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


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.


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/MAN [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
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.

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 1. – Population characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n/total n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male)</td>
<td>139/228</td>
<td>61</td>
</tr>
<tr>
<td>Area (urban)</td>
<td>127/228</td>
<td>56</td>
</tr>
<tr>
<td>Doctor-diagnosed asthma</td>
<td>125/217</td>
<td>58</td>
</tr>
<tr>
<td>Allergic to house dust*</td>
<td>95/227</td>
<td>42</td>
</tr>
<tr>
<td>Allergic to pet*</td>
<td>88/227</td>
<td>39</td>
</tr>
<tr>
<td>Allergic to pollen*</td>
<td>52/227</td>
<td>23</td>
</tr>
</tbody>
</table>

**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.

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Allergic†</th>
<th>Not allergic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak flow variability</td>
<td>0.13 (0.007)</td>
<td>0.12 (0.006)</td>
</tr>
<tr>
<td>Cough</td>
<td>0.47 (0.045)</td>
<td>0.52 (0.043)</td>
</tr>
<tr>
<td>Woken up with respiratory symptoms</td>
<td>0.16 (0.029)</td>
<td>0.11 (0.017)</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>0.29 (0.039)</td>
<td>0.20 (0.024)</td>
</tr>
<tr>
<td>Wheezing</td>
<td>0.19 (0.030)</td>
<td>0.11 (0.020)</td>
</tr>
<tr>
<td>Attacks of shortness of breath with wheezing</td>
<td>0.069 (0.018)</td>
<td>0.027 (0.008)</td>
</tr>
<tr>
<td>Bronchodilators</td>
<td>0.68 (0.14)</td>
<td>0.34 (0.087)</td>
</tr>
<tr>
<td>Maintenance medication</td>
<td>1.77 (0.28)</td>
<td>0.55 (0.12)</td>
</tr>
</tbody>
</table>

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

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)

<table>
<thead>
<tr>
<th>Variable</th>
<th>All subjects</th>
<th>Allergic to house dust†</th>
<th>Not allergic to house dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak flow variability</td>
<td>0.017 (0.006, 0.027)*</td>
<td>0.022 (-0.003, 0.047)*</td>
<td>0.012 (-0.000, 0.024)*</td>
</tr>
<tr>
<td>Cough</td>
<td>0.037 (-0.042, 0.116)</td>
<td>0.053 (-0.102, 0.208)</td>
<td>0.013 (-0.083, 0.109)</td>
</tr>
<tr>
<td>Woken up with respiratory symptoms</td>
<td>0.025 (-0.008, 0.58)</td>
<td>0.061 (-0.015, 0.137)</td>
<td>0.014 (-0.024, 0.52)</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>0.062 (0.003, 0.121)*</td>
<td>0.046 (-0.120, 0.212)</td>
<td>0.042 (-0.013, 0.098)</td>
</tr>
<tr>
<td>Wheezing</td>
<td>0.039 (-0.006, 0.083)*</td>
<td>0.059 (-0.053, 0.170)</td>
<td>0.031 (-0.016, 0.078)</td>
</tr>
<tr>
<td>Attacks of shortness of breath with wheezing</td>
<td>0.021 (-0.001, 0.043)*</td>
<td>0.005 (-0.059, 0.070)</td>
<td>0.026 (0.007, 0.046)*</td>
</tr>
<tr>
<td>Bronchodilators</td>
<td>0.098 (-0.080, 0.275)</td>
<td>0.164 (-0.262, 0.590)</td>
<td>-0.029 (-0.220, 0.162)</td>
</tr>
<tr>
<td>Maintenance drugs</td>
<td>-0.149 (-0.443, 0.145)</td>
<td>-0.509 (-1.23, 0.207)</td>
<td>-0.156 (-0.450, 0.138)</td>
</tr>
</tbody>
</table>

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 outcome variables. Coefficients for peak flow variability, shortness of breath, wheeze and attacks of shortness of breath were significantly different from zero (table 3).

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. 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 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 (4–14 µg·g⁻¹). *: upper quartile of distribution (0.145).

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 radioimmunosorbant 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, wheeze). 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 cooperation.

References

8. Tovey ER, Chapman MD, Wells CW, Platts-Mills TAE.


