

Mite and Cat Allergen Levels in Homes and Severity of Asthma

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The relationships between mite and cat allergen levels in the home, skin test reactivity, and severity of asthma were explored in 120 asthmatic subjects, 57 in Vancouver and 63 in Winnipeg. Patients in the two cities were similar in age, gender distribution, and severity of asthma. Skin tests were performed using 13 common allergens, including *D. pteronyssinus*, *D. farinae*, and cat dander, as well as control subjects. Patients recorded their asthma symptoms, medication requirement, and twice daily peak expiratory flow rate for 1 yr. Dust samples were collected every 3 mo during each season of 1992 through 1993 in both cities. Mite and cat allergen levels were determined with an ELISA using monoclonal antibodies against Der p I, Der f I, and Fel d I. There was no relationship between skin test reactivity and levels of mite and cat allergens. In children with positive skin tests to either mite allergen, total mite (sum of Der p I and Der f I) allergen level was positively related to the mean daily symptom score and negatively related to the daily mean PEF (% of predicted). There was no such relationship among adult asthmatic patients with positive skin tests to either mite allergen. No relationship was found between cat allergen level and the severity of asthma. **Chan-Yeung M, Manfredi J, Dimich-Ward H, Lam J, Ferguson A, Warren P, Simons E, Broder I, Chapman M, Platts-Mills T, Becker A. Mite and cat allergen levels in homes and severity of asthma.**

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Indoor aeroallergens, such as allergens from house dust mites and pets, have been recognized as important causes of asthma. Voorhorst and coworkers (1) in 1964 first suggested that the most important source of allergen in house dust is mites of the genus *Dermatophagoides*. *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae* and *Euroglyphus maynei* were identified as species of importance (2). House dust mites are ubiquitous, and sensitization to these antigens is common. Clinical studies have shown that the proportion of sensitized asthma patients as reflected by either positive skin tests or presence of specific IgE antibodies to house dust mite is significantly higher than for those without asthma (3-5). Improvement in asthma symptoms occurs in children in areas with low humidity and relatively few house dust mites (2). Effective mite reduction measures have resulted in improvement of nonallergic bronchial hyperresponsiveness, in reduction in the frequency and severity of symptoms, and in the need for antiasthma medication (6, 7). These findings strongly

implicate house dust mites as an important causal agent for asthma. However, recent studies have shown that exposure to pet allergens may be a more important cause of asthma than mite allergens in areas where house dust mites are not abundant, such as at high altitudes (8). There is little information on the relationship between cat allergen level and the severity of asthma.

The purpose of this study was to examine the relationship between mite and cat allergen levels and the severity of asthma in patients followed for 1 yr in two Canadian cities.

METHODS

Subjects

A total of 120 patients with asthma were recruited consecutively from tertiary referral university clinics in Vancouver and Winnipeg over a period of 2 mo for a study on environmental risk factors in asthma. The criteria for inclusion were as follows: (1) they lived within 10 km radius from the clinics, and (2) for those over the age of 55, the diffusing capacity was within normal limits. The subjects had to satisfy the diagnostic criteria for asthma: symptoms associated with variable airflow limitation and/or nonspecific bronchial hyperresponsiveness. They were studied four times in 1 yr.

Questionnaire

At the time of recruitment by trained interviewers, a questionnaire was administered. There were questions on asthma symptoms and their severity, medications required, aggravating factors, hospitalization, emergency room visits for asthma, personal and family history of atopy, smoking, and occupational history.

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Diary Card

The patients were asked to record on a diary card their chest symptoms and medication requirements for 1 yr. The symptoms included the following: cough, wheeze, and breathlessness during the day and night and activity level during the day. Each symptom was scored as follows: 0, no symptom or normal; 1, mild; 2, moderate; and 3, severe. The daily symptom score was calculated by adding the scores for each symptom (day and night cough, wheeze, breathlessness, and activity during the day). Daily use of bronchodilators and steroids was calculated as the total number of puffs or tablets and then converted to the actual dose in milligrams. In addition, they recorded their peak expiratory flow (PEF) each morning and evening before the use of inhaled bronchodilators. The mini-Wright® peak flowmeter was used. On each occasion, the patients were asked to perform a forced expiratory maneuver at least three times until there were at least two readings within 5% of each other. The best PEF was recorded on each occasion. The prediction equations for PEF were based on the data of Hsu and colleagues (9) for children and Nunn and Gregg (10) for adults. The mean daily PEF (% of predicted) was calculated by averaging the morning and evening PEF measurements. In addition, the diurnal variation was calculated (Δ PEF%) for each subject as the difference between the morning and the evening PEF and was expressed as a percentage of the morning PEF.

