
The relationship of housing and household characteristics to the indoor concentrations of Der f 1, Der p 1, and Fel d 1 measured in dust and air samples

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Background: Indoor dust mite and cat allergens have been related to the risk of atopic conditions. If allergen levels are influenced by modifiable residential characteristics, potential interventions to prevent disease could be deployed.

Objective: To evaluate relationships between allergen concentrations in air and dust samples and selected house and household characteristics using a large prospective study with multiple sequential allergen measurements from each residence.

Methods: Fel d 1, Der f 1, and Der p 1 were measured in paired air and dust samples collected at intervals throughout 4 years in suburban homes. House and household characteristics were examined for relationships to allergen concentrations in both univariate and multiple variate analyses.

Results: The relationships between house and household characteristics and allergen concentrations in both air and dust were complex. When the housing variables were considered in multiple variate analysis, concentrations of Der f 1 in dust increased with increasing number of residents and relative humidity and declined when forced air heating was used. Dust concentrations of Der p 1 were lower in new homes and during forced air heating use but higher with higher relative humidity and in the presence of dogs. The presence of cats was the dominant determinant of Fel d 1 in both air and dust, but when homes without cats were analyzed separately, dust levels of Fel d 1 were inversely related with relative humidity.

Conclusions: Air and dust concentrations of Der p 1 and Der f 1 were positively related to relative humidity and the size of the family. Fel d 1 was positively related to the presence of cats. The relationship of other house or household characteristics was inconsistent but different for Der f 1 and Der p 1.

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INTRODUCTION

Exposure to high concentrations of mite allergens, Der p 1 and Der f 1, has been reported to be related to allergic sensitization to these allergens and to asthma and asthma severity.^{1–5} Relationships between these allergens and atopic conditions have been extensively evaluated in both epidemiologic and clinical studies.^{1–8} Sensitization to dog and cat allergens has also been associated with asthma in children and adults.^{9–17}

From a prevention perspective, it is important for both researchers and clinicians to know if residential characteristics are associated with indoor allergen exposure. Numerous

studies^{4,5,16,18–22} exploring relationships between allergen concentrations in the dust and various house and household conditions have been reported. In general, these studies have been limited because they either were cross-sectional or had only a few sequential observations or a small number of houses. Another critical issue is how household characteristics are associated with settled dust vs airborne allergen concentrations.^{4,23} Airborne allergens presumably better represent the allergens people are actually exposed to, but airborne concentrations are highly dependent on the level of activity in a room immediately before or during air sampling.^{4,24} Allergen concentrations in dust samples are more stable but may not be as closely correlated with actual exposure. The purpose of this study is to relate airborne and dust concentrations of three major indoor allergens, Der f 1, Der p 1, and Fel d 1, to structural characteristics of the house and to household variables using a prospective cohort design.

METHODS

Study Population

The data used in these analyses were collected as part of an ongoing study evaluating environmental determinants of allergic diseases in a population of children followed up from birth. Selection of the study cohort has been previously

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described in detail.²⁵ Eligibility criteria included the following: residency in suburban Detroit, Michigan, age of 18 years or older, membership in a health maintenance organization, and pregnancy with a due date between April 1987 and August 1989. Study children with cord blood IgE levels of more than 0.56 IU/mL were followed up with monthly home visits during the first 2 years of life and every other month until the age of 4 years. At each home visit, air and dust samples were taken from the child's bedroom as previously described,²⁶ and the child's parent or caregiver was asked to complete a detailed questionnaire.

Air and Dust Sampling

Dust samples were obtained by vacuuming a 1-m² area of floor directly beside the child's bed for 2 minutes. Shortly after dust collection, 24-hour air samples were obtained from the same room using a volumetric air sampler (Air Sentinel; Quan-Tec-Air Inc, Minneapolis, MN) with the same type of filters as those in the vacuum. The sampling volume was 86.4 m³ of air at a rate of approximately 1 L/s.

