

Distribution and determinants of house dust mite allergens in Europe: The European Community Respiratory Health Survey II

Jan-Paul Zock, PhD,^a Joachim Heinrich, PhD,^b Deborah Jarvis, MD,^c Giuseppe Verlato, MD, PhD,^d Dan Norbäck, PhD,^e Estel Plana, MSc,^a Jordi Sunyer, MD, PhD,^a Susan Chinn, DSc,^f Mario Olivieri, MD,^g Argo Soon, PhD,^h Simona Villani, PhD,ⁱ Michela Ponzio, PhD,ⁱ Anna Dahlman-Hoglund, PhD,^j Cecilie Svanes, MD, PhD,^k and Christina Luczynska, PhD,^{f,†} for the Indoor Working Group of the European Community Respiratory Health Survey II *Barcelona, Spain, Neuherberg, Germany, London, United Kingdom, Verona and Pavia, Italy, Uppsala and Göteborg, Sweden, Tartu, Estonia, and Bergen, Norway*

Background: Several studies in European homes have described allergen levels from the house dust mite species *Dermatophagoides pteronyssinus* and to a lesser extent *Dermatophagoides farinae*, but geographic comparisons of exposure levels and risk factors have been hampered by a lack of standardized methods.

Objective: To study the distribution and determinants of the major house dust mite allergens Der p 1 and Der f 1 in 10 European countries using a common protocol.

Methods: During home visits with 3580 participants of the European Community Respiratory Health Survey II from 22 study centers, mattress dust was sampled and analyzed for Der p 1, Der f 1, and Der 2 allergen. Information on housing characteristics was obtained by both observations and interview. **Results:** Der 1 and Der 2 allergens were detectable ($\geq 0.1 \mu\text{g/g}$) in 68% and 53% of the samples, respectively. Large differences in allergen levels between study centers were observed, and geographic patterns for Der p 1 and Der f 1 were

From ^athe Center for Research in Environmental Epidemiology, Municipal Institute of Medical Research, Barcelona; ^bthe National Research Center for Environment and Health, Institute of Epidemiology, Neuherberg; ^cthe Respiratory Epidemiology and Public Health Group, National Heart and Lung Institute, Imperial College, London; ^dthe Department of Medicine and Public Health, University of Verona; ^ethe Department of Medical Science, Occupational and Environmental Medicine, Uppsala University; ^fthe Department of Public Health Sciences, King's College London; ^gthe Unit of Occupational Medicine, University of Verona; ^hthe Department of Public Health, University of Tartu; ⁱthe Department of Health Sciences, Section of Epidemiology and Medical Statistics, University of Pavia; ^jthe Department of Occupational and Environmental Medicine, Sahlgrenska University Hospital, Göteborg; and ^kthe Department of Thoracic Medicine, Institute of Medicine, University of Bergen.

[†]Deceased.

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Reprint requests: Jan-Paul Zock, PhD, IMIM, Dr Aiguader 80, E-08003 Barcelona, Spain. E-mail: jpzock@imim.es.

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different. Low winter temperatures reduced Der p 1 rather than Der f 1. Important risk factors for high allergen levels included an older mattress, a lower floor level of the bedroom, limited ventilation of the bedroom, and dampness for Der p 1 but not for Der f 1.

Conclusion: There are large qualitative and quantitative differences of house dust mite allergen levels in Europe, which can partly be explained by geographic and housing characteristics.

Clinical implications: Mite allergen exposure may be reduced by replacing the mattress regularly and increasing ventilation of the bedroom, particularly in winter. (J Allergy Clin Immunol 2006;118:682-90.)

Key words: House dust mites, allergens, housing, risk factors, geographic, ECRHS

Allergic sensitization is a recognized risk factor for the development and persistence of asthma.¹ House dust mites provide the predominant inhalant allergens in many parts of the world, but there are large geographic differences in the presence of mites and the prevalence of mite sensitization. The most common mite species that produce allergens are *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*. It is well recognized that both species are distributed widely in the United States.²⁻⁴ *D pteronyssinus* has long been regarded the predominant house dust mite species in Europe, but during the last decade, it has become clear that in certain European areas, *D farinae* is common.⁵⁻⁹

Identification of housing characteristics associated with dust mites is helpful to evaluate the effectiveness of allergen avoidance measures. Some studies have suggested that determinants for allergens of the 2 species are different.^{4,5,9,10} Although both species thrive at similar environmental conditions, *D pteronyssinus* is more susceptible to desiccation than *D farinae*. Consequently, the latter species is better able to survive periods of drought—for instance, related to cold winters with heated homes.²

Evaluation of geographic variations in house dust mite allergens has been hampered by a lack of standardized methods. The main aim of this study was to measure the major *Dermatophagoides* species allergens in homes of participants of a multicenter longitudinal study of asthma and allergy in adults living in Europe, using a common protocol. In addition, we studied determinants of allergens from the 2 mite species, both at the ecologic and at the home level.

