

Housing and house-dust mites

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Because the mite-allergen content in homes is highly variable even in the same geographic area, we tried to determine which variables influence mite infestation. We evaluated mite-allergen content in bedding relative to housing conditions and living habits. This cross-sectional study included 108 homes. Housing conditions were assessed by an architect and living habits by a researcher specialized in social and family economics. Group I allergen level was measured on the mattress dust with monoclonal antibodies, and relative humidity (RH) was monitored in the bedroom during a 2-week period. Homes with low RH did have low mite-allergen content. In contrast, homes with intermediate RH levels had very variable mite-allergen content. Using analysis of variance and a logistic regression analysis, we were unable to identify any variable predictive of mite-allergen content. Thus, factors other than relative humidity seem to influence mite infestation. Moreover, the absence of association between mite infestation and ventilation rate might be accounted for by the gentle climate in our area with notable outdoor RH.

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Several papers have clearly shown that the mite-allergen content in homes is highly variable in the range of 1000-fold (4, 20, 21).

Many variables relative both to the home itself (construction features, state of maintenance, heating, ventilation, exposure to sunlight, type of soil and drainage) and to living habits are thought to control indoor humidity and thereby mite infestation. For both prediction and prevention, it is desirable to determine which among the above-mentioned variables are most predictive of mite infestation. Thus, we designed a cross-sectional study to compare mite-antigen content in bedding with housing conditions and living habits.

Material and methods

Selection of homes

We contacted the families of children who had participated in a previous epidemiologic study (4). A total of 126 agreed to participate. These families live in southeastern France, in either Martigues or Briançon. Martigues is a town of 30 000 inhabitants on the Mediterranean coast near Marseille. The mean ($\pm$ SD) annual relative humidity (RH) in 1985–93 was $73.0 \pm 5.0\%$. The RH in winter (January–March) was 73.6 ± 4.2 . Briançon in the

French Alps is the highest city in Europe. It has a population of 10 000 inhabitants. Its mean ($\pm$ SD) annual RH in 1985–93 was 60.0 ± 3.7 (winter: 57.3 ± 3.0).

We gathered information on 1) mite-allergen content in mattresses and RH in bedrooms; 2) housing conditions; 3) living habits.

Measurement of mite-allergen content and relative humidity

A technician visited each home and vacuum-cleaned the child's mattress. The vacuum-cleaning was done according to the recommendations of the International Workshop on dust-mite allergens and asthma (18); i.e., a portable, hand-held vacuum cleaner was used for 2 min/m². Disposable paper bags were collected and stored at 4 °C until processing. Fine dust was collected and weighed. Mite-allergen content was determined by ELISA with monoclonal antibodies (16). The assay was done with two dilutions (in most cases 1/3 and 1/30) of the extracted sample, each in a double-control manner. The antigen concentration used for statistical analysis was the arithmetic mean of values in the linear section of the standard curve. These measurements were done on the same sample on two occasions, at a 1-month interval. Thus, each individual result provided was

the mean of eight measurements. Results were expressed in micrograms (μg) of group I antigens, defined as the sum of *Der p* I and *Der f* I per gram of house dust.

RH was measured during a 2-week period with calibrated hair-thermohygrometers (Feingarätbau K. Fisher GmbH, Drebach, Germany) delivered to the family. The thermohygrometers were calibrated in our laboratory according to the manufacturer's instructions; i.e., to obtain an RH of 95%, we wrapped the instruments in a wet towel. They were placed in the child's bedroom 1 m above the floor level, on a partition wall, away from the windows and radiators. Parents were instructed to take morning and evening readings of RH and temperature, and to register figures on a special form.

Assessment of housing conditions

An architect visited each home and recorded the following information: location of the house (down-town, suburb, rural), closeness to water, private house or apartment, year of construction, material used (traditional masonry, prefabricated house, wood), structure under the floor and over the ceiling, orientation of the child's bedroom, its proximity to rooms where humidity is generated (i.e., bathroom and kitchen), type of dividing wall, presence of damp spots, and opening of air vents.

