SHORT PAPER

Short term effects of airborne pollen concentrations on asthma epidemic

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Background: Few studies have used time series to investigate the relationship between asthma attacks and aeroallergen levels on a daily basis.
Methods: This study, based on time series analysis adjusting for meteorological factors and air pollution variables, assessed the short term effects of different types of allergenic pollen on asthma hospital emergencies in the metropolitan area of Madrid (Spain) for the period 1995–8.
Results: Statistically significant associations were found for *Poaceae* pollen (lag of 3 days) and *Plantago* pollen (lag of 2 days), representing an increase in the range between the 99th and 95th percentiles of 17.1% (95% confidence interval (CI) 3.2 to 32.8) and 15.9% (95% CI 6.5 to 26.2) for *Poaceae* and *Plantago*, respectively. A positive association was also observed for *Urticaceae* (lag of 1 day) with an 8.4% increase (95% CI 2.8 to 14.4).
Conclusions: There is an association between pollen levels and asthma related emergencies, independent of the effect of air pollutants. The marked relationship observed for *Poaceae* and *Plantago* pollens suggests their implication in the epidemic distribution of asthma during the period coinciding with their abrupt release into the environment.

Many studies have examined daily counts of asthma admissions or emergency room visits in relation to short term fluctuations in measured air pollutants.[1] However, few studies have used temporal series to investigate the relationship between asthma attacks and aeroallergen levels on a daily basis.

Some studies have reported that thunderstorms are associated with epidemics of acute asthma in which grass pollen appears to be important.[2] Other studies have found that grass pollen counts were significantly associated with asthma morbidity, which increased on wet and stormy days.[3] Rainfall and thunderstorms have been suggested to be important effect modifiers in the relationship between grass and asthma morbidity. Another study, performed in Mexico City, showed that grass pollen was associated with child and adult asthma admissions, and that aeroallergens may be statistically associated more strongly with asthma hospital admissions than air pollutants.[4] In addition, in the wet season the highest values of grass pollen were predicted to increase asthma admissions. Apart from the association between asthma and high pollen concentrations on stormy days, no consistent pattern has been found between asthma admissions and daily variations in airborne pollen.[1 5–7]

Because of its botanical and climatic characteristics, the city of Madrid has high levels of different types of airborne pollen with considerable allergenic capacity[8] and so offers an excellent setting for evaluating whether there is a relationship between such pollens and asthma related morbidity. This study analysed the short term association between asthma emergency hospital admissions in Madrid and different types of pollen, with due adjustment for air pollutants and meteorological factors.

METHODS

The daily number of asthma emergency hospital admissions from the Emergency Department of the Gregorio Marañón Hospital, covering an urban catchment area of 555 153 inhabitants, was studied for the period 1995–8. Diagnoses included the following (in literal form): asthma, asthmatic bronchitis, spastic bronchitis, and bronchospasm. Airborne pollen data were collected from the Madrid Regional Health Authority Palynology Network comprising 10 monitoring stations. Daily averages of all main pollen types with allergenic capacity in the Madrid area (*Olea*, *Plantago*, *Poaceae*, *Urticaceae*, *Artemisia*, *Chenopodeaceae*, *Cupressaceae* and *Platanus*) were collected.[8] Air pollution data were obtained from the Madrid Municipal Automatic Air Pollution Monitoring, Forecasting and Information System. Pollutants covered were as follows: daily averages of PM_{10} (from 13 monitoring stations), SO_2 and NO_2 (both from 15 monitoring stations), and 8 hourly maximum average of O_3 (from two monitoring stations). Mean temperature and mean relative humidity were registered by the Barajas meteorological observatory located 8 km northeast of the city. Information was also collected from the Gregorio Marañón Hospital Emergency Department on other potential confounders such as daily cases of acute respiratory infections.

Data were analysed using Poisson regression with generalised additive models fitting a cubic smoothing spline with degrees of freedom (df) approximately equal to the number of months of the study period to control for temporal trend and seasonality[9]; cubic smoothing splines of up to 4 df to control for the effect of acute respiratory infections, meteorological variables and air pollutants, with assessment of individual lags up to the fourth order; also dummy variables for day of the week and public holidays were used. The choice of the number of df for each non-parametric smoothing function was made on the basis of minimisation of the Akaike information criterion and of observed residual autocorrelation using the simple and partial autocorrelation functions.[9] Trend and seasonality were then fitted using a cubic smoothing spline with 72 df. Cubic smoothing splines with 4 df were included to adjust for the effect of temperature and with 2 df to adjust for relative humidity and acute respiratory infections, all for the concurrent day. Adjustment was made for the effect of air pollutants by using cubic smoothing splines with 2 df for PM_{10} (lag of 3 days) and SO_2 (lag of 3 days), 3 df for NO_2 (lag of 3 days), and 1 df for O_3 (lag of 1 day). The core model did not show residual autocorrelation or overdispersion. Finally, the effects of the current day and individual lags of up

