

Peak-flow variability in asthmatic children is not related to wall-to-wall carpeting on classroom floors

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The hypothesis was tested that wall-to-wall carpets on school classroom floors have a negative effect on the respiratory health of asthmatic children. Asthmatic patients ($n = 98$) were selected from the records of the Sophia Children's Hospital in Rotterdam. The patients were between 5 and 11 years old. All children had peak-flow measurements three times a day for a 1-month period. The parents of the children completed a diary in which respiratory symptoms and medication use were recorded daily for the same period. Dust samples were taken from classroom floors, living-room and bedroom floors, and mattresses of the children. The dust samples were analyzed for *Der p I* content, the major allergen of the house-dust mite *Dermatophagoides pteronyssinus*. The results of the study showed that there was no significant difference between children visiting schools with or without carpeted classroom floors in peak-flow variability, acute respiratory symptoms, or medication use. The *Der p I* content of dust collected from classroom floors was much lower than of dust collected from homes. There was a significant correlation between peak-flow variability and mattress dust *Der p I* content in asthmatic children sensitized to dust mites, but not between peak-flow variability and classroom floor dust *Der p I* content. We concluded that carpeted classroom floors do not contribute to asthma symptom severity, possibly because of the low levels of *Der p I* on them.

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Little research has been done on the effects of the school environment on the health of asthmatic children. A study from Denmark (5) has suggested that asthmatic children who had no carpets in their bedrooms, and who were living in homes without pets, but who attended schools with carpeted floors, had more asthmatic symptoms and used more medication than a comparable group of children who attended schools with smooth classroom floors. In other studies, dust from school floors was found to contain considerably less dust-mite allergen than dust from homes (2–4). A study from Sweden, however, has suggested that dust from classroom floors may contain enough cat allergen (*Fel d I*) to provoke symptoms among asthmatic children sensitized to cats (1).

Exposure to house-dust-mite allergens is well recognized as an important risk factor for the development of asthma, and for the provocation of symptoms of asthma (7, 17, 20). Since the discovery in the 1960s of this important house-dust allergen, many

studies have focused on the biology and immunology of the house-dust mite, on its role in the development of asthma, and on the possibilities of environmental control (10). *Dermatophagoides pteronyssinus* is the predominant house-dust mite in Europe and other parts of the world. The major allergen produced by this mite, *Der p I*, has been purified, and monoclonal antibodies have been developed against this purified allergen (8). The threshold levels of *Der p I* that form a risk for inducing sensitization and symptoms have been subject to debate (7, 11, 12, 17). A level of more than 2 µg/g of settled house dust has been supposed to be a risk factor for sensitization, whereas a level of more than 10 µg/g has been put forward as a level at which sensitized subjects may experience acute symptoms (11). The distribution of the *Der p I* allergen in houses has been studied frequently (6, 7, 13, 14, 17, 18).

In the present study, we investigated, in a population of asthmatic children living in the Netherlands, whether the variability of peak flow, respiratory

symptoms, and the use of bronchodilators was related to the presence or absence of wall-to-wall carpeting on classroom floors, and to *Der p I* exposure at home and in schools.

Material and methods

Population characteristics

The subjects in this study were asthmatic children, aged 5–11 years, selected from the records of the Department of Pediatric Respiratory Medicine of the Sophia Children's Hospital in Rotterdam, The Netherlands. These children had a diagnosis of asthma made by a pediatric pulmonologist on the basis of typical symptoms (repeated episodes of wheezing, nocturnal cough or wheeze, exercise-induced wheeze) and a favorable response to bronchodilator treatment. Most children had documented atopy and bronchial hyperresponsiveness. A letter was sent to the parents of 222 children; the parents of 115 were willing to participate in the study. The homes of the children were visited in the autumn of 1990. During these visits, one of the parents was interviewed to collect data on home characteristics, pets, parental smoking habits, and the respiratory symptoms of the child. Five children who visited special schools for asthmatic patients were excluded from further analysis, because these schools were not comparable to "regular" schools in several ways.

Health diaries and peak-expiratory-flow rates

Health diaries were used to investigate the health status of the children. During the home visits, the patients were told how to keep records of peak-expiratory-flow rates (PEFR) for a 4-week period. The peak flow was measured with mini-Wright peak-flow meters three times a day: morning (before intake of medication, if any was used), afternoon (immediately after school, i.e., about 1600), and evening (before dinner and before intake of medication). On each occasion, three tests were done, and the highest of the three values was recorded in the diary. Children and parents were trained in the use of the peak-flow meter and diary for the recording of flow rates. For each day, the amplitude (maximum minus the minimum PEFR) divided by the day's mean PEFR was calculated, resulting in a dimensionless indicator of peak-flow variability, the AMP/MEAN, AMplitude divided by MEAN (15). The mean PEF variability for school days was calculated for each child. The diaries were also used to record medication use, respiratory symptoms, and days of school absence. Medication was divided into two groups: 1) bronchodilators and 2) other ("maintenance") medication; i.e., antihistaminics, oral or inhaled steroids, and sodium cromoglycate. The recorded respi-

