

Asthma Exacerbations Attributable to Ozone Air Pollution in New England

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ABSTRACT

BACKGROUND: Ground-level ozone (O_3) is an air pollutant and known trigger for asthma exacerbation. We sought to estimate the number of summertime emergency department (ED) visits for asthma exacerbations attributable to ozone in each county in New England (Rhode Island, Massachusetts, Connecticut, New Hampshire, Maine, and Vermont) in 2010.

METHODS: We performed a health impact assessment using BenMAP. We used population and incidence rates in New England, daily maximum 8-hour O_3 levels, and a concentration-response function derived from the epidemiological literature to quantify ozone-attributable asthma ED visits.

RESULTS: We estimate that in 2010 there were 4,612 (95% CI 2192, 6866) excess ED visits for asthma exacerbation attributable to summertime ozone across New England. Rates of ozone-attributable asthma ED visits were highest in Connecticut and Massachusetts.

CONCLUSIONS: There was a substantial number of ozone-attributable asthma ED visits in New England in 2010 with geographic heterogeneity across states and counties.

KEYWORDS: climate change, ozone, asthma, emergency department visit

INTRODUCTION

Asthma affects 1.3 million people in the New England region of the United States.¹ Exposure to pollen, dust, infections, and air pollutants can exacerbate symptoms of the disease. One air pollutant – tropospheric ozone (O_3), or ground-level O_3 – is a well-described trigger for asthma exacerbations.² Tropospheric O_3 is formed by the reaction of nitrogen oxides and volatile organic compounds in the presence of sunlight and heat and, unlike stratospheric ozone, which provides protection from ultraviolet radiation from the sun, ground-level ozone is harmful to human health. Tropospheric O_3 concentrations tend to be highest during the summer months when temperatures are higher and sun exposure is prolonged. One study estimated that approximately 8–21%

of asthma emergency room visits in the United States are associated with O_3 exposure,³ although the incidence varies geographically. Although ozone is recognized as a contributor to unhealthy air and an important trigger of asthma exacerbations across New England,⁴ the burden of ozone air pollution on asthma across all states in New England has not been established. Accordingly, we sought to estimate the burden of disease in terms of summertime emergency department (ED) visits for asthma exacerbations attributable to ozone in every county in Rhode Island, Massachusetts, Connecticut, New Hampshire, Maine, and Vermont in 2010.