Allergy Skin Tests

A total of 13 allergens, as well as histamine and normal saline acting as positive and negative controls, were used for skin testing by the prick method. The allergens used included grass, tree, and weed pollens, mold spores, cat and dog epidermal antigens, *D. farinae*, and *D. pteronyssinus*. Normal saline and histamine (1 mg/ml) were used as negative and positive controls, respectively. Skin tests were read at 15 min. The wheals were outlined, and measurements were made of the maximal diameter of the wheal and its perpendicular diameter. The average of the two diameters was used in the analysis. A wheal diameter 3 mm greater than the negative control was considered a positive reaction. Atopy was defined as a positive skin test reaction to one or more of the allergens tested.

Spirometry

Spirometry was carried out at the onset of the study and every 3 mo for 1 yr. Measurements were performed according to the American Thoracic Society recommendations (11). Forced expiratory volume in one second (FEV₁), forced vital capacity (FVC), and maximal midexpiratory flow rate were measured. The prediction equations used for both children and adults were derived from the data of Knudson and coworkers (12), with a correction factor of 0.85 applied to the nonwhite adults (13).

House Dust Collection and Measurement of Mite and Cat Allergen Levels

Home visits were carried out on all patients every 3 mo during each season of the year, starting in the winter of 1991 and ending in the winter of 1992. On each occasion, dust samples were collected using a portable vacuum cleaner, with a special sock attachment. The material for the socks had pore sizes between 5 and 10 μ m in diameter. The patient's bedroom floor was vacuumed once, covering all areas. The bed mattress was vacuumed for 2 min. The socks were placed in Zip-Loc® bags and stored at -20° C until analyzed.

Large particles were removed by sieving through a 300 μ m mesh sieve before processing. Samples of dust were extracted in borate-buffered saline in the ratio of 100 mg to 2 ml, left overnight, and filtered. Extracts were stored at -20° C until being analyzed for mite allergen level.

Monoclonal antibodies against purified Der p I, Der f I, and Fel d I antigens were used in the ELISA for quantifying mite and cat allergen levels in these extracts (14, 15). The extracts of house dust were diluted 1:5, 1:10, and 1:100 for assay in duplicate. The species-specific monoclonal antibodies were used to coat microtiter plates, which were then incubated with the standard or the extracts. Bound allergen was detected using a separate biotinylated monoclonal antibody that recognized a different epitope on Fel d I for cat allergen and a common epitope on both Der p I and Der f I for mite allergen assay, followed by the addition of streptavidin-peroxidase and 2,2'-azino-bis-(3-ethylbenzthiazoline-6-sulfonic acid)/H₂O₂ substrate. The absorbance was read from an ELISA reader at 405 nm. The amount of antigen present in the dust sample

was calculated from a standard curve. The lower detection limit for each allergen was 0.5 ng/ml. Levels below the lower detection limit were treated as zero in value.

Statistical Analysis

The following data were used in the present analysis: the exposure to allergens was measured on quarterly visits to the subject's home. FEV₁ was obtained during the subject's visit to the laboratory within days of the home visit. The symptom scores, use of inhaled bronchodilators and steroids, average PEF, and Δ PEF were obtained for each subject by averaging the values obtained on the day of home visit and preceding 6 d. These values reflect the severity of asthma in that season.

The results were analyzed using the SPSS and SAS statistical packages on an IBM 486 personal computer. Logarithmic transformation was carried out on allergen levels to attempt to normalize the distribution. Demographic data were analyzed parametrically using Student's *t*-test. The chi-squared statistic was used to test for differences in proportions.

