

Reduction in Emergency Department Visits for Children's Ear and Respiratory Infections after the Introduction of Smoke-Free Legislation

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ABSTRACT

Despite the benefits of smoke-free legislation on adult health, little is known about their impact on children's health. We examined the effects of tobacco control policies on the rate of emergency department (ED) visits for childhood asthma, ear infections, and respiratory infections using hospital discharge data in Massachusetts and Vermont (2001-2010). We used negative binomial regression models to analyze the effect of local and state smoke-free legislation on ED visits for each health condition, controlling for cigarette taxes and health care reform legislation. We found that state smoke-free legislation was associated with a 13% reduction (adjusted IRR 0.871; $p=0.001$) and health care reform legislation with a 19% reduction (aIRR 0.813; $p<0.001$) in ED visits for ear infections. Similar reductions in ED visits for respiratory infections were seen for state smoke-free legislation (aIRR 0.885; $p<0.001$) and health care reform legislation (aIRR 0.755; $p<0.001$). For both outcomes, the effects were similar across children's ages and race. Although there was no overall change in ED visits for asthma after the enactment of tobacco control policies, state smoke-free legislation was associated with a 13% reduction in ED visits among children age 10-17 years (aIRR 0.867; $p<0.001$). Our results suggest that state tobacco control policies may be effective public health interventions to improve children's health by reducing ED visits for ear infections and respiratory infections across all ages and asthma among adolescents.

INTRODUCTION

The global expansion of smoke-free legislation has improved population health, with reductions in hospital admissions for coronary events and heart disease.^{1,2} Although more recent evidence suggests that these benefits may also extend to respiratory diseases, including asthma, the majority of research has focused on adults.² Despite decreases in secondhand smoke over the past decade in the US, children continue to have higher levels of exposure than adults.³ Children's principal source of exposure occurs in the home, particularly for young children.⁴ 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.⁵

The US Surgeon General⁴ and other systematic reviews⁶⁻⁹ 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 acute 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.^{10,11} Other studies have found decreases in hospital admissions or emergency department (ED) visits for asthma after the implementation of smoke-free legislation among all ages together,^{12,13} adults and children separately,^{14,15} or an effect among adults and not children¹⁶. However, methodological limitations include not having a control group,^{10,11,13,14} accounting for other tobacco control policies,¹⁰⁻¹⁴ or not distinguishing local from state policies^{13,16}. Despite plausible mechanisms, we are not aware of any studies that have examined the effects of secondhand smoke exposure on ear infections or respiratory infections.

Tobacco control programs often take a multi-pronged approach,¹⁷ 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.¹⁸ 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.¹⁹ Land and colleagues found that in the 30 months post-implementation, nearly 40% of Medicaid smokers used the benefit and smoking decreased approximately 26%.²⁰ 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.²¹ 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 local and state smoke-free legislation on the rate of ED visits for childhood asthma, ear infections, and acute respiratory infections in Massachusetts and Vermont, controlling for cigarette taxes and health care reform legislation.

METHODS

The Massachusetts Center for Health Information and Analysis²² and Vermont

Department of Financial Regulation²³ collects patient-level data on all ED visits as required by law. In Massachusetts, all 82 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 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.

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. Both states used the International Classification of Diseases ninth revision, clinical modification (ICD-9-CM) to code diagnoses associated with hospital utilization.²⁴ 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); and acute respiratory infections as codes 460-466 (acute upper and lower respiratory infections, including bronchitis) and 480-488 (pneumonia and influenza). For each patient contact, we also extracted the month/year of visit, age (0-4, 5-9, 10-17 years), race/ethnicity (white, non-white), sex (female, male), and zip code (linked to municipality of residence).

Policy measures

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

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.²⁵ 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.²⁵ Since 108 municipalities had either restaurant or workplace policies (51 had both), we coded exposure to any local smoke-free policy. 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, four municipalities had a smoke-free restaurant policy.

Cigarette excise taxes

We obtained the cigarette excise tax for each state from the *Tax Burden on Tobacco*,²⁶ which were translated into real December 2010 dollars based on the national Consumer Price Index.²⁷ In Massachusetts, cigarette tax increases occurred in July of 2002 and 2008 resulting in a tax of \$2.51 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.

