

Pollen Exposure and Associated Healthcare Utilization: A Population-based Study Using Health Maintenance Organization Data in the Washington, DC, Area

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Abstract

Rationale: Most studies of the healthcare utilization impact of pollen exposure have focused on emergency department visits or hospital admissions. However, other frequent but lower cost services—phone calls and e-mails to providers and office visits—may also be affected.

Objectives: The objective of our study was to estimate the impact of tree and grass pollen exposures on respiratory-related healthcare utilization across a range of medical services, including calls and e-mails to providers, nonurgent face-to-face visits, urgent and emergent care visits, and hospitalizations.

Methods: We conducted a retrospective observational study of daily tree and grass pollen counts linked to electronic health records of Kaiser Permanente beneficiaries in the metropolitan Washington, DC, area for 2013–2014.

Results: The proportion of Kaiser Permanente beneficiaries with respiratory-related healthcare utilization was significantly greater (for $P \leq 0.05$) given a 1 standard deviation increase in same-day

pollen exposure. For tree pollen, a 1 standard deviation increase in same-day pollen exposure was associated with relative increases in utilization ranging from 1.77% (95% confidence interval [CI], 0.07–4.17%) for urgent and emergent care visits to 12.84% (95% CI, 11.02–14.65%) for provider calls/e-mails. For grass pollen exposure, a 1 standard deviation increase in same-day pollen exposure was associated with relative increases in utilization ranging from 1.42% (95% CI, 0.39–2.46) for provider face-to-face visits to 11.09% (95% CI, 9.26–12.92) for provider calls/e-mails.

Conclusions: Increased pollen exposure was associated with increases in healthcare utilization across a range of services, with relatively higher increases in provider calls/e-mails and lower increases in emergent or acute care. If climate change increases intensity and geographic scope of pollen exposure as predicted and if this study's estimates of association of peak pollen exposure on healthcare utilization are generalizable, then the impact of climate change on healthcare utilization may be significant.

Keywords: pollen; healthcare utilization; environmental epidemiology; syndromic surveillance; population health

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Aeroallergen-related airway diseases are a prevalent complex of seasonal and chronic medical conditions afflicting children and adults in the United States. Seasonal or chronic allergic rhinitis is estimated to affect approximately 12–30% of children and adults (1), whereas asthma affects approximately 8–10% (2–4). These conditions frequently coexist or may foretell the onset of the other (5, 6). Chronic rhinitis and asthma, together with periodic exacerbations, increase children's school absences, employees' work absences, and medical services utilization and decrease quality of life (7–11).

Among persons with rhinitis or asthma, exposure to high concentrations of pollen and spores will trigger inflammatory responses, which will increase healthcare utilization when afflicted individuals seek advice or treatment for symptom alleviation. Responses to aeroallergen exposures can span a range of medical services. Some may seek information on symptom relief, as demonstrated by Internet searches or over-the-counter purchases of allergy medications (12–14). Others who are particularly sensitive and experience acute reactions or whose initial treatment fails to alleviate symptoms may require urgent or emergent care or hospitalization (15–24).

Most studies of the effects of pollen and spore exposure in the United States and Canada have focused on acute effects, as represented in hospital emergency department visits or admissions (12, 15–24). An ideal study of respiratory response to aeroallergen exposure would capture the space–time evolution of a syndrome from signals of an initial exposure (as people begin to seek information and obtain healthcare services) to its ultimate acute impact (as a disease progresses and people fail to respond to initial treatment and seek emergent or acute care services). This ideal study would also be able to estimate the proportion of persons requiring medical services at each stage of the evolution of a syndromic response (25).

Data routinely collected by healthcare systems, such as health maintenance organizations (HMOs), can be useful for population health surveillance by providing insight into the timing and intensity of response to an environmental exposure (26–35). Climate change is expected to alter the duration, intensity, and types of pollen exposure (35–45). Linking healthcare systems' data with pollen exposure can provide estimates of the direction and magnitude of community health effects attributable to

pollen exposure and improve, therefore, projections of future changes to population health given these anticipated changes to pollen exposure.

