

# Clinical aspects of allergic disease

## Mite allergen (Der p 1) concentration in houses and its relation to the presence and severity of asthma in a population of Sydney schoolchildren

Guy B. Marks, MBBS, PhD, Euan R. Tovey, PhD,  
Brett G. Toelle, B Appl Sc, Susie Wachinger, Jennifer K. Peat, PhD,  
and Ann J. Woolcock, MD Sydney, Australia

*House dust mite (HDM) allergen exposure and its relation to HDM allergy and asthma was assessed in a case-control study conducted over three seasons in 74 Sydney schoolchildren, 33 of whom were allergic to HDM and 12 of whom had current asthma. In each season, histamine inhalation tests and skin prick tests were performed, symptom questionnaires were administered, and dust samples were collected. The mean concentrations of HDM allergen (in micrograms of Der p 1 per gram of fine dust) were: bed, 38.9 (95% confidence interval [CI], 31.8 to 47.5); bedroom floor, 22.4 (95% CI, 18.3 to 27.5); and lounge room floor, 13.7 (95% CI, 10.7 to 17.6). The mean of the highest allergen concentration in each house was 51.0 (95% CI, 43.2 to 60.1). All but two subjects had at least one site in all seasons with an HDM allergen concentration greater than 10 µg/gm, the proposed threshold for asthma symptoms. Subjects with allergy to HDM, symptoms of asthma, or airway hyperresponsiveness did not have higher HDM allergen concentrations in their houses. In this study we were unable to test hypotheses concerning proposed thresholds for risk of sensitization and for risk of asthma symptoms because virtually all subjects were exposed to HDM allergen levels above the proposed thresholds. (J ALLERGY CLIN IMMUNOL 1995;96:441-8.)*

**Key words:** Asthma, allergens, house dust mite, risk

Over the past 30 years, there has been increasing evidence of a strong association among house dust mite (HDM) allergen exposure, allergy to HDM, and allergic disease.<sup>1-9</sup>

Subjects with asthma are more likely to be allergic to HDM than subjects without asthma.<sup>2, 3, 9</sup> In one study of atopic subjects, the level of HDM

### Abbreviations used

FEV<sub>1</sub>: Forced expiratory volume in 1 second  
HDM: House dust mite

From the Department of Medicine, University of Sydney, NSW Australia.

Dr. Marks was supported by a National Health and Medical Research Council of Australia Medical Research Scholarship. Additional financial support was provided by the Asthma Foundation of N.S.W., the National Health and Medical Research Council of Australia, the Community Health and Anti-Tuberculosis Association, the State Pollution Control Commission (of N.S.W.), Bankstown City Council, the N.S.W. Department of Health, and the Greater Union Organisation Pty Ltd.

Initially received for publication June 26, 1991; re-submitted in the same form June 26, 1994; revised Jan. 17, 1995; accepted for publication Jan. 18, 1995.

Reprints are not available.

Copyright © 1995 by Mosby-Year Book, Inc.

0091-6749/95 \$5.00 + 0 1/1/64732

exposure was correlated with the titer of anti-HDM serum IgE and the level of in vitro basophil response to allergen Der p 1.<sup>5</sup> Several population studies have shown that the level of previous or current exposure to HDMs influences the prevalence of asthma.<sup>4, 6, 8, 9</sup> The introduction of a new source of exposure to HDMs has been associated with the development of allergy to HDM and the manifestation of asthma.<sup>2</sup> On the other hand, removal from exposure to HDMs, either by admission to a hospital room<sup>10</sup> or moving to an alpine climate,<sup>11</sup> has been shown to reduce the severity of asthma.

It has been proposed that exposure to dust with concentrations of HDM allergen Der p 1 greater than 2 µg/gm is a risk factor for the development of IgE antibody and asthma and that exposure to

dust with an allergen concentration greater than 10  $\mu\text{g/gm}$  is a risk factor for acute attacks of asthma.<sup>6</sup> These threshold concentrations have been supported by several investigations,<sup>1, 4, 5, 8, 9</sup> although lower thresholds have been proposed.<sup>7</sup>

Several factors may affect the numbers of HDMs found in houses. In some countries with large seasonal fluctuations in climate, there are corresponding seasonal fluctuations in HDM numbers, with the highest numbers in the humid period, usually summer.<sup>4, 12, 13</sup> Some indoor environmental conditions appear to be more conducive to HDM growth and proliferation. Carpets and beds provide a reservoir of moisture and nutrients.<sup>14</sup> Gas appliances, which have been associated with a higher prevalence of respiratory symptoms among household occupants,<sup>15</sup> may alter indoor conditions, including humidity, to favor the proliferation of HDMs. Household pets shed skin scales, which are a food source for HDMs.<sup>16</sup>

Australia has a high level of morbidity associated with asthma and a high prevalence of allergy to HDM.<sup>17</sup> In a study of 1217 schoolchildren living in Sydney, 40% had ever experienced respiratory symptoms, 18% had wheezing in the preceding 12 months, and 11% had a combination of respiratory symptoms and airway hyperresponsiveness.<sup>17</sup> Thirty-two percent of these schoolchildren were allergic to HDM.