The air and dust samples were assayed for Der f 1, Der p 1, and Fel d 1 using previously described monoclonal antibody-based assays (Indoor Biotechnologies Ltd, Chester, England). The ranges of the standard curves were 1 to 125 ng/mL for Der f 1 and Der p 1 and 0.04 to 10 U/mL for Fel

d 1. The assays had been standardized at the University of Virginia by Martin Chapman, PhD. Interassay coefficients of variation were typically less than 12% for all three assays.²⁶

The units for dust measurements were micrograms per gram of dust ($\mu\text{g/g}$) for the dust mite allergens and units per gram of dust (U/g) for cat allergen. In the air, the units are expressed as micrograms per 100 m³ of air ($\mu\text{g}/100\text{ m}^3$) for dust mites and units per 100 m³ of air (U/100 m³) for cat allergen (1 U = 4 ng of Fel d 1).⁴ Temperature and humidity measurements were made in the child's bedroom at the time of the home visits using electronic thermohygrometers, which were calibrated every 3 to 4 months and whenever the battery was changed.

House and Household Characteristics

When the child was 6 years old, caregivers were asked to complete a questionnaire that included information about all houses the child had lived in since birth. The type of house was categorized as one-story (ranch), two-story (colonial), and other (split level, trilevel, bungalow, or other). Information about each house included the number of rooms, whether the house had a basement, and whether the study family was the first to occupy the house after its completion (defined as a new home). Additional data from each home visit included whether forced air heating or air-conditioning had been used

Table 1. Descriptive Statistics of House Characteristics (n = 118)*

Variable	n	Dust			Air		
		Der f 1	Der p 1	Fel d 1	Der f 1	Der p 1	Fel d 1
Housing type							
1-Story	60	4.0 $\pm$ 4.3	2.4 $\pm$ 3.9	7.5 $\pm$ 18.8	1.6 $\pm$ 0.9	2.6 $\pm$ 3.0	17.1 $\pm$ 76.5
2-Story	39	5.6 $\pm$ 8.0	1.5 $\pm$ 2.7	12.2 $\pm$ 30.4	1.6 $\pm$ 0.7	1.7 $\pm$ 2.0	13.1 $\pm$ 29.2
Other	19	7.3 $\pm$ 7.7	1.0 $\pm$ 1.1	8.7 $\pm$ 15.9	1.5 $\pm$ 0.9	1.7 $\pm$ 2.2	14.9 $\pm$ 35.1
New home							
No	98	4.9 $\pm$ 6.4	2.1 $\pm$ 3.5	9.2 $\pm$ 23.7	1.6 $\pm$ 0.9	2.3 $\pm$ 2.7	16.3 $\pm$ 63.2
Yes	20	5.9 $\pm$ 6.4	0.8 $\pm$ 0.8	9.2 $\pm$ 18.8	1.7 $\pm$ 0.8	1.5 $\pm$ 1.6	11.1 $\pm$ 25.1
Basement in house							
No	36	3.6 $\pm$ 4.1	2.6 $\pm$ 4.6	8.9 $\pm$ 23.5	1.5 $\pm$ 0.6	2.9 $\pm$ 3.6	24.3 $\pm$ 97.8
Yes	82	5.7 $\pm$ 7.1	1.5 $\pm$ 2.4	9.4 $\pm$ 22.7	1.6 $\pm$ 1.0	1.8 $\pm$ 2.0	11.5 $\pm$ 27.5
House has forced air heat							
No	5	4.8 $\pm$ 8.9	2.0 $\pm$ 3.0	1.2 $\pm$ 1.6	1.7 $\pm$ 0.6	3.0 $\pm$ 6.0	1.6 $\pm$ 2.3
Yes	113	5.1 $\pm$ 6.3	1.9 $\pm$ 3.3	9.6 $\pm$ 23.3	1.6 $\pm$ 0.9	2.1 $\pm$ 2.4	16.1 $\pm$ 56.7
House has air-conditioning							
No	54	5.3 $\pm$ 7.5	2.7 $\pm$ 4.4	10.3 $\pm$ 26.8	1.5 $\pm$ 0.7	2.6 $\pm$ 3.2	11.9 $\pm$ 26.9
Yes	64	4.9 $\pm$ 5.4	1.2 $\pm$ 1.7	8.3 $\pm$ 19.0	1.7 $\pm$ 1.0	1.8 $\pm$ 1.8	18.5 $\pm$ 75.6
Household pets							
Cats							
No	81	5.8 $\pm$ 7.1	1.8 $\pm$ 3.1	1.3 $\pm$ 1.4	1.6 $\pm$ 1.0	2.0 $\pm$ 2.4	0.8 $\pm$ 0.8
Yes	37	3.5 $\pm$ 4.2	2.0 $\pm$ 3.6	26.5 $\pm$ 35.3	1.5 $\pm$ 0.6	2.4 $\pm$ 2.9	47.6 $\pm$ 97.8
Dogs							
No	61	6.1 $\pm$ 7.6	1.2 $\pm$ 1.8	9.8 $\pm$ 28.1	1.7 $\pm$ 1.1	1.9 $\pm$ 2.3	17.0 $\pm$ 76.0
Yes	57	4.0 $\pm$ 4.6	2.5 $\pm$ 4.2	8.6 $\pm$ 15.6	1.4 $\pm$ 0.4	2.5 $\pm$ 2.9	13.8 $\pm$ 30.7
Birds							
No	110	5.3 $\pm$ 6.6	1.8 $\pm$ 3.1	9.7 $\pm$ 23.6	1.6 $\pm$ 0.9	2.1 $\pm$ 2.6	16.2 $\pm$ 60.5
Yes	8	1.9 $\pm$ 1.5	2.3 $\pm$ 4.9	3.2 $\pm$ 4.2	1.3 $\pm$ 0.3	2.5 $\pm$ 3.0	5.0 $\pm$ 8.0

