

Mite allergens during 18 months of intervention

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In Stockholm, Sweden, 17 children with newly diagnosed sensitization to house-dust mites (HDM) and 11 children with previously diagnosed HDM-sensitization were included in a study of HDM-allergen avoidance. Mattress dust was collected on repeated occasions during 18 months and assayed for concentration of major HDM allergens. During the first 12 months, the parents of the intervention group were instructed to intensify cleaning and airing of the child's bedroom. During the last 6 months of the study, the mattresses and pillows of seven children in the intervention group and sibling controls were encased in semipermeable polyurethane covers. The homes exhibited a high absolute indoor humidity throughout the year, and even during the winter the mean levels exceeded 7 g/kg. No mite allergen reduction was seen in the intervention group during the first year. However, among the newly diagnosed HDM-sensitized children, there was a mean reduction of the mattress mite allergen concentration of 83% ($P = 0.02$), and this was most pronounced in the homes with low humidity. At the end of the mattress encasement period, an average difference of 98% ($P < 0.001$) was found between the vacuumed amount of mite allergen on top of the covers and that underneath.

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Allergen avoidance is crucial in the self-management of allergic disease. Allergy to the house-dust mite (HDM) is a worldwide problem (19, 21, 25, 28), and various intervention programs have been proposed to reduce mite exposure. Since mite survival depends on humidity, improvement of ventilation is a suggested approach to the problem in some climatic regions (10). Dehumidification of mattresses with electric blankets has also been tried (14). Improved bed and bedroom cleaning and covering of pillows and mattresses have been considered to be important in this context (2, 3, 7, 11, 16, 26, 27). Mattress and pillow covers of vinyl may be uncomfortable, mainly because of increased perspiration, and can therefore be unsuitable, particularly for patients with atopic eczema. However, Gore-Tex[®] and polyurethane water-vapor-permeable covers do not have these disadvantages (6, 18). The use of acaricides has produced inconsistent results (8, 9, 22).

The present study was designed to investigate the effects on mite allergen levels of improved cleaning

combined with bedroom and mattress airing. The effect of semipermeable mattress covers on the mite-allergen concentration in dust obtained from the cover surface and from the mattresses underneath was also investigated.

Material and methods

Patients

Twenty-eight children were included, 18 girls and 10 boys aged 4–17 years (median 13). They suffered from bronchial asthma, atopic eczema, and/or allergic rhinitis and had exhibited a $\geq 2+$ skin prick test (SPT) reaction during the preceding year to *Dermatophagoides pteronyssinus* (Dpt) or *D. farinae* (Df). Mite infestation of the children's mattresses had been demonstrated by microscopic examination of mattress dust samples (12, 24). Seventeen of the children (reference group) had received a diagnosis of HDM sensitization within a year before the study started, and 11 had been diagnosed earlier (inter-

vention group) (29). Since the children varied in type of atopic disease, no systematic evaluation of symptoms during the study was performed. Five of the children in the intervention group lived in single-story, one-family houses, and the other six in multi-story, one-family houses, whereas in the reference group six children lived in single-story, one-family houses, nine in multistory, one-family houses, and two in apartments. The homes were constructed between 1930 and 1987, and the median years of construction in the intervention and reference groups were 1969 and 1974, respectively.

The study was performed during 18 months, from October 1989 until May 1991. The parents of the intervention group were given written instructions regarding the child's bedroom to do all of the following:

- remove all carpets
- use only quilts and pillows washable in hot water ($\geq 60^{\circ}\text{C}$) and to wash them at the beginning of the study
- wash bed linen every second week
- vacuum-clean mattress and pillow twice monthly
- air bedroom for 30 min twice daily
- remove all quilts, pillows, and bed linen during the day for the purpose of airing the mattress.

These instructions were repeated orally 1 month after the start of the study. The families of the reference group were asked not to change their living or house-cleaning habits during the study period, but were informed that their child's mattress was infested with HDM.