Little information on the concentrations of HDM allergen in Australian houses is available. However, *Dermatophagoides pteronyssinus* mites have been found in large numbers in coastal regions of Australia,<sup>18</sup> and preliminary measurements of HDM allergen Der p 1 have demonstrated high concentrations of this allergen in Sydney houses.<sup>19</sup>

The aims of this study were, first, to describe the distribution of HDM allergen concentrations in the houses of a group of Sydney schoolchildren and to identify some factors responsible for its variation; and, second, to examine the relationship between the HDM allergen concentration in dust in subjects' houses and both the presence of allergy to HDM and the presence and severity of asthma.

## METHODS

### Study design

A case-control study design was used with concurrent assessment of exposure (HDM allergen concentration) and outcomes (allergy to HDM and the presence and severity of asthma). All subjects were assessed in autumn (April), winter (July), and spring (October) in 1989. On each occasion, respiratory symptoms, airway responsive-

ness, allergy to HDM and other allergens, symptom score, and airflow variability were measured; and dust collected from each subject's bed and floor was assayed for HDM allergen Der p 1.

### Subject selection

Four hundred forty schoolchildren aged 8 to 10 years living in western Sydney were enrolled in a cross-sectional study of asthma and allergy in 1988.<sup>20</sup> Of these, 80 subjects were selected for this study to include equal numbers with and without airway hyperresponsiveness. Households were matched for the presence of carpets and household pets. There were five pairs of siblings in the study group. In the cases of three pairs of siblings who shared the same bedroom, only one floor sample was collected to represent the exposure of both children.

### Questionnaires

An initial questionnaire to parents included questions about the presence of carpets, gas appliances, and domestic pets within the house. At each assessment, the subject's parents were asked whether their child had experienced wheezing or nocturnal cough during the preceding 3 months. Subjects who were reported to have experienced one or both of these symptoms were classified as "symptomatic" for that period.

### Diary cards

Subjects completed a 2-week diary card during each assessment period. To represent the degree of interference with normal activity, symptoms were scored daily on a scale of 1 ("My breathing was good; I did everything") to 5 ("My breathing was very bad; I stayed at home all day"). The highest symptom score for each 2-week period was used as an indicator of asthma severity. Expiratory airflow was measured twice daily with an Airflometer (Glaxo, Inc., Research Triangle Park, N.C.).<sup>21</sup> The best of three attempts was recorded. Subjects who were using bronchodilators took readings before and 10 minutes after bronchodilator administration. Daily Airflometer variability was calculated as the range divided by the maximum reading, and the mean over 2 weeks was used as an indicator of asthma severity.

### Skin prick testing

Skin prick tests were performed on each subject's forearm as previously described.<sup>22, 23</sup> A battery of 14 common inhaled allergens (Hollister-Stier, Elkhart, Ind.) was tested: cockroach, house dust mix, the HDMs *D. farinae* and *D. pteronyssinus*, cat, dog, feathers, horse, ragweed, plantain, timothy grass, rye grass, and the molds *Alternaria tenuis* and *Aspergillus fumigatus*. A mean wheal size of 3 mm or greater was regarded as a positive response. Subjects were defined as being atopic if they had a positive response to any one of the allergens at any one of the three assessments, and they were defined as

being allergic to HDM if they had a positive response to *D. pteronyssinus* at any one of the three assessments.

### Lung function and airway responsiveness

Subjects were tested at least 6 hours after the last dose of inhaled bronchodilator and 12 hours after the last dose of oral bronchodilator. Lung function was measured on a Vitalograph dry spirometer (Vitalograph Co., Bucks, U.K.). Forced expiratory maneuvers were repeated until two values for forced expiratory volume in 1 second (FEV<sub>1</sub>), reproducible to within 100 ml, were obtained. The highest of these values was recorded.

Airway responsiveness was measured by means of a histamine inhalation test performed according to the rapid method.<sup>24</sup> Histamine was administered by a hand-held deVilbiss plastic nebulizer (no. 45; DeVilbiss Health, Inc., Somerset, Pa.) in doubling doses from 0.03 to 7.8  $\mu$ mol until FEV<sub>1</sub> fell by 20% or more. Salbutamol aerosol was administered to aid recovery in those subjects whose FEV<sub>1</sub> fell by 10% or more. The dose of histamine that caused a 20% fall in FEV<sub>1</sub> was read by linear interpolation from a plotted dose-response curve. Subjects with a greater than 20% fall in FEV<sub>1</sub> were regarded as having airway hyperresponsiveness. The dose-response slope was calculated as the final percentage fall in FEV<sub>1</sub> divided by total dose of histamine administered. This was used as an indicator of asthma severity, which could be calculated for all subjects in the study.<sup>25, 26</sup>

Subjects who had symptoms of wheezing or nocturnal cough during at least one assessment period and airway hyperresponsiveness on each occasion of testing were classified as having "current asthma."<sup>27</sup>

