

Domestic aeroallergen levels in Barcelona and Menorca (Spain)

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Exposure to common indoor allergens is known to be associated with sensitization and triggers of asthma. Levels of allergens have been barely described in Mediterranean countries. This study reports domestic allergen levels among the general population of two regions of Spain. Dust samples were collected from living rooms and mattresses in homes of infants in Barcelona ($n = 366$) and Menorca ($n = 475$) and assayed for house dust mite (*Der p 1*) and cat allergen (*Fel d 1*) concentrations by enzyme-linked immunoabsorbent assay (ELISA). Geometric mean values (95% CI) of *Der p 1* were 0.77 $\mu\text{g/g}$ (0.65, 0.92) in living rooms and 0.68 (0.56, 0.82) in children's mattresses in Barcelona, and 9.06 (7.93–10.34) and 3.12 (2.71–3.59) in Menorca, respectively. *Fel d 1* levels were 0.37 $\mu\text{g/g}$ (0.31, 0.45) and 0.14 (0.12, 0.18) in Barcelona, and 0.42 (0.35, 0.50) and 0.20 (0.18, 0.24) in Menorca. Home characteristics were not consistently related to levels of aeroallergens in either location. Differences in *Der p 1* levels in the two locations indicate that levels cannot be extrapolated from one part of a country to another with any certainty. Additionally, allergen reduction measures related to indoor sources must be specific to each location.

Xavier Basagaña¹, Maties Torrent², Warwick Atkinson³, Carme Puig⁴, Maria Barnes³, Oriol Vall⁴, Meinir Jones³, Jordi Sunyer¹ and Paul Cullinan³ on behalf of the AMICS study

¹Respiratory and Environmental Health Research Unit, Institut Municipal d'Investigació Mèdica (IMIM), Barcelona, ²Àrea de salut de Menorca, INSALUD, Spain, ³Department of Occupational and Environmental Medicine, Imperial College, London, UK, ⁴Pediatric Service, Hospital del Mar, Barcelona, Spain

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Dr Jordi Sunyer, Unitat de Recerca Respiratòria i Ambiental, Institut Municipal d'Investigació Mèdica (IMIM), Doctor Aiguader 80, E-08003 Barcelona, Catalonia, Spain
Tel.: +34 93 2211009
Fax: +34 93 2213237
E-mail: jsunyer@imim.es

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The role of exposure to common aeroallergens, particularly house dust mite, on sensitization and the triggering of asthma in children has been widely recognized (1, 2). Allergen levels, and their determinants, have been described in many countries in Europe but remain little known in Mediterranean countries. Only in France (3,4) levels of *Der p 1* have been reported in mattresses of unselected children living in the Alps and at sea level, and recently in Italy (5) levels for the same allergens were reported in a small sample of non-allergic subjects.

This paper describes indoor aeroallergen exposures in the homes of two cohorts of infants born in Barcelona and in Menorca (Spain). Homes were not selected by atopic or asthmatic inhabitants. This is the first study to examine domestic aeroallergen levels (*Der p 1* and *Fel d 1*), and their associations with indoor factors, in the general population of Spain.

Materials and methods

Cohort recruitment

The present study included families participating in the two Spanish cohorts (Menorca Island and Barcelona city) of the Asthma Multicenter Infants Cohort Study (AMICS). The AMICS study is a multicentre study composed of four cohorts in different countries, which aims to examine the effects of pre- and postnatal environmental exposures on the inception of atopy

Members of the AMICS (Asthma Multicenter Infants Cohort Study) Group: Ashford: Paul Cullinan, Jessica Harris, Warwick Atkinson, Pamela Mills, Susan Moffat, Carol White, Meinir Jones, Anthony Newman-Taylor; Barcelona: Goncal Figueras, Oriol Vall, Oscar Garcia, Carme Puig, Eva Sanchez, Josep M Antó, Jordi Sunyer, Xavier Basagaña; Menorca: Maties Torrent, M^a Victoria Estraña, Mireia García, Maria Victoria I-turriaga. The AMICS study is co-ordinated by Maria Barnes.

and asthma. All cohorts followed the same basic research protocol. The cohort was hospital based in Barcelona and population based in Menorca. We included all women presenting for prenatal care at all general practices in Menorca ($n = 485$) over 12 months starting in mid-1997; and women attending for ante-natal care at the obstetric department in the Hospital del Mar in Barcelona between 1996 and 1998 ($n = 487$), with permanent residence in the city and having a telephone. The study was approved by the corresponding research committees and mothers signed a written consent form.

