

The impact of climate change and aeroallergens on children's health

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ABSTRACT

There are unequivocal data that climate change is occurring and that there are resulting health impacts. Climate change can affect the prevalence and severity of allergic and respiratory disorders through projected increases in the temporal and spatial distribution and concentrations of some aeroallergens. This study was designed to critique and summarize existing knowledge on asthma-related impacts of aeroallergen exposure on children in the United States and to provide suggestions about reducing the negative impacts of climate change through increasing education, adapting current management strategies, and modifying distribution channels. A review and synthesis of published literature was performed. Five studies identified evaluated the relationship between aeroallergens and particular symptoms and six evaluated use of the emergency department and hospital care for asthma. Little is known about the relationship between aeroallergens and particular asthma symptoms. However, overall, there appears to be evidence that weed pollen is significantly associated with asthma exacerbations and use of emergency and hospital services. Activities that can help mitigate the impact of additional climate change-induced respiratory disease include continued research, physician and patient education, optimizing production and distribution, and actively considering the budgetary impact of increased prevalence and severity of respiratory disease. Although more research is needed on aeroallergens and respiratory disease, existing studies suggest that it will be essential to consider the health impacts on children. Strategies to reduce the impacts should be developed and implemented now.

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Key words: Air pollutants, allergies, asthma, bronchial diseases, climate change, environmental exposure, greenhouse effect, meteorological factors, pediatric

The Intergovernmental Panel on Climate Change Fourth Assessment Report (AR4) presents the state of knowledge of the physical science of climate change, the likely risks to human health, and strategies for reducing those risks through mitigation and adaptation.¹ The AR4 presents unequivocal evidence that climate is changing. Furthermore, compared with evidence from the past 10,000 years, the rate of change over the coming decades is likely to be unprecedented. Human health is likely to be directly affected by changes in average and extreme temperatures, precipitation patterns, and an increase in the frequency and intensity of extreme weather events, such as hurricanes and floods, and sea level rise. Indirectly, human health is likely to be affected by climate-related changes in disease transmission dynamics, including changes in the geographic range and incidence of climate-sensitive vector-, rodent-, and tick-borne diseases; water- and foodborne diseases; and diseases related to poor air quality.

Important findings from the AR4 include the type and extent of health impacts that are already occurring as a result of climate change. These include altering the distribution of certain infectious disease vectors, increasing the risk of death from heat waves, and changing the seasonality of many allergic species.² Worldwide, it is projected that there will be a continued change in the distribution and incidence of infectious diseases, an increase in the prevalence of malnutrition, a continued increase in deaths associated with extreme weather events, and an increase in cardiovascular and respiratory morbidity and mortality attributable to projected increases in ozone concentrations. In the short and medium term in the United States, the impacts are likely to vary in severity: impacts related to existing infectious diseases will likely not be a major threat, cardiovascular and respiratory events may be affected by projected increases in heat waves and ozone concentrations, and increases in concentrations of some aeroallergens could increase the incidence and/or severity of allergic and respiratory diseases.³

Several aspects of climate change can affect the timing and intensity of the pollen season and, subsequently, the burden of allergic and respiratory diseases. Higher carbon dioxide levels and air temperatures in urban settings appear to result in greater pollen production⁴ and increased allergenicity. More efficient wind pollination

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could result in wider geographic dispersion of allergenic plant species.⁵ The empiric question is whether these changes will eventually lead to changes in the timing or duration of the allergy season, a more intense allergy season, or a combination. Evidence suggests that although other factors also influence the outcomes, all of these possibilities are apparent,^{6–10} with synergistic effects of climate change and pollution creating additional health impacts.^{3,11} An earlier start to the pollen season has already been observed in North America.¹² Although the scientific community has not reached consensus on the role of allergen sensitization and the development of asthma, there is a possibility that increased pollen exposure and sensitization are directly responsible for some proportion of an increase in asthma incidence.^{13–15} Beggs and Bambrick suggest the an increase in the prevalence and severity of asthma may be an early indicator of anthropogenic climate change.¹⁶

The likely impact of aeroallergens on respiratory and allergic diseases has been the subject of a recent report from the Environmental Protection Agency.¹⁷ The report provides a thorough review of historical trends and estimates the expected economic and quality-of-life impacts of aeroallergens on asthma, rhinitis, and dermatitis in the United States. The objective of our report is less broad but more focused: to summarize what is known about climate change and potential effects of aeroallergen concentrations on children's respiratory health in the United States and to present strategies for adaptation and mitigation.