General linear models (GLM) for repeated measurements (16) were used to determine if the indicators of asthma severity (or exposure to allergens) were different in the two cities, whether they differed across the four seasons, and whether any seasonal variation that existed was consistent in each city. The model used is a split-unit analysis of vari-

ance (17). In this design, repeated observations in each season were obtained for each subject sampled within two cities. Cities and seasons were fixed effects, and subjects sampled within cities were random effects.

To determine whether symptom score (or mean PEF or Δ PEF) were (in addition to variation by city and season) related to exposure to allergens, the total mite allergen concentration and the use of inhaled bronchodilators and steroids were tested as covariates in this model. The data for children and adults were analyzed separately.

RESULTS

Characteristics of Patients

Equal numbers of males and females were recruited in each city. The characteristics of the children and adult patients are shown in Table 1. The prevalence rates of atopy were high. Over 85% of the children in both cities were atopic. Among adult patients, the prevalence of atopy was 72% in Vancouver and 90% in Winnipeg. A higher proportion of patients had positive skin test reactions to cat allergen than to either mite allergen. Other than a higher percentage of nonwhite patients in Vancouver, there were no significant differences between patients in the two cities.

There were also no differences in the socioeconomic status of patients in both cities as reflected by the patient education and occupation or in the characteristics of their homes, such as

TABLE 1
CHARACTERISTICS OF THE PATIENTS STUDIED

	Children	Adult
n	52	68
Male, %	59.6	38.2
Whites, %	82.7	85.3
Age, yr (mean $\pm$ SD)	9.9 $\pm$ 2.1	36.6 $\pm$ 13.7
Duration of asthma, yr (mean $\pm$ SD)	6.9 $\pm$ 3.2	15.6 $\pm$ 11.1
Smoking history, %		
Nonsmoker	100	64.7
Exsmoker	0	32.4
Current smoker	0	2.9
Either parent smokes	26.9	Not available
Immediate skin test reactivity, %		
Any allergen	90.4	80.9
<i>D. farinae</i>	40.4	42.6
<i>D. pteronyssinus</i>	46.2	44.1
Cat allergen	67.3	55.9
Past history, %		
Hospitalization	50	48.5
Emergency room treatment	84.6	57.4

TABLE 2
HOUSE DUST MITE AND CAT ALLERGEN LEVELS ($\mu\text{g/g}$ DUST, GEOMETRIC MEAN AND SD)
AND INDOOR RELATIVE HUMIDITY BY SEASON AND CITY

	Winter	Spring	Summer	Fall	p Value*
Total mite allergen (Der p I and Der f I)					
Vancouver	1.73 (3.03)	2.17 (3.04)	1.95 (2.73)	1.23 (2.41)	C: < 0.001
Winnipeg	0.94 (2.38)	0.77 (2.61)	0.50 (1.91)	0.40 (1.65)	S: < 0.001
					I: 0.080
Total floor mite allergen (Der p I and Der f I)					
Vancouver	1.33 (2.24)	1.81 (2.49)	1.56 (2.17)	1.18 (2.10)	C: 0.003
Winnipeg	0.76 (2.12)	0.83 (2.16)	0.74 (2.06)	0.58 (2.08)	S: 0.012
					I: 0.669
Mattress Fel d I					
Vancouver	0.89 (2.39)	0.79 (2.08)	0.65 (1.75)	0.67 (2.18)	C: 0.017
Winnipeg	1.92 (2.20)	1.69 (2.38)	1.05 (2.67)	0.68 (1.89)	S: < 0.001
					I: 0.016
Floor Fel d I					
Vancouver	0.90 (2.04)	0.74 (1.80)	0.78 (1.67)	0.83 (1.86)	C: < 0.001
Winnipeg	2.18 (2.15)	2.34 (2.16)	1.50 (2.79)	1.38 (2.03)	S: 0.035
					I: 0.007
Indoor Relative Humidity					
Vancouver	54.4 $\pm$ 10.0	57.1 $\pm$ 8.0	63.9 $\pm$ 7.6	55.9 $\pm$ 9.2	C: < 0.001
Winnipeg	40.5 $\pm$ 6.7	56.0 $\pm$ 18.2	56.2 $\pm$ 7.3	46.1 $\pm$ 5.7	S: < 0.001
					I: < 0.001

Definition of abbreviations: SD = standard deviation; C = cities; S = season; I = city $\times$ season interaction.

