House dust mite allergen in bedroom floor dust and respiratory health of children with asthmatic symptoms

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ABSTRACT: The purpose of this study was to investigate the effects of house dust mite allergen in bedroom floor dust on respiratory health of children with asthmatic symptoms.

Two hundred and twenty eight school children with reported attacks of shortness of breath with wheezing in the past year and/or with doctor-diagnosed asthma, were included in the study. Data on home characteristics, both past and present, were obtained. These included data on allergen avoidance measures because of the child's respiratory health. Dust samples were taken from the child's bedroom floor, and the allergen *Der p I* of the house dust mite *Dermatophagoides pteronyssinus* was measured. Health diaries were kept over 4 weeks. Acute respiratory symptoms and medication usage were recorded daily. Peak expiratory flow (PEF) was measured using Mini-Wright peak flow meters three times daily.

Levels of *Der p I* in dust from carpeted floors were significantly higher than in dust from smooth floors. We found a positive relationship of *Der p I* levels, in floor dust collected from carpeted floors, with PEF-variability and also with the prevalence of wheeze, shortness of breath, and attacks of shortness of breath with wheezing during the observation period. The effects on peak flow variability was larger in children allergic to house dust than in children not allergic to house dust. Peak flow variability was significantly increased at exposure levels well below 10,000 ng *Der p I*-g⁻¹ dust, which has been suggested to be a "threshold" for increased risk symptoms among sensitized asthmatics.

We conclude that exposure to high *Der p I* levels in the bedroom may be an important risk factor for the severity of asthmatic symptoms in sensitized children. *Eur Respir J.*, 1994, 7, 1254–1259.

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Keywords: Allergen avoidance measures
childhood asthma
house dust mite
peak flow

Received: June 16 1993
Accepted after revision March 29 1994

Exposure to house dust mite allergens is well recognised as an important risk factor for the development of asthma [1–3]. High levels of mite allergens in the house increase the risk of sensitization in atopic children [1, 4, 5], as well as the occurrence of acute asthmatic symptoms [3]. *Dermatophagoides pteronyssinus* is the predominant house dust mite in Western Europe. Since the discovery of the importance of allergens from these mites in 1964 [6], many studies have focused on the number of mites and, with the availability of assays for specific mite allergens, also on allergen levels in homes [5, 7–11].

There have been a few studies on the effects of exposure to mite allergens on the severity of asthma. VERVLOET *et al.* [12] found positive relationships between the mite allergen concentration in mattress dust and the number of asthma attacks and the medical treatment level, in 49 mite-allergic asthmatic patients. ZOCK *et al.* [13] found positive relationships of allergen level in mattress dust with peak flow variability and with frequency of wheezing in 96 asthmatic children.

Provisional standards for mite allergen levels have been recommended. A threshold level of 2,000 ng·g⁻¹ of settled house dust has been suggested to be a risk factor for sensitization, whereas 10,000 ng·g⁻¹ has been put forward as a threshold level for acute asthma in sensitized subjects [3].

Our present objective was to study the relationship between *Der p I* levels in bedroom floor dust and peak flow variability, respiratory symptoms and medication intake in children with asthmatic symptoms.

Subjects and methods

Study population

In August/September 1990, parent-administered questionnaires were distributed among all 11,184 pupils (aged 4–12 yrs) from 50 primary schools in The Netherlands, to assess chronic respiratory symptoms. Thirty schools

were located in an urban area and twenty in a rural area. The response rate to this questionnaire was 78%.

Children were selected who answered positively to one or more of the following questions:

- 1) attack(s) of shortness of breath with wheezing during the past year;
- 2) "asthma" diagnosed by a physician in the past;
- 3) treated for "asthma" by a lung physician during the past year.

In 657 out of 8,761 children, one or more of these questions were answered positively (7.5%). A random sample of these selected children was taken, and the parents were asked to join the study. Of those approached, 264 (85% of the sample) were willing to participate in the study. No further clinical assessment was made on the children.

