Original Article

Exposure to Extreme Heat Events Is Associated with Increased Hay Fever Prevalence among Nationally Representative Sample of US Adults: 1997-2013

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What is already known about this topic? Extreme heat events are projected to increase in frequency, duration, and intensity in coming decades in response to changing climate.

What does this article add to our knowledge? We show that exposure to extreme heat event is associated with increased hay fever prevalence among US adults.

How does this study impact current management guidelines? Future clinical guidance on allergen avoidance and medication initiation may need to consider frequency and timing of extreme heat events.

BACKGROUND: Warmer temperature can alter seasonality of pollen as well as pollen concentration, and may impact allergic diseases such as hay fever. Recent studies suggest that extreme heat events will likely increase in frequency, intensity, and duration in coming decades in response to changing climate.

OBJECTIVE: The overall objective of this study was to investigate if extreme heat events are associated with hay fever.
METHODS: We linked National Health Interview Survey (NHIS) data from 1997 to 2013 (n = 505,386 respondents) with extreme heat event data, defined as days when daily maximum temperature (TMAX) exceeded the 95th percentile values of TMAX for a 30-year reference period (1960-1989). We used logistic regression to investigate the associations between exposure to annual and seasonal *extreme heat events* and adult hay fever prevalence among the NHIS respondents.
RESULTS: During 1997-2013, hay fever prevalence among adults 18 years and older was 8.43%. Age, race/ethnicity, poverty status, education, and sex were significantly associated with hay fever status. We observed that adults in the highest quartile of exposure to extreme heat events had a 7% increased odds of hay fever compared with those in the lowest quartile of exposure (odds ratios: 1.07, 95% confidence interval: 1.02-1.11). This relationship was more pronounced for extreme heat events that occurred during spring season, with evidence of an exposure-response relationship ($P_{trend} < .01$).
CONCLUSIONS: Our data suggest that exposure to extreme heat events is associated with increased prevalence of hay fever among US adults. © 2016 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2016;■:■-■)

Key words: *Allergy; Allergic rhinitis; Climate change; Extreme heat events; Extreme weather events; Hay fever*

Hay fever affects 17.6 million (7.5%) adults in the United States annually and can have an impact on their quality of life.[1-3] In 2005, hay fever-related medical expenses in the United States amounted to $11.2 billion.[4,5]

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Abbreviations used
CI- Confidence interval
DSI-3200- Data set 3200
EHE- Extreme heat events
ETT_{95}- Extreme temperature threshold 95th percentile
GED- General education development
GHCN- Global Historical Climatology Network
MSA- Metropolitan statistical area
NCHS- National Center for Health Statistics
NHIS- National Health Interview Survey
OR- Odds ratio
TMAX- Daily maximum temperature

Hay fever, a term often used for seasonal allergic rhinitis, is a chronic condition caused by an inflammatory response to seasonal allergens, and is characterized by nasal congestion, clear rhinorrhea (runny nose), sneezing, and itching.[6-10] Hay fever is frequently underrecognized, misdiagnosed, and ineffectively treated.[11] The causes and triggers of hay fever are seasonal exposure to mold or trees, grass, and weed pollens.[6-10] Previous studies have linked a rise in ambient temperature with increases in respiratory diseases,[12-16] but no studies to date have investigated the role of extreme heat events on respiratory outcomes such as hay fever on a national scale.

An increasing body of literature suggests that the frequency, intensity, and duration of extreme weather events will continue to rise in the near future in response to changing climate.[17-19] The potential impact of these increases on allergic diseases is a growing concern that has not been empirically assessed for the contiguous United States. Prior studies have shown that increases in temperature and CO_2 concentrations affect plant phenology as well as concentration, distribution, and allergenicity of pollen.[20-22] This dynamic may worsen the burden of hay fever by increasing both the pollen season length and the potency of pollen.[22-24] An increased burden may differentially impact people living in urban versus rural areas, and those of low socioeconomic status, children, and older adults,[18] because of the urban heat island effect,[25] poor housing conditions,[26] and limited adaptive responses.[27]

Using 17 years of health outcome data (National Health Interview Survey [NHIS] 1997-2013; n = 505,386 respondents), we explored the association between exposures to increased frequency of extreme heat events and hay fever among a nationally representative sample of the adult civilian noninstitutionalized US population aged 18 years and older.