METHODS

Selection of homes

The methodology of the European Community Respiratory Health Survey (ECRHS) II has been described elsewhere.¹¹ Briefly, 29 study centers performed a follow-up investigation on asthma, allergy, and their known or suspected risk factors in a random population sample of men and women who were 20 to 44 years of age at the baseline survey (ECRHS I). Most study centers included an additional symptomatic sample of individuals who had reported current asthma symptoms and/or medication in a screening questionnaire being the

Abbreviations used

ECRHS: European Community Respiratory Health Survey
GM: Geometric mean
OR: Odds ratio
 r_s : Spearman correlation coefficient

initial stage of ECRHS I.¹² Twenty-two centers from 10 European countries agreed to take part in a detailed assessment of home exposures, including the sampling of mattress dust for allergen determination. The objective was to make measurements in 200 homes in each center, with priority to subjects who did not move home during the follow-up, provided a blood sample for serum specific IgE and IgG determination, and belonged to the random population sample.

Dust sampling and allergen determination

Given the large variation in housing characteristics related to favorable mite living conditions in Europe such as floor covers,¹³ mattresses were considered the most homogeneous and best comparable mite habitat across areas. Between July 2000 and November 2002, homes were visited, and a sample of dust was taken from the participant's mattress. The homes of each center were visited in random order covering all seasons. A short video showing the dust sampling procedure was shown to all fieldworkers during a locally arranged training meeting. The bed of the participant was stripped of bed linen that is regularly changed (sheets). Any mattress covers or protectors that had been in place for at least 3 months were left on the mattress. A template of 80 cm × 125 cm was placed on the area of the bed where the participant usually slept. An ALK dust collection filter (ALK-Abelló, Hørsholm, Denmark) was attached to an Electrolux Mondo vacuum cleaner (1300 W), and the area within the template (1 m²) was vacuumed for 2 minutes. Within the next 3 days, samples were frozen (−20°C) for 24 hours to kill mites and subsequently stored at room temperature until transported with a silica gel desiccant to 1 central laboratory. Samples were sieved (1 μm) to obtain fine dust for extraction. Extracts, 5% wt/vol, in borate-buffered saline of sieved dust samples were assayed for Der p 1, Der f 1, and Der 2 using mAb ELISA (Indoor Biotechnologies, Cardiff, United Kingdom). The lower limit of detection was 0.1 μg allergen per gram of dust, with no upper limit. The concentration of Der 1 allergens was calculated by summing Der p 1 and Der f 1 concentrations, ignoring levels below the detection limit.

Data on potential determinants

A face-to-face interview among all participants of ECRHS II¹¹ included several items regarding the home environment, such as type and age of the home, basic construction characteristics, heating and ventilation habits, and floor covers. During the home visit, direct visual assessment of residential characteristics was made by trained fieldworkers, including number of rooms, presence of damp and mold on the walls or ceilings in several rooms, size of the mattress, and types of bedding. Additional questions to the participant included the number of people living in the home, age of the mattress, and habits of vacuuming the bedroom floor and the mattress, among others. The household crowding index was defined as the total number of residents per household divided by the total number of rooms, excluding the kitchen and bathrooms.¹⁴ Weather data for the year 2001 were obtained from national or local meteorologic institutes. The average monthly temperature was calculated, and the temperatures of the coldest and hottest month were used to determine winter and summer temperature, respectively. The annual mean relative humidity was calculated for each city.

TABLE I. Descriptive statistics of house dust mite allergen levels in 22 study centers, ECRHS II

Country	City	Samples (n)	Analyzed* (n)	Der p 1 allergen		Der f 1 allergen		Der 1 allergens		Der 2 allergen	
				Detectable†	GM (μg/g)‡	Detectable†	GM (μg/g)‡	Detectable†	GM (μg/g)‡	Detectable†	GM (μg/g)‡
Iceland	Reykjavik	199	182	0.0%	—	0.5%	<0.01	0.5%	<0.01	0.0%	—
Sweden	Umeå	196	189	1.6%	<0.01	3.2%	<0.01	3.7%	<0.01	1.6%	<0.01
Sweden	Uppsala	196	183	5.5%	<0.01	12.6%	<0.01	16.4%	<0.01	6.0%	<0.01
Sweden	Göteborg	199	191	11.0%	<0.01	27.2%	<0.01	31.9%	0.02	19.4%	<0.01
Estonia	Tartu	186	182	44.5%	0.05	63.2%	0.24	74.7%	0.51	49.5%	0.09
Germany	Hamburg	176	168	72.0%	0.54	94.6%	3.63	96.4%	7.64	86.3%	1.23
Germany	Erfurt	197	193	40.4%	0.05	62.7%	0.26	73.6%	0.57	54.9%	0.12
UK	Norwich	167	164	88.4%	1.30	22.0%	<0.01	90.9%	1.54	68.9%	0.32
UK	Ipswich	105	104	84.6%	0.77	22.1%	<0.01	89.4%	1.05	67.3%	0.26
Belgium	Antwerp Center	99	96	81.5%	0.51	62.3%	0.30	94.4%	1.58	79.6%	0.37
Belgium	Antwerp South	175	162	80.2%	0.96	66.7%	0.20	90.6%	2.43	70.8%	0.58
France	Paris	169	166	58.4%	0.14	70.5%	0.39	84.3%	1.01	48.8%	0.09
France	Grenoble	180	174	30.5%	0.02	75.3%	0.64	76.4%	0.77	50.6%	0.12
Switzerland	Basel	132	130	23.8%	<0.01	70.0%	0.35	73.8%	0.51	49.2%	0.09
Italy	Verona	123	110	29.1%	0.02	80.0%	0.95	82.7%	1.20	52.7%	0.13
Italy	Pavia	86	72	38.9%	0.04	97.2%	7.48	97.2%	8.10	77.8%	0.63
Italy	Turin	84	75	12.0%	<0.01	76.0%	0.59	76.0%	0.59	38.7%	0.04
Spain	Oviedo	200	196	95.9%	6.60	73.5%	0.79	99.5%	14.71	95.9%	4.17
Spain	Galdakao	200	189	98.4%	9.54	44.4%	0.06	99.5%	12.82	98.4%	4.86
Spain	Barcelona	189	179	76.0%	0.60	83.2%	2.25	97.2%	7.38	87.2%	1.25
Spain	Albacete	187	177	10.2%	<0.01	4.5%	<0.01	13.0%	<0.01	6.2%	<0.01
Spain	Huelva	135	132	89.4%	2.78	11.4%	<0.01	89.4%	2.99	85.6%	1.49
TOTAL		3580	3414	48.4%	0.09	48.5%	0.09	67.6%	0.58	52.8%	0.14

