

House dust mite sensitization in children and residential characteristics in a temperate region

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House dust mite (Hdm) infestation used to be rare in Stockholm, but Hdm-sensitized children are now frequently observed, which probably indicates an increased infestation rate. This study was performed to elucidate determinants of Hdm sensitization in children living in the area. In a case-control study, 53 Hdm-sensitized children (cases), a group of non-Hdm-sensitized atopic children (N = 54), and a group of nonallergic neighborhood children (N = 53) were included. Mattress dust was analyzed with ELISA for content of Hdm allergens. Indoor humidity and temperature were measured, and questionnaire data were collected. Asthma was significantly more common in the Hdm-sensitized group than in the atopic control group. Hdm allergens were found in 40%, 19%, and 23% of the dust samples of the case group, atopic group, and neighborhood control groups, respectively. Only 15% of the dust samples of the Hdm-sensitized children contained Hdm allergens above the recommended threshold levels of sensitization of 2000 ng/gm of dust. Inadequate ventilation, which partly appeared to be a consequence of energy saving, appeared to be a risk factor for Hdm sensitization. This result may apply also to other temperate regions and suggests that the problem is preventable. (J ALLERGY CLIN IMMUNOL 1991;88:89-95.)

Key words: dust mites, ELISA, mite infestation, asthma, human dwellings, energy saving

Mites of the Pyroglyphidae family are cosmopolitans and can be found almost all over the world where there are human beings. Humidity is the most important limiting factor for their survival. A higher Hdm infestation and sensitization rate is observed in subjects living in humid and coastal areas¹⁻³ than observed in dry areas of the world,^{4,6} and excessive growth of Hdm has been estimated to occur at wintertime AIH of 7 gm of water per kilogram or more

Abbreviations used

Hdm:	House dust mite
Dpt:	<i>Dermatophagoides pteronyssinus</i>
Df:	<i>Dermatophagoides farinae</i>
Dm:	<i>Dermatophagoides microceras</i>
SPT:	Skin prick test
AIH:	Absolute indoor humidity
OR:	Odds ratio
CI:	Confidence interval
MAC:	Mite-allergen content
AR:	Allergic rhinitis
Ag:	Antigen

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of air.^{7, 8} Hdm Ags are in many parts of the world considered to be the most important allergens of house dust. Thus, the Hdm content is often related to the allergenicity of the dust.^{9, 10} The climatic conditions in middle and northern Sweden are unfavorable for Hdm growth, and in a study from Stockholm performed in 1975, Hdm-positive dust samples were found in only 1.5% of the homes of dust-sensitized adults, whereas a study from the same area 11 to 12

years later demonstrated Hdm allergens in 67% of bed mattress dust samples of Hdm-sensitized children.^{11, 12} Thus, mite infestation appears to have increased in our region.

The purpose of this study was to elucidate determinants of sensitization to Hdm in children with special emphasis on the construction of buildings, energy-saving measures, etc.

MATERIAL AND METHODS

Subjects

The study was designed as a case-control study. Atopic children, aged 3 to 17 years, attending the outpatient clinic of St. Göran's Children's Hospital, Stockholm, during January 1986 to September 1987, were included. A total of 555 children with bronchial asthma, AR, or atopic eczema had a positive SPT to at least one airborne allergen. Of the 555 children, 56 who exhibited a positive SPT reaction to *Dpt*, *Df*, or both, were included as cases, and another 56 consecutive children without such positivity constituted an atopic control group. A second control group, the neighborhood control group, included nonallergic children who were friends of the children in the case group and lived in their neighborhood. These children were chosen by the parents of the children in the Hdm-sensitized group. Other criteria for inclusion of the three study groups were (1) born and reared in the central or northern parts of Sweden in which Hdm infestation has been regarded as absent or minor, (2) lived for more than 2 years in the present residence, (3) had SPT performed not earlier than 1 year after having moved into the present residence, and (4) have parents with an appropriate knowledge of the Swedish language.