The primary objective of our study was to examine changes in the proportion of HMO beneficiaries experiencing healthcare utilization events across the complete range of service delivery options (provider e-mails and nurse calls, provider face-to-face visits, urgent and emergent care, and hospital admissions) in response to tree and grass pollen exposures. A secondary objective was to evaluate whether certain types of healthcare utilization events (e.g., phone call to advice nurse or e-mail on symptom onset) would be leading indicators of response to a spike in tree or grass pollen.

Methods

Study Setting

Incorporated in 1980, Kaiser Permanente Mid-Atlantic States (KPMAS) is an integrated delivery system that, at the time of this study, provided comprehensive medical care services to approximately 750,000 residents of the District of Columbia, Maryland (including Baltimore), and northern Virginia areas. The KPMAS beneficiary population reflects the racial and socioeconomic diversity of this community.

A call center is available to KPMAS beneficiaries 24 hours a day, 7 days a week. The call center assists beneficiaries by scheduling or canceling appointments, providing nurse advice, and accessing other medical services. Primary and specialist care is provided at 31 medical offices throughout the area. Urgent care units (UCs) and clinical decision units (CDUs), which triage patients for transport to hospitals, are available around the clock at eight KPMAS medical offices. Emergency department visits and hospital care are provided through contracts with eight hospitals.

The study protocol was reviewed, approved, and monitored by the institutional review boards of KPMAS and Georgia State University.

Study Data Sources

Pollen and temperature. The National Allergy Bureau of the American Academy of Asthma Allergy and Immunology maintains a network of monitoring stations that are responsible for reporting pollen and spore counts (46). Daily pollen count data are

categorized into grasses, trees, weeds, and spores. The DC station is operated by the U.S. Army Centralized Allergen Extract Lab located in Silver Spring, Maryland (approximately central to the DC metropolitan area) (47).

Daily average temperature data are collected at 16 weather monitors in Virginia and Maryland by the National Oceanic and Atmospheric Administration (48).

Healthcare utilization events. KPMAS implemented an Epic-based electronic health record (EHR) in 2005. All healthcare services provided by KPMAS clinicians are entered into the EHR. Healthcare services received from contract providers are received as claims for payment and integrated into the EHR.

Geocoded residential locations.

Residential addresses are available for each KPMAS beneficiary. Addresses are geocoded to determine the latitude and longitude coordinates, which can be associated with a census block group.

Study Sample

We limited analyses to KPMAS beneficiaries in the metropolitan DC area, which was defined as the District of Columbia; the counties of Montgomery, Prince George's, Arlington, Fairfax, and Loudon; and the cities of Alexandria, Fairfax, Falls Church, and Fredericksburg. Our analyses focus on these jurisdictions because only one pollen monitor was available, which was approximately in the geographic center of this area. Collectively, these jurisdictions cover 5,340 km².

Data Aggregation

By request of the KPMAS Institutional Review Board, data were aggregated into a dataset organized by U.S. Census blocks (based on the 2010 Census) and calendar days for 2013–2014. Census blocks with five or fewer KPMAS members were censored and excluded from the study. Each row in the dataset was identified by the census block Federal Information Processing Standard code and date. For each census block, we computed the median latitude and longitude of the KPMAS beneficiaries' residences to estimate the straight-line distance from this point to the latitude and longitude of the pollen monitor. Each column in the dataset represented information on pollen exposure and counts of each of four types of medical service events that were "respiratory related" (below).

Measures

Pollen exposure. For each day during the tree pollen season (February–June) and the grass pollen season (May–August), total pollen counts were obtained from the pollen monitor database. Only days with nonmissing values were used for exposure assessment. Daily pollen counts are not systematically collected out of season, and, during pollen seasons, pollen counts are typically not collected on weekends. Of 300 weekdays for February through June, data were not collected for tree pollen on 125 days. Of 246 weekdays for May through August in 2013–2014, data were not collected for grass pollen on 83 days.