Barcelona is a large coastal city in the north-east of Spain. Menorca is one of the Balearic Islands off the north east coast of Spain with a population living both in rural settings and in small villages.

Atopy, home characteristics and allergens in dust

Maternal atopy was identified by skin-prick tests (SPTs) performed during the third trimester of pregnancy in Barcelona, and 6 months after delivery in Menorca. A positive skin test was defined as a wheal of 3 mm or greater (mean of perpendicular measures) to the allergens (*Der p 1* and *Fel d 1*) in the presence of a positive histamine control and a negative uncoated control.

During the first year of the baby's life, trained nurses visited each home to administer an interview about indoor characteristics (visible damp, hours of ventilation, air conditioning, double glazing, type of heating, age of house, size of house, floor level, type of mattress, carpets, rugs, location, smoking habits, crowding, cat ownership and use of a vacuum cleaner) and to carry out a variety of exposure measurements, including dust collection for aeroallergen assays. Field workers were trained together to follow the same procedures. Dust samples were taken from two sites, the living room floor or sofa (given the lack of carpets or rugs) and the baby's bed, from 382 (78%) households in Barcelona and 475 (98%) in Menorca. A standard household vacuum cleaner (Globin Rio, 1000 W; Globin, Leeds, UK) was used, fitted with 8- μ m filter paper (Whatman, Maidstone, UK) in an ALK dust trap (ALK, Maidstone, UK), which was washed with soap and warm water between each sampling. Living room samples were standardized by vacuuming an area of 1 m² for 3 min. Mattress covers were left in place and the whole bed surface was measured and vacuumed for the same duration. Exposed filter papers were stored at -20°C in sealed Petri dishes until allergen analysis. To

obtain fine dust, each sample was sieved through a 355- μ m mesh sieve, recording weights before and after sieving. *Der p 1* and *Fel d 1* concentrations were determined using an enzyme-linked immunoabsorbent assay (ELISA) and was carried out at the Brompton Hospital (London, UK) according to standard procedures described elsewhere (6).

Social class was defined by current paternal occupation using the UK Registrar General's 1990 classification. In our analyses, high social class comprises professional, managerial and technical occupations (classes I and II). Seasons were allocated according to the month of sampling: March–May (spring); June–August (summer); September–November (autumn) and December–February (winter).

Statistical methods

As concentrations of both *Der p 1* and *Fel d 1* are log-normally distributed, all analyses were undertaken using log-transformed data, and geometric means (GM) with 95% confidence intervals (CI) reported. Differences in allergen concentrations between homes were analyzed using linear regression analysis, and results were expressed as relative changes. Thus, each reported estimate is the relative change in allergen concentration (in $\mu\text{g/g}$) per unit of increase of the explanatory variable (when it is continuous), or in comparison to the reference category (when it is categorical). A relative change of one means that there are no differences.

Analyses were carried out using Stata software, release 6.0 (StataCorp, College Station, TX, USA). Statistical significance was considered for $p < 0.05$.

Results

Levels of *Der p 1* were much lower in Barcelona than in Menorca, in both measured sites (Table 1), while levels of *Fel d 1* were very similar in both places. Almost half of the infants in Barcelona and 91% in Menorca lived in homes with *Der p 1* levels $> 2 \mu\text{g/g}$. Levels of both aeroallergens were significantly higher in the living room than in the child's mattress. The correlation of *Der p 1* levels between living room and mattress were low (Spearman correlation 0.28 and 0.22), while correlation for *Fel d 1* were higher in both places (0.43 and 0.44). All results were very similar when allergen concentration was expressed in ng/m^2 (data not shown).

