke-free prior to state-wide implementation. In Vermont, restaurants became 100% smoke-free in September 2005 and workplaces became 100% smoke-free in July 2009. We coded exposure to the state policy from September 2005 onwards. Prior to state-wide implementation, 4 municipalities had a smoke-free restaurant policy.

2.3. Cigarette excise taxes

We obtained the cigarette excise tax for each state from the *Tax Burden on Tobacco*, (Orzechowski and Walker, 2011) which were translated into real December 2010 dollars based on the national Consumer Price Index (US Department of Labor Bureau of Labor Statistics). In Massachusetts, cigarette tax increases occurred in July of 2002 and 2008 resulting in a tax of \$2.51 per pack in 2010. In New Hampshire, there were cigarette tax increases in July of 2005, 2007, 2008, and 2009 resulting in a tax of \$1.78 per pack in 2010. In Vermont, there were cigarette tax increases in July of 2002, 2003, 2006, 2008, and 2009 resulting in a tax of \$2.24 per pack in 2010.

2.4. Health care reform legislation

In April 2006, the Massachusetts legislature passed health care reform legislation which required all individuals to have health insurance (Commonwealth of Massachusetts). The law also mandated coverage for two types of tobacco cessation treatment for the Medicaid population: behavioral counseling and all Food and Drug Administration-approved medication. Since July 1, 2006, in every 12-month period Medicaid recipients have been allowed up to 16 individual or group counseling sessions and two 90-day courses of medications for smoking cessation. The co-payment is only \$1–3. More information is available online (Massachusetts Department of Public Health). In conjunction, there were informational fact sheets, website resources, and campaigns to increase the awareness of these benefits to providers and patients (Massachusetts Department of Public Health Tobacco Cessation and Prevention Program).

2.5. Statistical analysis

Our estimation procedure used a negative binomial regression model, which examined the effect of each policy on the number of ED visits. The dependent variable was the number of ED visits for each diagnosis (asthma, ear infection, and respiratory infections) collapsed to municipality-level counts for each subgroup, age-gender, for each month/year. To account for differences in the population of each subgroup, we used an exposure variable, *GroupPop*, constructed as municipality-level, group-specific, population counts. The denominator was created using census level data from 2000 and 2010, while the intercensal years were interpolated implementing a nonlinear smoothing interpolation technique using county-level data (Chen and Andrews, 2008).

Negative binomial regression, an extension of Poisson regression, is an appropriate technique for analyzing count data which exhibits overdispersion, with the variance of the error process larger than the conditional mean. In this formulation, individual municipality-level observations are assumed to follow a Poisson regression model, with mean $\mu_j = \exp(x_j\beta)$, with an omitted variable ν_j such that e^{ν_j} follows a Gamma distribution with mean 1 and variance α :

$$y_j \sim \text{Poisson}(\mu^*_j)$$

$$\mu^*_j = \exp(x_j\beta + \nu_j)$$

$$e^{\nu_j} \sim \text{Gamma}(1/\alpha, \alpha)$$

In this parameterization, α is the overdispersion parameter. Dispersion for the j^{th} observation is equal to $1 + \alpha \exp(x_j\beta)$, so that $\text{Var}(y_j) = \mu_j(1 + \alpha\mu_j)$. The exposure variable *GroupPop* is included in x_j as its logarithm, with coefficient constrained to 1.

The estimated regression coefficients are interpreted as incidence rate ratios (IRR), which is the change in the likelihood of ED visits associated with the policy change. We also adjusted for the proportion of children covered by Medicaid at the state-age-year level to account for increasing trends in public insurance (Racine et al., 2014). Calendar time, as month and year of visit, was included to control for known seasonality of asthma and other health conditions (Johnston and Sears, 2006; Nair et al., 2011). Municipality fixed effects control for time-invariant municipality-level characteristics that may be associated with the outcome of interest, including income and social norms related to smoking. To allow for correlation between the error terms at the municipality level, we clustered standard errors by municipality. As individual identifiers were not available, we were not able to cluster based on repeat visits for individual children.