Not more than one child per dwelling was included. A total of 166 children and their families fulfilled the criteria for inclusion. Questionnaires were obtained for 160 (96%) children, with three missing in the Hdm-sensitized group, two in the atopic control group, and one child missing in the neighborhood control group, making 53, 54, and 53, respectively, in the three study groups. Informed consent was given by the parents. The study was approved by the Ethical Committee of Karolinska Hospital, Stockholm.

Allergen preparations and SPT

Precoated lancets (Phazet, Pharmacia AB, Uppsala, Sweden) with allergen content corresponding to 100,000 BU/ml of aqueous solution were used for SPT in principle, as suggested in the Nordic guidelines.¹³ Skin tests were performed as single tests for *Dpt*, *Df*, birch, timothy, cat, dog, *Cladosporium herbarum*, and *Alternaria alternata*. Reactions were related to reactions of a lancet precoated with histamine hydrochloride corresponding to 10 mg/ml. Reactions were read 15 minutes after testing and regarded as positive if there was a wheal reaction of at least half the size of the histamine-induced wheal. A total atopy score was calculated as the sum of each individual's positive reaction for six of the eight allergens used, *Dpt* and *Df* excluded. This atopy score did not differ significantly between the Hdm-sensitized group and the atopic control group. In

the Hdm-sensitized case group, 48 (91%) children had a positive reaction to *Dpt* and only 20 (38%) to *Df*. Five children had a positive reaction to *Df* alone.

Dust sampling and assays of Hdm-Ag contents

Dust samples were collected from the children's bed mattresses by the parents during a period of 3 weeks in October to November 1987. The families' own vacuum cleaners were used with a nozzle containing a filter paper with an average pore diameter of 5 to 6 μm . The filter has been reported to retain all particles $>10 \mu\text{m}$ in diameter and 95% of the number of the particles between 1 to 10 μm in diameter (Allergologisk Laboratorium A/S, ALK, Hørsholm, Denmark). Vacuum cleaning was performed for 5 minutes on the upper surface of the children's bed mattresses after removal of the bed linen.¹⁴ All samples but two in the atopic control group contained sufficient amounts of dust for analysis.

The dust samples were delivered by regular mail and kept at -20°C until analysis. Aqueous extracts were prepared and the amounts of major allergens of the three *Dermatophagoides* species, *Dpt*, *Df*, and *Dm*, were measured with an ELISA with affinity-purified, monospecific rabbit antibodies to the major allergens, *Der f I* (*Df* 6) and *Der m I* (*Dm* 6).¹⁵ For the major allergen *Der p I*, a modification was used with monoclonal antibody *Der p I* as first-layer antibody.^{16, 17} Dilution series of a standard were assayed simultaneously. The detection limits of the assays were 20, 80, and 60 ng/gm of dust of the Ags, *p I* for *Dpt* (*Der p I*), *f I* for *Df* (*Der f I*) and *m I* for *Dm* (*Der m I*), respectively; $<0.1\%$ cross-reactivity was observed between the species-specific antisera. The assays were performed at Allergologisk Diagnose Laboratorium A/S, ALK.

Residential humidity and temperature measurements

Calibrated synthetic hair thermohygrometers (Fischer GmbH, Drebach, Germany) were delivered to the families, and daily readings of indoor humidity and temperature were performed by the parents during one of two specified consecutive calendar weeks in March 1988. The outdoor mean temperature in the area during this period was -3.5°C (Dagsten A. Personal communication, Swedish Meteorological and Hydrological Institute). The thermohygrometers were installed in the bedrooms of the children 1m above the floor level on a partition wall away from windows and radiators. Window vapor in the living room and in the child's bedroom was registered simultaneously. Relative humidity data were transformed to AIH. For technical reasons, these measurements failed in eight of the houses of the Hdm-sensitized group and in nine and seven houses of the atopic and neighborhood control groups, respectively.