Characterisation of the homes

The homes of the children were visited once. One of the parents was interviewed to obtain data on home characteristics both past and present (during the child's life). Characteristics were floor carpeting, mattress and bedding, pet keeping, smoking habits, damp stains and mould spots, and water heating equipment. Information on allergen avoidance measures, taken because of the child's respiratory disease, was also obtained.

A dust sample was taken by one of the investigators from the bedroom floor next to the child's bed, according to an internationally standardised protocol [3]. Dust from 2 m² floor surface was sampled using a vacuum cleaner connected to the ALK dust collecting device (Copenhagen, Denmark) with a paper filter. The sampling time was 2 minutes per m². To avoid seasonal effects, all dust samples were taken within two months (October and November 1990). Samples were taken by a total of four trained investigators using three identical vacuum cleaners. About 200 mg of dust from each filter was extracted in 2 ml 0.125 M ammoniumhydrogencarbonate, by agitating for two hours, followed by centrifuging at 1000 g for 15 min. The extracts were analysed for *Der p* I content by an enzyme immunoassay, following procedures previously described [7]. Concentrations were expressed in ng·g⁻¹ dust.

Health outcome

Questions on respiratory symptoms and allergies of the child were included at the interview. To investigate the day-to-day variations in respiratory health of the subjects, a diary was used. During the home visit, the parents were instructed how to keep records of respiratory symptoms, medication intake and peak expiratory flow (PEF) for a four week period in the autumn of 1990. The symptoms were "cough", "shortness of breath", "wheezing", "attacks of shortness of breath with wheezing", and "woken up with respiratory symptoms". These symptoms were recorded daily on a scale as 0 (not), 1 (slight), 2 (moderate) or 3 (severe). Medication intake was

recorded as number of puffs or capsules for each medicine. Peak expiratory flow (PEF) was measured using Mini-Wright peak flow meters three times a day: in the morning (before intake of medication, if any), in the afternoon (immediately after school) and in the evening (before dinner and before medication intake). On each occasion, three attempts were performed, and the highest of these three was recorded in the diary. Completing the diary took place in the period October-December 1990.

The medication intake was classified into two categories: 1) bronchodilators, and 2) other "maintenance" medication (antihistamines, inhaled steroids and cromoglycates). For each day, the peak flow variability (PV) was calculated. The daily amplitude (maximum minus the minimum PEF) was divided by the day's mean PEF for each child on each day, resulting in a dimensionless indicator of PV: the AMP/MEAN [14]. A high PV may indicate bronchial responsiveness.

For each subject, the symptoms, medication usage and peak flow variability were averaged over all 28 days of the study period.

Statistical analysis

Data were analysed using SAS package [15]. The distribution of the *Der p* I concentrations was found to be right-skewed, therefore the ln-transformed values were used in analyses. Differences in allergen levels and in health outcome variables between subgroups were compared by Student's unpaired t-test. We divided the children into those with carpeted and uncarpeted bedroom floors, respectively, in some of the analyses because removal of carpets from bedrooms is a frequently practiced allergen avoidance measure in the Netherlands. The relationships between health outcome variables and exposure variables were evaluated with multiple linear regression. Potential confounders were age of subject, gender, socio-economic status, area (urban/rural), floor carpeting, pet keeping, smoking habits, damp stains and mould spots, and presence of unvented water heaters. Odds ratios for high peak flow variability were calculated to investigate the effect of using different cut-off points for *Der p* I exposure.

Results

The study population consisted of 228 children with data from the diary, the interview and dust analysis. Population characteristics are shown in table 1. The mean age was 7.5 yrs (SD 2.2).