* Result of GLM procedure for repeated measurement.

the mean age of the house and the type of housing. The number of occupants in the home were also similar (data not shown).

Mite and Cat Allergen Levels

The levels of mite (sum of Der p I and Der f I) and cat allergen levels in mattress and bedroom floor dust samples and indoor relative humidity by season in the two cities are shown in Table 2. The mean mite allergen levels in both mattress and floor samples were significantly higher in the homes of asthmatic patients in Vancouver, compared with Winnipeg, during all seasons. This may be because of higher indoor humidity in Vancouver compared with Winnipeg. On the other hand, the mean Fel d I levels in mattress and floor samples were higher in Winnipeg than in Vancouver. The seasonal variation varied significantly between the two cities. Although there was little seasonal variation in Vancouver, the highest cat allergen levels were found indoors in homes in Winnipeg.

Allergen Levels and Skin Test Reactivity

The relationships between levels of allergen in the homes (average for the year) and skin test reactivity are shown in Table 3. There was no correlation between levels of allergens and the prevalence of positive skin test reactions to these allergens in either children or adults.

Severity of Asthma

As shown in Table 4, children in Winnipeg compared with Vancouver had more symptoms and used significantly more inhaled bronchodilators and inhaled steroids; they also had a higher mean PEF (% of predicted) and a lower mean diurnal variation in PEF, but not significantly different from those in Vancouver. The mean PEF varied significantly by season, and the seasonal pattern was similar in both cities: the highest values were achieved in winter. FEV₁ also varied significantly by season, although the pattern was significantly different for each city. There was no difference in any parameter between adult asthmatic subjects in the two cities (Table 5). Only the use of inhaled steroids varied significantly by season, with no difference in the pattern between the two cities.

Allergen Levels and Severity of Asthma

For children, symptom score was different between cities but not between seasons (Table 4). To determine if in addition there was a relationship to mite allergen and use of inhaled bronchodilators and steroids, these variables were added to the model as covariates. The model was run separately for children who were allergic and those who were nonallergic to mites. The same model was repeated for mean PEF and Δ PEF by replacing symptom score in the model by either of these two variables. The relationship between covariates (total mite allergen, and inhaled steroids and bronchodilators) and symptom score, mean PEF, and Δ PEF (%), respectively, for mite allergic and nonallergic children after the effects of cities, seasons, and between-subject differences have been controlled for are shown in Table 6. It can be seen that the total mite allergen was associated with symptom score and mean PEF only in children allergic to mites. In nonallergic children, there was a significant effect of bronchodilator use on symptom score and mean PEF. In adult patients with and without house dust mite allergy, there was no relationship between the total mite allergen levels and any of the clinical parameters after adjustment for these covariates.

TABLE 3
AVERAGE ALLERGEN LEVELS* ($\mu\text{g/g}$ DUST, GEOMETRIC MEAN AND SD) AND SKIN TEST REACTIVITY

	Skin Test Reactivity			
	Children		Adult	
	Positive ($\geq 3\text{mm}$)	Negative ($< 3\text{mm}$)	Positive ($\geq 3\text{mm}$)	Negative ($< 3\text{mm}$)
Cat Allergen				
Average Fel d I	2.04 (1.81)	3.16 (2.23)	2.87 (2.53)	1.79 (2.23)
<i>D. farinae</i>				
Average Der f I	1.07 (1.82)	1.19 (2.23)	1.50 (2.71)	1.33 (2.15)
Average Der p I	1.38 (2.58)	0.51 (1.89)	1.02 (2.43)	0.43 (1.87)
<i>D. pteronyssinus</i>				
Average Der f I	1.06 (1.98)	1.22 (2.14)	1.60 (2.64)	1.25 (2.19)
Average Der p I	1.18 (2.50)	0.55 (1.94)	0.97 (2.42)	0.45 (1.88)

* Mean of the sum of mattress and floor samples for all four seasons.