METHODS

Meteorological data

Daily weather data were obtained from 2 systems within the National Centers for Environmental Information—formerly known as the National Climatic Data Center—for the 1960-2013 period.[28] Data for the years 1960-2010 were extracted from the DSI-3200 data set. The DSI-3200 data set was discontinued in 2010 and replaced with the Global Historical Climatology Network (GHCN) data set that consists of additional stations that are not part of the original DSI-3200 network. Therefore, for the 2011-2013 period, we identified the DSI3200 stations within the GHCN using unique station identification and extracted information from this subset of stations to maintain consistency.

Exposure metric

Using daily maximum temperature (TMAX) for the 1960-1989 reference period, county-specific 30-year baselines for each calendar month were computed. On the basis of the distribution of these data, we identified the 95th percentile values of TMAX, referred to as Extreme Temperature Threshold 95th percentile (ETT_{95}) as previously described.[29] Daily TMAX values for each county were compared with their respective calendar-month-specific ETT_{95} and assigned a value of "1" if they exceeded the thresholds, and "0" otherwise. The ETT_{95} exceedances—referred to as *extreme heat events* (EHE_{95})—were summed over each calendar month for each county during the 1997-2013 period for which NHIS hay fever prevalence data were available.

Extreme heat event values were assigned to individual NHIS records for each survey year in 2 ways: (1) the cumulative number of *extreme heat events* for the county of residence in a 12-month window, which include the month of interview and the preceding 11 months, and (2) the cumulative number of *extreme heat events* for the county of residence in each of the 4 complete seasons over the 12-month window preceding the month of interview. Seasons were categorized as follows: winter—December, January, February; spring—March, April, May; summer—June, July, August; fall—September, October, November.

NHIS, 1997-2013 data

We combined NHIS data for 1997-2013 for this analysis. The NHIS is a nationally representative cross-sectional household interview survey of the civilian noninstitutionalized population of the United States that has been conducted since 1957, although the survey design and questionnaire have changed over time.[30] The NHIS is conducted continuously throughout the year. Between 1997 and 2013, approximately 40,000 households were sampled each year, with some households having multiple families. In each family, a sample adult is selected for detailed questions on health and health care.[30] During the 17-year period, the sample adult response rates ranged from 60.8% to 80.4%.

We used the restricted-use NHIS files geocoded to county Federal Information Processing Standard. These files are available through the National Center for Health Statistics (NCHS) Research Data Center. There are 516,140 sample adults 18 years of age or older in the 1997-2013 NHIS. Respondents were excluded from the analysis if they: (1) resided in a county that had less than 12 months of extreme heat data and had at least one nonvalid month for the development of the baseline (n = 1185); (2) resided outside the 48 contiguous states at the time of the interview (n = 5334); or (3) had missing data for any of the variables used in the analysis (n = 4235), for a total of 10,754 (2%) excluded respondents.

Hay fever was identified using responses to the question: "During the past 12 months, have you been told by a doctor or other health professional that you had hay fever?" Demographic characteristics considered included age (18-34, 35-49, 50-64, 65+ years), race/ethnicity (Hispanic, non-Hispanic black, non-Hispanic white, all other races and ethnicities), sex (female, male), education level (less than high school/general education development [GED], high school/GED, some college, Bachelor degree, Graduate degree), and family income relative to poverty threshold (less than 100%, 100% to less than 200%, 200% to less than 400%, 400% or above the poverty threshold).[31,32] We used the NHIS multiple-imputed income data to assign poverty status level to records with missing values (percent missing ranged from 4.5% to 10.0% over 1997-2013) using NCHS-recommended methods.[33]