A considerable number of allergen avoidance measures had been taken during the child's life. Removing carpets had been one of the most frequently applied measures. In 58 homes the inhabitants had changed the living-room floor cover, and in 77 homes the inhabitants had changed the bedroom floor cover, in response to the child's respiratory symptoms. The new living room floors (observed during the survey) were, in 57% of the cases

Table 1. – Population characteristics

	n/total n	%
Gender (male)	139/228	61
Area (urban)	127/228	56
Doctor-diagnosed asthma	125/217	58
Allergic to house dust*	95/227	42
Allergic to pet*	88/227	39
Allergic to pollen*	52/227	23
Home characteristics during survey		
Carpeted bedroom floor	128/228	56
Carpeted living-room floor	159/228	70
Pets in the house**	144/228	63
Smoking inmates	124/224	55
Unvented water heater	34/228	15
Allergen avoidance measures†		
Moved to another house	28/218	13
New floor cover in bedroom	77/227	34
New floor cover in living-room	58/227	26
New mattress	27/227	12
New blanket/quilt	66/227	29
Removed pets	55/228	24

*: allergy diagnosed by a physician in the past; **: mammals and/or birds; †: for child's respiratory health.

(33/58), carpeted floors; new bedroom floors were found to be carpeted in only 25% of the cases (19/77). In all other cases, carpets had been replaced by hard floors. In table 2, the health outcome variables in the groups of children allergic and non-allergic to house dust are presented. The allergic subjects experienced more asthmatic symptoms and used more medication. There was no significant difference in PV.

Table 2. – Mean values and standard errors of the health outcome variables in two subgroups, classified according to reported allergy for house dust

	Allergic† n=95		Not allergic n=132	
Peak flow variability	0.13	(0.007)	0.12	(0.006)
Cough	0.47	(0.045)	0.52	(0.043)
Woken up with respiratory symptoms	0.16	(0.029)	0.11	(0.017)
Shortness of breath	0.29	(0.039)#	0.20	(0.024)
Wheezing	0.19	(0.030)*	0.11	(0.020)
Attacks of shortness of breath with wheezing	0.069	(0.018)*	0.027	(0.008)
Bronchodilators	0.68	(0.14)*	0.34	(0.087)
Maintenance medication	1.77	(0.28)**	0.55	(0.12)

†: allergy diagnosed by a physician in the past; #: $p < 0.10$; *: $p < 0.05$; **: $p < 0.01$ (for difference between allergic and not allergic).

Der p I concentrations in bedroom floor dust ranged from 104–60,527 ng·g⁻¹. The geometric mean was significantly higher in dust collected from carpeted floors (2,077 ng·g⁻¹) than in dust collected from smooth floors (652 ng·g⁻¹).

The health outcome variables were positively related with PV and cough, except the intake of maintenance medication which was slightly negatively related.

As many parents were found to have changed the bedroom floor cover from carpet to hard floors in the past, we decided to analyse the data separately for children with hard floors (n=100) and carpeted floors (n=128) in their bedrooms respectively. Bivariate regression analysis with potential confounders showed that age, area and presence of an unvented water heater in the house were

Table 3. – Linear regression models for health outcome variables with ln of *Der p* I level in bedroom floor dust, standardized for age, area and presence of unvented water heater; coefficients denote difference in health outcome variable associated with a difference in *Der p* I exposure of 8,000 ng·g⁻¹ (10,000 ng·g⁻¹ compared to 2,000 ng·g⁻¹)

	All subjects n=128		Allergic to house dust† n=39		Not allergic to house dust n=88	
Peak flow variability	0.017	(-0.006, 0.027)* (+14%)	0.022	(-0.003, 0.047)# (+16%)	0.012	(-0.000, 0.024)# (+10%)
Cough	0.037	(-0.042, 0.116) (+7%)	0.053	(-0.102, 0.208) (+10%)	0.013	(-0.083, 0.109) (+3%)
Woken up with respiratory symptoms	0.025	(-0.008, 0.58) (+23%)	0.061	(-0.015, 0.137) (+49%)	0.014	(-0.024, 0.52) (+13%)
Shortness of breath	0.062	(0.003, 0.121)* (+25%)	0.046	(-0.120, 0.212) (+12%)	0.042	(-0.013, 0.098) (+22%)
Wheezing	0.039	(-0.006, 0.083)# (+29%)	0.059	(-0.053, 0.170) (+30%)	0.031	(-0.016, 0.078) (+29%)
Attacks of shortness of breath with wheezing	0.021	(-0.001, 0.043)# (+50%)	0.005	(-0.059, 0.070) (+7%)	0.026	(0.007, 0.046)* (+93%)
Bronchodilators	0.098	(-0.080, 0.275) (+25%)	0.164	(-0.262, 0.590) (+26%)	-0.029	(-0.220, 0.162) (-10%)
Maintenance drugs	-0.149	(-0.443, 0.145) (-18%)	-0.509	(-1.23, 0.207) (-34%)	-0.156	(-0.450, 0.138) (-30%)