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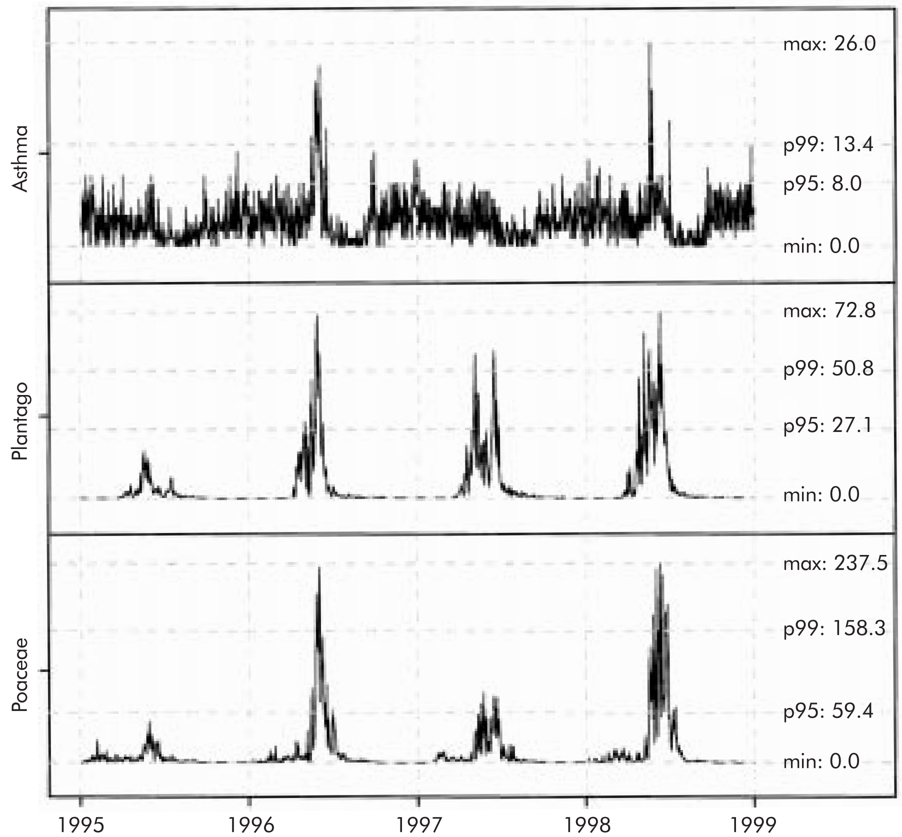

Figure 1 Temporal distribution of asthma related emergencies and *Plantago* and *Poaceae* pollen levels in Madrid, 1995–8.

to 1 week for the different types of pollens were assessed. Because of the large number of pollens and lag tests, this paper emphasises the consistency of associations across lags and measures and discusses only the more highly significant findings ($p<0.01$).

Analyses were performed with S-Plus (Insightful Corporation, Seattle, WA, USA) using more stringent convergence parameters for the GAM estimation procedure, recently suggested by NMMAPS[10] and APHEA-2[11] researchers to avoid possible biased regression coefficients and standard errors.

RESULTS

During the study period a total of 4827 daily emergencies were registered with a daily mean of 3.3 (range 0–26). Of this total, 50% were children aged 0–14 years, with 25% aged under 5 years.

Figure 1 shows the coincidence in time between the abrupt release of *Poaceae* and *Plantago* pollen into the environment (measured in grains/m^3) between the 95th (p95) and 99th (p99) percentiles and the asthma epidemic peaks during the last 2 weeks in May 1996 and the first 2 weeks in June 1998. It also shows that *Poaceae* and *Plantago* did not reach the p95 in 1995, so the levels were below the possible threshold that causes an increase in hospital asthma admissions. In 1997 there were many days of heavy rain during the pollen season. This might have split the distribution of *Poaceae* and *Plantago* pollen into two phases which resulted in reduced levels of *Poaceae* and *Plantago* pollen exceeded the p95 for only 8 days. This might explain the absence of epidemic increments during that period.