We introduced interactions between state smoke-free legislation and children's ages to determine whether there was a differential effect of smoke-free legislation. We did not explore interactions with local smoke-free legislation due to the minimal variation in municipalities with policies across all three states. We repeated this series of analyses, separately, for each health outcome. Based on the paper by Been and colleagues, (Been et al., 2015) we conducted analyses for upper and lower respiratory infections separately. We also tested for the differential impact of state smoke-free legislation across municipalities with and without local smoke-free legislation, but we found no evidence for an interaction for any health outcome (results not shown). As a robustness check we repeated the analysis with appendicitis, (Landers, 2014) as rates should not be affected by the implementation of tobacco control policies. All analyses were conducted using Stata statistical software, version 14.1.

3. Results

Fig. 1 illustrates the number of monthly ED visits for children age 0–17 years whose principal diagnosis was asthma, ear infections, or lower or upper respiratory infections in (a) Massachusetts, (b) New Hampshire, and (c) Vermont over the study period. Although there were more visits for all health outcomes in Massachusetts and New Hampshire compared to Vermont, the seasonal pattern for all outcomes was consistent across states. Overall, children age 0–4 years were more likely to visit the ED for asthma, ear infections, and respiratory infections than children ages 5–9 and 10–17 years (Table 2). Across all health outcomes and states, boys were more likely to visit the ED than girls.

In total, there were 128,807 ED visits for asthma across all three states. We found no changes in the overall rate of ED visits for asthma after the implementation of state or local smoke-free legislation, cigarette tax increases, health care reform, or changes in Medicaid coverage (Appendix A). However, an interaction with children's age showed that state smoke-free legislation was associated with a 12% reduction in ED visits for asthma among children age 10–17 years (adjusted IRR 0.88; 0.83, 0.93) (Table 3). In contrast, there was no evidence for an effect in younger children.

There were an additional 288,697 ED visits for ear infections. Similarly, we found no overall effect of state or local smoke-free legislation or cigarette taxes on ED visits for ear infections (Appendix A), but an interaction revealed that state smoke-free legislation was associated with an 8% reduction in ED visits for ear infections only among children age 10–17 years (0.92; 0.88, 0.97) (Table 3). The implementation of health care reform in Massachusetts and proportion of children covered by Medicaid were also associated with a 9% (0.91; 0.86, 0.96) and 63% (0.37; 0.23, 0.59) reduction in ED visits for ear infections, respectively.

Lower respiratory infections composed 25% of all respiratory infections. There were 139,239 ED visits for lower respiratory infections.

The implementation of state smoke-free legislation was associated with an overall 8% reduction in ED visits for lower respiratory infections (0.92; 0.87, 0.96) (Appendix A). According to the child's age, state smoke-free legislation was associated with a 10% reduction in ED visits for lower respiratory infections in 0–4-year-olds (0.90; 0.85, 0.94) and an 11% reduction for 10–17-year-olds (0.89; 0.84, 0.95) (Table 3). Every \$1.00 increase in cigarette taxes was associated with a 9% reduction in ED visits for lower respiratory infections (0.91; 0.84, 0.98). The proportion of children covered by Medicaid was also associated with a

78% reduction in ED visits for lower respiratory infections (0.22; 0.11, 0.43).

There were 410,686 ED visits for upper respiratory infections. Although we found no overall effect of state smoke-free legislation on ED visits for upper respiratory infections (Appendix A), the introduction of state smoke-free legislation was associated with a 9% reduction in ED visits for upper respiratory infections only among 10–17-year olds (0.91; 0.87, 0.95) (Table 3). The implementation of health care reform in Massachusetts and proportion of children covered by Medicaid were also associated with a 6% (0.94; 0.90, 0.99) and 59% (0.41; 0.26, 0.64) reduction in ED visits for upper respiratory infections, respectively. In contrast, we found no evidence for associations between local smoke-free legislation or cigarette taxes and ED visits for upper respiratory infections.

In a robustness check, we found no associations between the implementation of tobacco control policies and appendicitis (Appendix B).

4. Discussion

Using population-level data, we evaluated a natural experiment created by the enactment of tobacco control and health care policies within and across Massachusetts, New Hampshire, and Vermont. While we found no overall effect of state or local tobacco control policies on children's ED visits for asthma, ear infections, or upper respiratory infections, the enactment of state smoke-free legislation was associated with an 8–12% reduction in ED visits among children age 10–17 years after controlling for cigarette taxes and health care reform legislation. The one exception was lower respiratory infections, in that the enactment of state smoke-free legislation and a \$1.00 increase in cigarette taxes were associated with an overall 8–9% reduction in ED visits. Furthermore, the implementation of health care reform in Massachusetts was associated with a 6–9% reduction in children's ED visits for ear infections and upper respiratory infections. Our findings add to the growing body of evidence that the health benefits of tobacco control and health care policies extend to children.