Results are mean (95% confidence interval). % in brackets below are parameter estimate divided by mean of dependent variable, indicating the change (in %) of the dependent variable for a change in the *Der p* I level in bedroom floor dust from 2,000 to 10,000 ng·g⁻¹. †: allergy diagnosed by physician in the past. #: $p < 0.10$; *: $p < 0.05$ (for regression coefficient).

significantly related to the means of one or more of the health outcome variables. Multivariate regression models were used to adjust for these variables. The results of the calculations for children with hard floors in their bedrooms showed that, in this group, there was no relationship between *Der p I* exposure and any of the health outcomes. All coefficients were close to zero, some were negative and some positive. For children with carpeted floors in their bedrooms, the results were entirely different. Regression coefficients were positive for all health outcome variables with the exception of the use of maintenance medication. Coefficients for peak flow variability, shortness of breath, wheeze and attacks of shortness of breath were significantly different from zero (table 3). Coefficients were expressed in estimated percentage change from the population mean associated with a change in *Der p I* concentration from 2,000 to 10,000 ng·g⁻¹. Peak flow variability was increased by 14%, shortness of breath by 25%, wheeze by 29% and attacks of shortness of breath with wheeze by 50%.

Because we expected effects to concentrate in dust mite allergic children, we divided the population in children with doctor-diagnosed house dust allergy and children without doctor-diagnosed house dust allergy on the

Fig. 1. — Residual scatterplots of peak flow variability vs. $\ln \text{Der } p \text{ I}$ concentration in bedroom floor dust in subjects with carpeted bedroom floors, subdivided according to reported allergy to house dust. a): subjects allergic to house dust (n=39); b): subjects not allergic to house dust (n=88).

basis of the questionnaire. For one subject, data were missing. Of the remaining 127 children with carpeted bedroom floors, 39 were reported to be allergic to house dust, whereas 88 were not. Table 3 shows the regression coefficients and estimated % change in health outcome variables for total group and also the two sub-groups. Coefficients for all health outcome variables except attacks of shortness of breath were higher in the allergic population compared to the non-allergic population. Figure 1 shows plots of the adjusted relationship of peak flow variability with *Der p I* exposure in the two groups.

Figure 1 shows the scatterplots associated with the results reported in Table 3. In order to investigate the threshold level *Der p I* at which PV is increased, we

Odds ratio

Fig. 2. — Odds ratios for high peak flow variability*, with different cut-off levels of *Der p I* in bedroom floor dust; subjects with carpeted bedroom floors (n=128). Odds ratios were statistically significant ($p<0.05$) for all cut-off levels in the range from 4,000 to 14,000 ng·g⁻¹ (4–14 $\mu\text{g}\cdot\text{g}^{-1}$). *: upper quartile of distribution (0.145).

compared *Der p I* exposure between children with PV values over 0.145, the 75th percentile, to children with PV values below 0.145. We classified *Der p I* exposure as "high" or "low" using a number of different cut-off points. The results for subjects with carpeted bedroom floors (n=128) are shown in figure 2. Statistically significant odds ratios ($p<0.05$) were found for all cut-off points from 4,000 to 14,000 ng·g⁻¹.

Discussion

The subjects in this study were, on average, less severely asthmatic than in other studies [4, 5, 13]. Fifty eight percent had doctor-diagnosed asthma and 42% were allergic to house dust (table 1). Nevertheless, in a fairly large proportion of homes, allergen avoidance measures had been taken in the past. In another study that we conducted in homes of asthmatic children from an outpatient clinic [13], slightly more allergen avoidance measures had been taken, compared to the population described in this paper. In homes of symptom free children, we found a zero frequency of allergen avoidance measures [16].