UK, United Kingdom.

*Sufficient dust for extraction (and allergen analysis).

† ≥ 0.1 μg/g.

‡GM estimated using left-censored regression analysis.

Statistical analysis

Analyses were performed by using Stata version 8 (Stata Corp, College Station, Tex). Left-censored regression (tobit) models were applied throughout to allow for the large proportion of values below the limit of detection.^{15,16} Meta-regression was used to study associations between mite allergen concentrations and potential determinants at the center level. Associations between housing characteristics and mite allergen levels were evaluated with left-censored mixed regression models using data from study centers with at least 20% of detectable samples for any of the allergens. All models were adjusted for type of population sample, season of sampling, whether the mattress was sampled uncovered or with any type of cover in place, storage time of dust sample, and study center (the latter with random-effects adjustment). Factors associated with the allergen level ($P < .05$) were considered for multivariable modeling using backward stepwise regression. The final models for each of the 4 mite allergen indices contained determinants significant at the .05 level. For each determinant, the ratio of the geometric mean was obtained by calculating the anti-log of the regression coefficient to facilitate interpretation.

RESULTS

A total of 3679 homes were visited: 84% of the initial goal of 22×200 . According to information obtained for all participants of ECRHS II during the main interview, there were no major differences in basic housing characteristics between those with and without home visits.

A total of 3580 dust samples (97% of home visits) were obtained. One hundred sixty-six samples (4.6%; range, 1% to 16% across centers; Table I) had insufficient dust (<50 mg) for extraction and hence allergen analysis. The most important independent determinants of insufficient dust controlling for study center were sample taken from mattress with allergy-proof cover in place (frequency of determinant, 0.8%; odds ratio [OR], 7.8; 95% CI, 2.4–26), mattress less than 1 year old (7.7%; OR, 3.2; CI, 2.0–5.2), and mattress vacuumed more than once a month (13%; OR, 2.0; CI, 1.3–3.1).

Of the 3414 samples with sufficient dust, both Der p 1 and Der f 1 allergens were detectable (≥ 0.1 μg/g) in 48% of the samples, whereas 68% had detectable levels of either Der p 1 or Der f 1 (Table I). Large differences in allergen levels between study centers were observed, and geographic patterns for Der p 1 and Der f 1 were different (Table I and Fig 1). In Reykjavik, Umeå, Uppsala, and Albacete, few samples (<20%) were detectable for Group 1 allergens. Der p 1 was predominant in the English centers and Huelva, whereas Der f 1 was predominant in the Italian centers, in Basel, and in Grenoble. The rest of the centers had important numbers of detectable allergens from both species. The highest levels of Der p 1 were found in the Spanish centers near the Atlantic Ocean (Galdakao, Oviedo, and Huelva) whereas the highest levels of Der f 1 were found in Pavia, Hamburg, and Barcelona. Spearman

correlation coefficient (r_s) between Der p 1 and Der f 1 concentrations was 0.21 (CI, 0.18-0.25). No correlation between Der p 1 and Der f 1 was found (r_s , -0.03; $P = .27$) for the 1001 observations with both Der p 1 and Der f 1 above the detection limit. Der 2 allergens were overall detected in 53% of the samples with a large range across centers, consistent with patterns observed for Der 1 allergens. The concentrations were lower than those found for group 1 allergens, but a high correlation between Der 1 and Der 2 was found (r_s , 0.92; CI, 0.91-0.92).

Determinants of mite allergen levels

Allergens of both mite species were more common with decreasing latitude—that is, with more southern location (Table II). Der p 1 was lower in eastern as compared with western locations, whereas longitude did not affect Der f 1. Centers with a higher winter temperature had higher Der p 1 levels, whereas no obvious association with Der f 1 was seen (Fig 2). Annual mean relative humidity and altitude were not associated with mite allergen levels. The patterns for group 1 and group 2 allergens were similar.