Temperature. For each day during the tree and grass pollen seasons, we used the average daily temperature as a potential confounder. The temperature used for a census block was obtained from the closest of the 16 temperature monitors. “Closest” was defined as the shortest straight-line distance from the latitude and longitude of a temperature monitor to the median latitude and longitude of KPMAS beneficiaries’ residences in each census block.

Utilization event types. For each day, we counted the number of beneficiaries in the census block who had respiratory-related medical services in each of the following four utilization event types: 1) any phone contact or e-mail message contact between a KPMAS provider and a KPMAS beneficiary, 2) any KPMAS provider face-to-face visit with a KPMAS beneficiary (primary or specialty) during normal office hours, 3) any KPMAS UC/CDU or hospital emergency department visit (collectively, “UC/CDU/emergency department”), and 4) any hospital admission. *International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM)* diagnosis codes were examined to determine whether the provider visits, UC/CDU/emergency department visits, or hospital admissions were respiratory related (Table E1.1 in the data supplement). For advice nurse calls, a protocol number that represents the triage protocol invoked by a nurse in response to the patient’s reported symptom(s) was used to determine whether the call was respiratory related (Table E2.1). The investigator team and KPMAS collaborators developed these lists on the basis of a review of related literature and examination of ICD-9-CM and nurse advice protocol codes used at KPMAS. A patient was counted only once in an event type even if the patient had more than one respiratory-related event in that type on a day. Beneficiaries could

be counted in more than one type of event on any given day.

KPMAS beneficiary population.

Although the number of KPMAS beneficiaries in a census block can vary over time, we fixed the number of beneficiaries at the midpoint of the study period (December 31, 2013). Each census block was associated with several population characteristics of the residents included in the 2000 U.S. Census Summary File 3 dataset (49). We used the percentage of adults with a high school education or less and median household income in the census block as proxy measures for residential socioeconomic status.

Statistical Analysis

For each of the tree pollen and grass pollen datasets, descriptive statistics on the population, pollen exposure, and healthcare utilization were generated. The proportion of KPMAS beneficiaries in a census block with healthcare utilization events per day – for each of the 4 event types – was computed by dividing the count of beneficiaries with the event type in the day by the count of KPMAS beneficiaries in the census block as of December 31, 2013. We then multiplied these proportions by 100,000 to create proportions per 100,000 beneficiaries.

A linear regression model was estimated for each class of utilization event. To evaluate our primary objective, we estimated the following same-day pollen exposure model:

$$Y_{ij} = b(1) PE_{\bullet j} + b(2) CB_{i\bullet} + b(3) DOW + b(4) month + b(5) year + b(6) temp_{ij} + b(7) temp^2_{ij} + e_{ij}$$

in which Y is the proportion of KPMAS beneficiaries with the respiratory-related event, PE is the pollen exposure measure, CBs are census block residential characteristics, $DOWs$ are day of the week indicators, $month$ is the month of the year, $year$ is the year, $temp$ and $temp^2$ are temperature and temperature squared, $b(1)$ through $b(7)$ are parameter estimates, and e is an error term representing random variation for each of the census blocks “ i ” and days “ j ” in the study sample. Day of the week was included to account for the fact that rates of some medical care services (scheduled primary and specialty care provider face-to-face visits) occur only on weekdays and that rates of UC visits tend to increase on weekends compared with weekdays primarily because some patients with minor acute illness prefer to get care immediately rather than wait for a weekday provider appointment.

Pollen exposure varies by day but not by census block ($PE_{\bullet j}$) because there is only 1 monitor for the Washington, DC, area. Residential characteristics vary across census blocks but are invariant by day ($CB_{i\bullet}$). Temperature varies by day and census block because there are multiple temperature monitors. Day of the week, month, and year are treated as fixed effects.

To evaluate our secondary objective, we estimated alternative regression model specifications to account for lag effects in pollen exposure as follows: exposure the day before (i.e., lag of 1 day), distributed lag model (i.e., same-day, lags of 1 and 2 days), and moving average model (average of same, 1- and 2-day lags).