State hospital discharge data collect information on every hospital contact and are mandated by law, ([Massachusetts Division of Health Care Finance and Policy](#); [New Hampshire Department of Health and Human Services](#); [Vermont Department of Banking, Insurance, Securities and Health Care Administration](#)) removing potential sampling bias. Children attend EDs when there is an acute episode, which is likely a robust measure of changes in their environment. Secondhand smoke via parental smoking increases children's risk for asthma, ear infections, and respiratory illnesses ([US Department of Health and Human Services, 2006](#); [Tinuoye et al., 2013](#); [Jones et al., 2011](#); [Burke et al., 2012](#); [Jones et al., 2012](#)). After smoking in public places was banned in Scotland there were substantial reductions in fine particulate matter concentrations in pubs ([Semple et al., 2007](#)) and salivary cotinine levels, a metabolite of nicotine, in children ([Akhtar et al., 2007](#)). Hospital discharge data captures all urgent cases and we only used the children's principal diagnosis, suggesting that the data should be sensitive to recent policy changes. Linking zip codes to municipalities allowed us to distinguish between potential effects of state versus local smoke-free

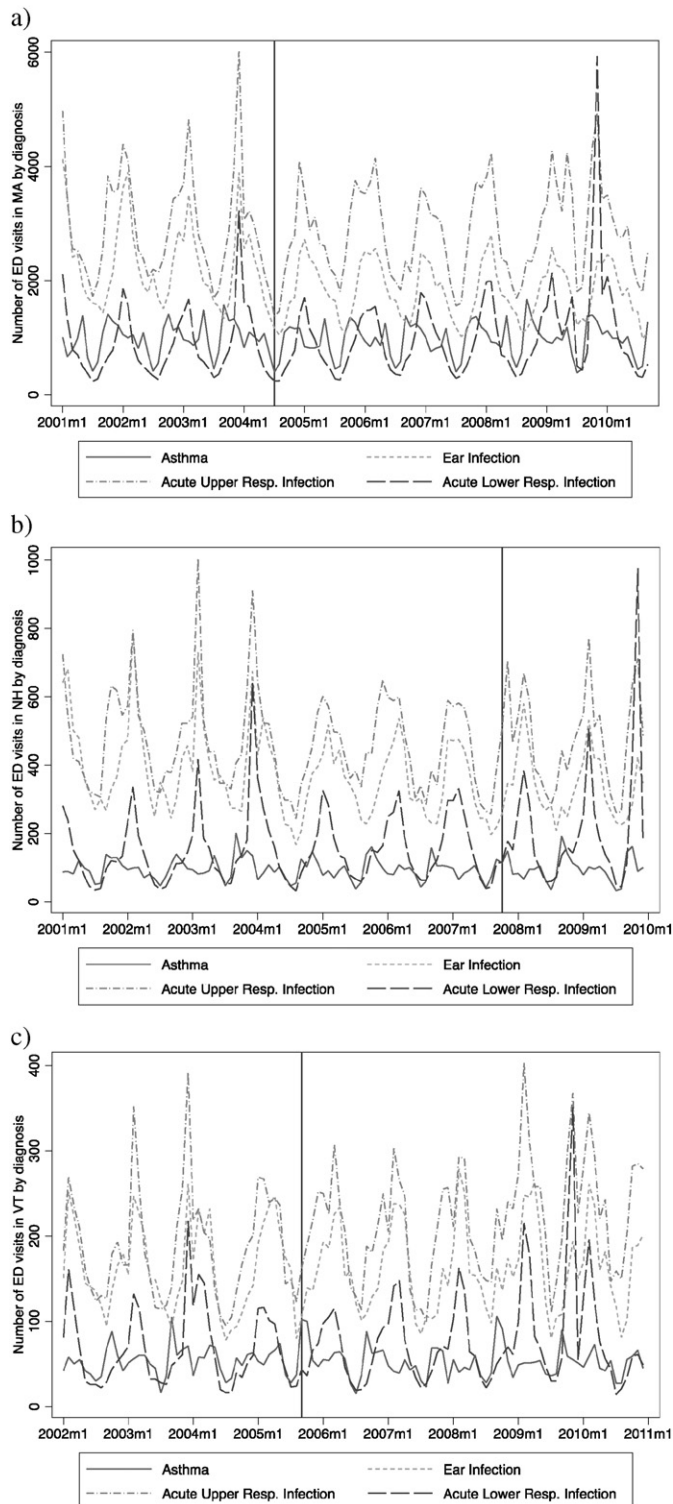


Fig. 1. Monthly emergency department visits for asthma, ear infections, and respiratory infections among children in a) Massachusetts between January 2001 and September 2010, b) New Hampshire between January 2001 and December 2009, and c) Vermont between January 2002 and December 2010. a) In Massachusetts, 100% smoke-free restaurant and workplace legislation was implemented in 07/2004 (shown), health care reform (smoking cessation treatment) was implemented in 07/2006, and cigarette tax increases occurred in 07/2002 and 07/2008 resulting in a tax of \$2.51 per pack in 12/2010. b) In New Hampshire, 100% smoke-free restaurant legislation was implemented in 09/2007 (shown) and cigarette tax increases occurred in 07/2005, 07/2007, 07/2008, and 07/2009 resulting in a tax of \$1.78 per pack in 12/2010. c) In Vermont, 100% smoke-free restaurant legislation was implemented in 09/2005 (shown), smoke-free workplace legislation was implemented in 07/2009, and cigarette tax increases occurred in 07/2002, 07/2003, 07/2006, 07/2008, and 07/2009 resulting in a tax of \$2.24 per pack in 12/2010.