Health care reform legislation

In April 2006, the Massachusetts legislature passed health care reform legislation which required all individuals to have health insurance.¹⁹ 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, 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.²⁸

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 acute respiratory infections) collapsed to municipality-level counts for each subgroup, age-race-gender, for each month/year. To account for differences in the population of each subgroup, we used an exposure variable constructed as municipality-level, group-specific, population counts. The denominator was created using census level data from 2000 and 2010, while the inter-census years were interpolated implementing a nonlinear smoothing interpolation technique using county-level data.²⁹ 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. Calendar time, as month and year of visit, was included to control for known seasonality of asthma and other health conditions.^{30,31} 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. We introduced interactions between state smoke-free legislation and children's ages and race to determine whether there was a differential effect of smoke-free legislation for each subgroup. We repeated this series of analyses, separately, for each health outcome. We also tested for the differential impact of state smoke-free legislation across municipalities with or without local smoke-free legislation, but we found no evidence for an interaction for any health outcome (results not shown). All analyses were conducted using Stata statistical software, version 13.1SE.

RESULTS

Figure 1 illustrates the monthly number of ED visits for children age 0-17 years whose principal diagnosis was asthma, ear infections, or acute respiratory infections in (a) Massachusetts and (b) Vermont over the study period. Consistent across all health outcomes (Table 2), older children were less likely to visit the ED than children age 0-5 years, while non-white children and boys were more likely to visit the ED than white children and girls, respectively.

Across both states, there were 118,679 ED visits for asthma. We found no changes in the

overall rates of ED visits for asthma after the implementation of local or state smoke-free legislation, health care reform, or cigarette tax changes (Table 2). However, state smoke-free legislation was associated with a 13% reduction in ED visits among children age 10-17 years (aIRR 0.867; $p < 0.001$) (Table 3). In contrast, there was no effect for younger children or differences by children's race.

There were an additional 249,464 ED visits for ear infections over the study period. We found that state smoke-free legislation was associated with a 13% reduction (adjusted IRR (aIRR) 0.871; $p < 0.001$) and health care reform legislation with a 19% reduction (aIRR 0.813; $p < 0.001$) (Table 2). There was no effect of local smoke-free policies or cigarette taxes on the rate of ED visits for ear infections.

There were a further 481,620 ED visits for acute respiratory infections over the study period. We found that state smoke-free legislation was associated with a 11% reduction (aIRR 0.885; $p < 0.001$), health care reform legislation with a 24% reduction (aIRR 0.755; $p < 0.001$), and every \$1.00 increase in cigarette taxes with a 13% reduction (aIRR 0.88; $p < 0.001$) in ED visits for respiratory infections (Table 2). In contrast, we found no effect of local smoke-free policies. We repeated analyses for acute upper and lower respiratory infections separately and found the same pattern of results (data not shown).

For both ear infections and respiratory infections we found similar reductions in ED visits across children's ages (0-4, 5-9, 10-17 years) and race (white, non-white) after the enactment of state smoke-free legislation (Table 3).

DISCUSSION

Using population-level data, we evaluated a natural experiment created by the enactment of local and state tobacco control policies within and across Massachusetts and Vermont. We have shown that state smoke-free legislation and health care reform legislation reduced ED visits for children's ear infections and respiratory infections and the effects of state smoke-free legislation were similar across children's ages and race. Although there was no overall change in ED visits for asthma after the enactment of tobacco control policies, state smoke-free legislation reduced ED visits among children age 10-17 years. Our study adds to the growing body of evidence that the health benefits of tobacco control policies extend to children.

State hospital discharge data collects information on every hospital contact and are mandated by law,^{22, 23} 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, acute ear infections, and acute respiratory illnesses.^{4, 6-9} After smoking in public places was banned in Scotland there were substantial reductions in fine particulate matter concentrations in pubs³² and salivary cotinine levels, a metabolite of nicotine, in children.³³ 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 local versus state smoke-free legislation as well as state differences in cigarette taxes and

health care reform legislation between Massachusetts and Vermont for childhood asthma, ear infections, and respiratory infections. Furthermore, the latter two outcomes have yet to be examined in the literature.

