Cat allergen level: Its determinants and relationship to specific IgE to cat across European centers

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Background: Cat allergen level in settled house dust and its determinants in Europe are unknown.
Objective: The aim of this study is to quantify the level of cat allergens in mattress dust, to study its determinants, and to analyze the relationship with cat specific IgE on community level across European centers.
Methods: Trained field workers collected dust from approximately 3000 mattresses during home visits in 22 European Community Respiratory Health Survey II centers. Sieved dust extracts were assayed for cat allergen using a mAb ELISA assay.
Results: The overall geometric mean cat allergen was 0.94 μg/g, ranging from 0.12 μg/g in Huelva, Spain, to 3.76 μg/g in Antwerp, Belgium. Current cat owners' homes showed substantially higher levels than past cat owners' and never cat owners' homes (geometric mean and 95% CI, 61.4 μg/g [48.4-77.9] vs 1.37 μg/g [0.97-1.9] vs 0.29 μg/g [0.27-0.31]). Community prevalence of cat ownership was moderately correlated with cat allergen levels in noncat owners ($r_s = 0.50$), but not for past or current cat owners. The multilevel model identified community prevalence of cat keeping as the only statistically significant determinant of mattress cat allergen levels for noncat owners. However, averaged cat allergen levels per center were not related to community prevalence of detectable specific IgE to cat.
Conclusion: Not having a cat in the home is associated with substantially lower Fel d 1 concentration, but does not protect against high Fel d 1 exposure in communities where cat ownership is common.
Clinical implications: People (including patients with cat allergy) who do not own cats may be exposed to high levels of cat allergen in their home, particularly if they live in communities with high levels of cat ownership. (J Allergy Clin Immunol 2006;118:674-81.)

Key words: *Cat allergen, Fel d 1, cat, mattress dust, indoor exposure, cat allergy, specific IgE to cat, ECRHS*

Epidemiologic studies have shown conflicting results on the influence of pet ownership, especially cat keeping in early life, on the subsequent development of sensitization and atopic diseases.[1] Potential explanations for inconsistent results are related to selective cat avoidance because of family members with allergy,[2] induced immune tolerance,[3] further concomitant exposures such as endotoxin,[4] further nonspecified lifestyle-related factors, or a combination of these suggested underlying mechanisms. Although each of these explanations seems plausible, there is no common accepted answer to the conflicting results on cat ownership. Exposure to cat allergen is a prerequisite and a main determinant of cat sensitization leading to development of asthma. The prevalence of cat allergy varies widely across Europe.[1,5] Studies, however, have shown that pet ownership is a poor surrogate for specific allergen exposure.[6,7] Cat allergens are ubiquitous because of the small size of cat dander, which is mostly airborne. In addition, the reported associations between cat allergen level measured in settled house dust samples and development of specific cat allergic sensitization and asthma from different studies are inconsistent.[3,8-14] Discrepancies between studies may also be a result of varying study designs, populations' level of exposure, community cat prevalence, definition of allergic sensitization, or expression of cat allergen level as per gram of dust or per sampled surface.

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Abbreviations used
ECRHS: European Community Respiratory Health Survey
GM: Geometric mean
LOD: Level of detection

The level of cat allergen in settled house dust in Europe is unknown, particularly among noncat owners. This study provided a unique opportunity to measure cat allergen levels in house dust across Europe in centers with large differences in the community prevalence of cat keeping, ranging from 10% to 50%. The aim of this study is to determine the level of cat allergens, to study determinants, and to analyze the relationship with cat specific IgE at the community level across European centers. We measured cat allergen level in mattress dust samples from 2800 adults living in 22 municipal areas across Europe.

METHODS

Study design and study population

The European Community Respiratory Health Survey (ECRHS) was designed as a multicenter cross-sectional study, which was extended as a multicenter cohort (ECRHS II) and has been described elsewhere.[15] A follow-up examination of a random population sample of adults, age 20 to 44 years at baseline examination (ECRHS I), was performed in 29 centers. In addition, most study centers included a symptomatic sample of subjects who reported respiratory symptoms in the ECRHS I screening questionnaire, but data from these symptomatic samples were not used for these analyses. Out of the 29 ECRHS II centers, 22 participated in the indoor protocol, which included a detailed inventory on indoor factors and a home visit to collect mattress dust for allergen measurements. Each center participating in the indoor protocol recruited about 200 subjects, with preference to subjects who did not move during the follow-up, provided a blood sample, and were selected in the random sample.