METHODS

An initial literature search was conducted in PubMed, using the search terms "asthma," "aeroallergens," and "United States" with limits of English-only publications and children (aged 0–18 years). This search yielded 57 articles to review. In addition, a citation pearl-growing strategy was used: reference lists from potentially relevant articles were reviewed, additional search terms ("meteorological," "pollen," and "mold") were added, and publications identified by PubMed as "related articles" were reviewed. Finally, general Internet searches were performed. The pearl-growing strategy was used, because it was clear that the initial searches did not find all of the relevant publications. Articles meeting the search criteria, specifically including an asthma outcome and providing data for children separately from adults, if adults were included, were abstracted. A total of 149 articles were identified as the most recent update of the search in September 2008.

RESULTS

There have been multiple studies evaluating the effect of aeroallergens on asthma-related outcomes

among children in the United States (Table 1). Five studies evaluated symptoms,^{18–22} and others have evaluated indications of severe exacerbations, *i.e.*, emergency room visits and hospital admissions.^{16–21} There are numerous methodological differences among the studies. For example, some have evaluated only same-day pollen and mold counts, while others also evaluated up to 5 days lag time. Also, the range of other pollutants, such as ozone and particulate matter, and meteorological data, such as temperature and humidity, included in the studies is not consistent, and so the findings do not always take into account the same set of interactions. Finally, aeroallergen and pollutant data were collected from various sources, with some studies looking at regional data and others having a single site for pollen counts. A previous study of pollutants examined several of these differences and suggested that they must be considered in interpreting results.¹⁹ However, overall, there appears to be evidence that weed pollen is significantly associated with asthma exacerbations and use of emergency and hospital services.

Asthma Symptoms

Delfino and colleagues conducted several studies of asthmatic children in southern California. The first analysis included 12 children who kept a daily symptom diary in 1993,¹⁸ another tracked outcomes for 25 children who recorded symptom information in 1995,¹⁹ and a third evaluated 22 children who recorded their symptoms in 1996.²⁰ In the first study,¹⁸ 12 children with physician-diagnosed asthma recorded a daily composite symptom score, with 0 indicating no asthma symptoms and 5 indicating symptoms that required a physician or hospital visit and use of as-needed inhalers. They also wore personal ozone samplers. During the study period, 462 person-days of observation were collected. Lagged daily mean fungal spores were significantly associated with increased symptom scores (0.12 increase in symptom score per increase of 1000 spores m⁻³) and with increased use of as-needed inhalers (0.14 increase in symptom score per increase of 1000 spores m⁻³). Problems with compliance to the ozone sampler severely inhibit the validity of the ozone-related findings.

Although the focus was on ozone and particular matter (PM) exposure, Delfino and colleagues also considered fungal spore concentrations and their impact on asthma symptoms.¹⁹ Among 25 children, the effect of fungi did not confound the effect of the primary analyses, suggesting that increases to the 90th percentile of ozone or PM₁₀ were associated with significant increases in asthma symptoms, using the same 6-point scale as the prior study, although the variable was dichotomized into ≤1 versus >1. Odds ratios for in-

Table 1 Summary of existing studies on effect of aeroallergens on asthma in children