### HDM allergen measurement

Three samples of fine dust were collected by vacuuming a 1 m<sup>2</sup> area each of bedding (mattress, pillows, and bed coverings), bedroom floor, and living room floor for 1 minute each. The bedroom floor was not vacuumed during the autumn assessment. The collection was performed with a portable vacuum cleaner (Makita, model 4071D, Makita Electric Works, Ltd., Anjo, Aichi, Japan), which was modified to incorporate a nylon bag behind a wire mesh filter at the front of the device.<sup>19</sup> A separate nylon bag was used for each collection. Extraction of the dust sample and assay of the extract for Der p 1 were performed as described by Tovey et al.,<sup>19</sup> with the minor modification that weighed portions of sieved fine dust (generally about 50 mg) were extracted in 1 ml of buffer. The Der p 1 allergen for calculation of standard curves was provided with the assay kit. The allergen concentration was expressed as micrograms of Der p 1 per gram of fine dust.

*D. pteronyssinus* is the predominant HDM species in coastal Australia.<sup>28</sup> The other clinically relevant mites, *D. farinae* and *Euroglyphus maynei*, are rare in Sydney.<sup>29</sup> In this study we have considered Der p 1 to be representative of HDM allergen levels.

### Statistical analysis

Because the distribution of allergen concentrations is positively skewed, the calculations were performed on log<sub>10</sub>-transformed values. Results are expressed as the geometric mean and 95% confidence interval of the mean. Population (large sample) 95% confidence limits were calculated with the standard deviation of the distribution. For each house, at each assessment, the value of the highest allergen level among the three sites (bed, bedroom floor, and living room floor) was used for comparing allergen exposure among subjects. This is in conformity with the method of analysis of Sporik et al.<sup>8</sup> There was no clear dichotomy in this measurement of the exposure, so it was analyzed as a continuous variable. Comparison between groups was done by *t* test or analysis of variance. The results of the one-way analyses were checked by nonparametric tests, and when conclusions were different, these are stated. The relation between continuous and ranked variables was measured by Spearman's rank order correlation coefficient. The calculations were performed with the SAS statistical package (SAS Institute, Cary, N.C.).

## RESULTS

### Subjects

Of the initial 80 subjects, six were lost to follow-up from the winter assessment and were excluded from all analyses. Of the remaining 74 subjects, all underwent skin prick testing and assessment of airway responsiveness in autumn and winter, but three were not tested in spring. The following numbers of subjects had missing questionnaire, diary card, and/or allergen data: 21 in autumn (1 questionnaire, 18 diary cards, and 6 allergen measurements), 16 in winter (14 questionnaires and fourteen diary cards), and 16 in spring (15 questionnaires, 10 diary cards, and 2 allergen measurements).

### Allergen concentrations

The mean concentrations of Der p 1 for each site in each season are shown in Table I. The allergen concentration in living room floor dust was higher in autumn than in winter or spring ( $p = 0.047$  and  $p = 0.040$ , respectively). There were no significant seasonal differences in allergen concentrations at other sites.

In each season, the allergen concentration was higher in dust from the bed than in that from the bedroom floor and higher in dust from the bedroom floor than in that from the living room floor (both  $p < 0.005$ ). The highest mean allergen concentration over all assessments was in dust from the bed in 47 cases (63.5%), in dust from the bedroom floor in 16 cases (21.6%), and in dust from the living room floor in 11 cases (14.9%).

**TABLE I.** Mean Der p 1 concentrations ( $\mu\text{g/gm}$  fine dust) by household site and season

| Season | Bed                  | Bedroom floor        | Living room floor    | Highest concentration |
|--------|----------------------|----------------------|----------------------|-----------------------|
| Autumn | 40.4<br>(32.0, 51.1) | —                    | 18.6<br>(13.3, 25.9) | 49.8<br>(39.9, 62.2)  |
| Winter | 39.1<br>(31.8, 48.2) | 23.6<br>(18.7, 29.8) | 11.8<br>(8.7, 16.1)  | 53.2<br>(45.1, 62.8)  |
| Spring | 37.6<br>(29.6, 47.9) | 20.9<br>(16.7, 26.2) | 12.0<br>(9.0, 16.8)  | 50.7<br>(41.4, 62.1)  |
| Mean   | 38.9<br>(31.8, 47.5) | 22.4<br>(18.3, 27.5) | 13.7<br>(10.7, 17.6) | 51.0<br>(43.2, 60.1)  |

Confidence intervals are given in parentheses.

**TABLE II.** Effect of domestic environment on mean concentration of Der p 1 ( $\mu\text{g/gm}$ )

|               | Gas appliances |      |                | Household pets |      |                | Carpets |      |                |
|---------------|----------------|------|----------------|----------------|------|----------------|---------|------|----------------|
|               | Yes            | No   | <i>p</i> Value | Yes            | No   | <i>p</i> Value | Yes     | No   | <i>p</i> Value |
| Number        | 31             | 43   |                | 19             | 55   |                | 69      | 5    |                |
| Bed           | 38.6           | 39.0 | 0.96           | 65.9           | 32.4 | 0.0017         | 40.2    | 24.6 | 0.23           |
| Bedroom floor | 22.7           | 22.2 | 0.92           | 26.3           | 21.3 | 0.37           | 23.9    | 9.3  | 0.018*         |
| Living room   | 14.5           | 13.1 | 0.67           | 14.6           | 13.4 | 0.77           | 14.4    | 6.8  | 0.13           |

\* $p = 0.058$  by Wilcoxon rank sum test.