For the evaluation of determinants at the home level, data from 4 centers (Reykjavik, Umeå, Uppsala, and Albacete) were excluded because less than 20% of the samples showed detectable allergen levels. Living in a flat, a higher floor level of the bedroom, a relatively new mattress, and sleeping with the bedroom window open in winter were associated with lower allergen levels of both Der p 1 and Der f 1 (Table III). Indicators of home dampness and not having central heating increased the levels of Der p 1 but not of Der f 1. Vacuuming the mattress and having an air brick or ventilation aperture in the bedroom were associated with lower levels of Der f 1, whereas the use of a gas oven was related to an increased level of Der f 1. Der p 1 was not significantly associated with these housing characteristics. Potential risk factors considered a priori that appeared not significantly ($P > .05$) related to either allergen included the use of an allergy-proof mattress cover, floor construction material (wood, concrete), double glazing, smokers in the home, use of anti-dust mite sprays, a feather duvet, an electric blanket, or washing the bed linen at 60°C or higher. Others factors such as air conditioning were related to allergen levels in unadjusted models ($P < .05$) but did not remain in the multivariable model.

Determinants were similar for group 1 and group 2 allergens (Table IV). Factors that were consistently related to higher mite allergen levels were older mattresses (or those with unknown age) and indicators of dampness in the bedroom, whereas factors that were related to lower allergen levels were living in a flat, bedroom above the first floor, sleeping with the bedroom window open in winter, an air brick or ventilation aperture in the bedroom, and an extractor fan over the hob in the kitchen. Mattresses that had been sampled with any type of cover in place had overall lower allergen concentrations (geometric mean [GM] ratio ranging from 0.63 to 0.93) than mattresses that had been sampled uncovered. Season of sampling was not clearly associated with mite allergen levels; only

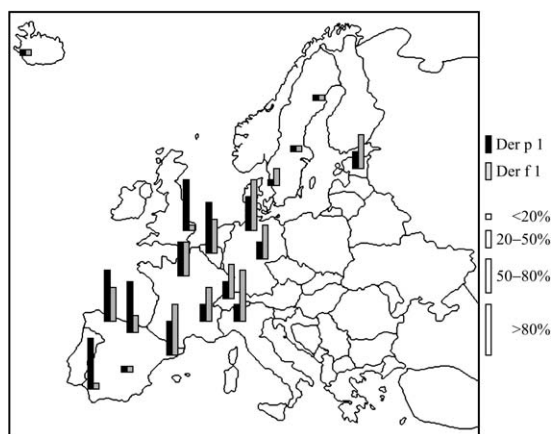


FIG 1. Distribution of Der p 1 and Der f 1 allergens in Europe (based on 3414 measurements in 22 study centers from 10 countries). Percentages of dust samples with detectable mite allergen levels (ie, ≥ 0.1 μg per gram of dust) are shown. Results for adjacent centers within the same country with similar results were combined (Ipswich and Norwich in East Anglia, United Kingdom; Pavia, Turin, and Verona in Northern Italy; Antwerp Center and Antwerp South in Belgium).

for Der 2, a significantly higher (1.29) mean level was found in autumn compared with spring.

DISCUSSION

The ECRHS II provides a unique set of house dust mite allergen measurements taken from 22 cities in 10 European countries, using 1 standardized protocol of which several procedures were comparable with methods used in other epidemiologic surveys. Overall, Der p 1 and Der f 1 were each detectable in mattress dust from half of the homes. Both mite species are widely distributed in Europe, although some regions show almost exclusively 1 of the 2 species. There is a wider distribution of *D farinae* than previously recognized. Both mite species are more common in southern Europe, but low winter temperatures reduce *D pteronyssinus* rather than *D farinae*. Modifiable risk factors related to a relevant reduction of mite allergen levels are having a relatively new mattress, a higher bedroom floor, and increased ventilation of the bedroom.

Dust mites flourish in homes because (human) skin scales provide food supply, indoor temperature is usually optimal, and ambient relative humidity is relatively high.² Signs of increased humidity in our study such as damp or mold spots or condensation on windows were associated with higher Der p 1 levels but did not affect Der f 1. This confirms results of other studies^{9,10} and is consistent with biological and ecologic differences between the 2 mite species, because *D farinae* is better able to survive periods of drought.² Indirectly, this was also reflected by lower Der p 1 levels when moving further east from the Atlantic, although mean outdoor relative humidity alone did not explain geographic variation. Likewise, a higher winter temperature was associated with higher mite