Questionnaire

A self-administered questionnaire was delivered by mail to the parents of the children under study in April 1988. Telephone interviews were used to clarify ambiguities and unanswered questions. The questionnaire focused on resi-

TABLE I. Sociodemographic and residential characteristics of Hdm-sensitized children and their families and of two control group

	Hdm-sensitized group (N = 53)	Atopic control group (N = 54)	Neighborhood control group (N = 53)
Age (yr) mean (range)	10.3 (4-17)	11.0 (4-17)	10.0 (4-17)
Boys	31 (58%)	37 (69%)	27 (51%)
Separated parents	12 (23%)	12 (22%)	12 (23%)
No. of persons/100 m ² mean (range)	3.7 (1.8-9.6)	3.4 (1.0-5.9)	3.5 (1.5-6.9)
Child sharing bedroom	13 (25%)	10 (19%)	7 (13%)
No. of families with pre- vious dwelling	29 (55%)	33 (62%)	39 (74%)
Previous dwelling located in the Stockholm area	26 (49%)	28 (52%)	36 (68%)
Holiday $\geq$ 14 days in known mite-infested area	17 (32%)	15 (28%)	19 (36%)
At least one smoker in the family	25 (47%)	24 (44%)	22 (42%)
No. of families with $\geq$ 5 cig- arettes smoked in the home daily	10 (19%)	9 (17%)	13 (25%)

Figures indicate number of subjects in each group except for age and population density.

dential environmental conditions of previous and present residences, including the type and construction of the dwellings. It also dealt with housing characteristics, such as installation of external thermal insulation, window and door draught proofing, new ventilation and heating systems, indoor materials, types of furniture and bed material, carpeted area, residential smoking, hobby activities, number/species of pets, etc. The total indoor water vapor load was estimated from the use of humidifiers, cooking time, tub bath habits, use of laundry, sauna within the house, aquarium, amount of flower water used per week, and distance to a lake. Special emphasis was put on indications of damp housing conditions, such as visual presence of mold, damp patches, and condensation on the inside of double-paned glass windows. The children's heredity for allergic diseases was also registered as well as their own symptoms.

Statistical analyses

Comparisons between various exposure groups were expressed as ORs with 95% CI according to the method of Cornfield.¹⁸

In addition, tests for trend were performed according to the method proposed by Mantel.¹⁹

Since the mite-allergen distribution was skewed, comparisons of the Hdm-sensitized case group with the two control groups were performed with Kruskal-Wallis' exact test with two-tailed *p* values.²⁰

RESULTS

The average age of the children was 10 to 11 years in the three groups, and there was a boy-to-girl ratio of 1.5:1. The case and control group families were found not to be different in any socioeconomic respect

under study (Table I). The children had lived an average of 7 years in their present residence. There were no differences between the groups in holiday visits to known mite-infested areas or smoking habits within the families.

Equal rates of parental history of asthma, AR, and eczema were registered in both groups of atopic children. However, the OR relating previous and present atopic diseases among both parents (double heredity) in the Hdm-sensitized group (14/53) to those in the atopic (11/54) and neighborhood control groups (5/53) was 0.5 (CI, 0.1 to 1.4) and 3.0 (CI, 1.2 to 7.4), respectively. Atopic heredity for at least one parent was 49% (26/53), 67% (36/54), and 42% (22/53) in the Hdm-sensitized, atopic, and neighborhood control group, respectively.

Asthma during the previous year was found in 44 (83%) of the group of Hdm-sensitized children and in 27 (50%) among the children of the atopic control group (Table II), which corresponds to an OR for asthma of 4.9 (1.8 to 13.2). This OR was only marginally affected by adjustment for sensitization to other asthmato-genic allergens, such as cat, dog, *C. herbarum*, and *A. alternata*. Asthma was not more common in the case group children with Hdm-positive than with Hdm-negative dust samples (data not presented). Similar rates of AR and atopic eczema during the previous year were found in the two groups of atopic children.