Assessment of living habits generating water vapor

Another researcher specialized in social and family economics recorded information on daily activities producing water vapor, ventilation, and heating system. Daily activities producing water vapor include cooking, washing dishes, use of showers and bath, use of washing machine and dryer, production of hot water, and raising pot plants, as well as the number of people living in the homes. Each of these sources of water vapor was quantified according to a precise scale (6) and expressed as grams of water vapor generated per hour. For example, production of water vapor by a washing machine depends on the number of inhabitants and the number of washings per week. Production of water vapor by cooking is calculated by an equation including number of inhabitants, type of utensil used for cooking vegetables or meat, number of meals cooked at home per day, and cooking system used. All these sources of water vapor were added to provide a single figure summarizing the hourly production (in grams) of water vapor in each home.

For assessment of ventilation, the questionnaire included questions on mechanical ventilation and its functioning (continuous or on demand); air vents in the kitchen, bathroom, and toilet; and use of win-

dows and shutters. The heating system was classified as either central or not central heating and, in the latter case, whether operated on a continuous or on-demand basis.

We did not gather information on sanitary conditions, e.g., cleaning of mattress and blankets, and vacuum-cleaning of the floor.

Logistics

The survey took place in both towns in November 1991. This time period was chosen because in a temperate climate, mite infestation occurs mainly during late summer and autumn (17). Data on housing and living habits were collected and house dust on mattresses was sampled during a single home visit. At that time, thermohygrometers were set in the child's bedroom for a 2-week period. They were mailed back to our department, together with the form including daily RH and temperature measurements.

Statistics

In all statistical analyses, we considered as the predicted or dependent variable mite infestation expressed as microgram of group I antigen level in mattresses per gram of dust.

To analyze continuous variables, we used correlation analysis and computed the correlation coefficient r and its statistical significance.

To analyze discrete variables, we first did unpaired t -tests or analysis of variance for each predicting or independent variable; i.e., we compared the group I antigen level for each category of the predicting or independent variable and the degree of significance of the difference. Then, using only those variables which seemed to influence group I antigen level in those univariate analyses, we did a logistic regression analysis (11) (BMDP Software, University of Berkeley, CA, USA), using as the dependent variable group I antigen level classified into two categories: lower than 10 μg ($n = 55$) and equal to or higher than 10 μg ($n = 23$).

Results

Of the 126 families who initially agreed to participate, 117 were visited by our team, and in 116 (95 in Martigues, 21 in Briançon) dust was sampled. In 18 of them, the dust amount was less than 100 mg. Thus, it did not allow assessment of group I allergen level. In the analysis, such samples were discarded. Twelve families did not provide a satisfactory daily diary for RH and temperature measurements. On diaries from the other families, there were 6.2% missing values for daily measurements of

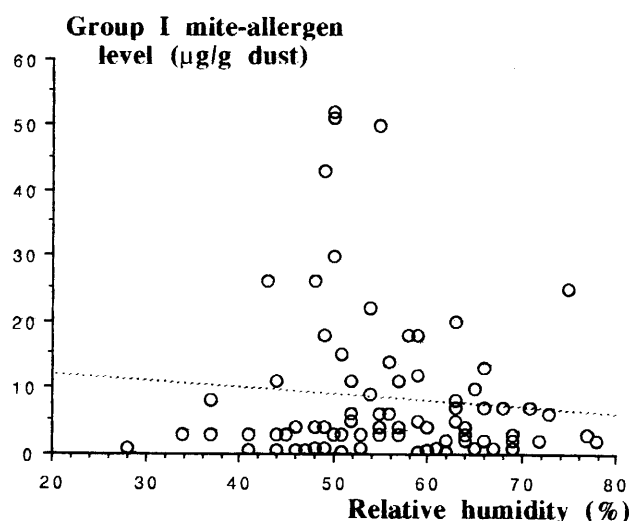


Fig. 1. Correlation between relative humidity (%) and group I antigen level ($\mu\text{g/g}$ dust). Note that slope of correlation line is close to zero (dotted line).

temperature and 6.1% for RH in measurements from Martigues. In Briançon, figures were equal to 3% for temperature as well as for RH. Because the number of homes studied was rather limited, it was not possible to do a separate analysis in each setting. Both groups of homes were considered together in the analysis.

