Document downloaded from http://www.elsevier.es, day 20/04/2018. This copy is for personal use. Any transmission of this document by any media or format is strictly prohibited.

Allergol Immunopathol (Madr). 2012;**40(4)**:231–237

ELSEVIER DOYMA

Allergologia et immunopathologia

www.elsevier.es/ai

ORIGINAL ARTICLE

Daily effects of air pollutants and pollen types on asthma and COPD hospital emergency visits in the industrial and Mediterranean Spanish city of Cartagena

L. Cirera[a,f,*], L. García-Marcos[b], J. Giménez[c], S. Moreno-Grau[d], A. Tobías[e], V. Pérez-Fernández[b], B. Elvira-Rendeles[e], J.J. Guillén[a,f], C. Navarro[a,f]

[a] *Public Health Authority, Murcia Regional Health Council, Murcia, Spain*
[b] *Allergy and Pulmonology Units, Virgen de la Arrixaca Children's Hospital, University of Murcia, Murcia, Spain*
[c] *Atmospheric Pollution Lab, Dept of Physics and Computer Architecture, Miguel Hernández University, Elche, Spain*
[d] *Dept of Chemical Engineering and Environment, Technical University of Cartagena, Cartagena, Spain*
[e] *Institute of Environmental Analysis and Water Research (IDAEA), Spanish Scientific Research Council (CSIC), Barcelona, Spain*
[f] *CIBER de Epidemiología y Salud Pública (CIBERESP), Spain*

Received 3 April 2011; accepted 28 July 2011
Available online 3 September 2011

KEYWORDS
Aeroallergen;
Pollen;
Air pollution;
Asthma;
Chronic obstructive pulmonary disease;
Emergency service;
Hospital;
Time series;
Mediterranean area;
Spain

Abstract
Background: Associations found in time-series studies on hospital emergency room (ER) visits due to asthma and chronic obstructive pulmonary disease (COPD) with single air pollutants show some lack of consistency. The respiratory effects of aeroallergens in the air pollution mix are not well established. Non-linear relationships of different airborne pollen types with certain respiratory diseases have also been described. We aim to study the short-term effects of major air pollutants and aeroallergen pollen on asthma and COPD hospital ER visits in the industrial and Mediterranean Spanish city of Cartagena during 1995–1998.
Methods: The association of asthma and COPD to ER visits with mean levels of sulphur and nitrogen dioxides (SO_2 and NO_2), total suspended particles (TSP), ozone (O_3), and the main allergenic airborne pollen types were analysed using Poisson regression with Generalised Additive Models, taking into account delayed effects and adjusting for long-term trends, seasonality, weather conditions, holidays and flu notifications.
Results: Multipollutant models showed a similar relative risk (RR) increase (in %), of around 5% in asthma and COPD ER visits per 10 $\mu g/m^3$ SO_2increments. The risk of an ER visit for the same NO_2 increment was 2.6% for asthma and 3.3% for COPD. Visits to the ER due to asthma showed a positive increase with both Urticaceae and Poaceae levels, but did not substantially modify the previous percentages.

* Corresponding author.
E-mail address: Lluis.Cirera@carm.es (L. Cirera).
URLs: http://www.ciberesp.es (L. Cirera), http://www.murciasalud.es/epidemiologia (L. Cirera).

0301-0546/$ – see front matter © 2011 SEICAP. Published by Elsevier España, S.L. All rights reserved.
doi:10.1016/j.aller.2011.05.012

Document downloaded from http://www.elsevier.es, day 20/04/2018. This copy is for personal use. Any transmission of this document by any media or format is strictly prohibited.

Conclusions: Air levels of SO_2 and NO_2 were associated with a substantial increased risk in ER visits due to asthma and COPD. The inclusion of Poaceae and Urticaceae pollen did not alter that association.
© 2011 SEICAP. Published by Elsevier España, S.L. All rights reserved.

Introduction

The influence of individual ambient air pollutants on hospital emergency room (ER) visits for asthma and COPD in epidemiological time-series studies has been shown to be inconsistent.[1–7] Airborne pollen effects on asthma have been shown at the population level on their own[8,9] or combined to an air pollutant mix.[10] However, few papers have been published on the effect of aeroallergens on COPD exacerbations.[11] Furthermore, there is some controversy on the independent relationship that pollen types may have with asthma and COPD because the atmospheric pollutants included in the models did not affect pollen estimators.[12,13] While some authors have found additive effects of air pollutants and airborne pollen on asthma,[14] others have not.[15] On the other hand, some studies have shown that in some cases the relationship between certain pollen types and respiratory diseases is not linear.[8,10]

Various studies have been conducted in the Spanish Mediterranean cities of Barcelona and Valencia during different periods using similar methodology. In Barcelona, an independent relationship was found between sulphur dioxide (SO_2) and black smoke (BS) levels with ER visits due to COPD exacerbations; and of NO_2 and BS concentrations with asthma ER visits.[2] In Valencia, ER visits for asthma were related to daily averages and maximum hourly concentrations of NO_2[4]; and the maximum hourly levels of ozone (O_3) and carbon monoxide (CO) increased the risk of ER visits due to COPD.[5]

The aim the present study was to establish the short-term effects of the major air pollutants and aeroallergen pollen types on hospital ER visits for asthma and COPD in an industrial and Mediterranean Spanish city, during the period 1995–1998.