At the end of the first study year, seven children in the intervention group used a mattress that was of the same age (± 2 years) as that of a sibling. These seven pairs were included in a further 6-month study of the effects of using semipermeable mattress and pillow covers (Allergy Control Products, Inc., Ridgefield, CT, USA). The mattresses of the siblings were not covered and served as controls. The families were instructed not to perform any bed vacuuming except for sampling, either of the covered bedding or of the bedding of the sibling control.

Skin prick tests and measurements of specific IgE antibodies

The children were retested with SPT on four occasions during the first 12 study months in October 1989 and March, June, and October 1990. On all occasions, capillary blood samples were drawn for determination of specific IgE antibodies in serum. SPT was performed with lancets precoated with *Dpt* and *Df* (Phazet, Pharmacia Diagnostica, Uppsala, Sweden). The skin reactions were read 15 min after skin puncture and the wheal sizes were calculated as the mean of the longest wheal diameter and its per-

pendicular. A chemiluminescence method was used to detect specific IgE antibodies against *Dpt* and *Df* (Magic Lite[®]/ALK), according to the instructions of the manufacturer, and IgE antibodies were expressed in relation to a reference serum.

Dust collection and assessment of HDM exposure

Within 1 week of all four occasions of skin prick retesting, i.e., October 1989 and March, June, and October 1990, dust was collected from the children's mattresses with the families' own vacuum cleaners equipped with a nozzle containing a collector and a filter paper (15). Instructions were given to the parents not to vacuum their child's mattress during the 2 weeks before sampling. Two dust samples were collected from each mattress, after vacuuming for 2.5 min of each mattress half divided lengthwise. The dust samples were sealed in plastic bags and stored at -18°C until processed. For the second period of the study, dust was sampled both from the cover surfaces and underneath the mattresses immediately after cover application. This was repeated after 1 and 6 months. The dust samples were analyzed for concentrations (ng/g dust) of *Dermatophagoides* major allergens (the sum of *Der p* I, *Der f* I, and *Der m* I) by enzyme-linked immunosorbent assay (ELISA) at ALK, Hørsholm, Denmark (13). No dust samples were obtained from three families in March 1990.

Indoor humidity and temperature registrations

During the first study year, indoor humidity and temperature of the child's bedroom were registered during 7 weeks evenly distributed over the year. Readings were performed on at least three consecutive mornings of each of these weeks. Thermohygrometers were used (Feingerätbau K. Fischer GmbH, Drebach, Germany) and calibrated with an electronic hygroscope (Rotronic DV2, Bern, Switzerland) at the beginning of the study and after 6 and 12 months. The mean of the three consecutive morning readings of indoor relative humidity was transformed to absolute indoor humidity (AIH) with a Mollier diagram and expressed as gram water vapor/kg air.

Questionnaire

After collection of the first mattress dust samples, the parents completed a questionnaire about residential characteristics. Frequency of floor and mattress vacuuming was asked for, as well as frequency of and temperature used at washing of linen. The questions were repeated after 12 months.

Statistical analyses

Wilcoxon's two-sample test with two-tailed P values was used, and correlation coefficients were determined by Spearman's rank correlation test.

Results

All children used washable quilts and pillows. At the start of the study and after 12 months, the general cleaning habits did not differ between the two groups. However, the reported frequency of mattress vacuuming had increased in both groups from every second month at the beginning of the study to an average of twice a month, and all carpets in the children's bedrooms had been removed. Linen washing in accordance with the instructions was reported by all families of the intervention group, but the mattresses had been aired in only four of 11 homes, and only one of the families had complied with the instruction to air the bedroom twice daily.

Indoor and outdoor humidity during the study period is depicted in Fig. 1. The registrations in January and March 1990, i.e., in the middle of winter, revealed average AIH levels exceeding 7 g/kg. In January, only seven of the 28 residences had an AIH below 7 g/kg, two in the intervention and five in the reference group, respectively. There was no difference in the AIH levels between the residences of the two groups, and a correlation ($r = 0.66$; $P < 0.001$) was found between AIH levels registered at the beginning and end of the study.