Among all the determinants of allergen concentration studied (Tables 2 and 3), only lower

Table 1. House dust mite (*Der p 1*) and cat allergen (*Fel d 1*) concentrations

	Barcelona		Menorca	
	Living room	Child's mattress	Living room	Child's mattress
<i>Der p 1</i> µg/g				
n	366	363	475	482
Geometric mean (95% CI)	0.77 (0.65, 0.92)	0.68 (0.56, 0.82)	9.06 (7.93–10.34)	3.12 (2.71–3.59)
Range	0.01–128.2	0.01–242.1	0.08–272.7	0.06–810.9
> 2.0 µg/g (%)	100 (27.5%)	106 (29.2%)	402 (84.6%)	286 (59.3%)
> 10.0 µg/g (%)	33 (9.0%)	27 (7.4%)	243 (51.2%)	104 (21.6%)
<i>Fel d 1</i> µg/g				
n	365	364	475	482
Geometric mean (95% CI)	0.37 (0.31, 0.45)	0.14 (0.12, 0.18)	0.42 (0.35, 0.50)	0.20 (0.18, 0.24)
Range	0.01–704.0	< 0.01–423.0	< 0.01–2556.5	< 0.01–213.0
> 8.0 µg/g (%)	26 (7.1%)	15 (4.1%)	38 (8.0%)	14 (2.9%)

Table 2. Descriptive analysis of relevant* variables

Variables	Mean or percentage	
	Barcelona	Menorca
Season		
Spring	34%	40%
Summer	23%	17%
Autumn	15%	23%
Winter	28%	20%
High social class (Classes I, II)	19%	16%
Number of people in the home	4.0	3.8
Number of older siblings	0.7	0.6
Visible damp (yes)	15%–16%†	16%–17%†
Number of hours of ventilation	3	12
Air conditioning (yes)	9%	7%
Foam mattress (yes)	65%	20%
Carpets (yes)	18%–12%†	31%–16%†
Total number of cigarettes smoked by inhabitants	15	13
Mother smokes (yes)	40%	31%
Smokers at home (yes)	65%	58%
High crowding (≤ 2 rooms per person)	62%	53%
Cat ownership (yes)	10%	14%
Frequency of vacuuming (reference = never)		
Once a week or less	20%	27%
More than once a week	14%	33%

*Only variables that in a subsequent analysis showed an association ($p < 0.10$) with either *Der p 1* or *Fel d 1* were reported among: season; sociodemographic: social class, race, family size; home characteristics: visible damp, hours of ventilation, air conditioning, double glazing, type of heating, age of house, size of house, floor level, type of mattress, carpets, rugs, location; family behavior: smoking habits, crowding, cat ownership, use of a vacuum cleaner.

†Percentage in living room and child's mattress, respectively.

cigarette consumption at home for *Der p 1*, cat ownership, fewer people in the home and higher frequency of vacuuming for *Fel d 1* were found to be statistically significant in both cohorts. The other determinants found associated in one or other of the cohorts were: for *Der p 1*, fewer hours of ventilation, not having air conditioning, not having a foam mattress, and the mother not

being a smoker in Barcelona; and high social class, having visible damp, and low crowding in Menorca. For *Fel d 1*, the determinants were fewer hours of ventilation, having air conditioning, and not having a foam mattress, in Barcelona; and, fewer older siblings, having carpets in the child's bedroom, and the presence of smokers at home in Menorca. Season had no consistent association with allergen concentrations (i.e. levels of *Fel d 1* were lower in the mattress in autumn in Barcelona and higher in the living room in autumn in Menorca, while levels of *Der p 1* were lower in autumn in Barcelona and higher in autumn in Menorca). Among the above factors, those remaining associated in a multivariate analysis, after adjusting for season, are shown in Table 4.

Maternal atopy to *Der p 1* was not associated with levels of *Der p 1* in any of the cohorts or the sites (Table 5). Maternal atopy to *Fel d 1* was only associated (positively) with levels of *Fel d 1* in the living room and only in Menorca.

Discussion

This report describes household concentrations of two common aeroallergens in two large series of homes, not selected by atopic or asthmatic status of inhabitants, in Northeast Spain. The results provide an estimate of infant allergen exposures among two cohorts of children who are being followed to the age of 6 years, allowing an examination of the nature and modifying influences of any relationships between early exposure and development of asthma. An identical companion study was conducted in Ashford (Southeast England) (6) and another is underway in Germany, which will provide a wide variation in domestic exposures and widely applicable results.