Dust-sample weights demonstrated a Gaussian distribution. The type and age of vacuum cleaners used,

TABLE II. Numbers of children with present atopic diseases in the Hdm-sensitized and atopic control groups

	HDM-sensitized group (N = 53)	Atopic control group (N = 54)	OR and 95% CI
Bronchial asthma	44	27	4.9 1.8-13.2
AR	32	39	0.6 0.2-1.4
Atopic eczema	26	28	0.9 0.4-2.0

TABLE III. AIH and housing characteristics of homes of Hdm-sensitized children and two control groups

	HDM-sensitized group (N = 53)	Atopic control group (N = 54)	Neighborhood control group (N = 53)	OR and 95% CI	
				Case group vs atopic control group	Case group vs neighborhood control group
AIH gm/kg $\geq 7.0^*$	8	5	6	1.6 0.5-5.4	1.3 0.4-4.1
Adjusted residences†	43	39	42	1.7 0.6-4.5	1.1 0.4-3.2
Extra insulation	15	5	10	3.9 1.2-13.5	1.7 0.6-4.7
Heating installation	15	11	13	1.5 0.6-4.1	1.2 0.5-3.1
Natural ventilation	38	38	32	1.1 0.4-2.7	1.7 0.7-4.1
Reduced ventilation‡	40	38	29	1.3 0.5-3.3	2.5 1.0-6.3

*AIH measurements were not performed in the homes of eight, nine, and seven of the Hdm-sensitized, atopic, and neighborhood control groups, respectively.

†Renovated or rebuilt residences installed with new heating systems, new ventilation systems, or equipped with improved thermal insulation, draught-proofings, etc.

‡Residences with no air-intake systems or with air-intake systems closed or partially closed.

carpeted areas, and case/control status did not influence the amount of collected dust. One child in the Hdm-sensitized group used eiderdown compared to five and six in the atopic and neighborhood control groups, respectively, and there were no differences among the three groups with respect to type of mattress used. The general cleaning habits were equal in the three groups except that the parents of both atopic groups, those in the case group in particular, reported slightly more frequent vacuum cleaning of the children's bed mattresses. Hdm allergens were found in 40% of the dust samples from the homes of the Hdm-sensitized group and in 19% and 23% of the homes of the atopic and neighborhood control groups, respectively. Large variations in amounts of Hdm allergen were found within each group (Fig. 1). The total MAC was significantly higher in the Hdm-sensitized group than in the atopic ($p = 0.01$) and neighborhood control groups ($p = 0.05$). Low levels of *Der p* I were found in all three groups. Only 14 of the children's samples in the case group held detectable amounts compared to five and eight samples of the two control groups, respectively. *Der f* I was al-

most absent in the dust samples of both control groups. The *Dm* major allergen, *Der m* I, was found to be the most common of the assayed allergens and reached a peak level of >2 mg/gm of dust. Each of the mite allergens analyzed were significantly more common ($p < 0.05$) in the case group than in the two control groups with the exception of *Der p* I in comparison to the neighborhood control group.

The mean and range of the AIH during the week of registration was 5.8 (3.8 to 8.9), 5.5 (3.2 to 8.4), and 5.6 (3.6 to 7.9) gm/kg in the Hdm-sensitized group and atopic and neighborhood control groups, respectively, and the differences were not significant. However, the mean AIH in the homes of the Hdm-sensitized group containing mite allergens was significantly higher than in homes without mite allergens, $p = 0.01$. The temperature during this period did not differ significantly among the three groups, and an overall mean temperature of 20.6° C (15.9° to 25°) was registered.

External thermal insulation had more frequently been installed in the last 15 years in the homes of the Hdm-sensitized group compared to the homes of the