Home visits and dust collection

Between July 2000 and November 2002, approximately 3000 homes from 22 centers were visited. There was only 1 individual per household in the study. During the home visit, we collected a house dust sample from each subject's mattress according to a standardized protocol. 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 (1 m^2) was placed on the area of the bed where the participant usually slept. An Electrolux Mondo vacuum cleaner (1300 W) equipped with special nozzles (ALK-Abelló, Hørsholm, Denmark) collected settled dust within the 1-m^2 templates for 2 minutes. Dust was collected on cellulose filters. Within 3 days, samples were frozen at −20°C for 24 hours to kill mites. The collected dust was stored at room temperature in a dark room in boxes with silica gel sachet to remove humidity until shipping to 1 central laboratory for extraction and cat allergen measurements.

Dust extraction and determination of cat allergen levels

The dust samples were sieved to remove larger particles and to obtain a more homogenous amount of fine dust for extraction. Extracts, 5% wt/vol, in borate-buffered saline of sieved dust samples were assayed for cat allergen *Felis domesticus* (Fel d 1) using a mAb ELISA assay (Indoor Biotechnology, Cardiff, United Kingdom). The analytic limit of detection (LOD) was 0.1 μg allergen per gram of fine dust. Concentrations were expressed per gram of sampled dust.

Questionnaire information on pet keeping and potential predictors of cat allergen levels

In addition to the home visits, a face-to-face interview with each participant in ECRHS II was conducted to collect data on cat keeping and indoor factors, such as type and age of building, basic construction, characteristics, heating and ventilation habits, floor covers, and pet keeping. During the home visits, trained fieldworkers assessed home characteristics such as number of rooms, presence of damp and mold on the walls or ceilings in several rooms, size of mattress, and types of bedding. In addition, participants were asked about the number of people living in the home, age of mattress, frequency of vacuuming the bedroom floor, and the mattress.

Blood measurements

Serum IgE to cat was measured by using the AutoCAP system (Pharmacia, Uppsala, Sweden). IgE was considered to be present if greater than 0.35 kU/L was detected.

Statistical analysis

Less than 5% of all dust samples had insufficient amounts of dust (<50 mg) for extraction. Cat allergen levels (Fel d 1) were expressed as microgram allergen per gram of dust. Analytic results below the LOD (<0.1 μg/g) were arbitrarily given a value of 0.05 μg /g (1/2 × LOD; n = 565). When the study subjects were stratified on cat ownership, levels of Fel d 1 had a log-normal distribution. Consequently, mean values are expressed as geometric means (GMs) with a 95% CI, or in addition, a 95% range is given. Therefore, we calculated log mean plus and minus 2 SDs as an approximate 95% range, and back-transformed these. This leads to an approximate 95% range.

Observations were grouped in 3 categories of never, past, and current cat owners on the basis of cat ownership at the 2 surveys. Subjects who owned a cat during ECRHS II were classified as current owners. Owners at ECRHS I but not at ECRHS II were classified as past owners, and subjects who did not own a cat at either survey were classified as never owners.

The following predictors for cat allergen levels were considered in analyses: cat ownership, community prevalence of cat ownership, study center, cat allowed in bedrooms, season of dust sampling, age of mattress, allergen removing compounds, anti–dust mite sprays, smoking habit, level on which bedroom situated, type of home, the total number of rooms per household (excluding kitchen and bathrooms), ventilation in rooms, total number of residents per household, and education level as a proxy for socioeconomic status.

Potential predictors which showed at least marginal effects ($P <$ .10) in univariate analysis were considered for multilevel analysis. To address the hierarchic structure of our data, multilevel mixed regression models were applied, with individual observations as first level and centers as second level. A random intercept model was fitted to these data to account for the different levels of the respective outcome per center. Procedure proc mixed of the Statistical Package SAS 9.1.3 (SAS Institute, Cary, NC) was used to estimate the models.