Previous studies have found decreases in hospital admissions or ED visits for childhood asthma either overall^{12, 13} or among children only,^{10, 11, 14, 15} with similar effects across ages and socioeconomic status.^{10, 11} However, methodological limitations, including not having a control group^{10, 11, 13, 14} or considering other tobacco control policies,¹⁰⁻¹⁴ reduces the ability to rule out alternative explanations. Landers recently examined the impact of county and state 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.¹⁵ These are the national version of our data, although Massachusetts was not included. Landers found that only county smoke-free legislation reduced asthma hospital discharges and higher cigarette taxes were also associated with fewer hospital discharges for children only.¹⁵ Although we showed that state smoke-free legislation and health care reform legislation reduced ED visits for ear infections and respiratory infections overall, we found the effect of smoke-free legislation reduced ED visits for asthma among children age 10-17 years. Higher cigarette taxes were also associated with decreases in respiratory infections. The Massachusetts 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 (3%) inpatient asthma visits in Vermont. 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 and not the county.²⁵ 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, including counseling and medications.²⁸ Since research has demonstrated reductions in smoking among Medicaid recipients and inpatient hospital claims for coronary events and heart disease,^{20, 21} our aim was to examine whether any health benefits extend to children. We found that health care reform legislation decreased ED visits for ear infections and respiratory infections with similar effects across children's ages and race. 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.³⁴ Reducing or eliminating smoking among adults would reduce children's secondhand smoke exposure and the likelihood of acquiring an acute ear infection or respiratory infection requiring an ED visit. Hospital discharge data does 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,³⁵ due to both greater subsidized coverage of children and indirectly through their parents' coverage.¹⁹ Although the hospital discharge data includes health insurance status, the census does not collect this information and we are not able to construct population denominators. A comparison of ED utilization between Massachusetts, Vermont, and New Hampshire 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.³⁶ 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 Massachusetts and Vermont in our analysis may potentially limit the generality of our findings to other states. Massachusetts has been at the forefront of tobacco control policies for the past decade.³⁷ We hypothesize that our findings could potentially underestimate the effect of policy changes among states with fewer or weaker tobacco control policies. As of January 2014, 14 states had no smoke-free legislation²⁵ and 20 states had cigarette taxes under \$1.00.³⁸ 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 including counseling and pharmacotherapy.³⁹ 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, secondhand smoke has been attributed to 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.⁴⁰ Our results contribute to the accumulating evidence base that state tobacco control policies may be effective public health interventions to improve children's health, as supported by reductions in ED visits for ear infections and respiratory infections overall and for asthma among adolescents. In North America secondhand smoke is attributed to 65 deaths from lower respiratory infections in children <5 years, 11 deaths from asthma in children <15 years, and 1 death from ear infections in children <3 years; however, worldwide secondhand smoke is attributed to 165,000, 1,150, and 71 deaths in children, respectively.⁴¹ Currently, 82% of the US population is covered by smoke-free policies,²⁵ compared to only 16% of the global population.⁴² Although further research is needed to confirm our findings, the benefits of smoke-free legislation on children's health could extend beyond asthma¹⁰⁻¹⁶ to reducing ear infections and respiratory infections.

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Table 1. Dates that cigarette taxes, smoke-free legislation, and health care reform legislation came into effect in Massachusetts and Vermont

	Massachusetts	Vermont
2001	Tax \$0.76	Tax \$0.44
2002	Tax \$0.76	Tax \$0.44
2003	Tax \$1.51 (7/25/02)	Tax \$0.93 (7/1/02)
2004	Tax \$1.51 7/5/04: Smoke-free workplaces, restaurants	Tax \$1.19 (7/1/03)
2005	Tax \$1.51	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 \$1.19
2007	Tax \$1.51	Tax \$1.79 (7/1/06)
2008	Tax \$1.51	Tax \$1.79
2009	Tax \$2.51 (7/1/08)	Tax \$1.99 (7/1/08) 7/1/09: Smoke-free workplaces
2010	Tax \$2.51	Tax \$2.24 (7/1/09)

Table 2. Emergency department visit incidence rate rates for smoke-free legislation and other tobacco control policies on asthma, ear infections, and respiratory infections among children in Massachusetts and Vermont