Methods

The city of Cartagena is located on the Mediterranean coast in southeast Spain. Its population in the 2001 census was 185,799 (332 inhabitants/km^2 in 558 km^2), concentrated in the city centre of an extensive municipality. Unplanned urban development led to large chemical and non-ferrous metallurgical factories being located close to residential areas. Cartagena has a semiarid Mediterranean climate. Weak or calm wind regimes prevail: the south-southeast wind, weak and lacking in humidity, and the north-northeast (40% of the winds) capable of producing rain (annual maximum 136–400 mL) caused by storms in the Gulf of Cadiz. Sunny days abound with a mean temperature range of 15–24 °C from cold to hot semesters with no very cold season. This zone is almost barren of trees; bushes and weeds are the characteristic vegetation. These bioclimatic conditions make flowering possible throughout the entire year. However, very stable anticyclones accumulate air masses above the city centre increasing atmospheric pollution due to slow dispersion via its port. The sea breeze additionally increases atmospheric pollution due to a very weak pressure gradient in the anticyclonic conditions. Steep mountains and a valley towards the sea surround Cartagena.[16]

Asthma and COPD hospital emergency room visits data

Following a standardised procedure based on previous experience, two trained nurses identified asthma and COPD cases among city residents from the ER registries of the two public general hospitals, those most frequently used for emergencies. In the event of doubt, a physician made the final assignation. The study period was between 1 January 1995 and 31 December 1998. Access to hospital emergency room departments of the Spanish National Health System is free and available to all citizens.

Air pollution and airborne pollen data

Air pollution data came from three urban automatic monitoring stations (*Lo Campano*, *Bastarreche* and *San Ginés)* and one suburban (*Alumbres*) from the municipal network. The three urban stations measured daily levels of total suspended particles (TSP) and SO_2, and two of them (*Bastarreche* and *San Ginés*) also collected data on NO_2. The suburban station (*Alumbres*) registered daily O_3 levels. Only those pollutants with data for more than 75% of the whole study period were considered. Completeness criteria for O_3 started on July 11 of the first year. Air pollution indicators were the daily (0–24 h) mean levels ($\mu g/m^3$) of TSP, SO_2 and NO_2 and the 9-h O_3 maximum.

For pollen counts, the well-known Hirst method sampler VPPS 2000 (Bologna, Italy) developed by Lanzoni™ was used. The sampler was located on the roof (10 m above ground level) of the central railway station (37°36′N/0°58′W), and Hirst's capture method and analysis were applied following the quality standards of the Spanish Aerobiological Network and European Allergy Networks. Pollens were identified by microscopic morphology and *taxa* grouped according to class and genus. Daily levels (grains/m^3) of the pollen types with the highest concentration with the major allergenic capacity were selected[17]: Poaceae (grass) and Urticaceae (including *Urtica* and *Parietaria*). Details of the pollen calendar have been previously reported.[18]

Weather and other data

Daily hour values of minimum and maximum temperature (°C), relative humidity (percentage) and air pressure (hPa), registered at the old quarter of the city were obtained from the Spanish National Agency of Meteorology (AENET). The

Document downloaded from http://www.elsevier.es, day 20/04/2018. This copy is for personal use. Any transmission of this document by any media or format is strictly prohibited.

Table 1 Daily emergency room visits for asthma and COPD, aeroallergen pollen types and air pollutants concentrations, and weather conditions indicators.

Indicators (metrics)	Mean	(SD)	Percentiles								
			Min.	5th	10th	25th	50th	75th	90th	95th	Max.
Asthma (no. visits)	1	(1)	0	0	0	0	1	2	3	4	10
COPD (no. visits)	2	(2)	0	0	0	0	1	2	3	4	11
Poaceae (grains/m^3)	2	(4)	0	0	0	0	0	2	5	9	53
Urticaceae (grains/m^3)	9	(13)	0	0	0	1	4	12	26	36	102
TSP 24-h (μg/m^3)	52	(18)	12	27	31	39	50	61	75	84	153
SO_2 24-h (μg/m^3)	32	(13)	5	14	16	21	31	41	49	53	151
NO_2 24-h (μg/m^3)	51	(23)	1	24	29	37	45	60	80	94	210
O_3 8-h (μg/m^3)	80	(18)	16	48	55	69	81	93	103	108	134
Temperature (°C)	20	(5)	9	12	15	15	19	24	27	28	31
Relative humidity (%)	70	(12)	18	48	53	63	72	78	83	85	94
Barometric pressure (h Pa)	1017	(6)	997	1006	1009	1012	1016	1020	1025	1028	1034

number of weekly influenza cases was collected from the regional registry of communicable diseases.