* Data are presented as mean $\pm$ SD.

in the previous month. Household characteristics included the number of full-time residents in the home and the type and number of pets in the home. The variables considered are presented in Tables 1 and 2.

Statistical Methods

A generalized estimating equation (GEE) approach to linear regression was used to assess the relationship between allergen concentration and various housing and residence characteristics.²⁷ The concentration of each allergen, as measured in air and in dust, was analyzed separately. For analysis, values below the detectable limit for each of the 3 allergens were set at 0.42 $\mu\text{g/g}$ and 0.01 $\mu\text{g}/100\text{ m}^3$ for Der f 1 in the dust and air, respectively; 0.08 $\mu\text{g/g}$ and 0.002 $\mu\text{g}/100\text{ m}^3$ for Der p 1 in the dust and air, respectively; and 0.04 U/g and 0.0009 U/100 m^3 for Fel d 1 in the dust and air, respectively. The distributions of the allergen concentrations were skewed, so a logarithmic transformation was used for analyses.

In all analyses, the unit of analysis or cluster was considered to be the home. It was assumed that different homes, even if occupied by the same family, were independent. The repeated measurements within a particular home over time defined the cluster of observations used in the GEE analysis. An exchangeable variance-covariance structure, assuming equal variances and equal covariances between groups, was specified for analysis, and $P < 0.05$ was considered statistically significant.

The independent variables type of house, number of rooms, presence of a basement, and whether the house was newly built were constant within the cluster. Variables that could change over time included the number of residents in the home, use of air-conditioning or forced air heating, presence of a pet and the type of pet (cat, dog, or bird), and relative humidity. The values for the time-dependent variables that could vary represent the month before the date of the in-home interview and sample collection.

In every model generated, the covariate season of observation was included. This variable was defined as 3 indicator variables for winter (December, January, and February), spring (March, April, and May), and summer (June, July, and August). The reference category was fall (September, October, and November). The inclusion of this covariate adjusts

for time of measurement, since allergen concentrations vary by season.^{19,28,29}

All independent variables were assessed individually for significance. A multiple variate approach using backward stepwise regression (GEE) identified the best set of predictors for each allergen. Because of the expected strong relationship between the presence of cats in a home and the concentrations of Fel d 1, secondary analyses were performed to examine house characteristics and air and dust concentrations of Fel d 1 restricted to homes without cats.