Table 2

Demographics of children's emergency department visits for asthma, ear infections, and lower and upper respiratory infections.

State	Asthma		Ear infections		Lower respiratory infections		Upper respiratory infections	
	ED visits n (%)	Mean ED visits per 1000 children	ED visits n (%)	Mean ED visits per 1000 children	ED visits n (%)	Mean ED visits per 1000 children	ED visits n (%)	Mean ED visits per 1000 children
Massachusetts	112,808		231,481		113,137		337,628	
Child's age								
0–4 years	46,322 (41%)	1.05	157,125 (68%)	3.56	72,657 (64%)	1.65	186,531 (55%)	4.23
5–9 years	30,387 (27%)	0.66	48,614 (21%)	1.06	18,878 (17%)	0.41	67,031 (20%)	1.46
10–17 years	36,099 (32%)	0.45	25,742 (11%)	0.32	21,602 (19%)	0.27	84,066 (25%)	1.05
Child's sex								
Female	44,548 (39%)	0.54	107,879 (47%)	1.30	50,205 (44%)	0.60	161,651 (48%)	1.95
Male	68,260 (61%)	0.78	123,602 (53%)	1.42	62,932 (56%)	0.72	175,977 (52%)	2.02
New Hampshire	10,317		39,653		18,149		50,728	
Child's age								
0–4 years	3567 (35%)	0.68	24,196 (61%)	4.63	9726 (54%)	1.86	23,310 (46%)	4.46
5–9 years	2715 (26%)	0.45	9737 (25%)	1.60	3586 (20%)	0.59	10,974 (22%)	1.80
10–17 years	4035 (39%)	0.37	5720 (14%)	0.52	4837 (27%)	0.44	16,444 (32%)	1.50
Child's sex								
Female	3931 (38%)	0.37	18,719 (47%)	1.77	8143 (45%)	0.77	25,076 (49%)	2.36
Male	6386 (62%)	0.55	20,934 (53%)	1.79	10,006 (55%)	0.86	25,652 (51%)	2.20
Vermont	5682		17,563		7953		22,330	
Child's age								
0–4 years	2166 (38%)	0.62	11,013 (63%)	3.13	5095 (64%)	1.45	12,053 (54%)	3.43
5–9 years	1413 (25%)	0.37	4233 (24%)	1.10	1239 (16%)	0.32	4314 (19%)	1.12
10–17 years	2103 (37%)	0.29	2317 (13%)	0.32	1619 (20%)	0.22	5963 (27%)	0.82
Child's sex								
Female	2253 (40%)	0.30	8305 (47%)	1.10	3601 (45%)	0.48	10,816 (48%)	1.44
Male	3429 (60%)	0.48	9258 (53%)	1.30	4352 (55%)	0.61	11,514 (52%)	1.61

Abbreviation: ED, emergency department.

legislation as well as state differences in cigarette taxes and health care reform legislation between Massachusetts, New Hampshire, and Vermont for childhood asthma, ear infections, and respiratory infections. Furthermore, ear infections have yet to be examined in the literature.