Statistical analysis

To estimate the short-term effects of air pollution and grains of different pollen types on asthma and COPD hospital ER visits, the Spanish adaptation of the APHEA-2 protocol was followed[19,20] using Poisson regression with Generalised Additive Models. A core model was fit, including the smoothing functions to remove long-term trends and seasonality with a period range of 90–210 days. Afterwards, weather indicators, influenza cases notification, day of the week, and public holidays (the last two factors as dummy variables), were added. The choice of degrees of freedom (df) for the smoothing *cubic splines* of any weather variables and influenza cases was made by minimisation of the Akaike Information Criterion, using between 2 and 4 df and on minimisation of the partial autocorrelation residuals. Once the core model was fit, the effects of the current day and individual lags of up to 4 days for air pollutants and pollen types were assessed using single-pollutant models. Furthermore, considering that simultaneous exposure to other pollutants might be a potential source of variation, multipollutant models were also considered in order to adjust for TSP, SO_2 and, NO_2 and O_3, respectively in pairs. Finally, pollen types were included in both multipollutant models. Possible non-linearity of air pollutants and pollen types were tested.

Because of the large number of pollen and lag tests, this paper emphasizes the consistency of associations across lags and measures and discusses only the more highly significant findings ($p < 0.01$). Analyses were carried out using S-Plus statistical software (Insightful Corporation, Seattle, WA, USA) using restrictive convergence parameters to avoid any bias in the iterative process,[21] and GAM exact estimations to avoid concurvity.[22]

Results

During the 4-year period, a total of 1617 asthma and 2322 COPD hospital ER visits were recorded, meaning a daily range from 0 to 10 and 0 to 11 ER, respectively (Table 1). No asthma or COPD epidemics were observed (Fig. 1).

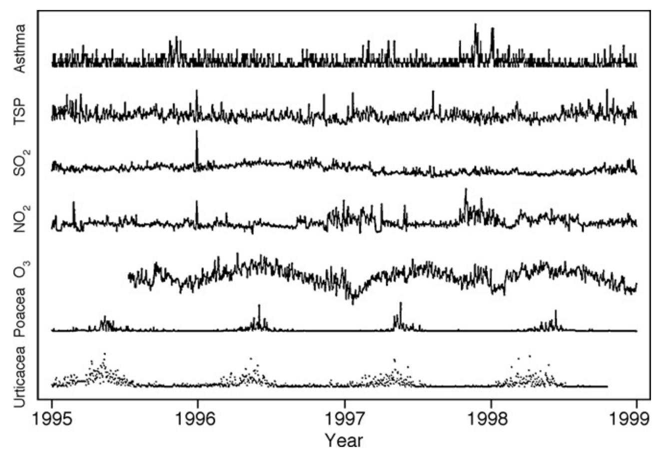

Figure 1 Daily number of hospital emergency room visits for asthma and COPD, and air pollutants (μg/m^3) and aeroallergen pollen types (grains/m^3) concentrations.

Total suspended particles showed a more predominant cold-season pattern, while ambient air SO_2 and NO_2 pollutants were distributed more homogeneously. Ozone showed a seasonal peak during the summer months. Poaceae (grass) levels had a seasonal distribution with higher concentrations between May and June, whereas Urticaceae flowered throughout the year, especially between March and June. Correlations between air pollutants, pollen counts and weather conditions are shown in Table 2.

The baseline GAM model finally selected used smoothing *cubic splines* function adjustments for long-term trends and seasonality with a frame window of 210 days for asthma and 150 days for COPD; for the temperature on the current day it was with 2 df and 3 df for influenza cases on the current day. Dummy variables for the days of the week and public holidays were included. The models did not show residual autocorrelation, overdispersion, or concurvity, after GAM exact estimations.

Table 3 shows the daily percentage of relative risks (%RR) and a 95% confidence interval (95% CI) on asthma and COPD

Document downloaded from http://www.elsevier.es, day 20/04/2018. This copy is for personal use. Any transmission of this document by any media or format is strictly prohibited.

Table 2 Correlation coefficients[a] among daily air pollutants aeroallergen and pollen types concentrations, and weather conditions indicators.