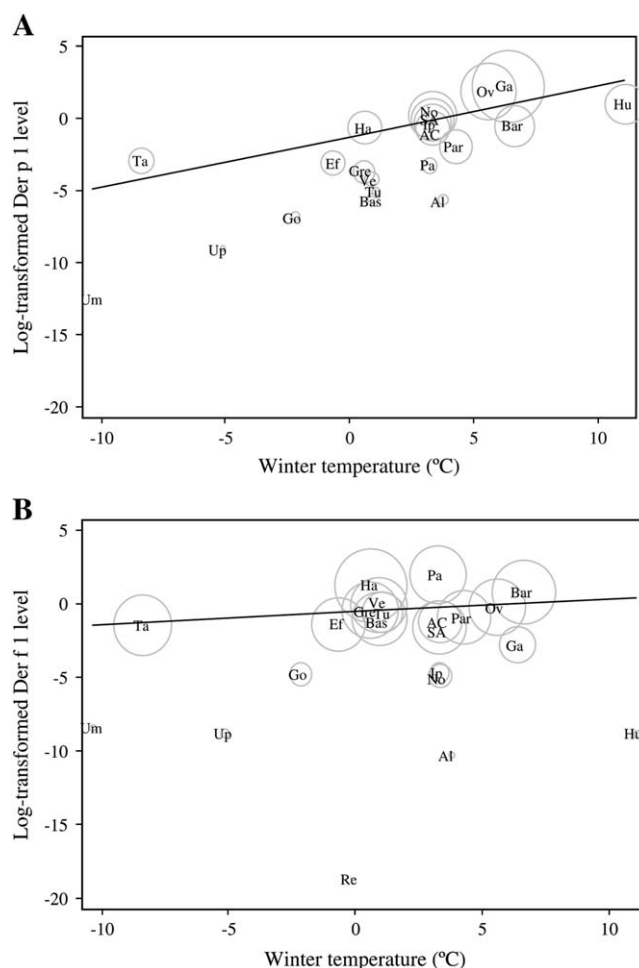


FIG 2. Ecological association between winter temperature and geometric mean Der p 1 (**A**) and Der f 1 (**B**) concentrations. Metaregression models for log-transformed allergen level on temperature in the coldest month by center. The circle sizes indicate the relative contribution of each center to the regression estimate.

TABLE II. Ecological determinants of house dust mite allergen levels*

	Range across centers	Der p 1 allergen†	Der f 1 allergen	Der 1 allergens	Der 2 allergen†
Latitude (per 10° N)	37° N to 64° N	0.18 (0.02-1.30)	0.27 (0.04-2.00)	0.12 (0.02-0.61)	0.18 (0.04-0.83)
Longitude (per 10° E)	22° W to 27° E	0.11 (0.03-0.39)	1.29 (0.24-6.95)	0.23 (0.06-0.89)	0.23 (0.08-0.69)
Altitude (per 100 m)	5 m to 700 m	0.63 (0.31-1.30)	0.84 (0.34-2.10)	0.67 (0.33-1.36)	0.64 (0.35-1.19)
Winter temperature (per 10°C)	-10° to 11°C	91.0 (8.76-944)	2.98 (0.16-56)	45.3 (5.20-394)	29.3 (4.44-193)
Summer temperature (per 10°C)	11° to 27°C	0.41 (0.01-25)	18.5 (0.32-1078)	7.34 (0.16-343)	1.43 (0.05-43)
Relative humidity (per 10%)‡	63% to 85%	0.54 (0.05-5.78)	1.12 (0.09-15)	0.62 (0.06-6.48)	0.82 (0.10-6.47)

*Meta-regression models for log-transformed allergen concentration on geographical and meteorological characteristics. Ratios of the center-averaged GM (95% CI) associated with the indicated change in determinant are shown. N = 3414 samples from 22 study centers. Statistically significant associations are presented in bold.

†Reykjavik, Iceland, was excluded (no detectable levels); data from 21 centers (N = 3232) could be used.

‡Data for 2 centers were missing.

allergen levels, particularly for Der p 1. Cold winters in combination with heated homes reduce *D pteronyssinus* more strongly than *D farinae*.² Interestingly, it has recently been shown that relatively cold winters in areas with a moderate climate in Germany and The Netherlands caused a more than 2-fold decrease of Der p 1 levels,^{17,18} but no such data are available for Der f 1. It is well

recognized that mites are uncommon at high altitudes. There was not much difference in altitude between the centers in our study; Albacete in central Spain was the only city located above 350 m (at about 700 m), and also had the lowest mean relative humidity. This went together with very low mite allergen levels, comparable with those in the Nordic countries.

TABLE III. Associations between housing characteristics and log-transformed mattress Der p 1 and Der f 1 concentrations*

