

Indoor determinants of Der p 1 and Der f 1 concentrations in house dust are different

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Summary

Background Exposure to mite allergens is a major risk factor for sensitization and the development of asthma. Der p 1 and Der f 1 content in homes and probably the proportion of both antigens is highly variable even in the same geographical area.

Objective We investigated specific indoor determinants of Der p 1 and Der f 1 concentrations in house dust of two German cities, Erfurt and Hamburg ($n = 405$ homes).

Methods Mite allergen levels were determined using monoclonal antibodies against Der p 1 and Der f 1 by the ELISA method. Indoor relative humidity and temperature were monitored continuously in the homes over 1 week. The characteristics of homes and occupants were assessed by questionnaire to obtain information on factors which may have an impact on the mite antigen concentration in house dust. These determinants were studied by multivariate regression analysis.

Results The correlation between concentrations of Der p 1 and Der f 1 inside the homes was weak ($r = 0.29$ – 0.35), indicating that different determinants are relevant. Concentrations of the allergens were significantly higher on lower floors (ratios 2–8 times, Der p 1, Der f 1), on old mattresses (ratios 3–13 times, Der p 1, Der f 1), in post-war buildings (ratio 6 times, Der p 1), for non-central heating (ratio 2 times, Der p 1), for old carpets (ratio 3 times, Der p 1) and for the presence of a dog in the house (ratio 3 times, Der f 1). Furthermore, mite concentration increases with raising relative humidity (ratio 1.03 per 1%, Der p 1) and with decreasing temperature (ratio 0.86 per 1 °C, Der p 1) indoors.

Conclusion Both Der p 1 and Der f 1 concentrations should be measured in house dust, since they are only weakly correlated and have different determinants.

Keywords: Der f 1, Der p 1, determinants, house dust mites, housing, indoor

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Introduction

Inhalant allergens play a major role in the pathogenesis of asthma and allergic rhinitis. The Group 1 allergens of house dust mite *Dermatophagoides pteronyssinus* and *D. farinae* (Der p 1 and Der f 1) are the predominant inhalant allergens in most parts of the world. Both species of mites are widely spread inhabitants of homes where they feed on organic matter. Indoor humidity was found to be associated with

mite numbers [1–3]. The house dust mites are unable to maintain their water balance when the relative humidity (RH) drops below a value corresponding with the so-called Critical Equilibrium water-vapour Activity (CEA). The value of the CEA depends on the temperature: at higher temperatures a higher RH is required by the mites [3]. From laboratory experiments we know that *D. pteronyssinus* is more susceptible to desiccation than *D. farinae* [4]. For prediction and prevention it is desirable to determine specific factors which are predictive of both antigens. Therefore, Der p 1 and Der f 1 levels in dust collected in 405 homes in two German cities were analysed with respect

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to housing and occupant characteristics which may influence each species.

Materials and methods

Population

The homes included in this study were inhabited by adults aged between 20 and 44 years who participated in a study on indoor and genetic influences on asthma and allergies (INGA) [5,6]. A total of 405 adults (204 in Erfurt and 201 in Hamburg) agreed to participate. The homes were visited by investigators between June 1995 and November 1996. A screening questionnaire on building and housing characteristics, and living habits was completed.

Germany has a temperate climate. Outdoor climate was measured centrally in both cities. The median temperatures in 1995 and 1996 were 10.0 °C in Erfurt and 8.9 °C in Hamburg. In the summer (April through September) and in the winter (October through March) the median outdoor temperature in each of the cities (Erfurt and Hamburg) was 14.6 °C and 3.3 °C and 13.8 °C and 2.7 °C, respectively. The median RH's in 1995 and 1996 were 75% (70% in the summer, 80% in the winter) in Erfurt and 80% (74% in the summer, 85% in the winter) in Hamburg.