RESULTS

Of 107 children with elevated cord blood IgE levels, 85 (79%), who had resided in a total of 118 homes during the study, were still in the study at 6 years. Fifty-six children lived in the same house throughout the study, 25 lived in two houses, and 4 lived in three houses. Household measurements were gathered during 2,289 visits (75% of the 3,060 planned) made uniformly by season: 23% during winter, 25% during spring, 26% during summer, and 26% during fall. One-story ranches accounted for 50.8% of the homes, whereas 33.1% were two-story colonials and 16.1% were other styles (Table 1). Nearly all homes had forced air heating, whereas 55.1% had air-conditioning. Forced air heat was used during the month that samples were collected 68% of the time and air-conditioning during 14.5% of the months.

Der f 1 concentrations were higher than Der p 1 in dust samples, whereas the reverse was true for air samples (Table 2). The number of persons residing in the houses ranged from 3 to 7, and cats or dogs were present in more than 50% of the homes.

Regression analysis of variables adjusted only for season of collection are presented in Tables 3 and 4. The coefficient indicates how much the estimate of the allergen concentration changes (in log units) for each unit change in the variable considered, with a positive coefficient indicating an increase and a negative one a decrease. When the variable is a yes/no indicator, the coefficient indicates the change in allergen concentration in log units when the variable is present vs absent.

Der p 1 and Der f 1 in the dust were significantly inversely related to the use of forced air heating and positively related to relative humidity. Der p 1 but not Der f 1 dust concentrations were significantly lower in new houses and tended to be higher in homes with dogs. Der f 1 but not Der p 1 dust concentrations tended to be significantly higher as the number of residents increased. The presence of neither cats nor birds influenced mite allergen concentrations in dust samples. The only variable significantly related to the concentrations of both mite allergens measured in air samples was relative humidity. Airborne Der p 1 was significantly lower in both new houses and houses with basements. Airborne Der f 1 concentrations increased significantly with the number of rooms and residents in the house. As expected, there was a strong and highly significant relationship between the presence of cats and Fel d 1 concentrations in both air and dust (Table 4). The only other

Table 2. Allergen Concentrations and Other Variables (n = 118)

Variable	Mean (SD)	Range
Der f 1, dust, $\mu\text{g/g}$	5.07 (6.39)	0.42–39.83
Der f 1, air, $\mu\text{g}/100\text{ m}^3$	1.59 (0.86)	0.88–7.31
Der p 1, dust, $\mu\text{g/g}$	1.87 (3.27)	0.08–19.51
Der p 1, air, $\mu\text{g}/100\text{ m}^3$	2.16 (2.59)	0.18–13.70
Fel d 1, dust, U/g	9.22 (22.83)	0.05–164.61
Fel d 1, air, U/100 m^3	15.44 (58.48)	0.13–583.70
Relative humidity, %	46.6 (5.8)	33.2–67.2
No. of rooms	6.4 (2.0)	3.0–13.0
No. of residents	4.1 (0.9)	3.0–7.0

Table 3. Variables Examined One at a Time to Predict Dust Mite Allergen Concentrations Measured in Dust and Air