TABLE 4
WEEKLY MEAN SYMPTOM SCORE/DAY, MEAN PEF (% OF PREDICTED),
 Δ PEF (%), MEDICATION USE, AND SEASONAL FEV₁ ACCORDING
TO SEASON AND CITY IN CHILDREN

	Winter	Spring	Summer	Fall	p Value*
Symptom score					
V	1.08 (1.36)	0.81 (1.29)	0.61 (1.29)	0.56 (1.76)	C: 0.04
W	1.36 (1.63)	1.77 (2.09)	1.64 (3.20)	1.73 (2.89)	S: 0.94 I: 0.57
Mean PEF, % of predicted					
V	93.7 (16.6)	96.3 (18.4)	101.8 (16.8)	104.3 (17.3)	C: 0.73
W	99.7 (15.4)	100.1 (13.3)	101.9 (15.2)	104.9 (12.6)	S: < 0.001 I: 0.12
Δ PEF, %					
V	-5.8 (10.8)	-4.5 (6.8)	5.8 (13.3)	-5.2 (9.2)	C: 0.14
W	-2.3 (8.2)	3.9 (8.3)	-1.9 (6.1)	-3.9 (9.2)	S: 0.95 I: 0.73
Bronchodilator, μ g/d					
V	155 (300)	159 (331)	105 (279)	110 (282)	C: 0.02
W	259 (277)	364 (255)	328 (241)	365 (282)	S: 0.13 I: 0.21
Inhaled steroid, μ g/d					
V	168 (340)	147 (288)	164 (253)	105 (174)	C: < 0.001
W	537 (429)	589 (348)	694 (602)	599 (548)	S: 0.21 I: 0.31
FEV ₁ , % of predicted					
V	100.6 (16.7)	105.1 (15.8)	109.3 (15.6)	107.2 (13.7)	C: 0.75
W	108.6 (25.7)	106.4 (20.8)	105.5 (31.7)	111.0 (28.8)	S: < 0.01 I: < 0.01

Definition of abbreviations: V = Vancouver; W = Winnipeg.

* Results of GLM procedure for repeated measurements.

The analysis was repeated using mattress mite allergen and floor mite allergen levels separately as covariates. Mattress allergen levels were directly associated with symptom scores and inversely correlated with the mean PEF, but floor mite allergen levels had no relationship with symptom scores but were inversely related to the mean PEF (data not shown).

The same model was also used to explore the relationship between the severity of asthma and cat allergen level, adjusting for the same covariates as in the preceding analysis. Levels of Fel d I were not significantly related to the total symptom score, the mean PEF, or the diurnal variation in PEF in either children or adults with or without allergy to cats (Table 7).

TABLE 5
WEEKLY MEAN DAILY SYMPTOM SCORE/DAY, MEAN Δ PEF (% OF PREDICTED),
 Δ PEF (%), AND MEDICATION USE AND SEASONAL FEV₁
ACCORDING TO SEASON AND CITY IN ADULTS

	Winter	Spring	Summer	Fall	p Value*
Symptom score					
V	1.56 (2.44)	1.62 (2.23)	1.09 (1.70)	1.23 (1.92)	C: 0.52
W	1.72 (2.04)	1.74 (2.56)	1.64 (2.59)	1.77 (3.02)	S: 0.52 I: 0.63
Mean PEF, % of predicted					
V	79.9 (15.3)	79.9 (16.9)	81.8 (16.3)	82.8 (14.8)	C: 0.67
W	80.0 (13.6)	80.2 (14.9)	79.1 (16.0)	77.6 (14.3)	S: 0.97 I: 0.22
Δ PEF, %					
V	-7.4 (11.8)	-5.6 (11.4)	-6.8 (15.5)	-4.0 (8.7)	C: 0.28
W	-8.2 (10.7)	-7.9 (15.7)	-0.3 (21.7)	-14.3 (27.1)	S: 0.26 I: 0.08
Bronchodilator, μ g/d					
V	400 (286)	358 (259)	339 (261)	384 (309)	C: 0.18
W	488 (375)	488 (390)	477 (356)	495 (422)	S: 0.26 I: 0.25
Inhaled steroids, μ g/d					
V	830 (508)	835 (565)	742 (551)	884 (651)	C: 0.56
W	709 (621)	710 (641)	794 (599)	889 (758)	S: 0.01 I: 0.23
FEV ₁ , % of predicted					
V	82.6 (19.2)	85.1 (18.3)	86.5 (20.3)	83.5 (18.4)	C: 0.58
W	87.1 (21.5)	88.9 (24.2)	86.7 (22.8)	84.8 (22.6)	S: 0.40 I: 0.39

Definition of abbreviations: V = Vancouver; W = Winnipeg.