Measurement of mite-allergen content and indoor climate

In each house, three dust samples were taken in a highly standardized manner [7,8] by vacuuming using the same type of vacuum cleaner (Flüsterjet Vitall 371, 1000 W, Philips, Hamburg, Germany), a single area of 1 m² of the living room floor, the bedroom floor and the mattress surface for 2 min each. The dust was collected on cellulose filters using sampling nozzles and filter boxes (ALK, Hørsholm, Denmark). After sampling, the filters with dust were stored in the filter boxes at -20 °C until extraction. The dust was not sieved. The total amount of dust was determined by weighing the filter before and after dust sampling. Analysis for Der p 1 and Der f 1 was done using a monoclonal enzyme-linked immunosorbent assay (ELISA) with the standards UVA 93/03 and UVA 93/02 (Indoor Biotechnologies, Deeside, Clwyd, UK). The interassay variation for repeated assays was 15 and 12%, and the intra-assay variation was 7 and 5% for Der p 1 and Der f 1, respectively [9]. The lower detection limit was 1 ng/mL for both antigens.

RH and temperature were measured with Tinytalk II Data Loggers (Gemini Data Loggers Ltd, Chichester, UK) for a period of 7 days. The data loggers were placed in the living room, roughly 2 m above floor level. The median RH and median temperature were used in further analysis. RH and temperature were converted to absolute humidity (AH). The additional humidity was calculated as the difference

between the AH in indoor and outdoor air, which was considered as a measure for the moisture balance of the house. A house was considered to be humid if this difference is higher than the third tertile (1.55 g/kg air) and to be dry if the difference is up to the first tertile (0.67 g/kg air).

Checklist on building and occupant characteristics

A checklist on building and occupant characteristics was developed and a trained interviewer completed the checklist in each dwelling. From this checklist, approximately 30 housing and occupant characteristics were derived for further evaluation. The heating system was classified as either central or non-central heating and the latter category included gas heating, fireplace heating and other non-continuous heating systems like coal or wood burning.

Data analysis

The distributions of allergen levels were log normal (ln) transformed. For concentrations less than the detection limit sample values were estimated by substituting one-half of the detection limit. The Spearman rank-order correlation coefficient was used to analyse continuous variables. In all statistical analyses, dependent variables were Der p 1 and Der f 1 concentrations (ng/g) on the floor and on the mattress. For the estimate of antigen levels on the floor, antigen measurements in the living room and bedroom were calculated as an average of these two locations.

The relationship between the housing and occupant characteristics and the allergen concentrations were first examined using bivariate linear regression analysis. The Wilcoxon-Mann-Whitney test and the Kruskal-Wallis test were used. Then, multivariate linear regression analyses were performed with variables which were found to have at least a marginally significant relationship ($P < 0.10$) with allergen levels in the bivariate analyses. The city and the season *a priori* could be thought to influence allergen levels on floors and mattresses. The means ratio of allergen concentration is the ratio of the geometric mean in the given category vs the reference category. In the tables R^2 is presented as it indicates the proportion of the variance of the allergen concentrations explained by the variables in the regression analysis, and the parameter estimate β . Statistical significance was set at a conventional 5% level. SAS (Statistical Analysis Software 6.08, Cary, NC, USA) was used for statistical analysis.

Results

Der p 1 and Der f 1 levels in floor and mattress dust and indoor climate

Statistically significant but weak correlations were found

between both antigen concentrations, ranging from 0.29 on the floor to 0.35 on the mattress. Average indoor RH ranged from 11 to 73% with a median of 45%. The average room temperature ranged from 9 to 28 °C with a median of 22 °C. There was no significant correlation between indoor temperature and RH indicating that warmer rooms do not necessarily contain lower RH. In summer a median indoor RH of 50% and a median indoor temperature of 22 °C was recorded, in winter 34% and 21 °C.

Housing characteristics and associations with allergen concentrations

For all appropriate characteristics the bivariate association with the Der p 1 and Der f 1 level was investigated for floor and mattress dust separately. The following factors were entered in addition to the *a priori* variables into all the models: building material, year of construction, storey of the dwelling, type of heating system, age of carpet or mattress, presence of a dog during the last 12 month, additional humidity, indoor RH and indoor temperature.

Der p 1 levels

Table 1 presents statistically significant results of multivariate linear regression analysis for Der p 1 concentrations in floor dust. High Der p 1 levels were related to high RH and low room temperature. Moreover, there was an association to the additional humidity in the dwelling. Figure 1 presents the estimated association between parameters of indoor climate and the means ratio of Der p 1 concentration in floor dust obtained by linear regression analysis and adjusted for the other parameters shown in Table 1. The means ratio is described as the ratio of geometric mean at a given RH and temperature and the geometric mean at 5th percentile of RH and temperature, respectively. At 23% RH and a temperature of 18.2 °C (5th percentile) the adjusted means ratio is 1. The means ratio was found to be positively associated with RH and negatively associated with temperature. With an increase of indoor RH up to 62% (95th percentile) at constant temperature at the 5th percentile the means ratio of Der p 1 level raises to 3.46.