There was no systematic change in mattress dust-mite allergen concentration (MAC) in the interven-

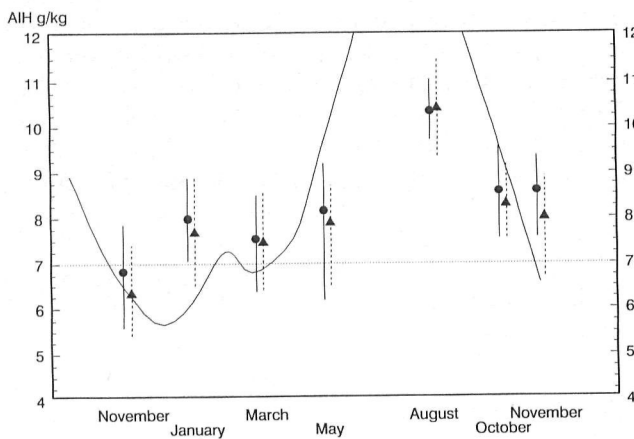


Fig. 1. Morning absolute indoor humidity (AIH) during 3 consecutive days measured in bedrooms of 28 mite-allergen-positive homes during November 1989–November 1990 in relation to average monthly outdoor humidity in Stockholm, Sweden. Circles and triangles denote mean indoor AIH in intervention and reference groups, respectively. Vertical lines denote middle quartiles. Absolute indoor humidity is expressed in gram of water vapor/kg air. Outdoor humidity is indicated by curved line.

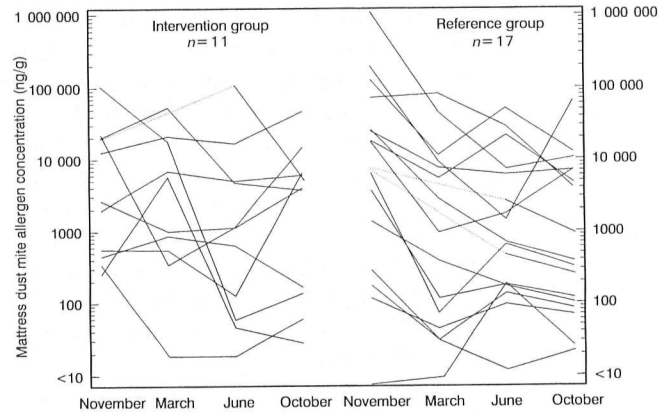


Fig. 2. Mattress dust mite allergen content (the sum of the major allergens *Der p* I, *Der f* I, and *Der m* I in ng/g dust) during 1 year of allergen avoidance in homes of HDM-sensitized children in Stockholm, Sweden ($n = 28$). Chained lines denote two missing dust samples in three children in March 1990.

tion group, when levels in November 1989 were compared with those of October 1990 (Fig. 2). The dust MAC had increased in four cases, and a decrease was observed in seven of the mattresses, giving an overall reduction of 25% ($P = 0.6$). In the reference group, however, the MAC decreased in most of the beds, and the average mite allergen reduction was 83% ($P = 0.02$).

At the beginning of the study, no relationship was found between AIH and mattress MAC in the two study groups combined, but a correlation ($r = 0.38$; $P = 0.05$) was found after 1 year which was more pronounced in the reference group ($r = 0.57$; $P = 0.02$). In that group the reduction of MAC was most pronounced in homes with low humidity; that is, there was a negative correlation ($r = -0.55$; $P = 0.03$) between the magnitude of reduction of

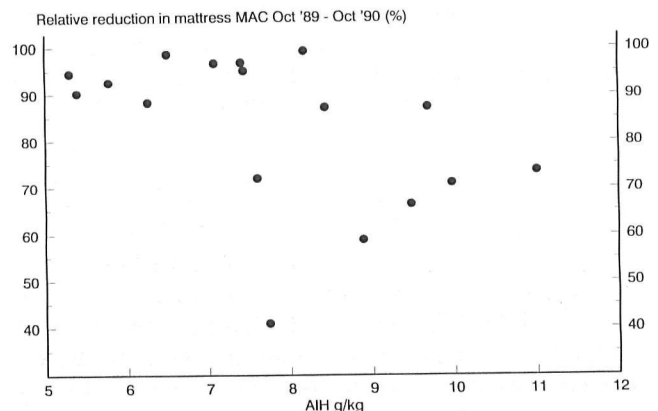


Fig. 3. Relative reduction in mite allergen concentration (MAC) of mattress dust samples during 1 year in relation to absolute indoor humidity (AIH), in January 1990, of 17 homes of the reference group children in Stockholm, Sweden ($r = -0.55$; $P = 0.03$).