Associations between Fel d 1 and its determinants are presented as ratios of GMs in relation to the respective reference category.

The association between cat specific IgE per center and community level of cat ownership and averaged cat allergen levels per center was analyzed in 2 steps. First, the prevalence rates for specific sensitization to cat were calculated after adjustment for age groups, sex, smoking, number of siblings, educational level, body mass index,

TABLE I. Descriptive statistics of cat allergen Fel d 1 levels (μg/g) in mattress dust of random samples of visited homes and cat ownership of the ECHRS II cohort in 22 study centers (N = 2800)

Country	Center	N	Above LOD† (%)	Cat allergen levels		Cat ownership in community* (%)
				GM	95% CI	
Belgium	Antwerp S	143	88.1	1.31	0.88-1.95	26.3
Belgium	Antwerp C	80	93.8	3.76	1.83-7.76	26.5
Germany	Hamburg	166	91.6	2.04	1.25-3.32	19.8
Germany	Erfurt	192	79.2	0.74	0.50-1.09	15.3
Spain	Barcelona	131	79.4	0.48	0.30-0.75	10.0
Spain	Galdakao	162	48.8	0.16	0.12-0.23	11.7
Spain	Albacete	132	61.4	0.17	0.13-0.22	7.0
Spain	Oviedo	137	63.5	0.28	0.19-0.43	11.7
Spain	Huelva	85	29.4	0.12	0.08-0.19	6.5
France	Grenoble	152	71.7	0.54	0.35-0.85	20.2
France	Paris	142	94.4	3.40	2.04-5.67	21.5
Italy	Pavia	69	75.4	0.67	0.38-1.18	27.6
Italy	Turin	39	94.9	2.99	1.08-8.28	15.9
Italy	Verona	103	90.3	1.09	0.65-1.83	16.0
UK	Ipswich	84	88.1	1.30	0.72-2.36	35.1
UK	Norwich	130	92.3	3.20	1.81-5.66	36.0
Iceland	Reykjavik	159	85.5	0.57	0.41-0.78	12.6
Sweden	Gothenburg	143	86.0	1.18	0.71-1.97	19.1
Sweden	Umea	162	75.9	1.60	0.95-2.69	23.9
Sweden	Uppsala	132	89.4	3.14	1.75-5.63	22.6
Switzerland	Basel	86	82.6	1.65	0.87-3.13	23.7
Estonia	Tartu	171	95.3	2.08	1.39-3.11	22.9
Total		2800		0.94	0.84-1.05	19.5

UK, United Kingdom.
*Cat ownership rates were calculated from the database of the ECHRS II cohorts.
†Percentage above (limit of detection) LOD and geometric means of cat allergens were calculated for random samples of visited home.

and history of parental asthma or allergy. Second, these adjusted prevalence rates were regressed against community prevalence of cat ownership and averaged cat allergen level per community.

All analyses were performed by using the Statistical Analysis System (SAS 9.1.3, SAS Institute).

RESULTS

Cat allergen levels and cat ownership across Europe

Data of the 2800 individuals with complete information on cat allergen levels in dust samples and complete data from the indoor questionnaire were analyzed. Descriptive analysis showed very large variation in cat allergen levels and cat ownership across Europe (Tables I and II). Grouping the study centers for geographic location in central (8) centers, northern (5) centers, and southern (9) centers, European regions showed substantial differences in the allergen levels. The highest cat allergen levels were found in the central European centers (GM, 1.79 μg/g; 95% CI, 1.48-2.15; n = 1023), followed by the northern centers (GM, 1.45 μg/g; 95% CI, 1.17-1.79; n = 767) and the southern European centers (GM, 0.35 μg/g; 95% CI, 0.30-0.41; n = 1010). A high allergen level (Fel d 1 > 8 μg/g dust) was observed in 559 (20%) observations of homes in total (see this article's Table E1 in the Online Repository at www.jacionline.org). Of noncat owners' homes, 97 (5%) had Fel d 1 concentrations above 8 μg/g dust (see this article's Table E1 in the Online Repository at www.jacionline.org).