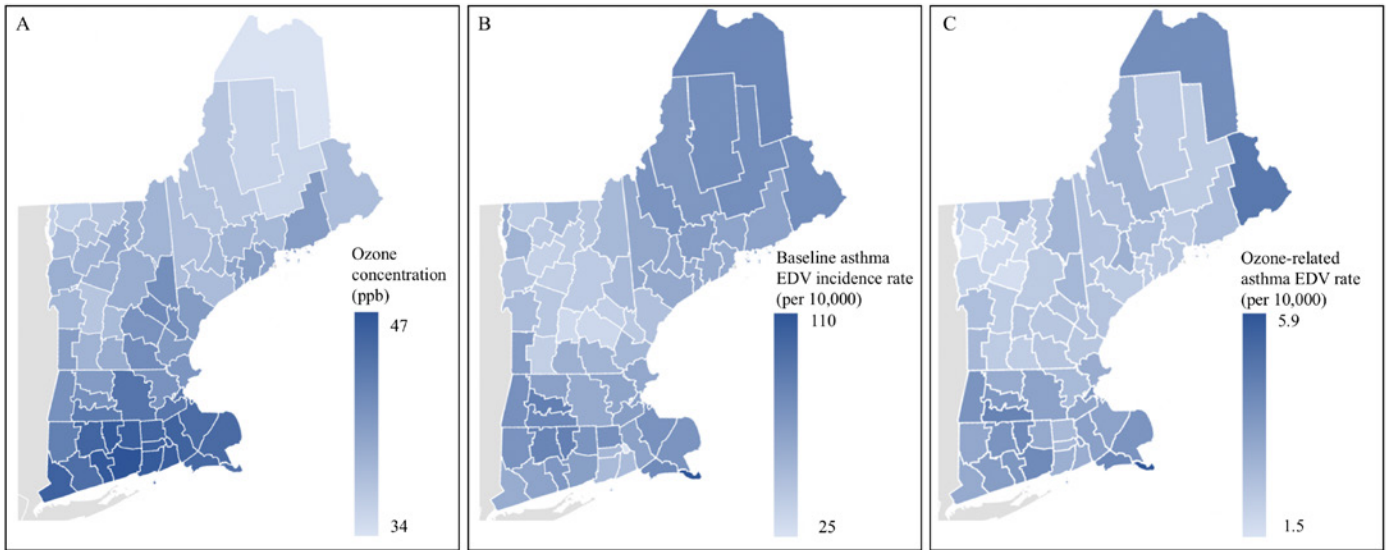
METHODOLOGY

We performed a health impact assessment to estimate the number of ozone-attributable asthma exacerbations in New England among all ages using the United States Environmental Protection Agency Benefits Mapping and Analysis Program (BenMAP), similar to prior studies.⁵ This approach requires multiple data inputs including estimates of ozone concentrations, baseline incidence rates of asthma-related ED visits, population counts, and a defined concentration-response function providing estimates of the association between ozone and asthma exacerbation. Conditional on these inputs (described below), we then quantified ozone-attributable asthma exacerbation ED visits on a county-level as follows (Equation 1):

$$Y = Y_0 \cdot (1 - e^{-\beta \cdot \Delta O_3}) \cdot Pop$$

where Y is the number of ozone-attributable asthma exacerbation ED visits, Y_0 is the baseline incidence rate for asthma, ΔO_3 is the concentration of daily maximum 8-hour O_3 , Pop is the population (age 0-99), and β is the risk coefficient on a natural log scale for asthma ED visits associated with daily O_3 exposure. County-level age-adjusted baseline incidence rates for asthma ED visits in 2010 are obtained from the National Environmental Public Health Tracking Network.⁶⁻⁸ Daily maximum 8-hour ozone concentrations during the summertime, defined as May 1 to September 30, 2010 in New England are based on air pollution monitor stations within each state. BenMAP calculates an inverse-distance weighted average of nearby monitors to determine county-level ozone concentrations, an approach called the Voronoi Neighbor Averaging algorithm.⁹ County-level population numbers are

Figure 1. Panel A: Average summertime (May 1–September 30), county-level ozone concentrations (parts per billion) in New England states in 2010. Panel B: Age-adjusted baseline asthma emergency department visit (EDV) rates per 10,000 population in 2010 on a county-level.⁸ Panel C: Rates of ozone-attributable asthma ED visits per 10,000 people in New England counties in 2010.



based on the 2010 U.S. Census. The risk coefficient is based on the meta-analysis by Ji et al. (2011) that reports a 2.90% (95% CI 1.33, 4.50) increase in risk of ED visit for asthma exacerbation for every 10 part per billion (ppb) increase in daily maximum 8-hour O₃.¹⁰

RESULTS

In the New England states, warm season averages of daily maximum 8-hour O₃ concentrations between May and September 2010 ranged from 34–47 ppb and were highest in New London County and Middlesex County in Connecticut (Figure 1). Aroostook County in Maine had the lowest concentrations of O₃.

We estimate that in 2010 there were 4,612 (95% CI 2192, 6866) excess ED visits for asthma exacerbation attributable to summertime ozone exposure in New England. The average rate of excess asthma-related ED visits was 3.2 (95% CI 1.52, 4.75) per 10,000 population. Connecticut and Massachusetts had the highest rates of ozone-attributable asthma ED visits per 10,000 population, with 3.65 (95% CI 1.74, 5.41) and 3.40 (95% CI 1.62, 5.06) respectively, while Vermont had the lowest at 1.98 (95% CI: 0.94, 2.96) (Figure 1). Rates of ozone-attributable asthma ED visits per 10,000 population varied by county, ranging from 1.5 to 5.9 (Table 1). In terms of absolute numbers rather than rates, Massachusetts had the highest absolute number of ozone-attributable asthma ED visits on a state-level in

2010 and Vermont had the lowest at 2,226 (95% CI 1058, 3314) and 123 (95% CI 59, 185), respectively.

DISCUSSION

Ozone concentrations and the attributable asthma ED visits varied geographically across New England. The health effects of ozone on asthma vary in part due to differences in baseline asthma incidence rates between counties. Indeed, a few counties such as Washington County, Maine, have high rates of asthma ED visits at baseline that would contribute to relatively higher rates of ozone-related asthma ED visits despite relatively lower summertime ozone concentrations.