Determinant	Frequency of determinant	Der p 1 allergen†	Der f 1 allergen†
Detached house/bungalow	19%	1.00 (Referent)	1.00 (Referent)
Semi-detached or terraced house/bungalow	18%	0.78 (0.57-1.06)	0.82 (0.54-1.23)
Flat or apartment	63%	0.39 (0.29-0.53)	0.60 (0.41-0.86)
Property built 1985 or later	23%	1.00 (Referent)	—
Property built 1975-1984	18%	1.17 (0.87-1.59)	—
Property built 1950-1974	32%	1.46 (1.12-1.91)	—
Property built before 1950	22%	1.36 (1.01-1.85)	—
Building year property unknown	6%	1.92 (1.10-3.35)	—
Household crowding index, mean (SD)§	0.82 (0.36)	1.88 (1.41-2.49)	—
Dog kept inside the house‡	13%	1.48 (1.12-1.95)	—
Central heating‡	72%	0.58 (0.46-0.73)	—
Radiators mostly used for heating bedroom‡	63%	—	1.40 (1.06-1.84)
No gas used for cooking	49%	—	1.00 (Referent)
Gas hob only	31%	—	0.96 (0.70-1.31)
Gas oven with or without a hob	19%	—	1.68 (1.22-2.31)
Extractor fan over the hob in kitchen‡	74%	0.78 (0.62-0.97)	—
Observed mold or mildew, living-room‡	4%	2.13 (1.27-3.56)	—
Observed mold or mildew, bathroom‡	11%	1.60 (1.18-2.17)	—
Observed damp patches, bedroom‡	8%	1.79 (1.24-2.59)	—
Condensation, bedroom window, on winter mornings‡	28%	1.60 (1.29-1.99)	—
Air brick or ventilation aperture, bedroom‡	13%	—	0.66 (0.46-0.96)
Bedroom level			
Ground floor or basement	23%	1.00 (Referent)	1.00 (Referent)
First floor	36%	0.59 (0.45-0.77)	0.86 (0.63-1.19)
Second floor	15%	0.37 (0.27-0.51)	0.49 (0.33-0.73)
Third floor or higher	26%	0.30 (0.22-0.40)	0.49 (0.35-0.70)
No carpet or rug on bedroom floor	36%	—	1.00 (Referent)
Carpet or rug on part of bedroom floor	34%	—	0.74 (0.56-1.00)
Carpet or rug on entire bedroom floor	30%	—	1.08 (0.79-1.48)
Windows open at night in winter			
Never	63%	1.00 (Referent)	1.00 (Referent)
Only occasionally	9%	0.57 (0.35-0.93)	0.63 (0.40-0.99)
Sometimes	10%	0.61 (0.44-0.86)	0.80 (0.54-1.19)
All of the time	18%	0.56 (0.43-0.72)	0.54 (0.39-0.74)
Age of mattress <1 y	7%	1.00 (Referent)	1.00 (Referent)
Age of mattress 1-9 y	56%	1.63 (1.10-2.40)	2.55 (1.58-4.13)
Age of mattress >9 y	36%	2.05 (1.37-3.05)	4.64 (2.83-7.62)
Age of mattress unknown	1%	3.51 (1.22-10.1)	4.56 (1.11-18.7)
Double bed (mattress ≥1.35 m wide)	77%	1.00 (Referent)	—
Single bed (mattress <1.35 m wide)	21%	1.19 (0.94-1.52)	—
Other (including bunk beds and water beds)	2%	0.33 (0.12-0.89)	—
Mattress cleaned by vacuuming‡	49%	—	0.61 (0.48-0.78)

*Multivariable left-censored mixed regression analyses using 2683 samples from 18 study centers with at least 20% detectable samples for either Der p 1 or Der f 1. Overall geometric mean levels were 0.26 and 0.25 µg/g for Der p 1 and Der f 1, respectively.

†Ratio of GM (95% CI) adjusted for all listed variables, plus type of population sample, whether mattress was sampled uncovered or with any type of cover in place, season, storage time (all fixed-effects adjustment), and study center (random-effects adjustment). A total of 125 and 209 observations had missing values for any of the explanatory variables for Der p 1 and Der f 1, respectively.

‡Yes vs no.

§Persons/room.

—, Variable not included in model ($P > .05$ in multivariable analysis); *hob*, a shelf beside an open fire where something can be kept warm.

TABLE IV. Associations between housing characteristics and log-transformed mattress Der 1 and Der 2 concentrations*

Determinant	Frequency of determinant	Der 1 allergens†	Der 2 allergen†
Detached house/bungalow	19%	1.00 (Referent)	1.00 (Referent)
Semidetached or terraced house/bungalow	18%	0.93 (0.71-1.22)	0.92 (0.68-1.24)
Flat or apartment	63%	0.54 (0.41-0.71)	0.54 (0.41-0.71)
Household crowding index: mean (SD)§	0.82 (0.36)	1.77 (1.40-2.25)	1.88 (1.46-2.42)
Central heating‡	72%	—	0.67 (0.55-0.83)
Extractor fan over the hob in kitchen‡	74%	0.69 (0.57-0.85)	0.74 (0.60-0.91)
Water damage to building in the last year‡	11%	1.32 (1.02-1.71)	—
Observed damp patches bedroom‡	8%	1.69 (1.24-2.30)	2.18 (1.59-3.00)
Condensation bedroom window on winter mornings‡	28%	1.45 (1.20-1.75)	1.56 (1.28-1.91)
Air brick or ventilation aperture bedroom‡	13%	0.55 (0.42-0.72)	0.60 (0.45-0.81)
Bedroom level			
Ground floor or basement	23%	1.00 (Referent)	1.00 (Referent)
First floor	36%	0.57 (0.46-0.72)	0.50 (0.40-0.64)
Second floor	15%	0.33 (0.25-0.45)	0.27 (0.20-0.36)
Third floor or higher	26%	0.28 (0.22-0.36)	0.24 (0.19-0.32)
Windows open at night in winter			
Never	63%	1.00 (Referent)	1.00 (Referent)
Only occasionally	9%	0.75 (0.55-1.03)	0.82 (0.57-1.16)
Sometimes	10%	0.75 (0.57-1.00)	0.73 (0.54-0.99)
All of the time	18%	0.63 (0.50-0.79)	0.63 (0.49-0.81)
Age of mattress <1 y	7%	1.00 (Referent)	1.00 (Referent)
Age of mattress 1-9 years	56%	2.28 (1.63-3.18)	2.14 (1.49-3.07)
Age of mattress >9 y	36%	3.27 (2.31-4.62)	2.90 (2.00-4.20)
Age of mattress unknown	1%	6.03 (2.23-16.3)	7.57 (2.76-20.8)
Double bed (mattress ≥1.35 m wide)	77%	1.00 (Referent)	—
Single bed (mattress <1.35 m wide)	21%	1.38 (1.11-1.70)	—
Other (including bunk beds and water beds)	2%	0.87 (0.42-1.82)	—
Under blanket or mattress protector‡	66%	—	0.71 (0.56-0.90)
Mattress cleaned by vacuuming‡	49%	0.80 (0.68-0.95)	—

*Multivariable left-censored mixed regression analyses using 2683 samples from 18 study centers with at least 20% detectable samples for either Der 1 or Der 2. Overall geometric mean levels were 1.71 and 0.36 $\mu\text{g/g}$ for Der 1 and Der 2, respectively.