ratory symptoms were "cough", "wheezing", "shortness of breath", "attacks of shortness of breath with wheezing", and "woken up by respiratory symptoms". These symptoms were recorded daily on the following scale: 0 (none), 1 (slight), 2 (moderate), or 3 (severe). Medication use was reported as the number of inhalations, capsules, etc. used per day. Both medication use and symptoms were also evaluated by the mean per child over school days. Twelve additional children were excluded from further analysis because their diaries had not been sent back or were found to be useless upon inspection of recorded flow rates; therefore, 98 children were left for analysis.

Exposure to house-dust-mite allergen (Der p I)

Dust samples were taken from the living-room floor (middle of the room), from the child's bedroom floor (beside the bed), from the uncovered mattress of the child's bed, and from the classroom floor (border and middle of the room). Dust samples were collected by vacuuming an area of 2 m² with a sampling time of 2 min/m². The upper mattress surface (± 2 m²) was vacuumed for 2 min (11). An ordinary vacuum cleaner was used, equipped with a dust-collecting device developed by ALK Laboratories in Denmark. In the dust samples, the *Der p I* allergen was determined by the enzyme-linked immunosorbent assay (ELISA) (ALK Laboratories, Copenhagen, Denmark) by procedures previously described (8). The allergen concentrations were expressed in ng/g dust and in ng/m² floor or mattress surface. The limit of detection was 20 ng/g dust. Concentrations below the limit of detection were arbitrarily given a value of two-thirds (13 ng/g) of the limit of detection in further calculations. Samples collected from plastic-covered mattresses ($n = 2$) were excluded from mattress dust analysis.

Statistical analysis

Data were analyzed with the SAS statistical software program (16). *Der p I* concentrations were ln-transformed because distributions were found to be right-skewed. After transformation, the distributions became symmetric; therefore, parametric tests which require normality of the underlying distributions could be used. A Pearson correlation coefficient was calculated between the *Der p I* levels of the two classroom samples; the coefficient was 0.58 ($P < 0.001$). It was decided, for further analysis, to use the mean allergen level of the middle and border dust samples. The correlation between the *Der p I* levels of the three home samples was also calculated. Allergen levels of samples from carpeted and uncarpeted floors were compared by Student's unpaired

t-test. The relationships between health outcome variables and *Der p* I exposure variables were evaluated with linear regression. These analyses were restricted to the children who were sensitized to house-dust mite, because we expected to see relationships between health end points (as defined) and exposure to dust-mite allergen only in this group.

Results

Population characteristics of the 98 children left for analysis are given in Table 1. As mentioned, all were diagnosed as having asthma by a pediatric pulmonologist in a tertial reference center; nevertheless, not all of the parents reported that their child had ever been diagnosed as asthmatic. Of these 98 children, 54 had a positive RAST (> 1) to house-dust mite.

Table 2 shows the *Der p* I concentrations found in the various samples. When expressed in ng/g, the mean allergen levels of dust from classroom floors were lowest of all sample types. However, more dust was collected, per square meter, from classroom floors than from living-room or bedroom floors. Expressed in ng allergen/m², the *Der p* I levels on carpeted classroom floors were slightly higher than those on uncarpeted living-room and bedroom floors, but still very much lower than the levels found on mattresses and on carpeted floors in the home.

On a ng/g basis, allergen levels in dust from houses were moderate (uncarpeted living-room floors and uncarpeted bedroom floors) to high (carpeted bedrooms and mattresses). Pearson correlation coefficients for *Der p* I concentrations in samples collected in houses were as follows: mattresses/bedroom floors $r = 0.54$ ($P < 0.001$); mattresses/living-room floors $r = 0.27$ ($P < 0.01$); bedroom floors/living-room floors $r = 0.15$ (not significant; $P > 0.05$). For carpeted bedroom floors only ($n = 34$), these values were, respectively, $r = 0.72$ ($P < 0.001$); $r = 0.41$ ($P < 0.05$); $r = 0.41$ ($P < 0.05$). Dust from carpeted floors contained significantly more *Der p* I than

Table 2. Geometric mean *Der p* I concentrations in dust, in ng/g dust, and in ng/m²

Sample type	ng/g	ng/m ²	n
Living room, uncarpeted	161 (2.8) ¹	9 (3.9)	37
Living room, carpeted	980 (7.1)	337 (7.5)	61
Bedroom, uncarpeted	154 (3.8)	6 (4.4)	63
Bedroom, carpeted	1663 (6.4)	423 (7.7)	35
Mattress	2753 (4.4)	594 (7.4)	96
Classroom, uncarpeted	21 (1.9)	3 (3.8)	35
Classroom, carpeted	35 (3.2)	19 (5.5)	63

¹ Geometric standard deviation.

dust from uncarpeted floors (Student's *t*-test: living rooms, $P < 0.001$; bedrooms, $P < 0.001$; and classrooms, $P < 0.01$).