Table 1. Counties in New England with the highest and lowest rates of summertime ozone-attributable asthma ED visits in 2010.

Counties with highest number of ozone-attributable asthma ED visits		Counties with lowest number of ozone-attributable asthma ED visits	
County, State	Asthma ED visit rate per 10,000 (95% CI)	County, State	Asthma ED visit rate per 10,000 (95% CI)
Nantucket County, MA	5.89 (2.8,8.76)	Chittenden County, VT	1.49 (0.7,2.22)
Washington County, ME	4.79 (2.27,7.17)	Orange County, VT	1.61 (0.76,2.4)
Hampden County, MA	4.41 (2.1,6.57)	Lamoille County, VT	1.62 (0.76,2.41)
Dukes County, MA	4.27 (2.03,6.35)	Washington County, VT	1.8 (0.85,2.7)
New London County, CT	4.23 (2.02,6.28)	Caledonia County, VT	1.81 (0.86,2.7)
Tolland County, CT	4.17 (1.99,6.19)	Addison County, VT	1.97 (0.93,2.94)
Aroostook County, ME	4.11 (1.94,6.16)	Grand Isle County, VT	1.98 (0.94,2.96)
Somerset County, ME	3.0 (1.42,4.49)	Sagadahoc County, ME	2.16 (1.02,3.22)
Berkshire County, MA	3.92 (1.86,5.85)	Cheshire County, NH	2.17 (1.03,3.25)
Hartford County, CT	3.91 (1.86,5.81)	Windsor County, VT	2.18 (1.03,3.26)

Differences in ozone concentrations also explain the geographic heterogeneity of the health impacts on asthma and likely stem from the distribution of precursor emissions of nitrogen oxides and volatile organic compounds as well as sunlight and heat. While ozone concentrations in New England in 2010 were, on average, below the current Ozone National Ambient Air Quality Standard, set at 70ppb¹¹ there remained a substantial number of ED visits attributable to ozone. Prior studies have shown that reducing ozone concentrations below the national standard would lead to fewer deaths and fewer respiratory hospitalizations.¹²

In the future, climate change will have significant implications for asthma in New England, in part due to the influence of heat on ozone formation.¹³ The Northeast is projected to have the fastest warming in the contiguous US, increasing 3°C by 2050 under some models.¹⁴ There is also emerging evidence describing a synergistic effect of heat on air pollution and human health.¹⁵ While our study estimates ozone-attributable asthma ED visits based on ozone concentrations in 2010, temperature increases in the future due to climate change will lead to more ozone formation while precursor emission levels are expected to decrease,¹⁶ and may inform adaptation and mitigation strategies.

One of the strengths of this study is the spatial scale. We report ozone-attributable asthma ED visits on a state and county level. Understanding the local burden of ozone on asthma can provide useful information for policy-makers. Another strength is the use of local baseline incidence rates for asthma ED visits rather than applying a national or state level incidence rate to a county-level, since rates vary geographically.

There are multiple limitations to this study. Ozone concentrations are based on monitor station data, which are not always located in every county in this study and thus may not reflect the ozone concentrations on finer spatial resolutions. Similar to prior studies, we use an interpolation method within BenMAP to estimate ozone concentrations based on surrounding air pollution monitors.¹⁷ Another limitation is the use of a single concentration-response function describing the relationship between ozone concentrations and asthma ED visits in all ages. Prior studies have reported differences based on sex and age in the concentration response relationship between ozone and asthma.¹⁸

Future work in this field would benefit from examining age-specific ozone-attributable ED visits for asthma exacerbation especially among vulnerable populations, such as children and elderly adults. Future research should also examine how mitigation strategies to address climate change affect ozone-attributable asthma ED visits.

CONCLUSIONS

Ozone air pollution is associated with thousands of asthma exacerbations requiring ED visit in New England. Rates of ozone-attributable asthma ED visits in New England varied by state and county in 2010, with the highest rates found in Connecticut and Massachusetts. These differences across space are likely due to a combination of varying demographic health characteristics and pollution levels, suggesting that efforts to reduce ozone-attributable ED visits should include improvements both to asthma treatments and air quality.

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