	TSP	SO_2	NO_2	O_3	Poaceae	Urticaceae	Temp.	Humidity
SO_2 24-h ($\mu g/m^3$)	0.1							
NO_2 24-h ($\mu g/m^3$)	0.1	0.0						
O_3 8-h ($\mu g/m^3$)	−0.1	0.0	−0.2					
Poaceae (grains/m^3)	0.0	0.0	0.0	0.3				
Urticaceae (grains/m^3)	−0.1	0.0	−0.1	0.2	0.5			
Temperature (°C)	0.1	−0.1	−0.2	0.4	0.1	0.1		
Relative humidity (%)	0.0	−0.1	0.0	−0.2	−0.1	−0.2	−0.1	
Barometric pressure (hPa)	0.1	0.1	0.1	−0.2	−0.1	0.0	−0.3	0.0

[a] All r, $p < 0.001$.

hospital ER visit variations for a 10 $\mu g/m^3$ increase in each air pollutant for both the single and multiple pollutant models. The lag describing the strongest association with asthma was the fourth day for all pollutants except O_3, which was related to the current day. For COPD, the greatest risk occurred on the same day as the contaminants except for O_3, which was at the fourth lag. Furthermore, SO_2 and NO_2 were the pollutants revealing a positive statistically significant association with asthma and COPD emergency visits. A 10 $\mu g/m^3$ rise in each pollutant was associated with a risk increase slightly less than 7% for both outcomes and SO_2; the increases for NO_2 were 2.6% and 3.8%, respectively.

The inclusion of TSP in the model with two pollutants reduces the SO_2 effect by 5.2%, whereas the insertion of O_3 in the model with two photochemical pollutants practically did not markedly affect the NO_2 estimation. Lastly, the models with two pollutants incorporated the pollen types with individual and combined inclusion of the current day Poaceae levels and the Urticaceae 4-day lag, as these evidenced the best adjustment in the models. The inclusion of pollen types and their interactions did not markedly change the magnitude of the estimated effect of SO_2 on asthma or COPD hospital ER visits.

A GAM model was used to assess possible non-linear effects of pollen types, adjusting simultaneously for all

Table 3 Relative risks and 95% confidence interval of asthma and COPD hospital emergency room visits for an increase of 10 $\mu g/m^3$ of air pollutant and of 1 grain/m^3 of aeroallergen pollen types.

Asthma	Models							
	TSP – SO_2 pollutants				Photochemical pollutants			
	%RR	(95% CI)	%RR	(95% CI)	%RR	(95% CI)	%RR	(95% CI)
	TSP − lag 4		SO_2 − lag 4		NO_2 − lag 4		O_3 − lag 0	
Single pollutant	2.0	(−0.9, 5.1)	6.1	(1.4, 11.0)	2.6	(0.4, 4.9)	−2.9	(−6.2, 0.6)
Multiple pollutants	1.2	(−1.8, 4.3)	5.2	(0.5, 10.1)	2.6	(0.3, 5.0)	−2.6	(−6.0, 0.8)
With pollen types								
+ Poaceae − lag 0	1.2	(−1.8, 4.3)	5.2	(0.5, 10.2)	2.7	(0.4, 5.0)	−2.7	(−6.1, 0.9)
+ Urticaceae − lag 4	1.2	(−1.9, 4.3)	5.6	(0.9, 10.6)	2.6	(0.3, 5.0)	−2.7	(−6.2, 0.9)
+ Both pollen types	1.2	(−1.8, 4.3)	5.7	(0.9, 10.6)	2.7	(0.4, 5.1)	−2.8	(−6.3, 0.9)
COPD	Models							
	TSP – SO_2 pollutants				Photochemical pollutants			
	%RR	(95% CI)	%RR	(95% CI)	%RR	(95% CI)	%RR	(95% CI)
	TSP − lag 0		SO_2 − lag 0		NO_2 − lag 0		O_3 − lag 4	
Single pollutant	3.2	(0.8, 5.7)	6.9	(3.3, 10.7)	3.8	(2.0, 5.6)	7.7	(1.9, 13.7)
Multiple pollutants	2.3	(−0.2, 4.8)	5.2	(1.5, 8.9)	3.3	(1.4, 5.3)	4.1	(−0.8, 9.2)
With pollen types								
+ Poaceae − lag 0	2.4	(−0.1, 4.9)	5.1	(1.5, 8.9)	3.3	(1.4, 5.3)	4.0	(−0.9, 9.1)
+ Urticaceae − lag 4	2.3	(−0.2, 4.8)	5.0	(1.3, 8.7)	3.2	(1.3, 5.2)	4.0	(−0.9, 9.2)
+ Both pollen types	2.4	(−0.1, 4.9)	5.0	(1.3, 8.7)	3.2	(1.3, 5.2)	4.0	(−0.9, 9.2)

Relative risks in %: %RR, 95% confidence interval: 95%CI. 95% CI values from negative to positive indicates no statistical significance.

Document downloaded from http://www.elsevier.es, day 20/04/2018. This copy is for personal use. Any transmission of this document by any media or format is strictly prohibited.