Fig. 1 shows that there was a linear distribution of the logarithm of HDM allergen concentration, except at the extremes. On the basis of the distribution of allergen concentrations observed, it was estimated that in this population 95% of beds had Der p 1 concentrations between 7.1 and 213.4  $\mu\text{g/gm}$ , 95% of bedroom floors had Der p 1 concentrations between 4.1 and 123.1  $\mu\text{g/gm}$ , and 95% of living room floors had Der p 1 concentrations between 1.7 and 109.6  $\mu\text{g/gm}$  (population 95% confidence limits).

In each season, the highest HDM allergen concentration was greater than 2  $\mu\text{g/gm}$  in all houses and was greater than 10  $\mu\text{g/gm}$  in all but one house (98.6%) in winter and spring and in all but two houses (97.1%) in autumn. Fig. 1 shows that the highest mean HDM allergen concentration over three seasons was greater than 10  $\mu\text{g/gm}$  in all but one house (98.6%).

#### Effect of domestic environment on allergen concentration

Table II shows that there was no significant difference in the mean HDM allergen concentration among the 31 houses with gas appliances (heater and/or cooker) and the 43 other houses. This remained the case when the analysis was confined to the winter allergen measurements. The

19 houses in which pets were allowed inside had higher HDM allergen concentrations in the subjects' beds than those without pets ( $p = 0.0017$ ), although there was no significant difference in floors. Only five houses had no carpets, and these tended to have lower allergen concentrations than the remaining houses. The difference was marginally significant in the bedroom floors but not at the other sites (Table II).

#### HDM allergen concentrations and allergy

Forty-five subjects were classified as atopic, and 33 of these subjects were allergic to HDM. Table III and Fig. 2 show that atopic subjects and those allergic to HDM did not have higher levels of Der p 1 in household dust than those who were not allergic. There was no apparent cutoff point that distinguished the allergen exposure of atopic subjects and those allergic to HDM from nonallergic subjects. Indeed, higher mean concentrations of allergen were found in the houses of subjects who were not allergic to HDM than in the houses of subjects allergic to HDM ( $p = 0.0059$ ). This is partly explained by the fact that four (12.1%) of the subjects who were allergic to HDM did not have carpets, compared with only one (2.4%) of the subjects who were not allergic to HDM. When terms for the presence of household pets and carpets were

**TABLE III.** Concentrations\* of HDM allergen Der p 1 ( $\mu\text{g/gm}$ ) in the presence and absence of various clinical outcomes in all subjects

|                             | Yes       | No        | <i>p</i> Value |
|-----------------------------|-----------|-----------|----------------|
| Atopy                       | 47.5 [45] | 60.0 [29] | 0.17           |
| HDM allergy                 | 40.5 [33] | 63.7 [41] | 0.0059         |
| Current asthma              | 33.4 [12] | 56.7 [62] | 0.018          |
| Any symptoms†               | 47.4 [39] | 57.8 [35] | 0.24           |
| Symptoms                    |           |           |                |
| Autumn                      | 51.5 [21] | 48.4 [46] | 0.80           |
| Winter                      | 42.8 [22] | 64.6 [38] | 0.032          |
| Spring                      | 45.4 [21] | 55.7 [37] | 0.41           |
| By season                   | 46.4      | 55.3      | 0.17           |
| Airway hyper-responsiveness |           |           |                |
| Autumn                      | 35.7 [18] | 57.7 [48] | 0.060          |
| Winter                      | 45.9 [24] | 59.1 [50] | 0.15           |
| Spring                      | 37.7 [23] | 61.5 [46] | 0.025          |
| By season                   | 39.9      | 59.4      | 0.0011         |

Numbers in brackets represent number of subjects with each clinical outcome.

\*The HDM concentration for each subject was calculated as the mean, over three seasons, of the highest level (among the three sites) at each assessment (except where data are presented separately for each season).

†Subjects with symptoms (wheezing or nocturnal cough) on at least one occasion.

included in the analysis of variance model, the significance of the difference in allergen concentrations between the subjects allergic to HDM and those not allergic to HDM decreased to  $p = 0.021$ .

### HDM allergen concentrations and disease

Thirty-nine subjects had symptoms of wheezing or nocturnal cough at least once during the study. Table III and Fig. 3 show that the mean, over three seasons, of the highest HDM allergen concentration at each assessment in these subjects' household dust was not significantly different from that found in the dust from houses of subjects without symptoms ( $p = 0.24$ ). This relationship did not differ significantly among the 33 subjects who were allergic to HDM and the remaining subjects ( $p = 0.45$  for the interaction term in analysis of variance).