Reference, Location, and Study Period	Population	Asthma End Point	Variables Measured	Findings
Symptoms Delfino <i>et al.</i> , 1996 ¹⁸ San Diego, CA, Sept.–Oct. 1993	Children with physician-diagnosed asthma of at least 1-yr duration currently taking asthma medications, aged 9–16 yr (<i>n</i> = 12)	Daily diary completed: asthma symptom impact, use of short-acting β -agonists	Pollen, fungus, aerosol acidity, ozone, PM _{2.5}	Lagged daily fungal spore concentrations were positive associated with symptom scores and with as-needed inhaler use
Delfino <i>et al.</i> , 1998 ¹⁹ Alpine, CA, Aug.–Oct. 1995	Children with physician-diagnosed asthma of at least 1-yr duration currently taking asthma medications, aged 9–16 yr (<i>n</i> = 25)	Daily diary completed each evening: asthma symptom impact	Fungus, ozone, PM ₁₀	Primary analyses focused on ozone and PM ₁₀ ; analyses of fungal concentrations were performed to evaluate robustness of primary analyses
Delfino <i>et al.</i> , 2002 ²⁰ Southern California, Mar.–Apr. 1996	Children with asthma aged 9–19 yr (<i>n</i> = 22)	Daily diary completed each evening: bother and severity of wheeze, sputum production, shortness of breath, chest tightness, presence of respiratory infection or hay fever	Pollen, fungus, ozone, nitrous oxide, PM ₁₀ , temperature, relative humidity	12-hr fungus and 24-hr pollen counts were significantly associated with a 90th percentile increase in pollutants, with associations divergent based on whether participants were taking anti-inflammatory medication
Neas <i>et al.</i> , 1998 ²¹ State College, PA, Jun.–Aug. 1991	Children entering fifth and sixth grade with no symptoms or history of asthma	Daily diary completed morning and evening: PEFr, cough, wheeze, colds	Pollen, fungus, temperature, precipitation, ozone, total sulfate particles, particle-strong acidity, sulfur dioxide, black carbon soot, PM _{2.1} , PM ₁₀	Several types of fungus spores associated with decrease in morning PEFr; wheeze, cough, and cold showed some associations with particle-strong acidity, and PM _{2.1}

Table 1 Continued

Reference, Location, and Study Period	Population	Asthma End Point	Variables Measured	Findings
Ostro <i>et al.</i> , 2001 ²² Los Angeles, CA, Aug.–Oct. 1993	African-American children with physician-diagnosed asthma and regular asthma medication use, 8–13 years (<i>n</i> = 138)	Daily diary completed (symptoms, medication use, respiratory infections, PEF, physician visits)	Pollen and mold concentrations, ozone, PM ₁₀ , PM _{2.5} , nitrogen dioxide, maximum and minimum temperature, relative humidity, precipitation, dew point	No significant association between pollen and asthma symptoms (shortness of breath, wheeze, or cough); small but significant associations between <i>Cladosporium</i> and <i>Alternaria</i> fungus concentration and asthma symptoms (range, 1.03–1.11); 3-day lag used for primary analysis; no association between increased use of medication and pollen or mold
ED visits and hospitalizations Babin <i>et al.</i> , 2007 ²³ Washington, DC, Oct. 2001–Sept. 2004	Children ≤18 yr visiting the ED or hospitalized for asthma	Asthma-related ED visit or hospitalization	Tree, grass, weed pollen, mold, ozone, PM _{2.5} , temperature	Significant association between same-day tree pollen and ED visits among 5- to 12-yr olds and between same-day weed pollen and admissions for all children and 5- to 12-yr olds; significant associations between lagged tree pollen and ED visits for 5- to 12-yr olds and between grass pollen (not all lagged days)
Im and Schneider 2005 ²⁵ New Jersey, 1993–1995	Children ≤14 yr hospitalized for asthma (<i>n</i> = 17,902 admissions)	Asthma-related hospitalization	Pollen (tree, grass, weed, ragweed), mold	Weed pollen was only variable with significant positive association with hospitalizations

Table 1 Continued

Reference, Location, and Study Period	Population	Asthma End Point	Variables Measured	Findings
Lierl and Hornung 2003 ²⁷ Cincinnati area, Apr.–Oct. 1996 and 1997	Children visiting the ED or hospitalized for asthma	Asthma-related ED visit or hospitalization	Pollen, fungus, ozone, PM ₁₀	Most significant predictor was 3- day lagged log of pollen count; was also associated with same-day and 1- and 2- day lags; no association between fungal spore concentration and asthma visits
Magas <i>et al.</i> 2007 ²⁴ Oklahoma City Metropolitan area, 2001–2003	Children ≤14 yr hospitalized for asthma (<i>n</i> = 1270 admissions)	Asthma-related hospitalization	Pollen, mold, ozone, PM _{2.5} , nitrous oxide, temperature, humidity	Main effects associated with hospitalizations were nitrous oxide, temperature relative to humidity, percentage of children <5 yr, and the number of children hospitalized the previous day
Wang <i>et al.</i> 2007 ²⁶ Delaware, Jan. 2000–Dec. 2003	Patients with an ED visit to a children's hospital	Asthma-related ED visits days (high- or low- visit days based on daily average during study period)	Tree, weed, grass, mold, temperature, precipitation, ozone, nitrous oxide, PM _{2.5}	Tree and weed pollen were higher (trend but not significant) on high-visit days vs low-visit days; no significant differences with grass or mold concentrations
Zhong <i>et al.</i> 2006 ²⁸ Cincinnati area, Apr.–Oct. 2002	Children ≤18 yr visiting the ED or hospitalized for asthma (<i>n</i> = 1254)	Asthma-related ED visit or hospitalization	Pollen, fungus, ozone, PM _{2.5}	Strongest predictors were lagged (up to 5-day) counts of ragweed, oak/ maple, and <i>Pinaceae</i> pollen (magnitude of Ors, 1.23–1.54)