In this study, house dust allergy was assessed by questionnaire. The same questionnaire was used in a case-control study on home dampness and respiratory disease in children [17], and in this study, specific serum immunoglobulin E (IgE) for house dust mite was measured. Using the same case definition as in our study, the sensitivity of the question regarding house dust allergy was found to be 66%, and the specificity 96% when compared to house dust mite allergy, defined as radio-immunosorbant test (RAST) class ≥ 1 . This suggests that there were probably very few non-allergic children in the group classified as "allergic" on the basis of the questionnaire. However, among those classified as "non-allergic" by the questionnaire, there were probably several with dust mite allergy, and this may explain why the relationship between *Der p* I exposure and health outcomes was not absent in this group.

Der p I levels in dust from carpeted floors were much higher than in dust from hard floors. This confirms the results of other studies [13, 16]. The *Der p* I levels were comparable to the results reported previously [17], but were higher than levels found in homes of more severely asthmatic children, both in smooth floors and in carpeted floors [13]. Because dust mite allergen levels on hard floors were so low, and because several of the more severely asthmatic children had hard floors in their bedrooms as a result of allergen avoidance measures, we were only able to analyse the relationship between dust mite allergen exposure and health outcomes in the children with carpeted bedroom floors. In this group, there were clear positive relationships between dust mite allergen exposure and peak flow variability, shortness of breath, wheeze and attacks of shortness of breath with wheezing.

The positive correlations between PV and respiratory symptoms indicate that measuring PEF and calculating PV provides an objective indicator for symptoms. Intake of maintenance medication was negatively correlated with PV. This may be due to the fact that these medicines are required to prevent acute symptoms and asthma attacks. Bronchodilators are mostly used to reduce asthmatic attacks (shortness of breath, wheezing). This explains the positive relations between use of bronchodilators and symptoms/PV.

In a small study among 98 more severely asthmatic children, Zock *et al.* [13] found no association of PV with the *Der p* I level in bedroom floor dust, whereas there was an association with the *Der p* I level in mattress dust. Only 36% of the children had a textile floor cover in the bedroom as opposed to 56% in this study. We did not sample mattress dust in our study; in the study by Zock *et al.* [13] the correlation between *Der p* I levels in dust collected from the 35 carpeted bedroom floors and in mattress dust was 0.72, and mattress levels were only slightly higher than levels found in dust from carpeted floors (2,753 vs 1,663 ng·g⁻¹ respectively, geometric means). In another study conducted in The Netherlands by our group [17] in which comparable methods for dust collection and analysis were used, the Pearson correlation coefficient between the ln (*Der p* I content) in dust collected from 370 carpeted bedroom floors and

in mattress dust was 0.65, and mattress levels were again slightly higher than levels found in dust from carpeted floors (5,317 vs 3,558 ng·g⁻¹ respectively, geometric means). It is, therefore, reasonable to expect that relationships between health outcomes and *Der p* I exposure will be found for both bedroom floor dust and mattress dust when a reasonable number of bedrooms with carpeted floors are included.

Our analysis of different cut-off levels indicates that the suggested threshold level of 10,000 ng·g⁻¹ of settled dust as a risk factor for acute asthma may be too high (fig 2). Even in the relatively small number of children we studied, significant relationships between *Der p* I exposure and peak flow variability were found at cut-off levels down to 4,000 ng·g⁻¹. Allergen levels in mattress dust might be somewhat higher, but in view of the results presented earlier from studies conducted by our laboratory [13, 17], it is clear that the difference is probably less than a factor of 1.5. It seems likely that increased peak flow variability and symptoms can be found at even lower levels of exposure in more severely asthmatic children.

In conclusion, exposure to *Der p* I found in dust from carpeted bedroom floors appears to increase the severity of asthma in children with a history of asthmatic symptoms.

Acknowledgements: We wish to thank the Dutch Asthma Foundation for financial support. Further, we are grateful to M. Boswijk, M. Koole, J. Schuit, F. Vergeest, F. de Waart and E. Wartena for their help, and of course to the children and their parents for their co-operation.

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