Results

Pollen Exposure

Table 1 displays descriptive statistics on ambient tree and grass pollen. Average tree pollen concentration during tree pollen season was 240 grains/m³, and average grass pollen concentration during grass pollen season was 7.13 grains/m³. We defined a “spike” as the difference between the 95th percentile and the median exposure. The spike for tree pollen was 1,129 grains/m³, and the spike for grass pollen was 33.2 grains/m³. These pollen concentrations are comparable with those reported in a previous study of pollen and emergency department visits in the DC area (15). The pollen concentrations that we identify as spikes are consistent with historic peak pollen days reported for this area (50)

The mean distance from a beneficiary’s residence to the pollen monitor was 28.7 km (standard deviation [SD] = 20.7 km). The median was 24.1 km (interquartile range, 12.8–39.2 km). These distances are generally within the 20–41 km range that other studies have found to have pollen concentrations correlated with a remote monitor (17, 51).

Healthcare Utilization Events

Table 2 displays descriptive statistics on the proportions of beneficiaries with respiratory-related healthcare utilization during the tree and grass pollen seasons. For example, during tree pollen season, 99.75/100,000 beneficiaries had a respiratory-related provider visit each day on average ($N = 16,129$ census blocks, measured for February–June); during grass pollen season, 82.87/100,000 beneficiaries had a respiratory-related provider visit per day on

Table 1. Distribution of tree and grass pollen exposure, 2013–2014

	Mean Tree Pollen at Pollen Monitor (100 grains/m ³)	Mean Grass Pollen at Pollen Monitor (10 grains/m ³)
Mean (SD)	2.40 (4.25)	0.713 (1.080)
95th percentile	11.820	3.578
75th percentile	3.390	0.607
Median	0.530	0.256
25th percentile	0.035	0.160

Definition of abbreviation: SD = standard deviation.

average (N = 16,129 census blocks, measured for May–August).

Regression Model Results

Tree pollen exposure. Table 3 displays effect estimates for absolute and relative increases in the proportion of beneficiaries who experienced a utilization event given incremental increases in tree pollen exposure. The overall pattern indicates that all four types of utilization events increased with incremental increases in tree pollen exposure. For example, if tree pollen exposure increased by 1 SD in a day (425 grains/m³), then the average proportion of the KPMAS population with same-day respiratory-related calls/e-mails increased by 12.84%, provider visits increased by 3.14%, UC/CDU/emergency department visits increased by 1.77%, and hospital admissions increased by 6.28%. In model specifications that included various

forms of lag effects (Tables E3.1 and E3.2), 1- and 2-day lag effects—in addition to same-day effects—were also noted.

Grass pollen exposure. Table 4 displays effect estimates for absolute and relative increases in the proportion of beneficiaries who experienced a utilization event given incremental increases in grass pollen exposure. As with tree pollen exposure, all four types of utilization events increased with incremental increases in grass pollen exposure. For example, if grass pollen exposure increased by 1 SD in a day (10.8 grains/m³), then the proportion of the KPMAS population with, on average, same-day respiratory-related calls/e-mails increased by 11.09%, provider visits increased by 1.42%, UC/CDU/emergency department visits increased by 7.02%, and hospital admissions increased by 5.23%. These relative increases in utilization are similar to the relative increases noted for tree pollen, with the exception of the proportion of beneficiaries

with a UC/CDU/emergency department visit on the same day, which is much higher for a 1 SD increase in grass pollen (7.02% vs. 1.77%).

Discussion

Our first objective was to estimate changes in respiratory-related medical services experienced by an HMO population in response to varying amounts of outdoor tree and grass pollen across a broad range of utilization event types. Most prior studies have focused on emergency department visits or hospital admissions because these data are readily available for research. In our study, we were able to acquire aggregated data on the full range of utilization event types, such as patient–provider e-mails and phone calls or provider office visits, not generally available in public datasets (52–54)

Across all event types, the proportion of HMO beneficiaries with healthcare utilization increased in proportion to tree pollen concentrations in the tree pollen season and to grass pollen concentrations in the grass pollen season. In response to higher pollen concentrations, more beneficiaries called or e-mailed for medical advice, visited a physician, had a UC/CDU/emergency department visit, or were admitted to the hospital on the same day. Larger effect sizes for calls/e-mails suggest patient preferences for lower resource, more convenient access to care in response to experience of mild symptoms. Calls and e-mails are “resource light” (patient