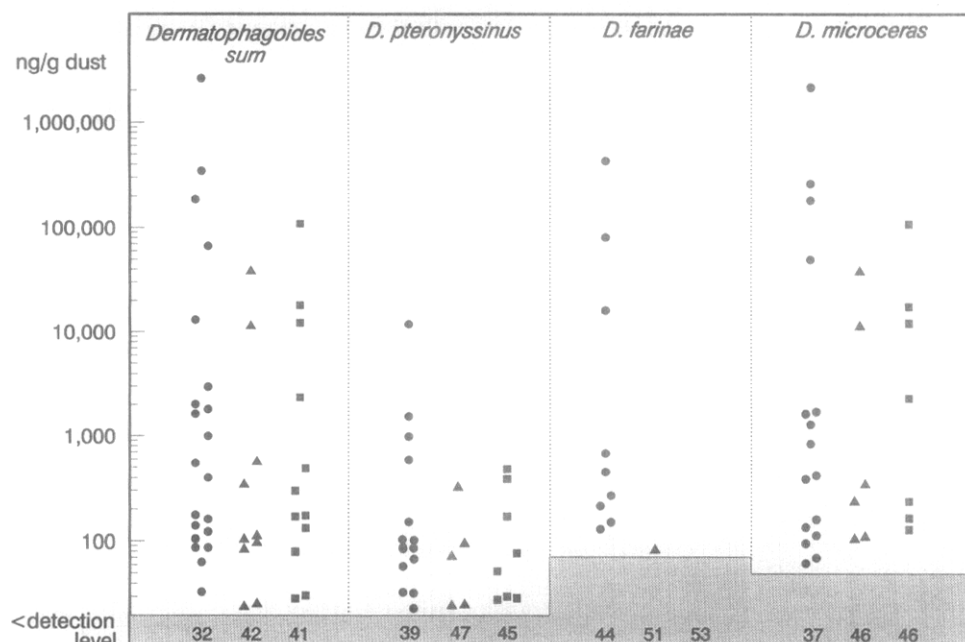


FIG. 1. Sum of the major Hdm allergen of the *Dpt*, *Df*, and *Dm* species are expressed as *Dermatophagoides sum*. Hdm-sensitized group of children (●); atopic children (▲); neighborhood group of children (■). Shaded area represents cutoff levels for detection of the Hdm major allergens; figures within this area denote number of dust samples below detection level.

atopic control group (OR, 3.9 [1.2 to 13.5]) and appeared slightly more common than in the homes of the neighborhood control group (OR, 1.7 [0.6 to 4.7]) (Table III). In Scandinavia, ventilation systems are often combined with outdoor air intakes to improve the airflow rate. Forty homes (75%) of the Hdm-sensitized group, compared to 37 (69%) of the homes of the atopic and 29 (55%) of the neighborhood control group, had no outdoor air intakes or an intake that was kept partially or totally closed.

During the week of registration, window vapor was reported in 13 (29%) of the homes of the Hdm-sensitized group, compared to five (11%) and 11 (24%) of the homes of the atopic and neighborhood control groups, respectively. Visible mold growth was reported in 16 (30%) of the homes of case group and in 11 (20%) and eight (15%) of the homes of the atopic and neighborhood control groups, respectively. Neither water vapor-producing activities nor distance from a lake differed among the three groups, and these results were not affected by population density (data not presented).

AIH and MAC in different types of dwellings in the whole residential material were studied. Individual homes, that is, bungalows, villas, and link and terrace houses, comprised 57% of all residences, and the rest were apartment blocks. A close association was found between type of dwelling and AIH (Table IV). AIH

was ≥ 7 gm/kg in seven (32%) of the single-storey individual houses compared to eight (14%) and four (7%) of the multistorey individual houses and flats, respectively. A close association between AIH and MAC within the homes was also observed. Thus, mite allergens were more often found in single-storey individual houses than in multistorey individual houses and apartment blocks (test for trend, $p < 0.001$).

DISCUSSION

Mite allergy is a common cause of disease in areas of the world where environmental conditions are favorable for mite growth.²¹ It was previously believed that conditions in Stockholm were unsuitable for mite growth because of a dry indoor climate caused by the prolonged heating period during the cold winters.¹¹ Taking the generally dry indoor climate in our region into account, the growth of mites in our dwellings may be regarded as abnormal in contrast to the situation in continental Europe and on the British Isles, where residential infestation of Hdm is more or less universal.²² In a recent study, however, we found high levels of Hdm Ags in many homes of Hdm-sensitized children.¹² The importance of faulty residential construction with regard to mite infestation has been emphasized by Korsgaard on the basis of studies undertaken in Denmark.^{3, 23, 24} One reason to conduct the present study in Stockholm was that such building