Variable	Der p 1, Dust		Der f 1, Dust		Der p 1, air		Der f 1, air	
	Coefficient (SD)	P Value	Coefficient (SD)	P Value	Coefficient (SD)	P Value	Coefficient (SD)	P Value
Housing type								
1-Story	0.297 (0.228)	0.20	-0.436 (0.273)	0.11	0.341 (0.192)	0.08	-0.002 (0.096)	0.98
2-Story	-0.085 (0.208)	0.68	-0.378 (0.297)	0.20	0.075 (0.181)	0.68	0.031 (0.098)	0.75
New home	-0.421 (0.157)	0.007	0.089 (0.258)	0.73	-0.271 (0.137)	0.047	0.056 (0.067)	0.40
Basement	-0.273 (0.248)	0.27	0.279 (0.181)	0.12	-0.439 (0.186)	0.02	0.050 (0.053)	0.34
No. of rooms	0.041 (0.052)	0.43	0.041 (0.048)	0.39	-0.027 (0.037)	0.46	0.025 (0.010)	0.01
Forced air heating	-0.276 (0.100)	0.006	-0.320 (0.064)	0.001	0.176 (0.104)	0.09	0.058 (0.038)	0.12
Air-conditioning	-0.151 (0.088)	0.09	0.033 (0.090)	0.71	0.026 (0.119)	0.83	0.013 (0.045)	0.77
No. of residents	0.119 (0.068)	0.08	0.119 (0.047)	0.01	0.056 (0.069)	0.41	0.077 (0.025)	0.002
Pets								
Cats	0.015 (0.147)	0.92	-0.058 (0.110)	0.60	0.122 (0.171)	0.47	-0.052 (0.054)	0.34
Dogs	0.283 (0.130)	0.03	-0.012 (0.146)	0.93	0.175 (0.176)	0.32	-0.083 (0.065)	0.20
Birds	0.464 (0.341)	0.17	0.242 (0.228)	0.29	0.034 (0.252)	0.89	-0.005 (0.064)	0.94
Relative humidity	0.009 (0.003)	0.001	0.004 (0.002)	0.03	0.013 (0.003)	0.001	0.002 (0.001)	0.048

Table 4. Variables Examined One at a Time to Predict Cat Allergen Measured in Dust and Air

Variable	Fel d 1, Dust		Fel d 1, Air	
	Coefficient (SE)	P Value	Coefficient (SE)	P Value
Housing type				
1-Story	-3.06 (0.407)	0.45	-0.108 (0.485)	0.82
2-Story	0.143 (0.451)	0.75	0.109 (0.528)	0.97
New home	0.040 (0.419)	0.92	-0.209 (0.470)	0.66
Basement	0.354 (0.316)	0.26	-0.134 (0.355)	0.71
No. of rooms	0.040 (0.072)	0.58	-0.034 (0.070)	0.62
Forced air heating	0.072 (0.100)	0.47	0.271 (0.083)	0.001
Air-conditioning	-0.158 (0.086)	0.07	0.129 (0.084)	0.13
No. of residents	0.021 (0.067)	0.75	0.003 (0.070)	0.97
Pets				
Cats	3.065 (0.223)	0.001	3.310 (0.253)	0.001
Dogs	-0.096 (0.204)	0.64	0.081 (0.167)	0.63
Birds	-0.650 (0.583)	0.26	-0.722 (0.546)	0.19
Relative humidity	-0.007 (0.004)	0.06	-0.003 (0.003)	0.38

significant relationship was an increase in Fel d 1 in the air when forced air heating was in use.

The results of the multiple variate analyses are summarized in Tables 5 and 6. The coefficients represent the change in the allergen concentration when all other variables in the model are constant, and the *P* value is conditional on all other variables being in the model. Der p 1 dust concentrations were lower in new homes and when forced air heating and air-conditioning were used and higher when a dog was present and when relative humidity increased (Table 5). Considering Der f 1, only a negative association with the use of forced air heat and a positive association with the number of residents were found.

When airborne concentrations of mite allergens were considered, the relationships changed. Airborne Der p 1 concentrations were higher in both one-story and two-story houses, when forced air heating was used, and when the relative humidity increased, but lower if the home was new or if a basement was present. Airborne Der f 1 concentrations were

positively associated with the number of rooms in the house and the number of residents. Fel d 1 increased with the presence of cats in the home and decreased with increasing relative humidity (Table 6). Fel d 1 in the air was negatively associated with basements and positively associated with forced air heat, air-conditioning, and the presence of a cat. Given the overwhelming effect of having a cat in the home, we repeated the analyses for Fel d 1 for homes without cats (Table 7). In both models for Fel d 1 in dust, the only significant relationship was an inverse relationship with humidity. The multiple variate analyses of airborne Fel d 1 revealed lower levels associated with the presence of a basement and higher levels with the use of forced air heating or air-conditioning.

DISCUSSION

When allergic patients inquire about household characteristics that might influence their disease, the clinician has many studies to consider, but the data are not necessarily clear.