On 25 occasions, subjects who had symptoms became free of symptoms, or vice versa, between adjacent seasons. These occasions were not associated with any significant fluctuations in allergen concentrations. The ratio of the highest allergen concentration when a subject had symptoms to the highest concentration when he or she was free of

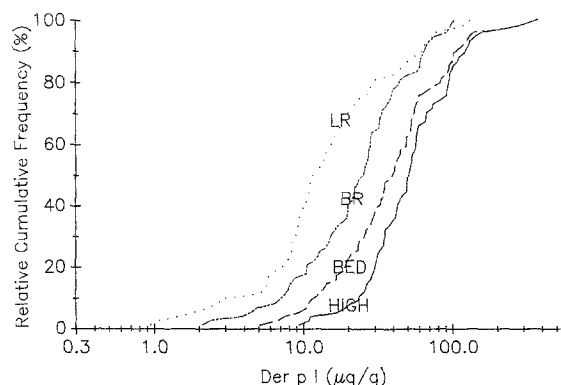


**FIG. 1.** Relative cumulative frequency distribution of mean (over all assessments) concentration of Der p 1 in living room floors (LR, dots), bedroom floors (BR, dash-dot), and beds (BED, long dash) and of the highest concentration in each house (HIGH, solid line). Means are calculated over all assessments.

symptoms was 0.97 (95% confidence interval, 0.64 to 1.48) ( $p = 0.90$ , by paired  $t$  test).

Twelve subjects were classified as having current asthma. Table III shows that the highest mean HDM allergen concentration in these subjects' houses was lower than in the remaining subjects' houses ( $p = 0.018$ ). Subjects who had airway hyperresponsiveness in any given season had lower HDM allergen concentrations in their household dust during that season than those without airway hyperresponsiveness ( $F_{1,205} = 10.9$ ,  $p = 0.0011$ , by two-way analysis of variance). Only one (8.3%) of the subjects with current asthma had a household pet compared with 18 (29.0%) of those without asthma. Inclusion of terms for the presence of carpets and household pets in the analysis of variance model reduced the significance of the difference between these groups to  $p = 0.043$  in the comparison of those with and without current asthma and to  $p = 0.0055$  in the comparison of those with and without airway hyperresponsiveness. When analysis was confined to subjects allergic to HDM, there was no significant difference in the highest allergen concentrations in the houses of subjects with and without current asthma or airway hyperresponsiveness. These relationships did not differ significantly between the subjects allergic to HDM and the remaining subjects ( $p > 0.8$  for the interaction terms in analysis of variance models).

Table IV shows the data from all subjects who had symptoms at one or more assessments ( $n = 39$ ). There was no significant correlation between the highest allergen concentration and either symptom score, Airflometer variability, or dose-response slope. The findings were similar when the

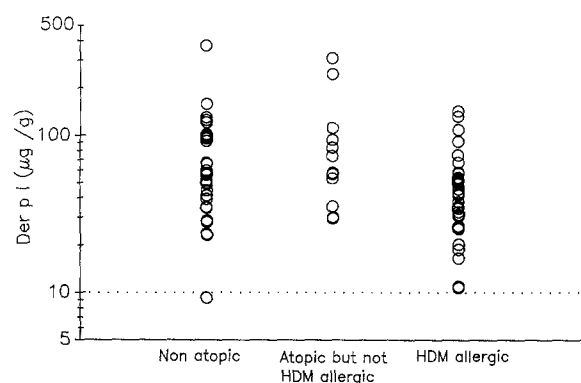


**FIG. 2.** Highest mean concentration of Der p 1 in subjects grouped according to the presence of HDM allergy and atopy. The dotted line at 10 µg/gm represents the proposed threshold level of risk for asthma symptoms in subjects allergic to HDM.

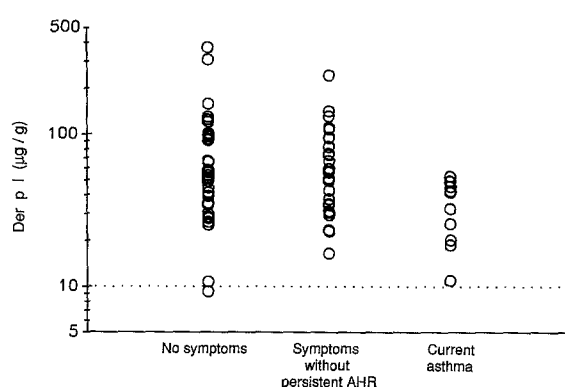


**FIG. 3.** Highest mean concentration of Der p 1 in subjects grouped according to the presence of asthma symptoms and airway hyperresponsiveness. The dotted line at 10 µg/gm represents the proposed threshold level of risk for asthma symptoms in subjects allergic to HDM. AHR, Airway hyperresponsiveness.