†Ratio of GM (95% CI) adjusted for all listed variables, plus type of population sample, whether mattress was sampled uncovered or with any type of cover in place, season, storage time (all fixed-effects adjustment), and study center (random-effects adjustment). A total of 206 and 157 observations had missing values for any of the explanatory variables for Der 1 and Der 2, respectively.

‡Yes vs no.

§Persons/room.

—, Variable not included in model ($P > .05$ in multivariable analysis); *hob*, a shelf beside an open fire where something can be kept warm.

Levels of Der p 1 and Der f 1 were only weakly correlated in our study, suggesting that both mite species thrive independently. There does not seem to be competition between mites; the presence of one species does neither enhance nor reduce the presence of the other species. This finding is consistent with a Dutch study,⁵ but others report modest ($r = 0.35$)⁹ to fair ($r = 0.47$)¹⁹ correlation coefficients in mattress dust. In many areas of the world, (epidemiologic) studies routinely measure only Der p 1 in house dust. In some areas outside Europe and North America, it has recently been shown that *D pteronyssinus*, *D farinae*, or both are common.^{10,20} Our study suggests that in many parts of Europe, measuring only 1 of the 2 allergens would result in an underestimation of total mite allergen exposure.

The identification of housing characteristics associated with elevated house dust mite allergen levels is important to prevent exposure and hence to reduce asthma exacerbations in sensitized patients. There is, however, uncertainty and controversy about the effectiveness of specific avoidance interventions in the management of asthma.²¹ One of the possible explanations of the fact that several randomized controlled trials have not found significant improvements in clinical condition is that the intervention did not reduce house dust mite exposure sufficiently, or only did so in 1 location within the home.²² Our study confirms that commonly applied interventions such as impermeable bedding encasements do not lead to a significant reduction in mite allergen levels.^{5,21} As shown in several studies,^{10,23} the easiest way to reduce mite allergen

exposure from the floor is removing carpets or rugs. For the mattress, it appears to be more difficult to identify strong modifiable risk factors. As observed by other studies,^{10,24} ventilation of the bedroom and reducing humidity may be helpful to decrease allergen levels, in particular in regions with considerable infestation of *D pteronyssinus*. An interesting finding in this study was a consistent reduction of allergen levels from both mite species in relation to opening windows at night in winter, irrespective of the frequency. Probably depending on the geographic location, this might be added to the list of simple and effective control measures.

We could not demonstrate increasing mattress mite allergen levels in bedrooms with carpets or rugs. For both mite species, but particularly for *D farinae*, allergen levels increased with increasing mattress age, and therefore one could advise to change the mattress regularly. We did not have information on mattress material. Some studies suggested that mite infestation is lower in inner sprung mattresses compared with foam mattresses,²⁵ and another study reported higher Der f 1 in kapok mattresses,¹⁰ but many studies were not able to show such differences.^{10,24,26} There were only 7 dust samples taken from waterbeds in our study. Two had insufficient dust for analysis, and the other 5 had all allergen levels below the limit of detection. Although because of the small numbers conclusions regarding this cannot be drawn from our analysis, it is not impossible that waterbeds form a type of mattress that is not easily infested by dust mites.

There are several limitations in our study that should be considered. First, we measured allergens from 2 mite species and do not have information on other species from the Pyroglyphidae family. *Dermatophagoides microseras* is considered generally uncommon, but has been suggested to be relevant in Sweden.²⁷ The dust mite species *Euroglyphus maynei* has been reported in some parts of both the United States² and Europe.⁶ The storage mite *Blomia tropicalis* commonly lives in homes in semitropical and tropical climates,² but it is unknown whether it can also flourish in warm areas in southern Europe. Nevertheless, we believe that by measuring *D pteronyssinus* and *D farinae* allergens, the vast majority of relevant mite allergens were included. Second, data on indoor temperature and humidity could have been provided more adequate determinants of mite growth than outdoor temperature and humidity. Because this information was not collected, we used questionnaire data on indicators of indoor temperature, ventilation, and humidity (such as presence of central heating, air brick or ventilation aperture, visible damp and mold, and extractor fan) and were able to associate mite allergen levels to these proxies.

Third, we sampled mattress dust only for allergen determination. Although mattresses are the best comparable mite habitat across areas, other sites like carpets and upholstered furniture are important mite habitats. Nevertheless, a common finding in studies with several measurement sites is that mite allergen levels in the mattress are higher than in other places inside the home, and are correlated within homes between different places. This has

been demonstrated in various studies from different countries.^{8,26,28,29} Therefore, although total mite allergen exposure will depend on other sources, we most likely provided valid allergen exposure estimates that are comparable across centers. Finally, we did not collect information on the sampled dust weight, and therefore could not express allergen levels per square meter of mattress surface. Notwithstanding, concentrations per gram of dust are typically used in practically all studies as they are more stable and less related to the amount of dust and hence to levels of other dust constituents such as microbial agents.