In addition to parameters of indoor climate we saw significantly lower Der p 1 concentrations in floor dust with increasing floor level. Further, in dwellings with a non-central heating system Der p 1 levels in floor dust were higher than in central heated homes. Carpets aged at least 5 years contained higher Der p 1 concentrations than carpets aged up to 12 months. In winter Der p 1 levels in floor dust were lower than in summer, but these findings were not statistically significant ($P = 0.06$). The place of residence, the building material and the presence of a dog did not affect Der p 1 levels in floor dust. On the mattress, however, a

twofold Der p 1 concentration was shown when a dog had been in the dwelling (Table 1). With the exception of the variables 'age of the mattress' and 'presence of a dog', the results of regression analyses of Der p 1 in mattress dust did not differ substantially from the results in floor dust.

Der f 1 levels

Results of multivariate regression analysis for Der f 1 concentrations in floor dust show that in contrast with Der p 1 antigen, Der f 1 level in floor dust was not affected by climate-related factors. Der f 1 concentrations were related to the location of floor level and 4 times higher levels were measured in the ground floor than on 4th floor and higher. The presence of a dog in the dwelling affected statistically significant 2–3 times higher Der f 1 levels in floor dust. In Hamburg, 2–3 times higher Der f 1 levels were measured than in Erfurt. With the exception of the variable 'age of the mattress' we found very similar results for Der f 1 levels in mattress dust. Mattresses at least 10 years old contained 13 times higher Der f 1 levels than new mattresses.

Discussion

The prevalence of mite species varies between countries, and even in the same country it may vary between regions. We analysed species of *Dermatophagoides pteronyssinus* and *D. farinae*. The concentrations of major mite allergens Der f 1 in floor and mattress dust were 2.5–3.5 times higher than Der p 1 levels (Table 2). This is similar to findings of other German studies [10,11] in which *D. farinae* was found to be the predominant species.

Indoor climate, outdoor climate and place of residence

The present results demonstrate a strong relationship between RH and temperature and growth of *D. pteronyssinus*, but not of *D. farinae*. In data analyses, we used RH rather than AH figures because acarologists believe that water balance and survival of mites are not dependent on the total amount of water in the air but on the degree of saturation of the air with water vapour [12]. Our results confirm findings of laboratory experiments that *D. pteronyssinus* is more susceptible to desiccation than *D. farinae* [4].

In our data, elevated levels of Der p 1 were associated with the additional humidity. This is in accordance with findings in Stockholm [13]. The additional humidity (difference between AH in indoor and outdoor air) is a function of the production of humidity in the home, sorption effects of humidity on surfaces, and the amount and humidity of supplied air [13]. The larger the additional humidity at given indoor climate, the higher the desorption of humidity from

Table 1. Multivariate association of different housing characteristics and the Der p 1 concentration in floor dust ($n = 317$; $R^2 = 0.35$) and mattress dust ($n = 320$; $R^2 = 0.28$). Based on ln-transformed data*