Table 5. Multiple Variate Models for Dust Mite Allergen Concentrations Measured in Dust or Air

Allergen	Variable	Coefficient (SD)	P Value
Der p 1, dust	New home	−0.357 (0.151)	0.02
	Forced air heat	−0.288 (0.101)	0.004
	Air-conditioning	−0.210 (0.090)	0.02
	Dogs	0.286 (0.133)	0.03
	Relative humidity	0.009 (0.003)	0.001
Der f 1, dust	Forced air heat	−0.316 (0.064)	0.001
	No. of residents	0.115 (0.046)	0.01
Der p 1, air	1-Story house	0.433 (0.197)	0.03
	2-Story house	0.383 (0.200)	0.055
	New home	−0.265 (0.133)	0.046
	Basement	−0.465 (0.191)	0.02
	Forced air heat	0.215 (0.102)	0.04
	Relative humidity	0.014 (0.003)	0.001
	No. of rooms	0.021 (0.010)	0.04
Der f 1, air	No. of residents	0.075 (0.024)	0.002

Published studies have often evaluated different house characteristics, partially because of the wide differences in the types of construction and the ages of homes in different cities.^{28,30–33} Some studies were performed in single-family dwellings, whereas others examined apartments or college dormitories.^{16,28,34–36} Studies also come from many different countries with widely varying climates.^{28,30–32} Many studies concentrated exclusively on dust mite allergens.^{19,22,32–37} Few studies provide data on large numbers of homes, longitudinal data on homes, or analysis of multiple factors simultaneously. Our study examined more than 100 homes across 4 years with up to 36 observations for a single home. We also examined multiple variables simultaneously. For example, the decrease in mite concentrations with forced air heating was typically assumed to be the result of decreased humidity with heating, but our analysis shows that for Der p 1 dust heating, air-conditioning, and relative humidity remain significant in the model, suggesting that they are providing different information. The results of our study are generally consistent with those of many other studies, but our results cannot be easily summarized.

The most consistent observation in the literature and in this study is that the presence of cats is the greatest determinant of Fel d 1 levels in air and dust samples.^{4,16,23,38–40} When homes without resident cats were considered separately, the only significant relationship to Fel d 1 levels in dust was a decline

with increasing humidity. Others have reported that Fel d 1 levels increase or remain unchanged with increasing humidity.^{18,41,42} We found that airborne Fel d 1 levels were increased when forced air heat or air-conditioning were in use and decreased when a basement was present. The increased levels with heating or air-conditioning may simply relate to the forced movement of air keeping higher levels of Fel d 1 suspended, but we cannot explain lower levels in homes with basements. Although it may be that cats are often kept, at least at night, in basements, we could not examine this possibility or find any published studies on this question. Since Fel d 1 is presumably brought into the home on the clothing of occupants, it is likely that exposure to cat allergens outside the home is a much more important factor related to Fel d 1 levels than any other household or housing characteristic.^{43,44}

The closely related variables most commonly associated with mite allergen levels are humidity, moisture, and ventilation.^{4,22,30–33,36,37,41,45–49} Additional variables related to the availability of water for mite growth are the climatic region in which the study was conducted and the use of air-conditioning and forced air heating.^{19,22,28} Consistent with most studies, we found that increasing levels of mite allergens in dust were associated with higher levels of relative humidity and that the use of forced air heating or air-conditioning in the month before the sample was associated with lower mite allergen levels. The only one of these factors related to airborne mite allergen concentrations was relative humidity. In our multivariate analyses, the only one of these water-related variables significantly associated with Der f 1 concentrations was use of forced air heating, whereas for Der p 1 concentrations forced air heating, air-conditioning, and relative humidity each independently contributed to the model. The results of models for airborne mite allergens were similar but not identical. The separate results for Der f 1 and Der p 1 are apparent for both dust and air samples. This is consistent with the literature⁷ and reinforces the consideration of sampling both allergens through both modes in studies that measure allergen exposure.