Table 3 shows the mean values for the health outcome variables (averages for the days spent at school) in the total population, and in four different subgroups, classified according to type of floor cover in the bedroom and in the classroom. The data gave no indication that peak-flow variability, acute respiratory symptoms, medication use, or all three were consistently higher in the children who had uncarpeted bedroom floors at home and who were attending schools with carpeted classroom floors, than in those who were attending school with uncarpeted classroom floors. Peak-flow variability was marginally higher ($P < 0.10$) in children with carpets in the bedroom and classroom than in children with carpets in the bedroom but not in the classroom. Children with no carpets in bedroom and classroom used more medication than children in some of the other subgroups.

Table 4 shows the relationship between the health outcome variables and the *Der p* I levels found in classroom floor dust and mattress dust, for children who were sensitized to house-dust mite. A significant positive relationship was found for PEF variability with mattress *Der p* I only. Coefficients were positive but not quite statistically significant for wheeze and attacks of shortness of breath with wheezing. To put the estimated effects into perspective, we have expressed the change in peak-flow variability and symptom score by the percent change from the group mean associated with an increase in *Der p* I exposure in mattress dust from 2000 to 10000 ng/g. The results show an estimated increase in peak-flow variability of 24%, and estimated increases in wheeze and attacks of shortness of breath with wheezing of +31% and +55%, respectively.

There was no significant relationship between any of the health outcome variables and the *Der p* I levels measured in living-room or bedroom floor dust, or in classroom floor dust. All analyses presented in Table 4 were adjusted for age and sex.

Table 1. Population characteristics ($n = 98$)

Characteristic	n/N	%
Female	36/98	36.7%
Chronic cough	34/95	35.8%
Wheeze last year	74/90	82.2%
Shortness of breath with wheeze last year	59/86	68.6%
Reported doctor-diagnosed asthma	82/97	84.5%
Pet allergy ¹	50/97	51.5%
Pollen allergy ¹	32/97	33.0%
Reported house-dust allergy ¹	62/97	63.9%
House-dust-mite allergy ²	54/88	61.4%

¹ From questionnaire.

² RAST class ≥ 2 in serum.

Table 3. Mean values and standard errors of health outcome variables in subgroups classified according to type of floor cover in classroom and in bedroom

Health outcome variable	B+C+ ¹ n = 24	B+C- ² n = 11	B-C+ ³ n = 39	B-C- ⁴ n = 24	Total n = 98
PEF variability	0.16 (0.02)	0.10 (0.01) ⁵	0.12 (0.01)	0.14 (0.02)	0.13 (0.09)
Bronchodilator use	1.49 (0.29)	0.75 (0.45)	1.47 (0.28)	2.52 (0.52) ⁶	1.65 (1.94)
Maintenance medication use	2.43 (0.32)	1.40 (0.64)	2.26 (0.31)	3.42 (0.69) ⁷	2.49 (2.37)
Cough	0.43 (0.10)	0.59 (0.17)	0.52 (0.09)	0.45 (0.10)	0.49 (0.50)
Wheezing	0.22 (0.06)	0.14 (0.07)	0.16 (0.05)	0.13 (0.04)	0.17 (0.26)
Shortness of breath	0.22 (0.05)	0.26 (0.10)	0.20 (0.05)	0.33 (0.08)	0.24 (0.33)
Shortness of breath with wheezing	0.02 (0.01)	0.01 (0.00)	0.02 (0.01)	0.05 (0.03)	0.03 (0.07)
Woken up by respiratory symptoms	0.18 (0.06)	0.07 (0.03)	0.17 (0.05)	0.09 (0.04)	0.14 (0.26)

¹ Bedroom floor carpeted and classroom floor carpeted.
² Bedroom floor carpeted and classroom floor uncarpeted.
³ Bedroom floor uncarpeted and classroom floor carpeted.
⁴ Bedroom floor uncarpeted and classroom floor uncarpeted.
⁵ B+C+ significantly higher than B+C- ($P < 0.10$, two-sided).
⁶ B-C- significantly higher than B+C- ($P < 0.05$) and B-C+ ($P < 0.10$).
⁷ B-C- significantly higher than B+C- ($P < 0.05$) and B-C+ ($P < 0.10$).