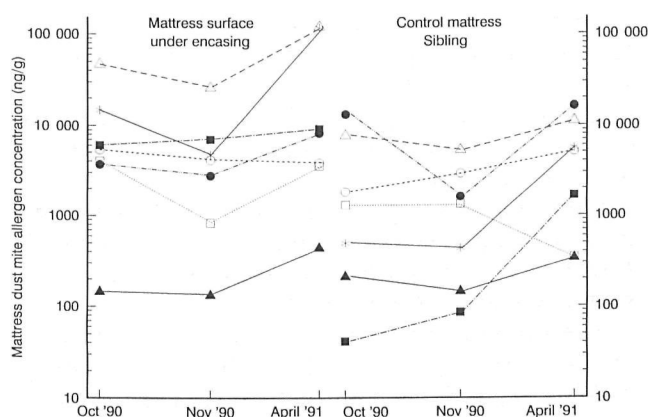


Fig. 4. Mite allergen concentration (the sum of major allergens *Der p* I, *Der f* I, and *Der m* I in ng/g dust) of mattress surfaces under covers and of sibling control mattresses during 6 months in Stockholm, Sweden. Each marker character in the covered mattress and sibling control groups, respectively, corresponds to the same home.

MAC during the study and winter (January) AIH (Fig. 3). The two families who were most compliant with the airing and cleaning program also had the most pronounced reduction of mattress dust MAC, from 106 000 to 138 and 258 to 28 ng/g of dust, respectively.

During the encasement period (November–April), no reduction of MAC was found in the mattress dust obtained under the covers or from the sibling control mattresses (Fig. 4). Instead there was a slight increase of MAC in both groups, an increase which was somewhat more pronounced in the dust from the sibling control mattresses than from the covered mattresses ($P = 0.2$ and $P = 0.7$, respectively).

At the start of the encasement period, only a little dust could be collected from the covers (data not shown). One cover sample of 0.07 g of dust held 63 ng mite allergen. Therefore, the mite allergen levels were expressed in total amount of sampled mite

allergen instead of ng/g of dust. At the beginning of the study and after 1 and 6 months, the average differences in total mite allergen content between the samples from the cover surface and of the mattresses underneath were 98.7%, 92.8%, and 98.0%, $P < 0.001$, in all periods, respectively (Table 1).

No change occurred in the two groups in degree of sensitization assessed by SPT reactivity or specific serum IgE antibodies against *Dpt* or *Df* during the study.

Discussion

Reduction of the allergen content in carpets, upholstered furniture, and mattresses is an important part of the management of allergic and asthmatic patients (17), but the efficacy of vacuuming for mite allergen removal has been questioned (4, 15). In the present study, the children in the intervention group had previously participated in an HDM study and had been promised a mite-allergen-avoidance program. The group including newly diagnosed children was incorporated with the same criteria of inclusion as for the intervention group. The parents of the intervention group were instructed to remove bed carpets and wash bed linen, and to vacuum the children's mattresses twice monthly. Except for airing of mattresses and bedrooms, adherence to these measures was reported to be very good. Yet MAC in the intervention group was largely unchanged after 1 year.