Table 2. Distribution of healthcare event rates for the tree pollen and grass pollen analysis samples, 2013–2014

		Event Type				
		Phone Calls and E-mails	Provider Visits	UC/CDU/Emergency Department Visits	Hospital Admissions	
Tree pollen analysis sample	Total N of beneficiary days			4,838,700		
	Total N of events	38,335	102,429	28,036	4,698	
	Total N of census blocks			16,129		
	Events per 100,000 beneficiary days by census block	Mean (SD)	37.33 (33.90)	99.75 (62.64)	27.30 (27.51)	4.57 (15.55)
		75th percentile	50.72	125.00	38.46	3.06
	Median	33.33	92.59	23.33	0	
	25th percentile	15.87	60.61	8.13	0	
Grass pollen analysis sample	Total N of beneficiary days			3,967,734		
	Total N of events	24,545	69,781	18,941	3,756	
	Total N of census blocks			16,129		
	Events per 100,000 beneficiary days by census block	Mean (SD)	29.15 (30.92)	82.87 (59.74)	22.49 (26.30)	4.46 (15.08)
		75th percentile	40.65	106.47	32.52	1.36
	Median	24.64	73.91	17.67	0	
	25th percentile	0	46.90	0	0	

Definition of abbreviations: CDU = clinical decision unit; SD = standard deviation; UC = urgent care unit. Utilization event counts and rates are for events that are likely respiratory related.

Table 3. Absolute and relative increases in numbers of beneficiaries with a likely respiratory-related event per 100,000 beneficiaries per day attributable to selected tree pollen exposure levels

				Increase in Number of Beneficiaries with an Event per 100,000 Beneficiaries per Day			
				Phone Calls and E-mails	Provider Visits	UC/CDU/Emergency Department Visits	Hospital Admissions
Effect Estimate: Same-Day Exposure Model				1.128 (0.968–1.287)	0.737 (0.496–0.978)	0.114 (0.004–0.224)	0.068 (0.0150–0.120)
Absolute increase in number of beneficiaries with a likely respiratory-related event per 100,000 beneficiaries per day	Tree pollen (100 grain units): same-day exposure	1 standard deviation	4.25 units/m ³	4.79 (4.12–5.47)	3.13 (2.11–4.16)	0.485 (0.019–0.950)	0.287 (0.064–0.511)
		Interquartile range	3.36 units/m ³	3.79 (3.25–4.32)	2.49 (1.67–3.29)	0.383 (0.015–0.751)	0.227 (0.050–0.404)
		Spike	11.29 units/m ³	12.73 (10.93–14.53)	8.32 (5.60–11.04)	1.29 (0.05–2.53)	0.763 (0.169–1.357)
Relative increase in number of beneficiaries with a likely respiratory-related event per 100,000 beneficiaries per day	Tree pollen (100 grain units): same-day exposure	1 standard deviation	4.25 units/m ³	12.84% (11.02–14.65)	3.14% (2.11–4.17)	1.77% (0.07–3.48)	6.28% (1.39–11.16)
		Interquartile range	3.36 units/m ³	10.15% (8.72–11.58)	2.48% (1.67–3.30)	1.40% (0.05–2.75)	4.96% (1.15–8.83)
		Spike	11.29 units/m ³	34.10% (29.29–38.92)	8.35% (5.62–11.07)	4.71% (0.17–9.25)	16.68% (3.69–29.66)

Definition of abbreviations: CDU = clinical decision unit; UC = urgent care unit.