	Asthma (N=682,596)		Ear infections (N=698,400)		Respiratory infections (N=636,012)	
	IRR ^a (95% CI ^b)	p value	IRR ^a (95% CI ^b)	p value	IRR ^a (95% CI ^b)	p value
State smoke-free legislation	0.952 (0.870, 1.043)	0.3	0.871 (0.801, 0.947)	0.001	0.885 (0.841, 0.932)	<0.001
Local smoke-free legislation	1.035 (0.924, 1.158)	0.6	1.009 (0.928, 1.097)	0.8	1.053 (0.973, 1.139)	0.2
Health care reform (MA only)	1.041 (0.939, 1.155)	0.4	0.813 (0.745, 0.886)	<0.001	0.755 (0.702, 0.813)	<0.001
Cigarette tax ^c	0.968 (0.858, 1.093)	0.6	0.960 (0.882, 1.044)	0.3	0.868 (0.815, 0.925)	<0.001
Child's age (years)						
0-5	1		1		1	
6-9	0.677 (0.645, 0.710)	<0.001	0.326 (0.314, 0.340)	<0.001	0.342 (0.331, 0.352)	<0.001
10-17	0.497 (0.462, 0.535)	<0.001	0.010 (0.095, 0.105)	<0.001	0.248 (0.237, 0.259)	<0.001
Child's race						
White	1		1		1	
Non-white	1.931 (1.767, 2.110)	<0.001	1.417 (1.307, 1.537)	<0.001	1.542 (1.437, 1.656)	<0.001
Child's sex						
Female	1		1		1	
Male	1.386 (1.347, 1.426)	<0.001	1.061 (1.046, 1.077)	<0.001	1.047 (1.031, 1.063)	<0.001

Abbreviations: IRR, incidence rate ratio; MA, Massachusetts

^a Adjusted for: Child's age, sex, race, month and year of visit, municipality

^b Standard errors are clustered by municipality

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

Table 3. Emergency department visit incidence rate ratios for smoke-free legislation and other tobacco control policies on asthma, ear infections, and respiratory infections among children in Massachusetts (2001-2010) and Vermont (2002-2010), stratum-specific rates for each subgroups

	Asthma		Ear infections		Respiratory infections	
	IRR ^a (95% CI ^b)	p value	IRR ^a (95% CI ^b)	p value	IRR ^a (95% CI ^b)	p value
Interaction with child's age						
State smoke-free legislation						
0-4 years	0.984 (0.895, 1.083)	0.7	0.864 (0.794, 0.941)	0.001	0.897 (0.852, 0.945)	<0.001
5-9 years	1.027 (0.931, 1.124)	0.6	0.904 (0.827, 0.981)	0.01	0.904 (0.854, 0.954)	<0.001
10-17 years	0.867 (0.786, 0.948)	<0.001	0.846 (0.771, 0.920)	<0.001	0.850 (0.804, 0.896)	<0.001
Local smoke-free legislation	1.033 (0.924, 1.154)	0.6	1.009 (0.928, 1.097)	0.8	1.052 (0.973, 1.138)	0.2
Health care reform (MA only)	1.038 (0.936, 1.151)	0.5	0.813 (0.745, 0.886)	<0.001	0.755 (0.702, 0.813)	<0.001
Cigarette tax ^c	0.969 (0.859, 1.095)	0.6	0.960 (0.882, 1.044)	0.3	0.868 (0.825, 0.926)	<0.001
Interaction with child's race						
State smoke-free legislation						
white	0.969 (0.881, 1.066)	0.5	0.882 (0.810, 0.961)	0.004	0.893 (0.846, 0.943)	<0.001
non-white	0.913 (0.808, 1.018)	0.1	0.839 (0.754, 0.924)	<0.001	0.861 (0.803, 0.919)	<0.001
Local smoke-free legislation	1.039 (0.923, 1.171)	0.5	1.011 (0.929, 1.101)	0.8	1.054 (0.973, 1.142)	0.2
Health care reform (MA only)	1.052 (0.943, 1.173)	0.4	0.819 (0.751, 0.894)	<0.001	0.759 (0.704, 0.818)	<0.001
Cigarette tax ^c	0.966 (0.855, 1.091)	0.6	0.958 (0.880, 1.043)	0.3	0.867 (0.814, 0.924)	<0.001