We conclude that there is a large variation in levels of Der p 1 and Der f 1 in Europe. Epidemiologic studies on mite sensitization and asthma should measure both mite allergens in dust samples. Practical recommendations for allergen reduction should include replacing the mattress regularly and increasing ventilation of the bedroom, particularly in winter. This may have a relevant beneficial public health effect in the general population. The use of a broader package of interventions in controlled trials probably improves the contrast in exposure between intervention and control group and increases the probability of detecting clinical improvement in mite-sensitized patients with asthma.

In Memoriam

We thank all field workers for collecting the dust samples, and Marcus Burrows, Sharon Hughes, and Kashif Cheema for processing and analyzing the dust samples in the central laboratory in London.

Christina Luczynska contributed to two of the papers published in this issue of the Journal. Sadly, she died before the work was completed.

Born to Polish parents in London, she worked on both sides of the Atlantic during her short life. After completing her doctoral studies with Maurice Lessof on human specific IgE responses to inhaled haptens, she moved to Syracuse University and then to the University of Virginia. Here she developed monoclonal immunoassays to study the distribution and particle size of environmental cat allergen. After a short interlude in industry, she moved to St Thomas' Hospital to manage the ECRHS. During the second survey, her laboratory was responsible for the IgE and environmental allergen assays.

Christina had a wonderful talent for bringing people together to enjoy science. She died as she had lived, organizing her friends, colleagues, and doctors, and she will be greatly missed by all of them.

Peter Burney
Josep M. Antó
Thomas Platts-Mills

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APPENDIX

Coordinating Center of ECRHS II

Project Leader: P. Burney; Statistician: S. Chinn; Principal Investigator: D. Jarvis; Project Coordinator: J. Knox; Principal Investigator: C. Luczynska; Assistant Statistician: J. Potts; Data Manager: S. Arinze.

Steering Committee for ECRHS II

Professor Josep M. Antó, Institut Municipal d'Investigació Mèdica, Universitat Pompeu Fabra; Professor Peter Burney, King's College London (Project Leader); Dr Isa Cerveri, University of Pavia; Professor Susan Chinn, King's College London; Professor Roberto de Marco, University of Verona; Dr Thorarinn Gislason, Iceland University Hospital; Dr Joachim Heinrich, GSF-Institute of Epidemiology; Assoc Professor Christer Janson, Uppsala University; Dr Deborah Jarvis, King's College London; Dr Nino Künzli, University of Basel and University of Southern California Los Angeles; Dr Bénédicte Leynaert, Institut National de la Santé et de la Recherche Médicale; Dr Christina Luczynska, King's College London; Dr Françoise Neukirch, Institut National de la Santé et de la Recherche Médicale; Dr J Schouten, University of Groningen; Dr Jordi Sunyer, Institut Municipal d'Investigació Mèdica, Universitat Pompeu Fabra; Dr Cecilie Svanes, University of Bergen; Professor Paul Vermeire, University of Antwerp; Dr Matthias Wjst, GSF-Institute of Epidemiology.

Principal Investigators and Senior Scientific Team

Belgium: South Antwerp and Antwerp City (P. Vermeire, J. Weyler, M. Van Sprundel, V. Nelen). Estonia: Tartu (R. Jogi, A. Soon). France: Paris (F. Neukirch, B. Leynaert, R. Liard, M. Zureik), Grenoble (I. Pin, J. Ferran-Quentin). Germany: Erfurt (J. Heinrich, M. Wjst, C. Frye, I. Meyer). Iceland: Reykjavik (T. Gislason, E. Bjornsson, D. Gislason, T. Blondal, A. Karlsdottir). Italy: Turin (M. Bugiani, P. Piccioni, A. Carosso, W. Arossa, E. Caria, G. Castiglioni, E. Migliore, C. Romano, D. Fabbro, G. Ciccone, C. Magnani, P. Dalmaso, R. Bono, G. Gigli, A. Giraudo, M. C. Brussino, C. Bucca, G. Rolla), Verona (R. de Marco, G. Verlato, E. Zanolin, S. Accordini, A. Poli, V. Lo Cascio, M. Ferrari), Pavia (A. Marinoni, S. Villani, M. Ponzio, F. Frigerio, M. Comelli, M. Grassi, I. Cerveri, A. Corsico). Spain: Barcelona (J. M. Antó, J. Sunyer, M. Kogevinas, J. P. Zock, X. Basagana, A. Jaen, F. Burgos), Huelva (J. Maldonado, A. Pereira, J. L. Sanchez), Albacete (J. Martinez-Moratalla Rovira, E. Almar), Galdakao (N. Muniozguen, I. Urritia), Oviedo (F. Payo). Sweden: Uppsala (C. Janson, G. Boman, D. Norback, M. Gunnbjornsdottir), Goteborg (K. Toren, L. Lillienberg, A. Dahlman-Höglund, R. Sundberg), Umeå (E. Norrman, M. Soderberg, K. Franklin, B. Lundback, B. Forsberg, L. Nystrom). Switzerland: Basel (N. Künzli, B. Dibbert, M. Hazenkamp, M. Brutsche, U. Ackermann-Liebrich). United Kingdom: Norwich (D. Jarvis, B. Harrison), Ipswich (D. Jarvis, R. Hall, D. Seaton).