Geometric mean of cat allergen was substantially higher in current cat keeping homes (GM, 61.4 μg/g; 95% CI, 48.4-77.9; n = 555) compared with only past cat keeping homes (GM, 1.37 μg/g; 95% CI, 0.97-1.91; n = 192) and never cat keeping homes (GM, 0.29 μg/g; 95% CI, 0.27-0.31; n = 2440). There was also great variation of mean cat allergen concentrations between centers in current cat keeping homes, ranging from 1.83 μg/g in Pavia to 207.5 μg/g in Hamburg (Table II). Besides the strong association between cat ownership and cat allergen levels, the community prevalence of cat ownership affected the level of cat allergens in mattress dust. A positive association (Spearman correlation coefficient $r_s = 0.50$) between community prevalence of cat ownership and mean cat allergen concentration was found for never cat owners, but these associations were attenuated in past cat owners ($r_s = 0.18$) and disappeared in current cat owners ($r_s = 0.05$; see this article's Fig E1 in the Online Repository at www.jacionline.org). The between-center intraclass correlation coefficient was 0.086—that is, between-center variation accounted for about 8.6% of total variation in Fel d 1. Concentrations of cat allergen levels in this study were lower in winter in univariate analysis, which was consistent in the 3 European regions.

TABLE II. Geometric mean of Fel d 1 levels (μg/g) by center and cat ownership in 2800 random samples of mattress dust

	Never cat owners			Past cat owners			Current cat owners		
Center	**Percent**	**GM**	**95% Range***	**Percent**	**GM**	**95% Range***	**Percent**	**GM**	**95% Range***
Antwerp South	62.9	0.40	0.02-7.0	7.0	1.14	0.16-8.3	30.1	16.52	0.18-1478.9
Antwerp City	64.6	0.88	0.01-57.5	7.6	5.02	0.00-6510.2	27.8	99.90	0.23-43,182.7
Hamburg	69.9	0.61	0.02-18.1	12.0	2.25	0.00-1219.2	18.1	207.53	0.24-176,335.2
Erfurt	82.3	0.34	0.01-13.3	3.6	0.37	0.00-54.8	14.1	82.62	0.43-15,953.6
Barcelona	85.5	0.20	0.02-2.0	3.1	4.51	0.00-31,920.1	11.5	160.60	2.63-9795.5
Galdakao	89.5	0.11	0.01-1.1	2.5	0.27	0.00-30.9	8.0	15.44	0.01-25,717.8
Albacete	90.2	0.14	0.01-1.7	2.3	0.07	0.03-0.2	7.6	2.81	0.01-1431.8
Oviedo	83.1	0.15	0.01-2.2	8.1	0.71	0.01-40.3	8.8	63.07	0.03-133,425.1
Huelva	97.6	0.10	0.00-4.1	0.0	—	—	2.4	44.47	21.90-90.3
Grenoble	80.3	0.18	0.01-2.5	4.6	2.15	0.07-69.6	15.1	113.34	0.95-13,559.1
Paris	66.7	0.70	0.02-24.6	6.4	2.06	0.04-99.9	27.0	187.94	3.07-11,494.3
Pavia	56.5	0.39	0.01-19.4	13.0	0.62	0.01-41.3	30.4	1.83	0.00-690.8
Turin	61.5	1.08	0.00-338.3	12.8	1.25	0.07-21.2	25.6	53.59	0.14-19,827.1
Verona	74.8	0.50	0.02-12.5	13.6	1.09	0.02-72.2	11.7	174.56	0.45-67,781.8
Ipswich	53.7	0.29	0.01-6.4	9.8	1.15	0.02-57.2	36.6	12.46	0.05-2861.0
Norwich	55.5	0.46	0.01-23.3	10.9	1.45	0.04-47.4	33.6	103.07	0.83-12,756.6
Reykjavik	80.5	0.32	0.02-4.9	7.5	1.23	0.01-243.0	11.9	16.17	0.38-695.4
Gothenburg	74.5	0.27	0.02-3.8	4.3	2.14	0.01-402.1	21.3	187.32	3.76-9321.7
Umea	60.5	0.17	0.01-2.2	6.2	2.81	0.11-71.3	33.3	85.74	0.92-7970.1
Uppsala	58.3	0.48	0.02-12.1	9.8	1.14	0.00-672.5	31.8	132.28	0.48-36,124.7
Basel	69.8	0.38	0.01-9.8	5.8	4.50	0.20-101.1	24.4	89.57	0.56-14,211.3
Tartu	69.0	0.71	0.03-19.1	8.8	1.70	0.03-102.6	22.2	63.30	0.33-12,314.2
Total	2044	0.29	0.01-8.3	192	1.37	0.01-149.3	555	61.40	0.22-17,072.8

*95% Range calculated as log mean plus and minus 2 SDs and back-transformed.