Table 4. Regression coefficients and standard errors for health outcome variables with *Der p* I level in mattress dust and classroom floor dust, standardized for age and sex; subjects sensitized to house-dust mite ¹ ($n = 53$)

Health outcome variable	Regression coefficients for:	
	In <i>Der p</i> I mattress	In <i>Der p</i> I classroom
PEF variability	0.020 (0.009)* (+24%) ²	-0.005 (0.015)
Cough	0.033 (0.046) (+11%)	-0.102 (0.076)
Wheeze	0.037 (0.024) (+31%)	-0.075 (0.039) ⁺
Shortness of breath	0.003 (0.036) (+2%)	-0.022 (0.060)
Attacks of shortness of breath with wheezing	0.012 (0.009) (+55%)	-0.018 (0.015)
Woken up by respiratory symptoms	-0.009 (0.025) (-10%)	-0.067 (0.041)
Bronchodilator use	-0.091 (0.191) (-7%)	-0.048 (0.320)
Maintenance medication use	-0.256 (0.235) (-15%)	-0.045 (0.393)

* $P < 0.05$.
⁺ $0.10 > P > 0.05$.
¹ RAST class ≥ 2 .
² Estimated percent change from group mean associated with increase in *Der p* I in mattress dust from 2000 to 10000 ng/g.

Discussion

In this study, we could not show a clear relationship between wall-to-wall carpeting in schools and the health of asthmatic children. Although a difference was found between *Der p* I levels in dust from carpeted and uncarpeted school floors, allergen levels in dust from carpeted schools were, in most cases, even lower than in dust from uncarpeted floors in homes. When expressed as ng/m², the levels found on carpeted classroom floors were somewhat higher than on smooth living-room and bedroom floors, but still much lower than on carpeted floors in homes and on mattresses. This confirms the results of former studies (2, 18).

The asthmatic children in this study used more than one dose of a bronchodilator, and more than two doses of a maintenance medication daily, on average. Although increased reporting of symptoms was related to increased use of bronchodilators, it is

not clear to what extent the symptoms were suppressed by the daily use of medication, which could lead to a masking of relationships between classroom floor type and acute respiratory symptoms. However, there was no relationship between classroom floor type and the daily use of either bronchodilators or maintenance medication either. Children having no carpets in bedroom and classroom used more medication than children in some of the other subgroups, probably reflecting that parents of more severely asthmatic children were more likely to have removed carpets from the bedrooms of their children.

Der p I levels found in dust collected from classroom floors were much lower than in dust collected from bedroom floors and mattresses. There was no single classroom floor on which more than 1 µg *Der p* I/g of dust was found. In contrast, mean mattress levels were well over 2 µg/g, a level supposed to be high enough to lead to sensitization (11, 12).

Although it must be considered that in crowded classrooms, settled dust may become resuspended in the air more easily than in the home, the difference in mean *Der p* I concentrations between dust collected from classroom floors and mattresses, respectively, was about 100-fold. It is likely that in this population of asthmatic children, many of whom were allergic to dust mites, the home environment provided more allergenic stimuli than the school environment; therefore, the small differences in allergen load between carpeted and uncarpeted classroom floors did not result in differences in peak-flow variability or symptom reporting between children visiting these two types of schools. Further support for this interpretation is given by the results of the analysis of the relationships between health outcome variables and allergen levels in the home. Peak-flow variability was found to be significantly correlated with the *Der p* I content of mattress dust in children sensitized to dust mites. Although the relationships with wheeze and attacks of shortness of breath with wheezing did not reach statistical significance, the magnitude of the estimated effect (expressed as percent change from the group mean) for these two variables was actually larger than the estimated effect on peak-flow variability. In a recent study among adult asthmatic patients in France, medication use was found to be correlated with the level of *Der p* I in mattress dust (19). In our study, the dose of medication (either bronchodilators or maintenance medication) was not associated with mattress dust *Der p* I levels, but peak-flow variability was, suggesting a modest effect not leading to a change in medication use.

The population of children studied was relatively small, and it cannot be excluded that subtle effects of the school environment were overlooked because of the small sample size. However, there was no trend in the data suggesting a negative effect of carpeted classroom floors on the respiratory health of the children in this study. Most children were mite allergic. It is conceivable that other allergens (such as the mobile cat allergens) are present in classroom floor dust to a greater extent than dust-mite allergens, and cat-allergic patients could for this reason have more symptoms when visiting schools with carpeted classroom floors. Recently, it has also been suggested that cat and dog allergens collect on chairs and tables rather than on floors in classrooms (9), to an extent that significant exposure of children could result.

In summary, this study has not been able to show that asthmatic children visiting schools with carpeted classroom floors had higher peak-flow variability or more respiratory symptoms or medication use than asthmatic children visiting schools with uncarpeted classroom floors, even when the type of

floor cover in the home of the children was taken into account. Levels of *Der p* I in dust collected from classroom floors were much lower than in dust collected from home floors and mattresses.

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