Respective vs reference group	<i>n</i>	β	Der p 1 concentration		<i>P</i> -value
			Means ratio†	95% CI	
<i>Floor dust</i>					
Place of residence					
Erfurt	143		1		
Hamburg	174	+ 0.29	1.33 ‡	(0.67; 2.66)	0.41
Building characteristics					
Year of construction					
After 1970	110		1		
1946–70	92	+ 1.80	6.03	(2.72; 13.36)	<0.01
Before 1946	115	+ 0.51	1.66	(0.68; 4.06)	0.27
Housing characteristics					
Storey of the dwelling					
Ground floor	114		1		
1st floor	63	– 1.08	0.34	(0.16; 0.72)	<0.01
2nd floor/3rd floor	86	– 1.73	0.18	(0.09; 0.36)	<0.01
4th floor and higher	54	– 2.08	0.13	(0.05; 0.30)	<0.01
Type of heating					
Central	204		1		
Non-central	113	+ 0.66	1.94	(1.06; 3.55)	0.03
Age of carpet					
<= 1 years	35		1		
2–4 years	99	+ 0.26	1.30	(0.52; 3.26)	0.58
5–9 years	111	+ 0.99	2.70	(1.05; 6.93)	0.04
>= 10 years	72	+ 1.01	2.74	(1.01; 7.42)	0.05
Indoor climate					
Additional humidity §					
> 1.55 g/kg	111		1		
>0.67–1.55g/kg	101	– 0.94	0.39	(0.19; 0.81)	0.01
<= 0.67g/kg	105	– 1.36	0.26	(0.12; 0.57)	<0.01
Relative humidity per 1%	317	+ 0.03	1.03	(1.00; 1.06)	0.02
Temperature per 1 °C	317	– 0.15	0.86	(0.75; 0.98)	0.02
<i>Mattress dust¶</i>					
Housing characteristics					
Age of mattress					
<= 1 years	53		1		
2–4 years	100	+ 0.72	2.05	(0.80; 5.25)	0.14
5–9 years	86	+ 0.74	2.09	(0.79; 5.58)	0.14
>= 10 years	81	+ 1.41	4.10	(1.53; 10.96)	0.01
Animals					
Dog during the last 12 months					
No	242		1		
Yes	78	+ 0.75	2.13	(1.03; 4.40)	0.04

*Season, building characteristics and animals did not show significant results. †Mutually adjusted for the other factors in the table. ‡The unadjusted means ratio for Hamburg vs Erfurt is 3.55. §Difference of absolute humidity indoor and outdoor. ¶Adjusted for the other factors (excluding the age of the carpet) shown in floor dust.

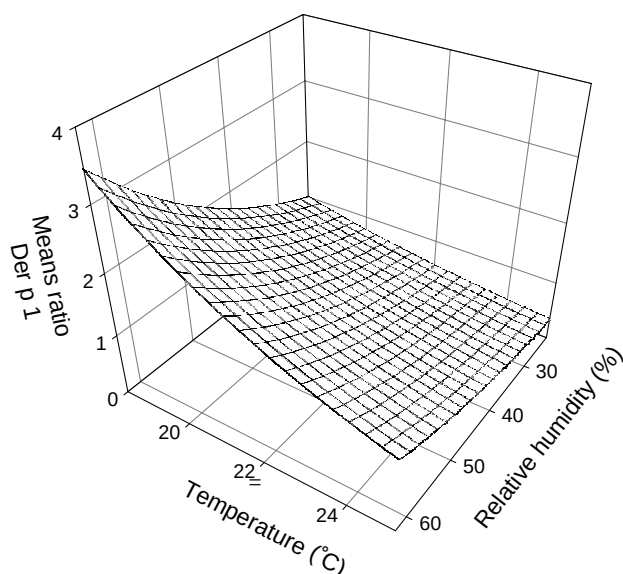


Fig. 1. Estimated association between relative humidity, room temperature and means ratio for Der p 1 concentration in floor dust after adjusting for the other variables listed in Table 1 (means ratio = 1, temperature = 18.2°C, RH = 23%)

surfaces in the home supporting *D. pteronyssinus* growth. However, we saw no association between additional humidity and Der f 1 levels.

Laboratory experiments have shown that the optimal condition for growth of *D. pteronyssinus* is around 25°C and 75%. Higher temperatures accelerate development, but other factors such as mortality, fecundity and metabolism result in lower reproductive rates [14]. Although we know metabolic, reproductive and other biological activities slow down at temperatures lower than 25°C [15], we found an inverse relation between temperature and Der p 1 level. This was not found for Der f 1. The negative association of Der p 1 concentration and room temperature is in accordance with findings by others [1,10]. However, all results are based on indoor climate measurements within a period of only 7 days. Probably there are other factors affecting mite growth which

are due to climate conditions indoors and not gathered in our measurements.