Home and participant determinants of cat allergen levels in never cat owners' homes and cat owners' homes

We stratified the statistical analyses on never cat owners (n = 2044) and current cat owners (n = 555).

The results for determinants of cat allergen levels in never cat owners' homes, using a multilevel model, are shown in Table III. Mutually adjusted determinants for high cat allergen levels were type of property, number of people living in home, number of rooms in home, type of mattress material, type of mattress, and community prevalence of cat, whereas only community prevalence of cat ownership was revealed as statistically significant (Table III).

Independent determinants of cat allergen levels in current cat owners' homes, besides cat keeping, were allowing cats inside the house and bedroom, number of people living in home, number of rooms, type of property, ventilation, and smoking (Table IV). The strongest associations were found for cats allowed inside a house or inside a bedroom, but also a low number of people living in home was statistically significantly associated with larger Fel d 1 concentrations.

Although community prevalence of cat ownership substantially contributed to averaged cat allergen concentration of noncat owners per center, we did not find a statistically significant association between averaged cat allergen levels and community prevalence of detectable cat specific IgE (P = .27). An increment of 10% of cat ownership was associated with an increase of 1.07% (95% CI, 0.90-3.05; see this article's Fig E2 in the Online Repository at www.jacionline.org). In addition, no statistically significant association was seen between community prevalence of cat ownership and adjusted prevalence of detectable cat specific IgE (P = 0.86). An increase of GMs of 0.1 of cat allergen levels was associated with an increase for cat specific IgE of −0.05 (−0.68 to 0.58; see this article's Fig E2 in the Online Repository at www.jacionline.org). Using 0.7 kU/L as a higher cutoff, the results were not substantially different.

DISCUSSION

Interpretation of different cat allergen levels in mattress dust across Europe

The community prevalence of cat ownership is one of the main determinants of averaged cat-allergen concentrations for never cat owners, but not for past or current cat owners. The percentage of noncat owners' homes with high Fel d 1 concentration (>8 μg/g dust) of 5% in this study is substantially lower than the 11%[7] and 26%[16] reported previously. In children's mattresses, the estimates of 4%[17] and of "very few"[18] are lower than in our study. Numerous studies also identify cat keeping as the major source for cat allergen concentration in floor and mattress dust.[6,19-21] The underlying mechanism for the association between community prevalence of cat ownership and Fel d 1 concentration in noncat owners' homes seems plausible. Almqvist et al[22] and others[23,24] have shown that the cat allergen is transferred from cat owners' clothes to noncat owners' clothes. A study in noncat keeping

TABLE III. Association among housing, sampling, and study participant characteristics and mattress Fel d 1 levels in never cat owners of the random sample (N = 2044) from 22 study centers*

Determinant	N	Ratio of GMs	95% CI	*P* value
Type of property				
Detached house/bungalow	419	1.00		.069
Building built as house converted into flats	40	1.73	1.00-2.98	
Building originally built as a flat/apartment	1272	1.12	0.88-1.42	
Terraced house	149	1.25	0.93-1.69	
Semidetached house/bungalow	164	0.84	0.62-1.14	
Number of people living in home				
5 Or more persons	298	1.00		.101
4 Persons	623	0.84	0.67-1.05	
3 Persons	485	0.84	0.66-1.06	
2 Persons	436	0.97	0.75-1.25	
1 Person	202	1.18	0.84-1.64	
Number of rooms in home				
5 Or more rooms	299	1.00		.623
4 Rooms	403	1.03	0.81-1.32	
3 Rooms	685	1.14	0.89-1.46	
2 Rooms	427	1.08	0.81-1.45	
1 Room	206	1.26	0.88-1.83	
Which material was sampled?				
Mattress only	1076	1.00		.080
Mattress and an allergy proof cover on it	15	0.50	0.22-1.15	
Mattress and a plastic cover on it	21	0.90	0.45-1.81	
Mattress and cloth protector	921	0.84	0.72-0.98	
Type of mattress sampled				
Other	17	1.00		.422
Double bed	1548	0.60	0.28-1.30	
Single bed	472	0.59	0.27-1.30	
Prevalence of cat ownership in community	22	1.05	1.02-1.08	.002