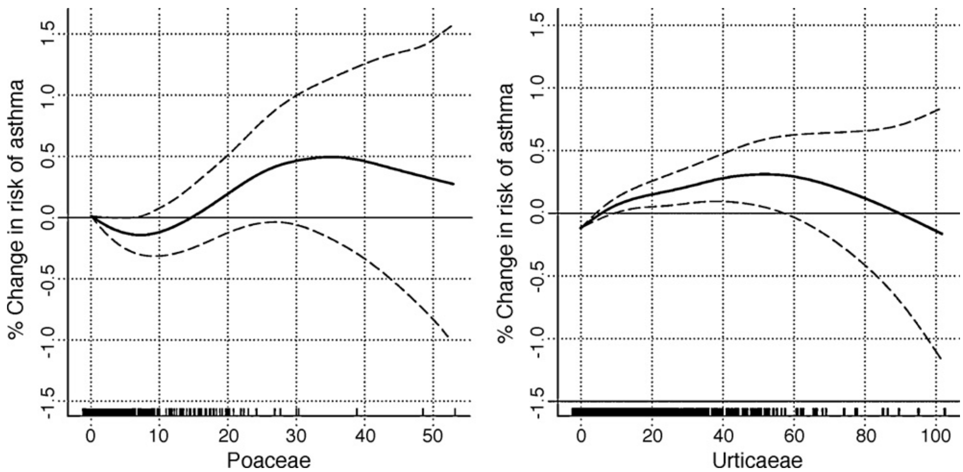

Figure 2 Non-parametric figure of the continuous relative risks values among the daily relationship of aeroallergen pollen types counts (grains/m^3) on asthma hospital emergency room visits.

Table 4 Relative risks and 95% confidence intervals of asthma hospital emergency room visits for an increase of 1 grain/m^3 in the aeroallergen pollen type.

	%RR	(95% CI)
Poaceae — lag 0		
Range 0–10 grains/m^3	−3.7	(−7.7, 0.6)
Range 10–28 grains/m^3	7.2	(3.1, 11.4)
Range 28–53 grains/m^3	−4.2	(−10.7, 2.7)
Urticaceae — lag 4		
Range 0–15 grains/m^3	1.1	(−0.1, 2.6)
Range 15–50 grains/m^3	0.5	(−0.4, 1.5)
Range 50–102 grains/m^3	−1.1	(−3.0, 0.9)

Day lag showed the strongest association from actual to last day lags. Relative risks: %RR, 95% confidence interval: 95%CI. 95% CI of %RR from negative to positive indicates no statistical significance.

air pollutants and including both pollen types with natural cubic spline functions, with 3 df for Poaceae and 4 df for Urticaceae. Fig. 2 illustrates the non-parametric adjustment of the relationship between pollen types and asthma emergency room visits, revealing a clear non-linear relationship of asthma, with inflection points at levels of 10 and 28 grains of Poaceae and 15 and 50 grains of Urticaceae. Table 4 shows the RR of emergency room visits for asthma associated with a pollen rise of 1 grain/m^3 for both pollen types in three linear ranges, defined from the inflection points observed in Fig. 1. A statistically significant increased risk of 7.2% was observed for a rise of 1 grain/m^3 in the 10–28 grain range. For Urticaceae, a quantitative 1.1% increase in risk was obtained in the 0–15 grain range.

Discussion

Ambient air levels of SO_2 and NO_2 related positively and significantly with a substantial increase in asthma and COPD emergency room visits in the present study. The multipollutant and multipollen model did not modify these associations. Pollen types did not demonstrate an adverse effect on COPD hospital ER visits. However, the risk of asthma showed a positive increase with Urticaceae (0–50 grains/m^3) and significance with mild (10 and 28 grains/m^3) levels of Poaceae.

Mucociliar epithelial mucus, as a rich source of antioxidants, plays a major role in protecting bronchial airways against inhaled particles and SO_2. Its overproduction is a pathogenetic feature of asthma and COPD and mediated by some cytokines.[23] Both diseases show systemic inflammation with common and disease-specific markers.[24] The distinction between asthma and COPD is blurred in severe asthma, asthmatic smokers, and in exacerbations.[25] Some authors have argued that PM_{10} toxicity is higher with decreasing particle size, does not depend much upon chemical composition, and damages airway epithelium through oxidative stress in the susceptible population.[26] However, in a study in Barcelona of mortality effects of Saharan dust outbreaks, found risk associated to coarse particles (PM_{10} to >2.5) but not to $PM_{2.5}$, showing that particulate matter differences in chemical composition did not explain these results.[27] It is unlikely that pollutants could convert a non-atopic individual into an atopic one; yet with a genetic predisposition and enough exposure, someone could become sensitised to allergens.[28]

The SO_2 was the gas least often associated to asthma emergencies. A study in Tel-Aviv (Israel) reported a significant association to current or previous-day SO_2 levels.[29] Other studies found no such effects on asthma.[10,30] Moreover, a lack of association was reported in Spain, in cities including Barcelona,[2] Valencia[4] and Madrid.[6] Contrary to this, ER visits for COPD in Barcelona[2] and Saint John (Canada)[10] increased significantly along with increases in SO_2 levels. Longer term exposure to extremely high and steady levels of industrial SO_2 in Cartagena in the past decades – a mean yearly range between 200 and 300 $\mu g/m^3$ in the 1980s,[31] might have caused or exacerbated chronic bronchitis or COPD, while increasing airway inflammation and hyperresponsiveness in asthmatics.