- Model effect estimates are based on observations with events that are likely respiratory related.
- Absolute increases in numbers of beneficiaries with the event are computed from the effect estimates (Table 3) times the number of beneficiary days for the tree pollen sample (Table 2).
- Relative increases in the numbers are computed as the absolute increases in numbers of beneficiaries with the event per 100,000 beneficiaries per day (Table 3) divided by the average proportion of beneficiaries with an event per 100,000 beneficiaries per day (Table 2).
- “Spike” is defined as the difference between the 95th percentile and the median for an exposure measure (Table 1).

effort or cost or healthcare system costs are relatively minimal per event), whereas emergent care or hospital admissions are “resource heavy” and involve relatively high patient costs (time, copayments, or coinsurance and transportation) and healthcare system costs (specialized personnel and material). Nevertheless, all healthcare utilization involves some cost borne immediately by patients, healthcare systems, and, ultimately, society as a whole. The increased burden of symptoms indicated by calls/e-mails is a health impact that has been missed in studies of emergency department visits or hospitalizations only.

The increases in UC/CDU/emergency department visits and hospital admissions with higher concentrations of pollen exposure are consistent with other published studies (15–24). A 2–3% relative increase in emergency department visits with a 1 SD increase in tree pollen was noted in a study of the Atlanta metropolitan area (16). In a meta-analysis of pediatric asthma studies, Erbas and colleagues found an approximately 2% increase in emergency department visits with

each 10 grains/m³ increase in grass pollen (18). We found an approximately 2% increase in respiratory-related UC/CDU/emergency department visits and a 6% increase in hospital admissions per 1 SD, which, in our study, is approximately 10.8 grains/m³ (Table 3). The Atlanta study also reported a 10–15% increase in emergency department visits with their equivalent of our “spike” (16); we found an approximately 17% increase (Table 3).

Our second objective was to evaluate whether an increase in certain types of healthcare utilization events such as phone calls or e-mails might indicate the initial onset of a syndromic response to pollen exposure before an increase in acute events (e.g., UC/CDU/emergency department visits or hospital admissions) (31). Patient-provider e-mails and nurse advice calls demonstrated primarily same-day increases in response to pollen exposure. The distributed lag model (Table E3.2) yielded inconsistent evidence of a prodromal phase, which would have been indicated by significant increases in respiratory-related event rates 1 or 2 days before the event day.

Study Limitations

Aggregation of data to units defined by census block-day measures of healthcare utilization diminished our ability to detect within-day sensitivity of utilization response to aeroallergen exposure. Beneficiary-level measures on an event-specific scale would have allowed us to examine within-day sequences of events, such as calls/e-mails followed by visits or hospital admissions later in the day. This would have allowed for within-day lags as well as across-day lags in event sequences. Aggregation to census block-day units prevented us from doing more refined beneficiary-level adjustments for comorbidities, age, sex, and race that might affect an aeroallergen response.

Factors other than aeroallergen exposure can affect healthcare utilization. Patient preferences for alternative services, which we did not measure, could also affect healthcare utilization. Patient insurance and financial status, cost-sharing, ability to access a service, and perceptions of the severity of a symptom and the value of alternative service options to alleviate the symptom affect how a patient responds and which healthcare services are used.

Table 4. Absolute and relative increases in numbers of beneficiaries with a likely respiratory-related event per 100,000 beneficiaries per day attributable to selected grass pollen exposure levels

				Increase in Number of Beneficiaries with an Event per 100,000 Beneficiaries per Day			
				Phone Calls and E-mails	Provider Visits	UC/CDU/ Emergency Department Visits	Hospital Admissions
Effect Estimate: Same-Day Exposure Model				2.992	1.092	1.461	0.216
Absolute increase in number of beneficiaries with a likely respiratory-related event per 100,000 beneficiaries per day	Grass pollen (10 grain units): same-day exposure	1 standard deviation	1.08 units/m ³	(2.498–3.487)	(0.298–1.886)	(1.046–1.876)	(0.033–0.398)
		Interquartile range	0.447 units/m ³	3.23	1.18	1.58	0.233
		Spike	3.32 units/m ³	(2.70–3.77)	(0.32–2.04)	(1.13–2.03)	(0.035–0.430)
Relative increase in number of beneficiaries with a likely respiratory-related event per 100,000 beneficiaries per day	Grass pollen (10 grain units): same-day exposure	1 standard deviation	1.08 units/m ³	1.34	0.488	0.653	0.096
		Interquartile range	0.447 units/m ³	(1.12–1.56)	(0.133–0.843)	(0.468–0.839)	(0.015–0.178)
		Spike	3.32 units/m ³	9.97	3.64	4.86	0.718
				(8.32–11.61)	(0.99–6.28)	(3.48–6.25)	(0.109–1.326)
				11.09%	1.42%	7.02%	5.23%
				(9.26–12.92)	(0.39–2.46)	(5.02–9.01)	(0.80–9.64)
				4.59%	0.59%	2.90%	2.16%
				(3.83–5.35)	(0.16–1.02)	(2.08–3.73)	(0.33–3.99)
				34.19%	4.39%	21.63%	16.09%
				(28.53–39.84)	(1.20–7.58)	(15.48–27.78)	(2.45–2,973)