*Multilevel model: ratio of GMs for random intercept model to allow clustering for center.

school-aged children used cat ownership in their classmates as an indirect surrogate for cat allergen exposure and found increasing risks for cat-specific allergic sensitization with increasing frequencies of cat keeping classmate per class and per school.[25] Another study in Sweden indicated that passive transport of cat allergen attached to clothes causes respiratory symptoms in students with asthma and cat allergy.[22] Fel d 1 has been detected in many other public places such as hospitals, buses, cinemas, and hotels, where cats are not present.[19,20,23,24]

Determinants of cat allergen concentrations in noncat and cat owners' homes

Besides cat ownership and community prevalence of cat ownership, there are several further determinants that should to be considered. The production of Fel d 1 from cats is on average approximately 3 to 7 μg/d,[26] but showed a considerable range from day to day. Further influences are related to castration, breeds, washing routines, and so forth. A study in Germany showed also higher cat allergen concentration in mattress dust when the home was less often dusted. Dusting (wet or dry), but not vacuuming the floor, substantially reduced cat allergen levels on mattress dust and also in floor dust.[6] This study also did not show a statistically significant association between Fel d 1 concentration and frequency of vacuuming.

Cat allergen levels of this study were lowest in winter in univariate analysis (univariate results not shown). This result is in line with a German study[6] that reported substantially lower Fel d 1 means in floor dust in cat owners' homes and homes without a cat. Studies from the United States[21,27] and Sweden,[20] however, found higher levels of Fel d 1 in winter compared with warmer seasons. Chew et al[27] ascribed the winter increase to cats spending more time inside during the colder months. A representative sample of 831 US homes also showed slightly higher levels (nonsignificant) of Fel d 1 in winter.[21] The higher level in warmer seasons suggested by the results of this study and the German survey seem biological plausible, because they coincide with fur shedding cycles of cats. Furthermore, season is a surrogate measure for several other factors, such as humidity and ventilation, that may influence cat allergen levels.[28-30]

Mattresses serve as a major reservoir for dust and cat allergen, in particular for cat owners. Cat allergen in mattress dust increases with increasing age of the mattress, as other studies have shown.[6] Interestingly, our large study confirmed a previous finding of higher cat allergen levels in floor dust, in smokers' homes, in particular if a cat is present.[6] We are assuming a positive association between airborne cat allergen concentration and cat allergen levels in settled house dust, in line with others, although

TABLE IV. Association among housing, sampling, and study participant characteristics and log-transformed mattress Fel d 1 levels in cat owners from 22 study centers (N = 555)*

Determinant	N	Ratio of GMs	95% CI	*P* value
Type of property				
Detached house/bungalow	216	1.00		.126
Building built as house converted into flats	10	0.33	0.06-1.72	
Building originally built as a flat/apartment	201	1.08	0.56-2.09	
Terraced house	68	1.90	0.92-3.92	
Semidetached house/bungalow	60	0.75	0.36-1.56	
Are cats allowed inside a house?				
Yes	517	1.00		<.0001
No	35	0.10	0.04-0.28	
Are cats allowed inside a bedroom?				
Yes	389	1.00		<.0001
No	158	0.22	0.13-0.36	
Number of people living in home				
5 Or more persons	95	1.00		<.001
4 Persons	146	0.82	0.42-1.60	
3 Persons	140	2.12	1.07-4.19	
2 Persons	132	2.64	1.28-5.41	
1 Person	42	1.59	0.54-4.68	
Number of rooms				
5 Or more rooms	127	1.00		.253
4 Rooms	136	1.02	0.55-1.88	
3 Rooms	137	1.47	0.77-2.80	
2 Rooms	94	1.50	0.68-3.32	
1 Rooms	52	2.98	1.04-8.53	
Ventilation				
Yes	418	1.00		.043
No	115	0.56	0.32-0.98	
Have you ever smoked for as long as a year?				
Yes	327	1.00		.032
No	228	0.63	0.41-0.96	