Document downloaded from http://www.elsevier.es, day 20/04/2018. This copy is for personal use. Any transmission of this document by any media or format is strictly prohibited.

Particulate matter less than 10 μm in aerodynamic diameter (PM_{10}) has been the most-used air pollutant in time-series studies of short-term effects. Some studies have shown that particles exert a significant adverse effect on asthma emergency room visits.[1,6,32] Moreover, a review paper on COPD and air pollution referred to a certain consistent association of BS and PM_{10} in hospital emergencies, being particulates the second trigger for COPD.[11] However, population studies using TSP or BS failed to find significant association with asthma[2,4] or COPD.[3] An explanation on the lack of deleterious effects from the mix of total particles (PM_{10} and BS) in Cartagena suggests that this mix is probably composed mainly of industrial white fumes (bicalcic phosphate), local soil erosion and African intrusion dust, but not from engine combustion pollutants.[16,33]

The photochemical pollutant most frequently studied in European cities has been NO_2, but the APHEA framework did not detect that association in Barcelona using hospital emergency admissions as the main outcome.[34] Conversely, in Valencia an increase of the risk of asthma ER visits of 7.6% (2.0–13.4%) for a 10 μg/m^3 pollutant increase at lag 0 was observed.[4] A similar risk was found in Madrid for asthma (3.3%, 1.3–5.4%) associated to the pollutant level of the third-day lag,[6] which is similar to that obtained in our study for lag 4. In Atlanta (USA), four million ER visits at 31 hospitals showed that the maximum 1-h daily level of NO_2 was positively and significantly associated with asthma ER visits at 5- and 8-day lags. Furthermore, the levels of that pollutant were even more strongly associated with COPD ER visits at the current and 1-day lag.[7]

Ozone has been the pollutant most often related to hospital emergencies for asthma in North America[10,35] and Europe.[4,6] While the magnitude of the relationship varied considerably, so did the lag for the best association. Ozone is the atmospheric pollutant posing the most consistent risk for COPD emergency room visits.[11] In Spain, O_3 1 h-max ambient air levels were significantly higher on days with larger numbers of COPD ER visits in Barcelona[2] and Valencia, which was positively related to asthma.[5] Photochemical multipollutant models in Cartagena established the association with COPD on the current day for NO_2 and the fourth for O_3. In our case, O_3 was always associated positively with asthma ER (generating at least a 4% risk excess), but it lost significance with NO_2 addition of O_3. Furthermore, the NO_2 1 h-max was over 140 μg/m^3 during more than 18 days, all years; while O_3 8-h did not exceed 120 μg/m^3 in more than 25 days per year during the 3 years studied.[36] Although the O_3 8 h-max levels were higher than in Barcelona or Valencia, the NO_2 24 h was lower than in these cities.[19] Thus, the levels recorded at the NO_2 stations were not the only precursors of O_3, probably due to the winds and hills which are perpendicular to the sea shore.

Asthma ER visits in Cartagena showed a non-linear association with Urticaceae and Poaceae pollens. This non-linear relationship has already been reported in other Spanish cities.[8,9] An increased risk for low-to-medium levels of both pollen types was observed, possibly revealing the induction of non-epidemic asthma outside the period of maximum pollination. This phenomenon was reported earlier for the same pollen types and asthma ER visits in Madrid.[8] Our results were consistent with the literature using ER outcomes.[8,10,13,15] These studies described an effect for grass pollen levels on asthma morbidity between lags of to 4 days. The delayed effect may be consistent with the biological action mechanism of aeroallergens through a so-called priming effect,[37] which shows a higher clinical impact as the pollen season advances. In our study, 10 grains/m^3 was the threshold for a grass pollen effect, which was limited to 50 grains/m^3 in another study.[15] Other authors found asthma morbidity not associated to some pollen types.[7] This lack of consistency might be due to allergen types and pollination calendars in different geographical and climate patterns[14] as well as atopy prevalence.[38]

Several authors in metropolitan areas (Madrid, London, Paris, and Atlanta) included different pollen types in their analyses[6,7,10,14] observing an independent relationship of air pollutant effects on asthma of pollen types. Doubts exist about the presence of a modifier effect in the relationship between pollen and asthma indicators,[14,39] but this was not found in our data, nor so in another recent one in the metropolitan area of Paris.[40]

Our study suffers from the typical limitations of time-series studies concerning ambient air exposure accuracy and the small magnitude of associations, which must be interpreted with caution, although it is relevant in public health from the community general exposition. Furthermore, only major and classical cold-season (TSP-SO_2) and photochemical air pollutants were considered. Based on our study, Mediterranean cities should implement monitoring programs for pollen types with higher allergenicity power, preferably in combination with air pollutants network. Both kinds of pollutants, atmospherical and biological, represent a risk factor for patients suffering from asthma or COPD.