Previous studies have found decreases in hospital admissions or ED visits for childhood asthma either overall (Naiman et al., 2010; Herman and Walsh, 2011) or among children only (Mackay et al., 2010; Millett et al., 2013; Rayens et al., 2008; Landers, 2014) after the

Table 3

Emergency department visit stratum-specific incidence rate ratios by age group for smoke-free legislation and other policies on asthma, ear infections, and lower and upper respiratory infections among children in Massachusetts (2001–2010), New Hampshire (2001–2009), and Vermont (2002–2010).

	Asthma IRR ^a (95% CI ^b)	Ear infections IRR ^a (95% CI ^b)	Lower respiratory infections IRR ^a (95% CI ^b)	Upper respiratory infections IRR ^a (95% CI ^b)
Interaction with child's age				
State smoke-free legislation				
0–4 years	1.00 (0.95, 1.06)	0.97 (0.92, 1.01)	0.90 (0.85, 0.94)	1.03 (1.00, 1.08)
5–9 years	1.05 (0.99, 1.11)	0.98 (0.94, 1.03)	1.01 (0.95, 1.08)	0.96 (0.92, 1.01)
10–17 years	0.88 (0.83, 0.93)	0.92 (0.88, 0.97)	0.89 (0.84, 0.95)	0.91 (0.87, 0.95)
Local smoke-free legislation	1.02 (0.94, 1.11)	1.01 (0.93, 1.09)	1.03 (0.94, 1.12)	1.06 (0.98, 1.14)
Cigarette tax ^c	0.95 (0.89, 1.01)	0.97 (0.92, 1.02)	0.91 (0.84, 0.98)	0.98 (0.94, 1.02)
Health care reform (MA only)	1.02 (0.96, 1.08)	0.91 (0.86, 0.96)	1.00 (0.94, 1.06)	0.94 (0.90, 0.99)
Medicaid	0.81 (0.40, 1.62)	0.37 (0.23, 0.59)	0.22 (0.11, 0.43)	0.41 (0.26, 0.64)
Child's sex				
Female	1	1	1	1
Male	1.28 (1.23, 1.33)	1.04 (1.02, 1.05)	1.08 (1.06, 1.11)	1.03 (1.01, 1.05)

Abbreviations: IRR, incidence rate ratio; MA, Massachusetts.

^a Adjusted for: Month/year of visit and municipality.^b Standard errors are clustered by municipality.^c Translated into real 2010 dollars from national Consumer Price Index.

introduction of country, state, or local smoke-free legislation, with similar effects across ages and socioeconomic status (Mackay et al., 2010; Millett et al., 2013). Only two studies have reported decreases in ED visits for respiratory infections (Been et al., 2015; Lee et al., 2016). However, methodological limitations, including not having a control group (Mackay et al., 2010; Millett et al., 2013; Herman and Walsh, 2011; Rayens et al., 2008; Been et al., 2015; Lee et al., 2016) or not considering other tobacco control policies, (Mackay et al., 2010; Millett et al., 2013; Naiman et al., 2010; Herman and Walsh, 2011; Rayens et al., 2008; Been et al., 2015; Lee et al., 2016) reduces the ability to rule out alternative explanations. Landers examined the impact of state and county smoke-free legislation on asthma hospital discharges in adults and children using the Healthcare Cost and Utilization Project state inpatient data for 12 intervention and 5 control states (Landers, 2014). These are the national version of our data, although Massachusetts and New Hampshire were not included. Landers found that only county smoke-free legislation reduced asthma hospital discharges and higher cigarette taxes were associated with fewer hospital discharges for children only (Landers, 2014). We found that state smoke-free legislation was associated with reductions in ED visits for asthma, ear infections, and upper respiratory infections only in 10–17-year-olds. In previous work, we have shown that parents of adolescents are less likely to have a no smoking policy and more likely to smoke indoors than households with younger children (Hawkins and Berkman, 2011a; Hawkins and Berkman, 2011b). Adolescents are also more likely to spend time in settings where smoke-free ordinances are implemented than younger children. Together, state smoke-free legislation may particularly benefit this older age group.