House-dust mite allergens and indoor RH

There was no overall linear correlation between mean RH (Fig. 1) (mean of all morning and evening readings for 2 weeks) and group I antigen level. This held true with either *Der p* I or *Der f* I or their logarithmic counterparts as indices of mite-allergen exposure. However, Fig. 1 shows that mite-allergen content in mattresses was always lower than $10 \mu\text{g/g}$ dust in homes with RH less than 40%. In contrast, samples from homes with RH ranging from 40 to 65% had a very wide range of allergen content, from less than 0.1 to $22 \mu\text{g/g}$ dust. Most samples from homes with RH higher than 65% had an allergen content less than $10 \mu\text{g/g}$ dust. Overall, the *Der p* I to *Der f* I ratio (computed with specific immunoassays) was 0.72. Mite-allergen measurements were

Table 2. Mean morning and evening bedroom temperature and relative humidity in homes with and without central heating

Type of heating	Mean bedroom temperature ($^{\circ}\text{C}$)		Mean relative humidity (%)	
	Morning	Evening	Morning	Evening
Central ($n=30$)	21.0 ± 2.4	21.5 ± 2.1	48.6 ± 7.6	49.1 ± 7.4
Not central ($n=65$)	17.9 ± 2.5	18.8 ± 2.9	58.3 ± 11.6	56.8 ± 11.6

** $P < 0.001$; *** $P < 0.0001$.

reproducible. The correlation coefficient between measurements taken at a 1-month interval was 0.98.

Results of univariate analysis relating group I antigen level to housing and living conditions

Table 1 shows dichotomous variables which *a priori* could be thought to influence mite-allergen levels in mattresses. Of the variables studied, none did influence mite-allergen levels. Other variables such as those listed in Table 1, i.e., type of residency (urban or rural), presence of air vents, use of windows and shutters, and presence of humidifiers, did not influence allergen levels either.

Mean temperature and RH were markedly different in homes which did or did not have central heating (Table 2). Mean morning and evening RH was much lower in homes with central heating.

Result of logistic regression analysis

With group I allergen levels as dependent variable and ventilation, type of heater, type of home, and production of water vapor as independent variables, the logistic regression analysis did not detect any association.

Discussion

This study shows that, of many variables of housing and living habits, none could predict mite infestation. Measurements of mite-allergen levels in mattresses seemed to be quite reproducible. Thermo-hygrometers were calibrated according to the manufacturer's instructions.

Table 1. Univariate analysis relating group I antigen level in mattresses and housing or living habits

Variable	Mechanical ventilation		Production of water vapor		Child's bedroom orientation		Heating	
	Yes ($n=21$)	No ($n=74$)	Low ($< 400 \text{ ml/h}$) ($n=46$)	High ($\geq 400 \text{ ml/h}$) ($n=50$)	Sunny ($n=66$)	Not sunny ($n=30$)	Central ($n=28$)	Not central ($n=60$)
Mean group I antigen level ($\mu\text{g/g}$ dust)	7.1 ± 10.0	NS 8.0 ± 11.3	9.5 ± 12.8	NS 7.0 ± 10.1	9.1 ± 12.0	NS 6.2 ± 10.1	7.8 ± 11.6	NS 8.7 ± 11.4

Several negative findings from this study warrant discussion. First of all, we did not find any statistical correlation between mean RH measured in a home over a 2-week period and group I antigen level in the mattress. In fact, Fig. 1 shows a bell-shape curve. Homes with low indoor RH did have low mite-allergen content. In contrast, homes with intermediate RH levels had very variable mite-allergen content. These results suggest that indoor air dryness is indeed associated with low mite infestation. In the literature, most authors have reported a correlation between RH and mite infestation (12, 17). Danish studies (12) concluded that there are few mites in homes when mean absolute humidity (AH) is less than 7 g of water vapor per cubic meter of dry air. For an indoor temperature equal to 19°C, this figure corresponds to an RH of 43%. From Fig. 1, it appears that mite-allergen levels are very low for RH levels lower than 40–45%. In our study, higher RH levels were not necessarily associated with high mite infestation, possibly because factors other than RH such as food supplies or presence of molds influence mite proliferation, because of successful mite avoidance measures, or both.

Another hypothesis is a strong predominance of *Dermatophagoides farinae*, a species of house-dust mite less sensitive to low RH in dust samples. Actually, the *Der p* I/*Der f* I ratio was equal to 0.72. This predominance of *Der f* I has been found in a study in Berlin, Germany (13), whereas *Der p* I was almost exclusive in a study in São Paulo, Brazil (3). In the Scandinavian climate, however, a predominance of *D. farinae* antigens was to be expected. The competing presence of storage mites may also be adduced. However, because of a cross-reactivity between antigens from house-dust mites and storage mites (14), this coinfection should not lower mite-allergen levels.