**TABLE IV.** Correlation of HDM allergen concentration with airflow variability, symptom score, and dose-response slope in all subjects with symptoms

|                     | Autumn                      | Winter                      | Spring                       |
|---------------------|-----------------------------|-----------------------------|------------------------------|
| Airflow variability | -0.10<br>( <i>p</i> = 0.60) | 0.05<br>( <i>p</i> = 0.78)  | -0.04<br>( <i>p</i> = 0.83)  |
| Symptom score       | -0.23<br>( <i>p</i> = 0.24) | -0.13<br>( <i>p</i> = 0.46) | -0.30<br>( <i>p</i> = 0.085) |
| Dose-response slope | -0.22<br>( <i>p</i> = 0.20) | -0.12<br>( <i>p</i> = 0.47) | -0.32<br>( <i>p</i> = 0.058) |

analysis was confined to the 23 subjects with symptoms who were allergic to HDM.

## DISCUSSION

In this study we found very high HDM allergen concentrations in the household dust of schoolchildren living in western Sydney. Subjects with allergy to HDM or with current asthma did not have higher concentrations of HDM allergen in their houses than other subjects.

The concentrations of HDM allergen in this region were higher than those reported anywhere else in the world. In studies conducted in 14 centers around the world, six found mean HDM allergen concentrations of less than 10 µg/gm<sup>4, 30-33</sup> and five others found mean concentrations of less than 25 µg/gm.<sup>8, 32, 34-36</sup> Two studies in the United Kingdom and one in Brazil, all of which had small numbers of subjects with mite allergy, found mean HDM allergen concentrations of 28.3 µg/gm,<sup>37</sup> 38.4 µg/gm,<sup>38</sup> and 38.4 µg/gm,<sup>39</sup> respectively.

We found little seasonal variation in HDM allergen concentrations, except that the levels in the living room floor areas were higher in autumn than in winter or spring. The finding of marked seasonal variation by others may reflect the greater weather changes that occur between the seasons in Europe and the United States.<sup>4, 34, 37</sup> The absence of seasonal variation in HDM allergen concentrations suggests that good indoor conditions for mite growth exist throughout the year in our study region.<sup>4, 40</sup> This reflects the year-round mild and humid outdoor conditions. The average outdoor temperature range and relative humidity at 9:00 AM in this part of Sydney are 12.5° C to 23.8° C and 75% in April, 4.6° C to 17.1° C and 77% in July, and 11.8° C to 23.1° C and 63% in October.<sup>41</sup>

Although gas appliances might be expected to increase indoor humidity, their presence was not associated with an increase in HDM allergen concentration, presumably because the humidity was already sufficient for mite proliferation. This was the case even in winter when houses tended to be more tightly closed and heaters were used. There were only five uncarpeted houses. These tended to have lower allergen levels than the houses with carpet, but the levels were not very low. Household pets, which presumably deposit mite nutrients in the form of skin scales wherever they lie, were associated with higher HDM allergen concentrations in the beds. The reason for a lack of significant difference in floor areas may be that samples were not necessarily collected from the part of the floor where the pets habitually lay.

Our finding that HDM allergen concentrations

were higher in beds than floor areas is in accord with the findings of other researchers.<sup>4, 39, 42</sup> We also found higher levels in samples from the bedroom floor than the living room floor. These differences may have related to the greater shedding of skin scales in the bedroom, the movement of mites and mite allergen from the bed to the floor, and the dilution of allergen by the presence of heavier, non-allergen-containing sand in samples collected from the living room floor.

The mean of the highest HDM allergen concentration over the three assessments was greater than 10  $\mu\text{g/gm}$  Der p 1 for all but one subject. Exposure to dust with a higher HDM allergen concentration than these levels has been proposed as a risk factor for allergy to HDM and for asthma symptoms in subjects with HDM allergy.<sup>6</sup> Because none of subjects had household allergen concentrations less than 10  $\mu\text{g/gm}$ , we were not able to test this hypothesis. In our study population, we did not find that children with allergy to HDM and manifestations of asthma were exposed to higher levels of HDM in their houses. We also did not find that changes in symptom status between seasons were associated with changes in HDM allergen concentrations. There was no correlation between HDM allergen concentration and any of the three markers of disease severity that we measured, that is, symptom score, airflow variability, or dose-response slope (as shown in Table IV). The failure of some parents to return questionnaires in the July and October assessments and poor compliance with completion of the diary cards may have reduced the number of subjects who were classified as having symptoms and the power to detect a correlation with symptom score and airflow variability. However, in view of the trends that were observed, it is unlikely that these problems have influenced the conclusions.

Other studies, which have examined the dose-response relationship between HDM allergen exposure and the prevalence of allergy and allergic disease, have been conducted in communities with much lower overall allergen levels than those observed in this study. Lau et al.<sup>5</sup> calculated odds ratios for the risk of allergy to HDM by comparing its prevalence in subjects grouped according to the concentration of HDM allergen in their household dust. The highest category used in this comparison was mite allergen concentration greater than 10  $\mu\text{g/gm}$ . In this study virtually all subjects would have been in that category. In Korsgaard's case-control study,<sup>1</sup> which demonstrated an increased risk of asthma in subjects exposed to high mite

levels, the mean mite number in the houses of control subjects was very low. However, in this study the HDM allergen levels were high in all houses studied. In a study of 59 children, Sporik et al.<sup>8</sup> found only nine subjects exposed to concentrations of Der p 1 greater than 50  $\mu\text{g/gm}$ , six of whom were allergic to mites, compared with 14 of 34 subjects exposed to concentrations between 10 and 50  $\mu\text{g/gm}$ . They did not find any significant difference between the mite allergen concentrations in the homes of subjects with and without asthma. Price et al.<sup>7</sup> found that 46 of 68 atopic children with asthma lived in homes with a carpet dust concentration of Der p 1 less than 2  $\mu\text{g/gm}$ .