Been and colleagues reported that decreases in respiratory infections after smoke-free legislation was implemented in England were primarily attributed to a reduction in lower respiratory infections, while upper respiratory infections had a slower decline (Been et al., 2015). Recently, Lee and colleagues found that the enactment of smoke-free legislation in Hong Kong was associated with a reduction in hospital admissions for lower respiratory tract infections, with a larger effect among 6–18-year-olds than preschool children (Lee et al., 2016). We also found decreases in lower respiratory infections among all children after the implementation of state smoke-free legislation and cigarette tax increases, while state smoke-free legislation only reduced upper respiratory infections in older children. By taking into account multiple policy changes over this time period we identified additional policies benefiting childhood health, including the implementation of health care reform in Massachusetts and the proportion of children covered by Medicaid, which were both associated with reductions in ED visits for ear infections and upper respiratory infections among all children.

The Massachusetts hospital discharge data included ED visits that did not result in admission to an inpatient or outpatient observation stay, so we were not able to examine the most severe cases and there were very few inpatient asthma visits in New Hampshire (2%) or Vermont (3%). It is possible that some of the most severe cases of asthma, and thus the most responsive to policy changes, were missed. Local smoke-free legislation in New England is primarily created at the municipality level and not the county level (American Nonsmokers' Rights Foundation). For example, there are 14 counties in Massachusetts and 351 municipalities. Collapsing cities into counties removes some of the within and between variation necessary to separate local and state effects. Evaluating the downstream policy effects of smoke-free legislation on child health is an emerging field. Additional research is needed that addresses current limitations in the evidence base, uses consistent definitions of health outcomes, and expands the focus to other outcomes causally associated with secondhand smoke exposure.

As of July 2006, Massachusetts Medicaid recipients were provided access to free and low-cost tobacco cessation therapies (Massachusetts Department of Public Health). Since research has demonstrated reductions in smoking among Medicaid recipients and inpatient hospital

claims for coronary events and heart disease, (Land et al., 2010a; Land et al., 2010b) our aim was to examine whether any health benefits extend to children. We found that health care reform legislation in Massachusetts decreased children's ED visits for ear infections and respiratory infections. Although we were not able to examine mechanisms, there are two potential reasons for these findings. First, low-income households have higher levels of secondhand smoke exposure than households at or above the federal poverty level (Homa et al., 2015). Reducing or eliminating smoking among adults would reduce children's secondhand smoke exposure and the likelihood of acquiring an ear or respiratory infection requiring an ED visit. Hospital discharge data do not collect information on parental smoking or smoke exposure in the home. Second, Massachusetts health care reform has been shown to reduce the number of uninsured children, (Kenney et al., 2010) due to both greater subsidized coverage of children and indirectly through their parents' coverage (Commonwealth of Massachusetts). Although the hospital discharge data includes health insurance status, the census does not collect this information. We included an indicator of the proportion of children covered by Medicaid at the state-age-year level to account for increasing trends in public insurance, which was also associated with a reduction in ED visits for ear and respiratory infections. A comparison of ED utilization between Massachusetts, New Hampshire, and Vermont over the time that Massachusetts implemented health care reform revealed no changes in the trends; in fact, from 2004 through 2009, the ED utilization trend continued upwards in all three states (Chen et al., 2011). Regardless of the mechanism for reducing ED visits, our findings have important implications for the Affordable Care Act. Focusing on prevention either by reducing parental smoking or utilizing primary care physicians rather than the ED for care will likely improve children's health as well as reduce health care costs.

Only including three states in New England in our analysis may potentially limit the generalizability of our findings to other states. Massachusetts has been at the forefront of tobacco control policies for the past decade (Koh et al., 2005). We hypothesize that our findings could potentially underestimate the effect of policy changes among states with fewer or weaker tobacco control policies. As of October 2015, 14 states had no state-wide smoke-free legislation (American Nonsmokers' Rights Foundation) and 18 states had cigarette taxes under \$1.00 (Campaign for Tobacco-Free Kids). Furthermore, many of the smoking cessation benefits through the Affordable Care Act are similar to those from Massachusetts health care reform, such as providing Medicaid coverage of tobacco cessation therapies (Centers for Medicare and Medicaid Services). Once the Affordable Care Act is fully implemented, it will be important to evaluate the downstream effects of local and state smoke-free policies and cigarette taxes before and after national health care reform on children's health.