ED = emergency department; OR = odds ratio; PEFR = peak expiratory flow rate; PM = particulate matter.

creases in asthma symptoms associated with fungal concentrations were 1.36 for the 24-hour average and 1.25 for the 12-hour average.

Models evaluated the relationship of symptoms from a 90th percentile increase in pollutants or aeroallergens across all participants and separately for those taking

anti-inflammatory medications versus those who were not.²⁰ The medication classification was an important variable, with the associations detected largely attributable to the lack of anti-inflammatory medication use. However, with such a small study, the findings should be considered preliminary.

Evaluation of a symptom diary completed by 108 nonasthmatic children during the summer of 1991 in State College, PA, found that 12-hour daytime fungus spore counts, specifically *Cladosporium*, *Epicoccum*, *Coprinus*, and *Xylaria*, were associated with decreased morning peak expiratory flow rate of one-half to 1.5 L/minute.²¹ Morning cough episodes showed a significant association with *Epicoccum* spore concentrations.

Among 138 African-American children in Los Angeles who recorded their asthma symptoms (shortness of breath, wheeze, and cough) and medication use over a 13-week period, small but significant associations were found between two fungus types (*Cladosporium* and *Alternaria*) and the onset of asthma symptoms.²² There was no significant association between pollen exposure and asthma symptoms. Further analyses of *Alternaria* exposure found that patients with moderate or severe asthma, high income, and those who were taking anti-inflammatory medications had stronger associations between exposure and asthma symptoms. There were no associations between fungus concentrations or pollen with use of extra medication.

Emergency Department (ED) Visits and Hospital Admissions

Babin and colleagues compared regular air quality and aeroallergen data from several locations in the District of Columbia and northern Virginia with daily counts of asthma-related ED visits and subsequent hospital admission among children aged 1–17 years from October 2001 through September 2004.²³ The study evaluated the effects of grass, tree, and weed pollen, and mold count. There was a same-day effect of tree pollen and ED admissions for older children, *i.e.*, aged 5–12 years (increase of 100 grains m^{-3} associated with 1.8% increase in visits), and between weed pollen and subsequent admissions among all children (increase of 10 grains m^{-3} associated with 7.7% increase in admissions), and among older children (increase of 10 grains m^{-3} associated with 10% increase in admissions). Weed pollen count also showed a significant association with hospital admissions from the ED for the whole group and among older children. Lagged effects showed associations between ED visits and grass pollen at 3 days for all children (increase in 10 grains m^{-3} associated with 2.6% increase in visits) and older children, as well as associations between tree pollen and visits for older children at all time periods (increase of 100 grains m^{-3} associated with an increase of 1.8–1.1%

in visits). Socioeconomic analyses suggest that some, but not all, of the high utilization in poorer communities may be explained by use of the ED as primary care.

A study in the Oklahoma City metropolitan area found that ambient air pollution had little effect on daily asthma-related hospitalizations among children ≤ 14 years old from 2001 to 2003.²⁴ The study considered pollen and mold counts. Neither pollen nor mold counts were significant predictors of hospitalizations. However, the authors caution, ambient air pollution levels are generally low in the Oklahoma City area and thus the lack of a significant effect is not unexpected. Instead, factors that were not included in this study, including indoor air quality, quality of life, and family history, are likely stronger predictors in this scenario.

Another study also looked at asthma hospitalizations for children ≤ 14 years old.²⁵ This study evaluated pediatric admissions in New Jersey from 1993 through 1995. Correlation analyses showed that weed and ragweed pollen showed significant correlations; these variables were included in regression analyses. The 3-day lagged weed pollen concentration explained 5.8% of hospital admissions. Admissions were highest in the fall. The researchers suggest that turning on forced-air heating systems in schools or the need for pollen exposures to reach a particular threshold before effects are seen may explain the findings.