* Result of CLM procedure for repeated measurements.

TABLE 6
THE EFFECT OF MITE ALLERGEN EXPOSURE AND MEDICATION USE ON SYMPTOM SCORE,
MEAN PEF, AND DIURNAL VARIATION IN PEF*

	Symptom Score		Mean PEF (% of predicted)		Δ PEF (%)	
	Effect	CI	Effect	CI	Effect	CI
Children						
Mite nonallergic						
Total mite allergen, $\mu\text{g/g}$ dust	0.03	(-0.64, 0.70)	-1.73	(-5.36, 1.90)	2.29	(-0.43, 5.01)
Inhaled steroid, 100 $\mu\text{g/d}$	-0.1	(-0.30, 0.10)	1.0	(-0.18, 2.18)	0.9†	(0.12, 1.68)
Inhaled bronchodilator, 100 $\mu\text{g/d}$	0.3†	(0.10, 0.50)	-2.0†	(-3.96, -0.04)	0.4	(-0.58, 1.38)
Mite allergic						
Total mite allergen, $\mu\text{g/g}$ dust	0.9†	(0.14, 1.74)	-4.93‡	(-8.14, -1.72)	-1.75	(-5.02, 1.52)
Inhaled steroid, 100 $\mu\text{g/d}$	-0.1	(-0.30, 0.10)	-0.1	(-0.69, 0.49)	0.1	(-0.49, 0.69)
Inhaled bronchodilator, 100 $\mu\text{g/d}$	0.3	(0.10, 0.50)	-0.4	(-1.38, 0.58)	-1.0†	(-2.96, 0.96)
Adults						
Mite nonallergic						
Total mite allergen, $\mu\text{g/g}$ dust	-0.63	(-1.32, 0.06)	-0.44	(-2.24, 1.36)	-1.06	(-3.71, 1.59)
Inhaled steroid, 100 $\mu\text{g/d}$	0.2	(0.18, 0.22)	-0.1	(-0.30, 0.10)	0.1	(-0.10, 0.30)
Inhaled bronchodilator, 100 $\mu\text{g/d}$	0.3	(0.10, 0.50)	-0.7†	(-1.30, -0.11)	-0.8	(-1.58, -0.02)
Mite allergic						
Total mite allergen, $\mu\text{g/g}$ dust	0.06	(-0.41, 0.53)	-0.04	(-1.78, 1.70)	3.16	(-0.86, 7.18)
Inhaled steroid, 100 $\mu\text{g/d}$	0.1	(-0.19, 0.21)	-0.1	(-0.30, 0.10)	-0.7	(-1.48, 0.08)
Inhaled bronchodilator, 100 $\mu\text{g/d}$	0.3†	(0.10, 0.50)	-0.3	(-0.89, 0.29)	-0.1	(-2.57, 0.57)

* Controlled for the effect of cities, seasons, and individuals (see text for description of models). Only the results for the continuous variables are shown.

† $p < 0.05$.

‡ $p < 0.01$.

DISCUSSION

House dust mites have long been suspected of being associated with asthma. A high proportion of patients with asthma are sensitized to house dust mite, in comparison with those without asthma (3-5). Ecologic correlations between levels of house dust mite in the homes and the prevalence of asthma have been observed. For instance, in such areas as coastal regions, where the relative humidity is high, the prevalence of asthma is also high, but in such areas as high-altitude and cold climates, where mite allergen levels are low, the prevalence of asthma is also low (18-24). High mite allergen exposure has also been found to increase the risk of sensitization in atopic children and young adults (24). Sporik and colleagues (25) found that children whose homes

had high mite allergen levels during the second year of life were at a higher risk for developing asthma than those with low levels. Moreover, the higher the levels of exposure, the earlier the development of symptoms of asthma and the more severe the asthma. Arshad and coworkers (26) conducted a randomized clinical trial on children at high risk of developing allergy and asthma. The prophylactic group had measures to reduce house dust mite exposure in addition to dietary restriction (by the mother for the breast-fed babies and special formula for the non-breast-fed ones). The control group had no treatment. At the end of 12 mo, those in the control group had four times the risk of developing asthma, defined as recurrent wheezing, than those in the prophylactic group. However, at the end of 24 mo, the effect on wheezing illness was not obvious (27).