Both Der f 1 and Der p 1 levels have been observed to increase with increasing numbers of people in homes, consistent with our findings.^{28,32} Others have also reported differences in mite allergen levels related to the presence of basements, floors above the ground floor, and new homes consistent with our findings with Der p 1.^{28,30,45,50} We were surprised that new homes did not have significantly lower concentrations of Der f 1. Possible reasons for the lack of an association between new homes and Der f 1 concentrations include the higher dust concentrations of Der f 1 compared with Der p 1 and the possibility that *Dermatophagoides farinae* mites may be able to colonize new homes more rapidly in the climatic conditions typical of the midwestern United States. The presence of a dog being related to increased Der p 1 levels has been previously reported in the literature.¹⁵

Table 6. Multiple Variate Models for Cat Allergen Concentrations Measured in Dust and Air

Allergen	Variable	Coefficient (SE)	P Value
Fel d 1, dust	Cats	3.072 (0.225)	0.001
	Relative humidity	−0.008 (0.003)	0.01
Fel d 1, air	Basement	−0.454 (0.179)	0.01
	Forced air heat	0.210 (0.079)	0.008
	Air-conditioning	0.171 (0.083)	0.04
	Cats	3.346 (0.251)	0.001

Table 7. Summary of Results for Analysis of Households without Cats

Variable	Fel d 1, dust		Fel d 1, air	
	Coefficient (SE)	P Value	Coefficient (SE)	P Value
Variables considered individually				
Housing type				
1-Story	−0.296 (0.200)	0.14	−0.042 (0.140)	0.76
2-Story	−0.147 (0.213)	0.49	−0.253 (0.147)	0.08
New home	−0.009 (0.167)	0.95	−0.163 (0.143)	0.25
Basement	0.220 (0.126)	0.08	−0.287 (0.139)	0.04
No. of rooms	0.014 (0.028)	0.60	−0.034 (0.028)	0.19
Forced air heating	−0.079 (0.112)	0.48	0.210 (0.084)	0.01
Air-conditioning	−0.106 (0.084)	0.21	0.124 (0.068)	0.07
No. of residents	0.040 (0.065)	0.54	0.051 (0.066)	0.44
Pets				
Dogs	−0.144 (0.157)	0.36	0.212 (0.132)	0.11
Birds	0.196 (0.196)	0.32	0.034 (0.238)	0.89
Relative humidity	−0.008 (0.004)	0.03	0.001 (0.003)	0.69
Multiple variate models				
Relative humidity	−0.008 (0.004)	0.03		
Basement			−0.302 (0.143)	0.04
Forced air heat			0.246 (0.085)	0.004
Air-conditioning			0.175 (0.068)	0.01

The most important strengths of this study are the repeated allergen measurements during a 4-year interval, the relatively large number of houses, measurements of three allergens, and simultaneous air and dust measurements. Our study is unique in the large number of longitudinal measurements from a single house (up to 36). This, coupled with the number of houses studied (118), resulted in a study with high statistical power for analysis, allowing the confirmation of less precise estimates found in smaller previous studies.

As with many studies, we were limited to a single geographic area, with a midcontinental-type climate, that is, relatively cold winters and hot summers with widely varying levels of outdoor humidity. It would have been valuable for us to have measured ventilation rates in the homes and humidity during relatively long intervals, such as a week, rather than the spot measurements during home visits.^{31,46,47} The homes we studied were also so uniform (96%) in the use of forced air heating that we were unable to compare forced air vs other types of heating. We did not attempt to gather data on certain construction details, such as vapor barriers or insulation in outer walls, nor did we attempt to inspect for signs of water damage.^{4,18,31,46}

The analyses in this study are consistent with other analyses from this cohort of children that show that there are major differences between air and dust allergen measurements.²⁶ The air measurements we used were taken during a 24-hour interval and therefore represent an average of the fluctuations in allergen levels that result from varying amounts of disturbance in the child's bedroom.^{4,24} Unfortunately, we do not have information on how much day-to-day variation there would have been if these measurements had been taken for several days in succession.

When considered together, our findings and those of others suggest that Fel d 1 levels are controlled by the presence or absence of a cat with little effect from the type of house or household characteristics. Der f 1 and Der p 1 levels are related to several variables, presumably all associated with the availability of water for mite growth, but there are significant differences in these patterns that may be related to subtle biological differences between these mite species.

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