Definition of abbreviations: CDU = clinical decision unit; UC = urgent care unit.

- Model effect estimates are based on observations with events that are likely respiratory related.
- Absolute increases in numbers of beneficiaries with the event are computed from the effect estimates (Table 4) times the number of beneficiary days for the tree pollen sample (Table 2).
- Relative increases in the numbers are computed as the absolute increases in numbers of beneficiaries with the event per 100,000 beneficiaries per day (Table 4) divided by the average proportion of beneficiaries with an event per 100,000 beneficiaries per day (Table 2).
- “Spike” is defined as the difference between the 95th percentile and the median for an exposure measure (Table 1).

We did not conduct a medical record review to determine whether our definitions of likely respiratory-related events were sensitive and specific. We assume, on average, that the ICD-9-CM codes represent the patient’s condition as to whether it is respiratory related or not.

To simplify analyses, we assumed a geographically static population. Residential location was fixed as of December 2013. Some proportion of people move into and out of census blocks over a 2-year period. Pollen exposure was associated with residential location, but exposure may differ by subgroups. School-age children or older, nonworking adults are likely to concentrate activities (school, shopping, and recreation) in the residential area; however, employed adults might spend considerable amounts of time at a distance from the monitor closest to their residence.

For measured pollen counts, missing values are common and missing not at random because of the pollen collection schedule. Pollen samples are collected manually, primarily on weekdays when staff are on site

and rarely on weekends or holidays (even during pollen season) when staff are not on site. The data collection schedule affects estimation of distributed lag and moving average models, which require exposure measures on consecutive days. Thus, we limited our lag and moving average models to “look-back” periods of 2 days or less to decrease the likelihood that the pollen measurement period will include weekend days (when pollen data are not collected), and, therefore, the observation is deleted from the model estimation dataset.

Regression models included daily temperature as a covariate but did not include daily measures of humidity or other aeroallergens such as fine particulate or ozone. These other factors, if covarying with daily pollen counts, might contribute to part of the association of pollen variation with healthcare utilization variation.

Estimates of the relative association of a pollen concentration change with a healthcare event change (Tables 3–4) may be contingent on the size of our sample. Because we divide by

the total number of beneficiaries (Table 2), larger or smaller denominators would result in smaller or larger relative effect sizes for the same absolute effect estimate.

Public Health Implications

Healthcare systems can be an important source of information for surveilling population health and for measuring, monitoring, and responding to syndromic situations. Recognizing the value of HMOs’ EHR data for syndromic surveillance is important because, with climate change, we might expect substantial changes in the duration, intensity, and types of pollen exposure, which, subsequently, will significantly affect types and amounts of healthcare utilization. Further exploration of the value of HMO EHR data at the patient level with detailed date and time information to sequence events is warranted.

Conclusions

We found significant increases in the proportion of an HMO’s beneficiaries who obtained medical services across a broad range

of healthcare utilization types in response to tree and grass pollen concentrations during peak seasons. Although the costs to a healthcare system differ by utilization type, any increases in healthcare utilization have resource and, therefore, cost implications. If projections about prolonged pollen seasons

and greater pollen concentrations are correct, then climate change will require healthcare systems to consider this factor in future resource planning. ■

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