TABLE 7
EFFECT ON CAT ALLERGEN EXPOSURE AND MEDICATION USE ON SYMPTOM SCORE,
MEAN PEF, AND DIURNAL PEF VARIATION*

	Symptom Score		Mean PEF (% predicted)		Δ PEF (%)	
	Effect	CI	Effect	CI	Effect	CI
Children						
Cat not allergic						
Total Fel d I, $\mu\text{g/g}$ dust	0.17	(-0.66, 1.0)	-1.94	(-5.19, 1.31)	-0.67	(-6.0, 4.66)
Inhaled steroid, 100 $\mu\text{g/d}$	-0.1	(-0.30, 0.10)	0.1	(-0.49, 0.69)	-0.5	(-1.48, 0.48)
Inhaled bronchodilator, 100 $\mu\text{g/d}$	1.0†	(0.80, 1.20)	-1.0	(-2.57, 0.57)	-0.8	(-3.35, 1.75)
Cat allergic						
Total Fel d I, $\mu\text{g/g}$ dust	0.69	(-0.11, 1.49)	-2.39	(-6.47, 1.69)	-0.04	(-2.57, 2.49)
Inhaled steroid, 100 $\mu\text{g/d}$	-0.1	(-0.30, 0.10)	0.5	(-1.48, 1.48)	0.2	(-0.39, 0.79)
Inhaled bronchodilator, 100 $\mu\text{g/d}$	0.1	(-0.10, 0.30)	-0.7	(-1.88, 0.48)	-0.6	(-1.19, -0.01)
Adults						
Cat not allergic						
Total Fel d I, $\mu\text{g/g}$ dust	0.58	(-0.05, 1.21)	-0.55	(-2.26, 1.16)	-0.56	(-3.40, 2.28)
Inhaled steroid, 100 $\mu\text{g/d}$	-0.1	(-0.22, 0.02)	-0.1	(-0.30, 0.10)	0.1	(-0.29, 0.49)
Inhaled bronchodilator, 100 $\mu\text{g/d}$	0.2†	(0.004, 0.40)	-0.8	(-1.3, -0.21)	-1.0	(-1.98, -0.02)
Cat allergic						
Total Fel d I, $\mu\text{g/g}$ dust	-0.09	(-0.44, 0.26)	-0.07	(-1.54, 1.40)	-0.72	(-3.97, 2.53)
Inhaled steroid, 100 $\mu\text{g/d}$	0.1†	(-0.10, 0.30)	-0.1	(-0.30, 0.10)	-0.9	(-1.68, -0.12)
Inhaled bronchodilator, 100 $\mu\text{g/d}$	0.3†	(0.10, 0.50)	-0.1	(-0.70, 0.50)	-0.6	(-1.97, 0.77)

* Controlled for the effects of cities, seasons, and individuals (see text for description of models). Only the results for the continuous variables are shown.

† $p < 0.05$.

Although there have been studies showing that reducing mite allergen level in homes is associated with improvement in asthma, indicating that house dust mite exposure in sensitized subjects is clinically important (7, 8), there are very few studies to examine the relationship between house dust mite allergen levels and the severity of asthma. Van der Heide and coworkers (28) found that there was a significant relationship between the level of house dust mite allergen and the degree of nonspecific bronchial hyperresponsiveness in nine patients with house dust mite allergy observed over a period of 1 yr. The degree of nonspecific bronchial hyperresponsiveness was lowest in the months August to November, when the mite allergen level was highest. De Blay and coworkers (29) reported exacerbations of asthma symptoms or rhinitis in mite-allergic patients when they were in houses with high mite allergen levels; in houses with low allergen levels, these patients had no symptoms. Kivity and colleagues (30) also examined the relationship between mite allergen levels in homes and asthma severity in 12 children studied over a period of 6 mo. There was no correlation between monthly measurements of house dust mite in mattresses with symptom score, lung function, or non-specific bronchial hyperresponsiveness. The authors concluded that the lack of correlation was caused by the high levels of dust

mites with little seasonal variation in the homes.