In regions with a temperate climate, there is a wide distribution of mite allergen levels in homes, ranging from zero to high levels (29), whereas in warm coastal regions mite allergens are more ubiquitous in mattress dust (5, 25). The great variation in temperate regions appears to be a consequence of differences in indoor humidity among different types of homes (29). Nevertheless, it seems likely that in houses with indoor winter AIH just below the lowest level re-

Table 1. Total amount of vacuumed mite allergen from seven mattresses and the respective cover surfaces at beginning of study and after 1 and 6 months of encasement with semipermeable mattress and pillow covers

Pat. no.	Mattress* subcover	Cover surface	Reduction (%)	Mattress subcover	Cover surface	Reduction (%)	Mattress subcover	Cover surface	Reduction (%)
	Oct 1990			Nov 1990			April 1991		
1	12688	3	100	2360	6	99.8	65251	480	99.3
2	4469	63	98.6	956	59	93.8	1649	145	91.2
3	4000	288	92.8	294	13	95.6	2167	22	99.0
4	84994	13	100	26260	140	99.5	161269	558	99.7
5	7430	44	99.4	1848	137	92.6	12460	103	99.2
6	10956	0	100	4938	9	99.8	12816	54	99.6
7	213	0	100	16	5	68.8	413	9	97.8
Mean reduction			98.7			92.8			98.0
P value	<0.001			<0.001			<0.001		

* In October 1990, only 50% of the mattress surface was vacuumed. Thus, the vacuumed amount of mite allergen in that period is doubled.

quired for mite survival, there may be a suitable microclimate for mite growth in mattresses or carpets. Hypothetically, then, very small changes in cleaning and airing habits that may be undetectable by questionnaires may disturb this microclimate, making it unsuitable for mite survival. The reduction of mite allergen in the mattress samples of the reference group was more pronounced in the homes with low winter AIH than in those which were more humid. The two families in the intervention group who were the most compliant with the airing program exhibited the most pronounced reduction of the mattress dust-mite allergen concentration. Thus, the observed changes in MAC levels seem to relate to lowering of the mattress humidity in homes with an indoor air humidity not reaching extreme values.

At the beginning of the study, the parents of the reference group were asked not to change their general cleaning habits, but at the end of the study, mattress vacuuming was performed to the same extent as in the intervention group. Thus, it appears that parental awareness of a possible mite infestation problem leads to changes in cleaning habits. The minor reduction seen in the intervention group during the study may be a consequence of such parental awareness and of the possibility that measures taken before entering the study had already reduced the mite levels to a minimum.

In the second part of the study, the effect of placing semipermeable covers on mattresses and pillows was investigated. The application of covers resulted in a more than 10-fold reduction of the total mite allergen content, as seen by comparing dust from the cover surfaces with that underneath as well as with the control mattresses. Furthermore, the increase of HDM antigen in mattress dust collected under the covers was not more pronounced than in dust of control mattresses, indicating that mite replication inside the mattresses was not favored by the covers. As regards the occurrence of mite allergens in dust from the cover surface, there was a very low penetration through the covers, since intense vacuuming of the cover surface at the start of the encasement period yielded an almost negligible HDM allergen amount. Contamination as from quilts and clothes or by airborne allergens, followed by colonization, seems to be the most likely explanation of the mite allergen level in cover dust during the study with the exception of one cover (patient no. 3, October 1990).

The high AIH levels measured in the summer reflect outdoor humidity. However, those recorded in the winter were almost as high, and in 21 of 28 (75%) homes they were above 7 g/kg. In a previous case control study, we investigated residential characteristics for HDM-sensitized and other atopic and control children (24). In that study, which used the same method for indoor humidity measurements as

the present, only 15% of the HDM-sensitized and 12% of other atopic and healthy control children lived in homes with winter AIH ≥ 7 g/kg. In our study, homes that were particularly humid were included. It is noteworthy that the homes generally did not dry out during the winter, and exhibited little seasonal variation of mite allergen levels. This contrasts with other studies performed on occurrence of HDM in countries with a much warmer and more humid climate in the winter (1, 20, 23).

Several different approaches regarding preventive measures in house-dust mite allergy are used today. It is still very difficult to make definite recommendations, but to ensure compliance for allergen avoidance such programs should preferably be simple. Our results indicate that the application of semipermeable mattress covers markedly reduces exposure of mite allergen in beds and could be useful in clinical practice. Cleaning showed little efficacy in the most humid homes, indicating that measures that lower the indoor humidity may prove particularly rewarding in temperate climates.

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