The finding that subjects with HDM allergy or asthma had lower HDM allergen concentrations in their houses was unexpected. This observation could have been due to HDM avoidance measures taken by subjects allergic to HDM; however, the difference was only partially explained by the relatively few pets and carpets in these subjects' houses. We did not collect data on deliberate avoidance measures taken by the subjects.

In conclusion, we have found HDM allergen concentrations in the homes of a group of Sydney schoolchildren, which universally exceeded the proposed levels of risk for HDM allergy and asthma. The absence of a positive association between the level of exposure to HDM allergen and the presence of allergy or asthma or the severity of asthma suggests that there was no dose-response relationship at allergen exposure levels well in excess of those proposed as the thresholds for risk.<sup>6, 7</sup> In individuals exposed to allergen levels above these thresholds, genetic and other environmental factors must play a role in conferring immunity from allergic sensitization and the development of disease.

We thank the New South Wales Department of Education for allowing us to study children at their schools and all the parents and children who took part. We also thank the following members of the Institute of Respiratory Medicine staff: Ms. Melanie Shearer for field and laboratory assistance, Mr. Mark Matthews for performing the allergen assays, and Ms. Cheryl Salome for reviewing the manuscript.

## REFERENCES

1. Korsgaard J. Mite asthma and residency. A case-control study on the impact of exposure to house-dust mites in dwellings. *Am Rev Respir Dis* 1983;128:231-5.
2. Dowse G, Turner K, Stewart G, Alpers M, Woolcock A. The association between *Dermatophagoides* mites and the increasing prevalence of asthma in village communities within the Papua New Guinea highlands. *J ALLERGY CLIN IMMUNOL* 1985;75:75-83.