TABLE IV. AIH, MAC, and type of dwellings in the whole study material of Hdm-sensitized children and two control groups

MAC (ng/gm)	≥ 20 ng	≥ 400 ng	Test for trend	
			<20 ng vs ≥ 20 ng	<400 ng vs ≥ 400 ng
AIH gm/kg				
≤ 5.4	14/64 (22%)	5/64 (8%)	χ^2 , 4.30 $p = 0.038$	χ^2 , 4.14 $p = 0.043$
5.5-6.9	17/52 (33%)	9/52 (17%)		
≥ 7.0	9/19 (47%)	5/19 (26%)		
Apartment blocks	7/69 (10%)	1/69 (1.5%)	χ^2 , 24.47 $p < 0.001$	χ^2 , 30.13 $p < 0.001$
Multistorey individual houses	21/68 (31%)	6/68 (9%)		
Single-storey individual houses	15/23 (65%)	12/23 (52%)		

characteristics are more likely to be apparent in which the indoor climate is generally dry. Furthermore, the energy consumption of detached houses and apartment buildings in Sweden has been reduced by 18% during the time interval 1975 to 1986.²⁵ This reduction was partly achieved by addition of external and roof insulation, and it should be noted that energy-saving measures, such as additional thermal insulation and reduced ventilation, appeared to be risk factors for Hdm sensitization in our study. We may at this time be facing a consequence of exaggerated energy conservation.

It is possible that parental awareness of the importance of allergen sanitation in the two groups of atopic children had some influence in this study, causing unduly low Hdm Ag levels in the bed mattress samples of these two groups. In fact, the cleaning habits in these two groups were slightly more thorough than were cleaning habits in the neighborhood control group. In addition, some degree of overmatching may have resulted from the selection of children for the neighborhood control group. Similarities with the Hdm-sensitized children and families, for example, in type of housing, may have resulted in higher Hdm Ag content than in a sample of the study base.

In comparison with our previous study, which used the same method of allergen detection, *Dm* and *Df* dominated instead of *Dpt*.¹² This finding may be explained by the inclusion of slightly different homes, that is, with lower indoor humidity, in the present study. That, taking the high humidity dependency of *Dpt* into account, possibly could also explain the different outcomes of the two studies.²⁶ Our data are similar to data of a recent study by Lau et al.²⁷ from Berlin in which the *Df* group species were found to predominate. That study did not, however, differentiate between *Dm* and *Df*. The former species is in fact likely to have been overlooked and misclassified as *Df* in previous studies with microscopy, since the

two are morphologically very similar (Korsgaard J. Personal communication).

It is evident from our data that the Stockholm area is still one of low degree Hdm infestation, and clinical mite allergy is not as important as in more humid areas. Most mattress dust samples held mite allergens in concentrations below the suggested threshold level of sensitization (≥ 2000 ng of mite allergen per gram of dust),²² and many of the children had positive SPT reactions to Hdm of low degree, indicating sensitization but not necessarily clinical allergy.

There was a high rate of bronchial asthma among the children in the case group. This finding was not explained by a higher mite infestation rate. Respiratory symptoms, such as bronchial asthma/wheezing, have, by other investigators, been found not only to be associated with sensitization to Hdm^{28, 29} but also to damp/"moldy" indoor environmental conditions.³⁰⁻³² Damp housing with increased emission from various building materials and microbiologic growth may contribute to an unhealthy and sensitizing indoor climate. This finding should be investigated in further studies and may be of concern in the construction of buildings in the nineties.

CONCLUSIONS

1. Increased mite allergen levels are more often found in homes of children sensitized to Hdms than in homes with children without such sensitization.
2. Despite low Hdm allergen levels, 85% below 2000 ng/gm of dust in the Hdm-sensitized group, a close association was found between bronchial asthma and Hdm sensitization.
3. Indications of poor ventilation were more common in the homes of the Hdm-sensitized children than in homes of the control group, a possible effect of energy-saving measures.
4. Hdm allergens were more prevalent in individual single-storey homes than in individual multistorey homes and apartment buildings.

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