Table 3. Univariate association. Relative change (95% CI) in allergen concentration ($\mu\text{g/g}$) per unit of increase of each variable. Each estimate is a separate model

Variables†	Relative change (95% CI)			
	Living room		Child's mattress	
	Barcelona	Menorca	Barcelona	Menorca
Models with <i>Der p 1</i> ($\mu\text{g/g}$)				
High social class (Classes I, II)	0.80 (0.76, 2.03)	1.65 (1.16–2.36)*	0.79 (0.47, 1.35)	1.14 (0.77, 1.67)
Visible damp (yes)	0.79 (0.48, 1.28)	1.05 (0.73, 1.62)	1.13 (0.66, 1.95)	1.39 (0.95, 2.05)¶
Number of hours of ventilation	0.93 (0.89, 0.99)*	1.01 (0.99, 1.02)	1.01 (0.94, 1.07)	1.01 (0.99, 1.02)
Air conditioning (yes)	0.81 (0.44, 1.48)	1.02 (0.59, 1.73)	0.47 (0.24, 0.93)*	1.06 (0.59, 1.90)
Foam mattress (yes)			0.63 (0.41, 0.94)*	1.05 (0.74, 1.51)
Total number of cigarettes smoked by inhabitants	1.003 (0.993, 1.013)	0.988 (0.980, 0.996)*	0.988 (0.977, 0.998)*	0.999 (0.990, 1.008)
Mother smokes (yes)	1.04 (0.73, 1.49)	0.79 (0.59, 1.05)	0.70 (0.47, 1.04)¶	1.21 (0.90, 1.63)
High crowding (≤ 2 rooms per person)	1.09 (0.76, 1.57)	0.76 (0.58, 0.99)*	1.02 (0.68, 1.54)	0.78 (0.59, 1.03)¶
Models with <i>Fel d 1</i> ($\mu\text{g/g}$)				
Number of people in the home	0.89 (0.76, 1.02)¶	0.91 (0.76, 1.11)	0.79 (0.67, 0.93)*	0.85 (0.73, 1.00)*
Number of older siblings	1.00 (0.78, 1.27)	0.78 (0.61, 0.99)*	0.96 (0.72, 1.27)	0.84 (0.68, 1.01)¶
Number of hours of ventilation	0.90 (0.85, 0.96)*	0.99 (0.97, 1.01)	0.95 (0.88, 1.02)	1.01 (0.99, 1.02)
Air conditioning (yes)	1.82 (0.96, 3.46)¶	0.92 (0.45, 1.90)	1.42 (0.66, 3.06)	0.91 (0.50, 1.65)
Foam mattress (yes)			0.54 (0.34, 0.85)*	0.86 (0.59, 1.22)
Carpets (yes)	1.43 (0.87, 2.36)	1.13 (0.76, 1.65)	1.23 (0.64, 2.41)	1.49 (1.03, 2.18)*
Smoker at home (yes)	0.75 (0.50, 1.12)	1.35 (0.94, 1.93)¶	0.90 (0.57, 1.42)	1.19 (0.89, 1.58)
Cat ownership (yes)	21.98 (12.68, 38.09)*	11.47 (7.24, 18.71)*	8.67 (4.39, 17.29)*	5.64 (3.86, 8.25)*
Frequency of vacuuming (reference = never)				
Once a week or less	1.68 (2.75, 1.02)*	1.45 (0.93, 2.27)	1.93 (1.09, 3.24)*	1.46 (1.02, 2.10)*
More than once a week	2.34 (1.32, 4.10)*	1.23 (0.81, 1.88)	2.36 (1.22, 4.57)*	1.43 (1.02, 1.99)*

* $P < 0.05$.†Only variables with a $p < 0.10$ were reported among: season; sociodemographic: social class, race, family size; home characteristics: visible damp, hours of ventilation, air conditioning, double glazing, type of heating, age of house, size of house, floor level, type of mattress, carpets, rugs, location; family behavior: smoking habits, crowding, cat ownership, use of vacuum cleaner.¶ $0.05 < p < 0.10$.

Blank = not available.