3. Peat J, Britton W, Salome C, Woolcock A. Bronchial hyperresponsiveness in two populations of Australian schoolchildren. III. Effect of exposure to environmental allergens. *Clin Allergy* 1987;17:291-300.
4. Platts-Mills T, Hayden M, Chapman M, Wilkins S. Seasonal variation in dust mite and grass-pollen allergens in dust from the houses of patients with asthma. *J ALLERGY CLIN IMMUNOL* 1987;79:781-91.
5. Lau S, Falkenhurst G, Weber A, et al. High mite-allergen exposure increases the risk of sensitization in atopic children and young adults. *J ALLERGY CLIN IMMUNOL* 1989;84:718-25.
6. Platts-Mills T, de Weck A. Dust mite allergens and asthma—a worldwide problem. *J ALLERGY CLIN IMMUNOL* 1989;83:416-27.
7. Price J, Pollock I, Little S, Longbottom J, Warner J. Measurement of airborne mite allergen in homes of asthmatic children. *Lancet* 1990;336:895-7.
8. Sporik R, Holgate S, Platts-Mills T, Cogswell J. Exposure to house-dust mite allergen (*Der p I*) and the development of asthma in childhood. A prospective study. *N Engl J Med* 1990;323:502-7.
9. Platts-Mills T, Ward G, Sporik R, Gelber L, Chapman M, Heymann P. Epidemiology of the relationship between exposure to indoor allergens and asthma. *Int Arch Allergy Appl Immunol* 1991;94:339-45.
10. Platts-Mills T, Tovey E, Mitchell E, Moszora H, Nock P, Wilkins S. Reduction of bronchial hyperactivity during prolonged allergen avoidance. *Lancet* 1982;2:675-7.
11. Vervoelet D, Penaud A, Razzouk H, et al. Altitude and house dust mites. *Am Rev Respir Dis* 1982;69:290-6.
12. Murray A, Zuk P. The seasonal variation in a population of house dust mites in a North American city. *J ALLERGY CLIN IMMUNOL* 1979;64:266-9.
13. Arlian L, Bernstein I, Gallagher J. The prevalence of house dust mites, *Dermatophagoides* spp, and associated environmental conditions in homes in Ohio. *J ALLERGY CLIN IMMUNOL* 1982;69:527-32.
14. Hart B, Whitehead L. Ecology of house dust mites in Oxfordshire. *Clin Exp Allergy* 1990;20:203-9.
15. Melia R, Florey C, Chinn S. The relation between respiratory illness in primary schoolchildren and the use of gas for cooking. I. Results from a national survey. *Int J Epidemiol* 1979;8:333-8.
16. Spieksma F. Cultures of house-dust mites on animal skin scales. *Allergol Immunopathol (Madr)* 1976;4:419-428.
17. Hurry V, Peat J, Woolcock A. Prevalence of respiratory symptoms, bronchial hyperresponsiveness and atopy in schoolchildren living in the Villawood area of Sydney. *Aust N Z J Med* 1988;18:745-52.
18. Green W, Woolcock A, Stuckey M, Sedgwick C, Leeder S. House dust mites and skin tests in different Australian localities. *Aust N Z J Med* 1986;16:639-43.
19. Tovey E, Marks G, Matthews M, Green W, Woolcock A. Changes in mite allergen *Der p I* in house dust following spraying with a tannic acid/acaricide solution. *Clin Exp Allergy* 1992;22:67-74.
20. Peat J, Salome C, Bauman A, Toelle B, Wachinger S, Woolcock A. Repeatability of histamine bronchial challenge and comparability with methacholine bronchial challenge in a population of Australian schoolchildren. *Am Rev Respir Dis* 1991;144:338-43.
21. Friedman M, Walker S. Assessment of lung function using an air-flow meter. *Lancet* 1975;1:310-2.
22. Pepys J. Skin tests in diagnosis. In: Gell P, Coombs R, Lachmann P, eds. *Clinical aspects of immunology*. Oxford: Blackwell Scientific, 1975:55-80.
23. Peat J, Salome C, Woolcock A. Longitudinal changes in atopy during a 4-year period: relation to bronchial hyperresponsiveness and respiratory symptoms in a population sample of Australian schoolchildren. *J ALLERGY CLIN IMMUNOL* 1990;85:65-74.
24. Yan K, Salome C, Woolcock A. Rapid method for measurement of bronchial responsiveness. *Thorax* 1983;38:760-5.
25. O'Connor G, Sparrow D, Taylor D, Segal M, Weiss S. Analysis of dose-response curves to methacholine. *Am Rev Respir Dis* 1987;136:1412-7.
26. Peat J, Salome C, Berry G, Woolcock A. Relation of dose-response slope to respiratory symptoms in a population of Australian schoolchildren. *Am Rev Respir Dis* 1991;144:663-7.
27. Toelle BG, Peat JK, Salome CM, Mellis CM, Woolcock AJ. Toward a definition of asthma for epidemiology. *Am Rev Respir Dis* 1992;146:633-7.
28. Tovey E. Mite populations in Sydney household bedding with particular reference to nursery sheepskins. *Med J Aust* 1975;2:770-2.
29. Green W. The house dust mite, *Dermatophagoides farinae*, in Australia. *Med J Aust* 1983;00:259-60.
30. Miller J, Miller A, Luczynska C, Rose G, Platts-Mills T. Effect of tannic acid spray on dust-mite antigen levels in carpets [Abstract]. *J ALLERGY CLIN IMMUNOL* 1989;83:262.
31. Huss K, Squire E, Carpenter G, et al. House dust mite education—what effects? [Abstract]. *J ALLERGY CLIN IMMUNOL* 1990;85(suppl):186.
32. Charpin D, Birnbaum J, Haddi E, et al. Altitude and allergy to house-dust mites. *Am Rev Respir Dis* 1991;143:983-6.
33. Colloff M, Stewart G, Thompson P. House dust acarofauna and *Der p I* equivalent in Australia: the relative importance of *Dermatophagoides pteronyssinus* and *Euroglyphus maynei*. *Clin Exp Allergy* 1991;21:225-30.
34. Smith T, Kelly L, Heymann P, Willfins S, Platts-Mills T. Natural exposure and serum antibodies to house dust mite of mite-allergic children with asthma in Atlanta. *J ALLERGY CLIN IMMUNOL* 1985;76:782-8.
35. Haddi E, van der Brempt X, Herkert A, et al. Mite-allergen content in mattresses and allergic symptoms [Abstract]. *Am Rev Respir Dis* 1989;139:A390.
36. Sakaguchi M, Inouye S, Yasueda H, Irie T, Yoshizawa S, Shida T. Measurement of allergens associated with dust mite allergy. *Int Arch Allergy Appl Immunol* 1989;90:190-3.
37. Owen S, Morganstern M, Hepworth J, Woodcock A. Control of house dust mite antigen in bedding. *Lancet* 1990;335:396-7.
38. Henderson A, Kennedy C, Thompson S, Carswell F. Temporal association between *Der p I* exposure, immediate hypersensitivity and clinical severity of eczema. *Allergy* 1990;45:445-50.
39. Nasbitz C, Arruda L, Rizzo M, et al. Mite allergy and indoor allergen exposure in asthmatic children in Brazil [Abstract]. *J ALLERGY CLIN IMMUNOL* 1990;85(suppl):183.
40. Korsgaard J. House-dust mites and absolute indoor humidity. *Allergy* 1983;38:85-92.
41. Bureau of Meteorology. *Climatic averages Australia*. Meteorological summary July 1988. Canberra: Australian Government Publishing Service, 1988.
42. Tovey E, Chapman M, Wells C, Platts-Mills T. The distribution of dust mite allergen in the houses of patients with asthma. *Am Rev Respir Dis* 1981;124:630-5.