*Multilevel model: ratio of GMs for random intercept model to allow clustering for center.

this is controversial.[28,31] Luczynska et al[32] and Munir et al[20] observed increasing Fel d 1 concentrations in settled dust with increasing airborne particles. Presumably cat allergen is bound on airborne particles, and these particles can coagulate and deposit on indoor surfaces. Smoking is a strong source of indoor concentration of particulate matter.[33-35] Because of the binding of small amounts of cat allergens on smoking-related particulate matter, the concentration of airborne cat allergens might be increased, and consequently, allergen concentrations might also be increased in settled dust. This association was restricted to cat owners' homes. We speculate that the amount of cat allergen transferred into a noncat owning home is not sufficient to interact with tobacco smoke–related particles, or the size of the cat passive-transported allergen is too big to be bound on small airborne tobacco smoke–related particles, or a combination of both.

Comparison of cat allergen levels in mattress dust between different studies

There is no common accepted protocol for collecting dust samples in terms of whether on sheets or on removed sheets, sampling duration and area size, flow rates, filter material, dust storage, sieving, extraction, or assaying the dust. The magnitude of the effects of these methodologic differences could not be estimated. Therefore, any comparisons of cat allergen levels in mattress regardless of the different underlying methods seem to us to be invalid. Therefore, we have not compared the cat allergen levels of these studies with results of other numerous studies. However, determinants of Fel d 1 could be compared between studies.

Interrelationship between exposure to cat allergen and specific IgE to cat on the community level

This study did not support the speculation that current second-hand exposure to cat allergen assessed by community prevalence of cat ownership or averaged Fel d 1 levels were associated with community prevalence of detectable IgE to cat. However, this result should be interpreted with caution. The assessment of current second hand exposure to cat allergen did not reflect the relevant time window for exposure to develop allergic sensitization, which is early life.[8-10,12] Current community prevalence of cat ownership and measured cat allergen levels in mattress dust samples may not be a valid proxy for exposure to cat allergen early in life. In addition, the power

of this study to identify associations between community prevalence of cat ownership and detectable cat IgE per center is smaller than in a previous study using baseline data from ECRHS.[5]

Strengths and limitations

A major strength of this study is the identical protocol for dust collection used in all centers and that Fel d 1 was measured in 1 single laboratory using identical batches of kits. The multivariable models showed biologically plausible determinants.

Several other characteristics of the indoor factor substudy of ECRHS II should be considered as further strengths: the variation between the European centers with differences in culture, lifestyle factors, housing, climate, and many other factors.

There are also several limitations of our study that need to be considered. First, the result of this study is restricted to larger municipal areas (administrative boundaries of 150,000 inhabitants) and therefore could not be considered as representative for entire countries or the whole of Europe. Including rural areas might lead to different results. Second, because of passive transport of cat allergens by shoes and clothes, the levels are higher on floor dust samples (if the floor is not smooth) than mattress. We only sampled mattress dust and might have missed further important cat allergen reservoirs such as sofas.[21] However, cat allergen levels are highly correlated between floor and mattress dust, with a correlation coefficient of approximately 0.75[21] to 0.8,[6] because of the ubiquitous distribution of cat allergens in homes. Fel d 1 in mattress dust might serve as a valid proxy for the total exposure to indoor cat allergen. In addition, the mattress is closer to the breathing zone when sleeping at night, and it might be therefore more relevant because people spend a significant part of their time in bed. Third, we did not ask for species, numbers, and sex of the cats and therefore could not analyze their associations with cat allergen concentration.

There is a large variation in cat ownership and Fel d 1 concentrations in Europe. Passive transport of Fel d 1 in noncat owning homes is a major issue in Europe. Not having a cat substantially reduces Fel d 1 concentration, but does not protect against high Fel d 1 exposures in communities where cat ownership is common. Cat owners should not allow cats inside the house to reduce the Fel d 1 exposure, and should be aware that indoor smoking increases the level of cat allergen.

In Memoriam

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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