Two other studies also failed to show a clear-cut relationship between indoor RH and mite infestation. Schober (19), from the von Brunswick group, plotted number of mites against indoor RH. For low RH, there was a trend for an increase in mite counts when RH increased. However, for higher RH, a plateau effect could be shown. The author speculated that, in a home with high RH, mites may compete with molds for survival. Recently, Harving et al. (10) showed a correlation between both variables. However, from their data, it is quite obvious that the increase in mite allergens is not proportional to increase in RH. This latter study also showed a plateau effect.

In data analysis, we used RH rather than AH figures because acarologists believe that AH is not a useful concept in describing the metabolism of house-dust mites. For example, Arlian (2) showed that house-dust mites can be cultured at 20°C and

79% RH but die and cannot be cultured at 27°C and 56% RH, although the AH is the same for both sets of temperature and RH. Maelzer's experiments (15) have confirmed that AH is not as useful a concept as RH or saturation deficit. Dusbabek (7) did serial dust sampling in mattresses and compared mite counts with RH and temperature measurements in the bedroom. He concluded that the dynamics of mite occurrence was mainly dependent on RH, and that temperature *per se* was not a decisive factor.

Secondly, mechanical ventilation did not show up as a discriminating variable. However, few homes had such equipment. Besides, in our Mediterranean area, outdoor air is not as cold and dry as in Scandinavian countries. Mean outdoor RH in our area was far higher than RH measured in bedrooms. Thus, input of outdoor air within the house cannot noticeably lower RH. Consequently, this negative result does not rule out a possible beneficial effect of mechanical ventilation in fighting mite infestation in areas where outdoor air is dry, cold, or both. In an experimental study, a Danish group (8, 9) showed that mechanical ventilation increasing the average air exchange from 0.3 to 1.3 per hour lowered RH, and significantly decreased house-dust mite counts. Moreover, the same group showed (10) an inverse relation between house-dust mite concentration and indoor air-exchange rate. It should be noted that the study was done in Århus, Denmark, where the mean outdoor temperature in winter falls to 0°C. In a recent editorial (5), Colloff emphasized that the effect of mechanical ventilation in controlling house-dust mites is, unfortunately, greatest in those countries where domestic dampness does not appear to be a major public health problem.

Thirdly, production of water vapor correlated neither with mite-allergen levels nor with indoor RH. This is hardly surprising because mite-allergen levels were measured in bedrooms. High water-vapor production may accompany a high ventilation rate in rooms where water vapor is generated.

Fourthly, those houses which have central heating do not have a lower group I allergen level than those which do not have central heating although they have a higher mean temperature lowering relative humidity (Table 2). This suggests that variables other than RH may influence mite infestation (see above). The influence of heating systems has not been scrutinized in published studies related to housing and mite allergy.

Lastly, mite-allergen levels in mattresses from single houses were not higher than in mattresses from apartments. However, Wickman et al. (22) showed that mite-allergen levels were highest in bungalows, intermediate in multistorey individual houses, and lowest in apartment buildings. Measurement of absolute indoor humidity in this latter

study exhibited large differences, with the highest mean values in bungalows and the lowest in apartment buildings. These authors postulated that in multistorey homes and apartment buildings a "chimney effect" improves the natural ventilation. Andrae et al. also reported a higher prevalence of allergic symptoms among children living in one-family houses with signs of dampness than among those living in apartments (1). Such a "chimney effect" is likely to be inefficient in our area where outdoor RH is higher than indoor RH.

In conclusion, this multivariate study scrutinized a large number of housing conditions and living habits which might influence mite-allergen levels in bedding. Surprisingly, none of the study variables proved to be linked to mite-allergen levels. In homes with low (i.e., <40%) RH, mite-allergen content was low, in keeping with data from the literature. However, there was no correlation between indoor RH in the range of 45–65% and mite infestation, possibly because factors other than RH could influence mite infestation in homes, because mite-avoidance procedures could have been implemented, or for both reasons. In view of the discordant studies done mostly in Scandinavian countries, it might be that different weather conditions, e.g., air dryness in winter, could also account for this discrepancy. For example, ventilation rate seems to be a major determinant of mite infestation in Scandinavian countries. In our climate, it is probably ineffective because outdoor air has a higher RH than indoor air. We believe that the relationship between housing conditions and infestation by house-dust mites might be very different according to the geographic area under study.

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