Table 1 shows the association between asthma emergency room admissions and pollen levels as the percentage change (and 95% confidence interval) in the mean number of

Table 1 Percentage increase (95% CI) for a variation in range between the 99th (p99) and 95th (p95) percentiles of pollen distribution

				Model with one pollen		Model adjusted for all types of pollen	
Type of pollen	No of days*	p99-p95 (grains/m)	(Lag)	p99–p95 % increase (95% CI)	p value	p99–p95 % increase (95% CI)	p value
Olea	664	106.2	(1)	4.8 (–4.4 to 14.9)	0.1606	1.8 (–7.9 to 12.5)	0.3634
Plantago	873	22.9	(2)	22.8 (16.1 to 29.9)	<0.0001	15.9 (6.5 to 26.2)	0.0003
Poaceae	1306	98.4	(3)	27.5 (17.0 to 38.9)	<0.0001	17.1 (3.2 to 32.8)	0.0070
Urticaceae	1324	4.1	(1)	10.7 (5.8 to 15.9)	<0.0001	8.4 (2.8 to 14.4)	0.0016
Artemisia	407	2.1	(1)	3.9 (–6.1 to 15.1)	0.2284	4.4 (–6.6 to 16.7)	0.2257
Chenopodiaceae	973	11.2	(2)	6.4 (–7.7 to 22.7)	0.1966	3.6 (–11.2 to 21.0)	0.3266
Cupressaceae	1359	194.6	(3)	7.2 (–2.3 to 17.7)	0.0699	6.0 (–3.4 to 16.5)	0.1100
Platanus	336	413.3	(2)	3.7 (–7.3 to 16.1)	0.2616	3.9 (–7.9 to 17.2)	0.2675

*Number of days in the study period with levels >0 grains/m^3 for a type of pollen.

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admissions associated with a 95–99th percentile increase in the pollen levels. The results are shown according to two types of models. The first model registered the best lag in terms of greatest effect and statistical significance for just one type of pollen. The most marked associations were registered for *Poaceae* (lag of 3 days) and *Plantago* (lag of 2 days), representing a variation in range between the 99th and 95th percentiles of 27.5% (95% CI 17.0 to 38.9) and 22.8% (95% CI 16.1 to 29.9), respectively. A positive association was also observed for *Urticaceae* (lag of 1 day) with a 10.7% increase (95% CI 5.8 to 15.9), but not for the remaining pollens. On adjusting for all types of pollen in the second model, the associations remained in evidence although the effects were reduced: 17.1% (95% CI 3.2 to 32.8) for *Poaceae*, 15.9% (95% CI 6.5 to 26.2) for *Plantago*, and 8.4% (95% CI 2.8 to 14.4) for *Urticaceae*. These associations had small p values providing good evidence for a relationship even after a conservative Bonferroni correction.

DISCUSSION

This study, using a time series approach, provides evidence to support an association between airborne pollen levels and asthma related emergencies which is independent of the effect of air pollutants and meteorological factors.

The possibility of air pollution induced confounding in the relationship between pollen and asthma is of special methodological interest. As in a previous study,[4] we found that the effect of pollen levels on asthma related emergencies was independent of the effect of air pollutants. One limitation of this study is that the temporal coincidence of *Plantago* and *Poaceae* pollens leads to a collinearity effect which, in turn, might entail a dilution of the potential effect of the abrupt release of *Poaceae*.

Our results are consistent with other studies which found that grass pollen counts were significantly associated with asthma morbidity,[2 3] but it is at odds with studies which found no association between asthma admissions and daily variations in airborne pollen.[5–7] There may be several reasons for this lack of consistency. It may result from geographical differences in the allergen levels,[5] in the prevalence of atopy and bronchial responsiveness,[12] and in the clinical and pathological nature of asthma. It could also be due to residual confounding by pollutants.[5] Furthermore, the main types of pollen of high allergenic capacity in Madrid which are associated positively with asthma related hospital emergencies are different from the pollens identified in other studies.

On the other hand, our results agree with other studies[3 4] in suggesting that the response to environmental factors may be delayed or accumulated over 1–3 days. This is in line with the biological mechanisms of allergens, since the clinical consequences of a given pollen load increased as the pollination season progressed. This probably represents a priming effect.[13]

In conclusion, our findings are consistent with the hypothesis of a relationship between daily variation in pollen levels in Madrid and epidemic asthma. In the case of *Poaceae* and *Plantago*, our results may help to explain the epidemic increase in this disease during the season of year in which pollen is abruptly released into the environment.

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