Wang and colleagues looked at asthma-related ED visits to the Alfred I. duPont Hospital for Children over a 4-year period and classified days as low visit days (no ED visits for asthma) and high-visit days (≥ 7 visits for asthma).²⁶ There was a trend toward significance with higher tree pollen and weed pollen levels on high-visit days versus low-visit days, but there were no differences with other aeroallergens (grass pollen or mold). The seasonal distribution of high- and low-visit days may be associated with viral infections, the authors suggest. The classification of high- and low-visit days may mask other interesting associations.

Two studies evaluated asthma exacerbations among children receiving treatment at the Cincinnati Children's Hospital. Lierl and Hornung examined the association between aeroallergens and ED visits and subsequent hospitalizations from April through October in 1996 and 1997,²⁷ while Zhong and colleagues evaluated the association in 2002.²⁸

The hospital database as well as daily logbooks from the ED were scoured to identify asthma visits during the two observation seasons that Lierl and Hornung studied.²⁷ Air quality data, including pollen and fungus concentrations, were obtained for the time period. Various models were used to look at the same-day and up to 5-day lagged relative risks for asthma visits. The 3-day lagged log of the pollen count was the strongest predictor of asthma visits. Fungal counts were not predictors of visits. Furthermore, models that explored

months and seasons (fall versus spring and summer) found significant interaction effects. A synergistic effect was found between pollen and particulate levels. Although the model did not explore different pollen sources, it suggests that there is a strong relationship between overall pollen counts and asthma-related ED visits in the spring through fall in Cincinnati.

Hospital records were evaluated to identify asthma-related visits, including ED visits and outpatient clinic visits among children from April through October 2002.²⁸ More than 1200 unique patients were identified, with a mean age of 7 years. Aeroallergens measured include grass, oak/maple, *Pinaceae*, ragweed, and total pollen, and *Cladosporium*, *Aspergilli*, *Alternaria* and total fungal spore counts. Notable findings include that the relative risks associated with increases in oak/maple, *Pinaceae*, and ragweed pollen of 100 m⁻³ were associated with significant increases in daily asthma visits of 1.23–1.54 over lags of 3–5 days.

DISCUSSION

Critique and Future Opportunities

There are gaps in what is known about asthma exacerbations associated with aeroallergens. First, existing studies have focused on use of emergency care resources, specifically asthma-related ED visits and subsequent hospital admissions. Although these proxies are certainly evidence of exacerbations, they identify only the most severe episodes. Patients may experience increases in the frequency or intensity of symptoms without requiring emergency care, or they may go to an urgent care center or to their primary care physician to evaluate treatment options. In this case, additional studies could help identify the impact of these less serious events. The studies that evaluated symptoms have done so fairly inconsistently (*i.e.*, 6-point composite scale, collapsed scale, and individual symptoms). Another difficulty with the use of hospital records is that miscoding can occur. The use of a medical record review to supplement pulling records from a database, such as Lierl and Hornung²⁷ conducted, can help identify visits that might have been miscoded but that handwritten notes indicate were asthma-related, although the costs of this type of review can be prohibitive. Furthermore, focusing exclusively on the number of emergency visits and hospital admissions to the exclusion of other indicators of disease severity may be ignoring the impact on quality of life for children whose asthma is intensified but not to the extent of requiring emergency care. The impact of asthma on a child's quality of life can be substantial and is related both to severity and intensity.²⁹

An interesting metric not yet fully studied is whether medication use changes with increased exposure to aeroallergens, specifically an increase in the use of

rescue medications. Existing studies have attempted to quantify typical use but have used self-report rather than an objective marker.^{18,19} Analysis of a claims database could help address this question in terms of use of rescue medication in a season expected to trigger more symptoms. Distribution of medication in canisters with event recorders could evaluate day-to-day use. A related question is what proportion of asthma costs can be attributed to changes in patterns of aeroallergen presence associated with climate change. In addition to the direct costs of additional medication and treatment needed for maintaining asthma control, there are costs associated with missed work (for caregivers) and missed school. Although there is no clear consensus on how to value school absenteeism, absences can have an impact on school funding in districts funded by attendance as well as student progress.

In addition, although one study suggested that the increased use of emergency care in typically poor zip codes suggests that some children may be more vulnerable to the effects of aeroallergens,²³ it is important to consider whether children are brought to the emergency room because it is the best care option or because they have inadequate insurance coverage. Even though Medicaid should be available in the United States, many children in poorer areas may not have a regular source of care or may not have been diagnosed with asthma previous to the exacerbation noted in each study.