Concentrations of *Der p 1* in Barcelona were higher than in north Italy (5), in the Alps in France (3), in Scandinavian countries (7), in Estonia (8) and in Canada (9), and lower than in general population studies in Ashford (UK) (6), in Germany (10), in France at the sea level (3), in Baltimore (USA) (9), in the Netherlands (9), in Singapore (11), in South Africa (9), in New Zealand (12), and in Australia (13). However, half of the infants in Barcelona lived in homes where the concentration of *Der p 1* in living room or mattress dust samples was $> 2 \mu\text{g/g}$ [a proposed threshold for sensitization to this allergen (14)], while 15% lived in homes where the concentration reached $10 \mu\text{g/g}$ [a level reported to produce symptoms of wheeze in sensitized persons (14)]. Levels of *Der p 1* were much higher in Menorca, and are exceeded only by those reported in France at sea level (3), in South Africa (9), in New Zealand (12) and in Australia (13). In Menorca, the proportion of homes with levels $> 2 \mu\text{g/g}$ in one of the sites was 91%, and 61% had levels $> 10 \mu\text{g/g}$.

Among the studied variables, only a negative association of *Der p 1* with smoking was found in both centres, coinciding with other studies (6,8,15). The fact that in Barcelona and Menorca the floor was not covered by carpet, and houses were more ventilated than in Northern countries may explain why we did not find other house conditions related to *Der p 1* levels. The absence of any consistent relationship with the usual domestic characteristics (such as visible damp, hours of ventilation, double glazing, floor level, type of mattress, presence of carpets, use of vacuum cleaner and crowding) raises the question of which factors explain the variability within the same area. Indoor climate (i.e. temperature and humidity), a known determinant of mite-allergen concentration, has not been directly evaluated and could explain part of the variability in each center. However, we have data on some related variables such as reported dampness, frequency of ventilation and air conditioning, which were only associated with *Der p 1* levels in one of the cohorts. A consequence of the

Table 4. Multivariate models. Relative change (95% CI) in allergen concentration ($\mu\text{g/g}$) per unit of increase of each variable. One model per each allergen, site and location

Allergen	Site	Location			
		Barcelona		Menorca	
		Variables†	Relative change (95% CI)	Variables†	Relative change (95% CI)
<i>Der p 1</i>	Living room	Number of hours of ventilation	0.93 (0.89, 0.99)*	Summer	0.70 (0.47, 1.02)
				Winter	0.69 (0.48, 0.98)*
				High social class	1.58 (1.12, 2.27)*
				High crowding	0.78 (0.60, 1.02)
				Total number of cigarettes smoked by inhabitants	0.99 (0.98, 1.00)*
	Child's mattress	Autumn	0.31 (0.17, 0.57)*	Visible damp	1.43 (0.98, 2.10)
		Air conditioning	0.45 (0.23, 0.90)*	High crowding	0.78 (0.59, 0.96)
		Foam mattress	0.62 (0.41, 0.93)*		
		Total number of cigarettes smoked by inhabitants	0.99 (0.98, 1.00)*		
<i>Fel d 1</i>	Living room	Number of hours of ventilation	0.87 (0.84, 0.93)*	Summer	1.51 (0.94, 2.41)
		Cat ownership	19.69 (11.02, 35.52)*	Autumn	1.72 (1.13, 2.59)*
		Vacuuming (reference = never)		Number of older siblings	0.76 (0.61, 0.95)*
		Once a week or less	1.52 (0.98, 2.39)	Cat ownership	11.36 (7.24, 17.99)*
		More than once a week	1.88 (1.11, 3.16)*		
	Child's mattress	Summer	0.58 (0.33, 0.97)	Number of people in the home	0.79 (0.68, 0.90)*
		Autumn	0.40 (0.21, 0.78)*	Carpets	1.45 (1.02, 2.08)*
		Number of people in the home	0.83 (0.70, 0.97)*	Cat ownership	4.76 (3.25, 6.96)*
		Cat ownership	8.25 (4.01, 16.78)*		
		Vacuuming (reference = never)			
		Once a week or less	1.65 (0.96, 2.86)		
		More than once a week	2.23 (1.17, 4.22)*		

*P < 0.05.

†Including variables with a p < 0.10 in univariate models in Table 3.