Conflict of interest

The authors have no conflict of interest to declare.

Acknowledgements

We would like to thank partial funding from CIBER Epidemiología y Salud Pública (CIBERESP), Spain. Also thanks go to José Medrano and Mª Aurelia Martínez-Victoria for data collection; Drs. María Jesús Avilés and Soledad Zamarro for clinical advice; Juan Carlos Casado for his comments on air pollution legislation; and to Agustín Vidal, on behalf of the former Air Pollution Centre Control of the Cartagena City Council, for providing data of pollutants.

References

1. Atkinson RW, Anderson HR, Strachan DP, Bland JM, Bremner SA, Ponce de Leon A. Short-term associations between outdoor air pollution and visits to accident and emergency departments in London for respiratory complaints. Eur Respir J. 1999;13:257–65.
2. Stieb DM, Burnett RT, Beveridge RC, Brook JR. Association between ozone and asthma emergency department visits in Saint John, New Brunswick, Canada. Environ Health Persp. 1996;104:1354–60.
3. Tobías A, Sunyer J, Castellsagué J, Saez M, Antó JM. Impacto de la contaminación atmosférica sobre la mortalidad y las urgencias por enfermedad pulmonar obstructiva crónica y asma en Barcelona, Spain. Gac Sanit. 1998;12:223–30.

Document downloaded from http://www.elsevier.es, day 20/04/2018. This copy is for personal use. Any transmission of this document by any media or format is strictly prohibited.