The climates in Erfurt and Hamburg are different, which might explain regional differences in allergen levels. We found levels of Der p 1 or Der f 1, respectively, 4 times and 5–7 times higher in Hamburg without adjusting for other factors. In multivariate analyses of Der p 1 levels the differences between the cities are distinguished. Therefore, for *D. pteronyssinus* the other factors included in the regression model explain the different allergen levels in Erfurt and Hamburg. However, the multivariate analyses of Der f 1 show statistically significant higher concentrations in Hamburg. This implies that there are other factors potentially housing characteristics supporting *D. farinae* growth in Hamburg not gathered in the analyses. The Hamburg–Erfurt comparison is published elsewhere [16].

Relevant housing and occupant characteristics

The floor level seems to be a major determinant for mite infestation. We found higher levels of both mite allergens on ground floors than on higher floors. Similar results have also been observed in Northern Sweden [17] and in five German cities [18]. Thus, it seems that living in homes located on ground floors is a risk for high mite allergen exposure. Ground floors are more prone to develop floor moisture than upper floors, because they are in direct contact with the soil.

Centrally heated homes designed for maximum energy efficiency are especially airtight, and RH can attain high levels. Our data show slightly higher mean RH and significantly higher temperatures in homes with central heating. Despite slightly higher RH in these homes, Der p 1 levels are twice as low. This may be due to the higher temperatures which tend to reduce *D. pteronyssinus* infestation. We found no effect on Der f 1 levels. In a French study [19] mite antigen levels in houses with central heating were not found to be lower than in non-central-heated homes although they have a higher mean temperature lowering RH. Both results suggest that variables other than RH may influence mite infestation.

Table 2. Der p 1 and Der f 1 concentrations (ng/g) for the three different sampling locations and mean antigen concentrations on the floor (Geometric means GM and 95% confidence intervals CI)

Location	n	Der p 1 concentration		Der f 1 concentration		Der p 1 + Der f 1 concentration	
		GM	95% CI	GM	95% CI	GM	95% CI
Living room floor	405	26	21–33	83	64–108	212	165–273
Bedroom floor	365	55	41–75	188	141–253	523	391–700
Floor (average)	405	59	45–77	188	144–246	508	391–661
Mattress	405	169	125–229	421	304–582	1.403	1.040–1.892

The optimal conditions for reproduction and population growth apparently involve climatic as well as nutritional factors. We found that the presence of a dog is related to higher Der p 1 levels in mattress dust and higher Der f 1 levels in floor and mattress dust. A dog produces skin scales and these are known to be a good food source for mites and the nutritional quality may affect reproduction. Nevertheless, the findings of different studies are inconsistent [1,20,21].

The highest numbers of mites are found in places where dust accumulates. On the other hand, no mites were detected on floors of new houses until humans occupied their homes for a few weeks [20]. Der p 1 was found to be associated with the age of the carpet. An increasing level of both antigens was shown with increasing age of the mattress. This effect was stronger for Der f 1. Our findings may have different reasons. There is an accumulation of mite antigens over time as well as an accumulation of skin scales, etc., in dust acting as a food source. In addition, older mattresses probably contain different materials and since we could not control for mattress type this might be a reason for the observed differences.

We found higher Der p 1 levels in floor dust and a tendency towards higher levels in mattress dust in homes constructed between 1946 and 1970 compared to homes built after 1970. Conflicting results about the correlation between allergen levels and the age of the house are described in the literature [20,22]. The differences in investigations are potentially due to different building types and varied indoor climates dependent on the geographical region.

Other characteristics

Building material and other factors, e.g. cleaning procedures are not associated with allergen levels. No association was found also between allergen levels and ventilation practice during the year. Ventilation rate appears to be a main determinant of mite infestation during winter season when outdoor air reaches extremely low AH [23]. In our data, mean outdoor AH was far higher than indoor RH. Thus, outdoor air entering the house cannot remarkably lower RH. The relationship between housing conditions and mite infestation might be very different according to the geographical area under study.

In conclusion, our results indicate that it is necessary to determine at least Der p 1 and Der f 1 concentrations in studies about allergen exposure and health effects since exposure to both mite antigens is highly variable. Both concentrations are only weakly correlated, due to different indoor determinants. High levels of Der p 1 are seen especially in homes with high humidity and low temperatures. Der f 1 occurrence was found to be independent of

temperature and humidity. It seems to be both feasible and important to control indoor humidity and temperature in order to minimize mite allergen exposure.

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