Implications and Responsibilities

It is reasonable to expect further changes in timing and intensity of aeroallergen exposure will take place as global temperatures continue to increase. Several programs and activities could minimize the burden of diseases associated with aeroallergens. First, it is essential to continue research into the impacts of climate change and aeroallergens on respiratory disease, with the results incorporated into the development or revision of guidelines for management and treatment of disease. The recently updated National Asthma Education and Prevention Panel's Expert Report discusses avoiding environmental triggers but specific wording about minimizing risk by avoiding climate change-induced triggers may be appropriate for future revisions.³⁰

Second, physician and patient education will be necessary. Particularly in regions in which these impacts are likely to be strongest, it will also be important to develop mechanisms for communication to physicians and other care providers. Physicians and other care providers will benefit from increased understanding of seasonal shifts and their implications for treatment. Patient education may be challenging, particularly with children. However, asthma education programs

have been shown to reduce asthma-related ED visits and hospitalizations.³¹ Although evidence supports an increase in asthma exacerbations and hospitalizations associated with increased pollen concentrations, it is less clear that specific symptoms are affected. Thus, it may be more difficult for patients to recognize an increase in symptoms, or it may be that exacerbations associated with aeroallergens develop very quickly and may be difficult to prevent once exposure has increased. Although it remains important to continue to evaluate symptoms and other disease markers, at a minimum, existing patient management programs and systems should explicitly consider climate and aeroallergen-related effects on asthma to help guide patients even when they are not yet experiencing negative impacts. Because it is nearly impossible to avoid aeroallergenic triggers, asthma patients should be instructed to make sure to refill routine medications as well as short-acting bronchodilators (*i.e.*, “rescue” medication) and keep their inhalers available. Increased awareness of the possibility of an exacerbation may minimize the number and severity of aeroallergen-related episodes.

Third, manufacturers of products used to prevent exacerbations can optimize their production and distribution systems. As data are available to project pollen counts at the local and regional levels, manufacturers of these medications should build distribution systems to respond to these projections and make products available where and when they will be needed.

Another route to mitigate negative health impacts is the development and support of early warning systems to forecast when allergy seasons may be more severe than average because of changes in weather patterns. For example, El Niño events generally bring increased rain to the southeastern United States, which can affect the quantity of pollen produced the following year. Analyzing associations between weather patterns and pollen quantity could identify situations where advance warning could be forecast, with response systems established to inform physicians and the public of actions to take to reduce the likely impacts of increased pollen concentrations. Predicting the timing and severity of pollen season is not simple, but more complex and more accurate models are under development.³²

Finally, there also will need to be consideration of the budgetary impact of increases in resource utilization related to respiratory health. Although no recent study has estimated the costs associated with asthma for children in the United States, the costs of asthma overall are substantial.³³ More outpatient visits, emergency care, and prescriptions will increase health care costs and may affect the ability to adhere to existing budgets. A Japanese study estimated the impact of cedar pollinosis on the national health care budget and even

though the assumptions included many sources of uncertainty, there was a strong need for the government to consider the impact of this aeroallergen in light of climate change.³⁴ Support for disease management or other educational programs to help control these rising costs will need to occur at the organizational level at both public and private insurers. In addition to increased responsibility and costs from the perspective of insurers, employers will be affected in two ways: not only through employee benefit costs but also through absenteeism resulting from parents staying home to care for their children.

Despite the certainty of climate change affecting human health, awareness far exceeds preparedness. A recent survey of local health officials in the United States found that although most are concerned about the effect of climate change on public health, they admit to being critically underprepared.³⁵ Strong evidence suggests climate change is affecting the start date, and possibly the intensity, of the pollen season, which affects the burden of asthma in children. Primary prevention of these health outcomes is not likely because there is no evidence that humans can physiologically adapt to higher pollen concentrations. Therefore, research is needed to better understand where and when climate change could affect the timing, quantity, and allergenicity of pollen, as well as the most effective and efficient actions that governments, agencies, physicians, and individuals could take to reduce possible health impacts. Particularly for a vulnerable population that is highly dependent on the assistance of caregivers in staying healthy, considering and mitigating the respiratory health impacts of climate change is essential.³⁶

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