Annually in the US, more than 290,000 cases of asthma for children age 0–14 years and nearly 100,000 cases of recurrent ear infections for 0–5-year-olds are attributed to secondhand smoke (Healton et al., 2004). Our results contribute to the accumulating evidence base that tobacco control policies may be effective public health interventions to improve children's health. Despite older children having fewer visits to the ED for asthma, ear infections, and respiratory infections, we found that state smoke-free legislation further reduced ED visits for these health conditions among children age 10–17 years. Our findings suggest that the benefits of smoke-free legislation on children's health could extend beyond asthma (Mackay et al., 2010; Millett et al., 2013; Naiman et al., 2010; Herman and Walsh, 2011; Rayens et al., 2008; Landers, 2014; Shetty et al., 2011) and respiratory infections (Been et al., 2015; Lee et al., 2016) to reducing ear infections.

Conflicts of interest

All authors declare there are no conflicts of interest.

Transparency document

The [Transparency document](#) associated with this article can be found in the online version.

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Appendix A. Supplementary data

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Appendix A. Emergency department visit incidence rate ratios for smoke-free legislation and other policies on asthma, ear infections, and lower and upper respiratory infections among children in Massachusetts (2001-2010), New Hampshire (2001-2009), and Vermont (2002-2010)

	Asthma	Ear infections	Lower respiratory infections	Upper respiratory infections
	IRR ^a (95% CI ^b)	IRR ^a (95% CI ^b)	IRR ^a (95% CI ^b)	IRR ^a (95% CI ^b)
State smoke-free legislation	0.97 (0.92, 1.02)	0.96 (0.92, 1.01)	0.92 (0.87, 0.96)	0.98 (0.94, 1.02)
Local smoke-free legislation	1.02 (0.94, 1.11)	1.01 (0.93, 1.08)	1.02 (0.94, 1.12)	1.06 (0.98, 1.14)
Cigarette tax ^c	0.95 (0.89, 1.01)	0.97 (0.92, 1.02)	0.91 (0.84, 0.97)	0.98 (0.94, 1.03)
Health care reform (MA only)	1.02 (0.96, 1.09)	0.91 (0.86, 0.96)	1.00 (0.94, 1.06)	0.94 (0.90, 0.99)
Medicaid	0.83 (0.42, 1.62)	0.37 (0.23, 0.58)	0.20 (0.10, 0.40)	0.44 (0.28, 0.69)
Child's age				
0-4 years	1	1	1	1
5-9 years	0.66 (0.62, 0.70)	0.31 (0.29, 0.33)	0.25 (0.23, 0.27)	0.35 (0.34, 0.37)
10-17 years	0.48 (0.43, 0.54)	0.09 (0.08, 0.10)	0.16 (0.14, 0.18)	0.26 (0.24, 0.27)
Child's sex				
Female	1	1	1	1
Male	1.27 (1.22, 1.33)	1.04 (1.02, 1.05)	1.08 (1.06, 1.11)	1.03 (1.01, 1.05)

Abbreviations: IRR, incidence rate ratio; MA, Massachusetts

^a Adjusted for: Month/year of visit and municipality

^b Standard errors are clustered by municipality

^c Translated into real 2010 dollars from national Consumer Price Index

Appendix B. Emergency department visit incidence rate ratios for smoke-free legislation and other policies on appendicitis among children in Massachusetts (2001-2010), New Hampshire (2001-2009), and Vermont (2002-2010)

		Appendicitis
		IRR ^a (95% CI ^b)
State smoke-free legislation		0.98 (0.79, 1.23)
Local smoke-free legislation		0.95 (0.77, 1.17)
Cigarette tax ^c		1.27 (0.93, 1.73)
Health care reform (MA only)		2.22 (1.77, 2.78)
Medicaid		0.12 (0.01, 1.59)
Child's age		
0-4 years		1
5-9 years		4.21 (3.10, 5.72)
10-17 years		6.34 (4.21, 9.54)
Child's sex		
Female		1
Male		0.84 (0.76, 0.93)

Abbreviations: IRR, incidence rate ratio; MA, Massachusetts

^a Adjusted for: Month/year of visit and municipality

^b Standard errors are clustered by municipality

^c Translated into real 2010 dollars from national Consumer Price Index