Table 5. Relative change (95% CI) in allergen concentration ($\mu\text{g/g}$) in homes with mothers with atopy† with respect to homes of non-atopic mothers. Each estimate is a separate model

	Maternal atopy	
	To <i>Der p 1</i>	To <i>Fel d 1</i>
Barcelona		
Living room		
<i>Der p 1</i>	1.08 (0.66, 1.77)	2.27 (0.73, 7.03)
<i>Fel d 1</i>	0.97 (0.57, 1.65)	1.31 (0.39, 4.44)
Child Mattress		
<i>Der p 1</i>	1.16 (0.68, 1.99)	0.41 (0.13, 1.32)
<i>Fel d 1</i>	1.17 (0.64, 2.16)	0.57 (0.15, 2.10)
Menorca		
Living room		
<i>Der p 1</i>	0.99 (0.73, 1.34)	0.80 (0.42, 1.52)
<i>Fel d 1</i>	1.21 (0.81, 1.82)	3.22 (1.7, 35.61)*
Child Mattress		
<i>Der p 1</i>	1.03 (0.75, 1.42)	0.65 (0.33, 1.27)
<i>Fel d 1</i>	1.16 (0.84, 1.62)	1.86 (0.93, 3.67)

*P < 0.05

†Defined as a positive skin-prick test (similar results when defined as self-report of ever having had eczema, rhinitis or asthma).

absence of an equivalent association with usual variables found in England (6) or Scandinavian

countries (7) is that the usual allergen reduction measures suggested from research in other European countries could have little meaning in these Mediterranean settings. In fact, in France (4) none of the possible determinants studied (including indoor humidity) was associated with *Der p 1* levels, and in Italy (5), only floor and pillow material were predictors of *Der p 1* levels.

The high levels in Menorca in comparison with Barcelona were neither explained by the determinants analyzed here (i.e. socio-demographic, home characteristics, familial behavior) nor by season or setting of the study (i.e. rural, urban) (data not reported). The method of dust collection does not explain the differences between centers, as a detailed analysis of the proportion of dust taken from the floor or sofa in the living room did not modify the differences between Menorca and Barcelona. An alternative explanation is that the relative humidity of an island could explain the high levels in Menorca (13), although the yearly average relative humidity in the two locations is similar (76.2% in Barcelona and 76.0% in Menorca; 73.4 and 75.8 in Spring,

70.8 and 72.1 in Summer, 80.6 and 76.3 in Autumn, and 80.0 and 80.1 in Winter, respectively). Differences in indoor climate could also explain the differences between centers. However, prevalence of variables related to indoor climate in Barcelona and Menorca was only different in the number of hours of ventilation, which was greater in Menorca.

Levels of *Fel d 1* in Barcelona and Menorca were similar to Estonia (8) and Singapore (11) but much lower than those in the UK (6), Germany (10) and New Zealand (12), which may be explained by a lower rate of cat ownership (only 10% and 14%, respectively). Not surprisingly we found cat ownership to be a determinant of *Fel d 1* levels in both sites. Levels of *Fel d 1* increased in houses with fewer people, despite adjusting for cat ownership. This was also observed in Ashford (6). The positive association with frequency of vacuuming found in both centers remained in the multivariate model in Barcelona. This association could be due to a removal of the suspended cat dander not completely eliminated by vacuuming.

Maternal atopy was not related to having lower levels of allergens, which suggests that females with atopy in Barcelona and Menorca do not take effective measures to reduce allergen exposures. The fact that women sensitized to *Fel d 1* had higher levels of this allergen at home, emphasizes the conclusion that atopy did not lead them to avoid exposure. In another European study, only the presence of symptoms modified the association between atopy to *Fel d 1* and having a cat (16). However, in our mothers, self-reporting symptoms of asthma and/or allergy did not modify the association between atopy to *Fel d 1* and levels at home (data not reported). Furthermore, there were no differences in cat ownership by maternal sensitization to *Fel d 1*.

We have reported domestic aeroallergen levels (*Der p 1* and *Fel d 1*) in Spain for the first time. Differences in *Der p 1* levels between the two locations suggest that levels cannot be extrapolated from one part of a country to another with any certainty. Finally, the lack of consistent relationships with domestic conditions suggests that allergen reduction in these places, which is focused on the usual indoor sources, has to be specific to each location.

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