Abbreviations: IRR, incidence rate ratio; MA, Massachusetts

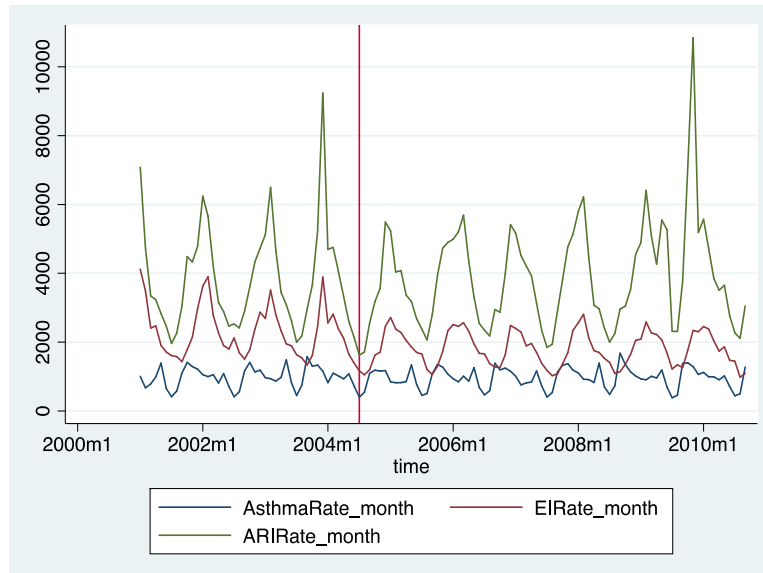
^a Adjusted for: Child's age, sex, race, month and year of visit, municipality

^b Standard errors are clustered by municipality

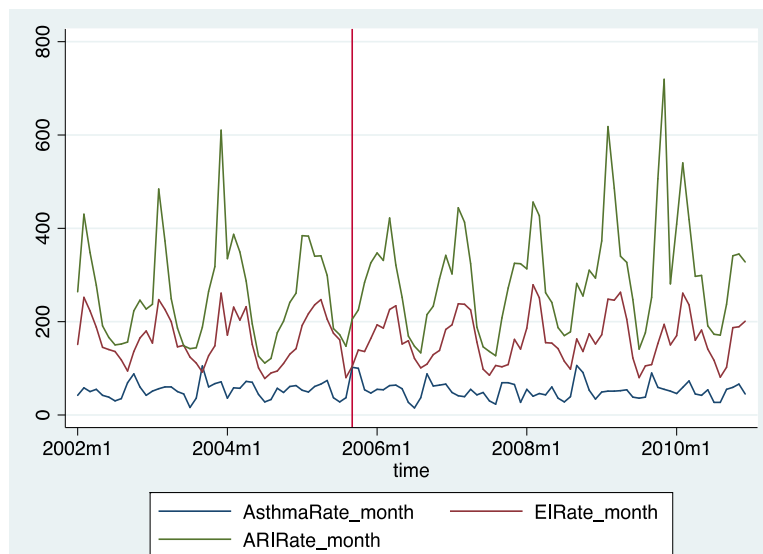
^c Translated into real 2010 dollars from national Consumer Price Index

Figure 1. Monthly total emergency department visits for asthma, ear infections, and respiratory infections among children in a) Massachusetts between January 2001 and September 2010 and b) Vermont between January 2002 and December 2010.

Abbreviations: ARI, acute respiratory infections; ER, ear infections



Note: In Massachusetts, smoke-free legislation was implemented in July 2004 (shown), health care reform (smoking cessation treatment) was implemented in July 2006, and cigarette tax increases occurred in 07/2002 and 07/2008 resulting in a tax of \$2.51 per pack in 2010.



Note: In Vermont, smoke-free restaurant legislation was implemented in September 2005 (shown) and smoke-free restaurant legislation was implemented in July 2009, and cigarette tax increases occurred in 07/02, 07/03, 07/06, 07/08, and 07/09 resulting in a tax of \$2.24 per pack in 2010.

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