4. Tenías JM, Ballester F, Rivera ML. Association between hospital emergency visits for asthma and air pollution in Valencia, Spain. Occup Environ Med. 1998;55:541–7.
5. Tenías JM, Ballester F, Pérez-Hoyos S, Rivera ML. Air pollution and hospital emergency room admissions for chronic obstructive. Arch Environ Health. 2002;57:41–7.
6. Galán I, Tobías A, Banegas JR, Aránguez E. Short-term effects of air pollution on daily asthma emergency room admissions. Eur Respir J. 2003;22:802–8.
7. Peel JL, Tolbert E, Klein M, Metzger KB, Flanders WD, Todd K, et al. Ambient air pollution and respiratory emergency department visits. Epidemiology. 2005;16:164–74.
8. Tobías A, Galán I, Banegas JR. Non-linear short-term effects of airborne pollen levels with allergenic capacity on asthma emergency room admissions in Madrid, Spain. Clin Exp Allergy. 2004;34:871–8.
9. Hanigan IC, Johnston FH. Respiratory hospital admissions were associated with ambient airborne pollen in Darwin, Australia, 2004–2005. Clin Exp Allergy. 2007;37:1556–65.
10. Stieb DM, Beveridge RC, Brook JR, Smith-Doiron M, Burnett RT, Dales RE, et al. Air pollution, aeroallergens and cardiorespiratory emergency department visits in Saint John, Canada. J Expo Anal Environ Epidemiol. 2000;10:461–77.
11. Sunyer J. Urban air pollution and chronic obstructive pulmonary disease: a review. Eur Respir J. 2001;17:1024–33.
12. Atkinson RW, Strachan DP, Anderson HR, Hajat S, Emberlin J. Temporal associations between daily counts of fungal spores and asthma exacerbations. Occup Environ Med. 2006;63:580–90.
13. Erbas B, Chang JH, Dharmage S, Ong EK, Hyndman R, Newbigin E, et al. Do levels of airborne grass pollen influence asthma hospital admissions. Clin Exp Allergy. 2007;37:1641–7.
14. Anderson HR, Ponce de Leon A, Bland JM, Bower JS, Emberlin J, Strachan DP. Air pollution, pollens, and daily admissions for asthma in London 1987–92. Thorax. 1998;53:842–8.
15. Newson R, Strachan D, Archibald E, Emberlin J, Hardaker P, Collier C. Acute asthma epidemics, weather and pollen in England, 1987–1994. Eur Respir J. 1998;11:694–701.
16. Cirera L, Rodríguez M, Giménez J, Jiménez E, Saez M, Guillén JJ, et al. Effects of public health interventions on industrial emissions and ambient air in Cartagena, Spain. Environ Sci Pollut Res Int. 2009;16:152–61.
17. Subiza Garrido-Lestache J. Pólenes alergénicos en España. Allergol Immunopathol (Madr). 2004;32:121–4.
18. Moreno-Grau S, Bayo J, Elvira-Rendueles B, Angosto JM, Moreno JM, Moreno-Clavel J. Statistical evaluation of three years of pollen sampling in Cartagena, Spain. Grana. 1998;37:41–7.
19. Ballester F, Saez M, Pérez-Hoyos S, Iñíguez C, Gandarillas A, Tobías A, et al. The EMECAM project: a multicentre study on air pollution and mortality in Spain: combined results for particulates and for sulfur dioxide. Occup Environ Med. 2002;59:300–8.
20. Saez M, Ballester F, Barceló MA, Pérez-Hoyos S, Bellido J, Tenías JM, et al. A combined analysis of the short-term effects on photochemical air pollutants on mortality within the EMECAM project. Environ Health Persp. 2002;110:211–27.
21. Katsouyanni K, Touloumi G, Samoli E, Gryparis A, Monopolis Y, LeTertre A, et al. Different convergence parameters applied to the S-Plus GAM function. Epidemiology. 2002;13:742–3.
22. Dominici F, McDermott A, Hastie T. Improved semi-parametric time series models of air pollution and mortality. J Am Stat Assoc. 2004;468:938–48.
23. Nakao I, Kanaji S, Ohta S, Matsushita H, Arima K, Yuyama N, et al. Identification of Pendrin as a common mediator for mucus production in bronchial asthma and chronic obstructive pulmonary disease. J Immunol. 2008;180:6262–9.
24. Higashimoto Y, Yamagata Y, Taya S, Iwata T, Okada M, Ishiguchi T, et al. Systemic inflammation in chronic obstructive pulmonary disease and asthma: Similarities and differences. Respirology. 2008;13:128–33.
25. Barnes PJ. Immunology of asthma and chronic obstructive pulmonary disease. Nat Rev Immunology. 2008;8:183–92.
26. MacNee W, Donaldson K. Exacerbations of COPD: environmental Mechanisms. Chest. 2000;117 Suppl. 2:390S–7S.
27. Perez L, Tobias A, Querol X, Künzli N, Pey J, Alastuey A, et al. Coarse particles from Saharan dust and daily mortality. Epidemiology. 2008;19:800–7.
28. Diaz-Sanchez D. Pollution and the immune response: atopic diseases – are we too dirty or too clean? Immunology. 2000;101:11–8.
29. Garty BZ, Kosman E, Ganor E, Berger V, Garty L, Wietzen T, et al. Emergency room visits of asthmatic children, relation to air pollution, weather, and airborne allergens. Ann Allergy Asthma Immunol. 1998;81:563–70.
30. Schwartz J, Slater D, Larson TV, Pierson WE, Koenig JQ. Particulate air pollution and hospital emergency room visits for asthma in Seattle. Am Rev Respir Dis. 1993;147:826–31.
31. Guillén JJ, Guillén F, Medrano J, García-Marcos L, Aguinaga I, Níguez JC. Afluencia inusual por asma y enfermedad pulmonar obstructiva crónica en urgencias hospitalarias y contaminación atmosférica por SO2 en Cartagena. Rev Esp Salud Públ. 1995;69:305–14.
32. Lipsett M, Hurley S, Ostro B. Air pollution and emergency room visits for asthma in Santa Clara Country, California. Environ Health Perspect. 1997;105:216–22.
33. Guillén JJ, Cirera L, García-Marcos L, Jiménez-Torres E, Barber X, Martínez MJ, et al. Impacto a corto plazo de la contaminación atmosférica en la mortalidad. Resultados del Projecto EMECAM in Cartagena, 1992–96. Rev Esp Salud Pública. 1999;73:215–24.
34. Sunyer J, Spix C, Quénel P, Ponce-de-León A, Pönka A, Barumandzadeh T, et al. Urban air pollution and emergency admissions for asthma in four European cities: the APHEA project. Thorax. 1997;52:760–5.
35. Cody RP, Weisel CP, Birnbaum G, Lioy PJ. The effect of O3 associated with summertime photochemical smog on the frequency of asthma visits to hospital emergency departments. Environ Res. 1992;58:184–94.
36. Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe [OJ L 152, 11 June 2008].
37. Frenz DA. Interpreting atmospheric pollen counts for use in clinical allergy: allergic symptomatology. Ann Allergy Asthma Immunol. 2001;86:150–8.
38. Janson C, Antó J, Burney P, Chinn S, de Marco R, Heinrich J, et al. The European Community Respiratory Health Survey II: what are the main results so far? Eur Respir J. 2001;18:598–611.
39. Dales RE, Cakmak S, Judek S, Dann T, Coates F, Brook JR, et al. Influence of outdoor aeroallergens on hospitalization for asthma in Canada. J Allergy Clin Immunol. 2004;113:303–6.
40. Huynh BT, Tual S, Turbelin C, Pelat C, Cecchi L, D'Amato G, et al. Short-term effects of airborne pollens on asthma attacks as seen by general practitioners in the Greater Paris area, 2003–2007. Prim Care Respir J. 2010;19:254–9.