In this study, we examined the relationship between mite allergen levels and asthma severity of 120 patients with asthma. We found that mite allergen levels were directly related to the daily mean symptom score and inversely related to the mean PEF (% of predicted) averaged over a period of 7 d before dust sample collection, only in children who had positive skin tests to mite allergens. This finding indicates that the level of mite allergens is an important determinant of asthma severity in these children. Such a relationship was not found in children without house dust mite allergy. These observations differ from those made in Kivity's study of asthmatic children in Israel (30). There are several reasons for the discrepancy in findings between the two studies. The levels of house dust mite allergens in the two Canadian cities were low throughout the year, compared with measurements made in many parts of the world, such as the United Kingdom and in coastal regions in Australia, where mite allergen levels greater than 10 µg/g dust are often found (8, 20). The levels of mite allergens in the homes of these two cities were similar to those reported in Scandinavian homes (31-34). In addition, we mea-

sured mite allergen levels rather than counting the number of mites.

Although the number of subjects in this study is small, the power to detect significant effects was increased by repeated observations on the same subjects. Using the GLM procedure for repeated measures, the effects were estimated within subjects. In the analysis, the effects were either strongly significant or not significant at all. There were very few instances with "borderline" significance levels in which a larger number of subjects could be important. We believe that the compliance was generally good. There is no evidence that compliance was better or worse at the beginning or the end of the study or between different subgroups (mite allergic versus nonallergic) that might explain the findings of this study. The analysis is unlikely to be biased by the fact that the reduction of mite allergen exposures occurred in mite-allergic children but not the nonallergic children because the reduction in exposure to mite allergen in both groups were similar from the onset to the end of the study.

As expected, we found that mite allergen levels in mattress samples were more important than levels in floor samples as a determinant of asthma severity in children with house dust mite allergy. We were unable to show a relationship between mite allergen levels and the severity of asthma in adults with house dust mite allergy as reported by van der Heide and coworkers (28).

On the other hand, our adult patients were older and, on average, had a longer duration of asthma. These patients may have less reversible asthma than those with a shorter duration of symptoms, as observed for children. This is similar to occupational asthma, when those with the longest duration of symptoms are less likely to recover (35). The other possibility is that children are more likely to be in the same home at the time of the study as the time of sensitization, but adults were more likely to have changed their place of residence several times since sensitization.

It is interesting to note that in this population with relatively low exposure to house dust mite allergens, one can still observe the effects of house dust mite exposure on children. Despite the high prevalence of sensitization to cat allergen among this group of patients, the level of cat allergen in the homes was not related to severity of asthma in those with cat allergy. This difference between cat and mite allergens may be because there was insufficient seasonal variation in cat allergen levels or that measurement of cat allergen in settled dust is less reliable as an indicator of the concentration present in the air (15). House dust mite exposure is more consistent in the children than cat allergen exposure because cats may have been introduced or removed from homes during the child's lifetime.

We failed to demonstrate a relation between skin test reactivity and current allergen exposure, with the exception of skin test reactivity to *D. pteronyssinus*. There have been several reports of high levels of Fel d I in schools and in homes without cats (36, 37). It is possible that sensitization to these indoor allergens might have occurred in the past, and in cat allergen, it might have taken place outside the homes.

We found that the mite allergen levels were related to the mean daily symptom scores and the mean PEF of the week before the collection of house dust samples but not to FEV₁, which was measured within 2 to 3 wk of house dust sample collection. Because asthma is a disease characterized by variable airflow limitation, serial measurements of PEF and daily symptom score are more sensitive methods of assessing asthma severity.

Our findings underscore the importance of house dust mite allergens in determining the severity of asthma in children with house dust mite allergy. Physicians should test for house dust mite allergy in children with asthma and prescribe the known effective measures to reduce house dust mite exposure in sensitized subjects.

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