

The effects of season, climate, and air-conditioning on the prevalence of *Dermatophagoides* mite allergens in household dust

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Background: Clinical evidence reveals a strong relationship between dust mite allergen levels and asthma. This study suggests the relative importance and interactions among factors that influence mite allergen levels in human dwellings.

Methods: *Dermatophagoides pteronyssinus* allergen (Der p I) and *D. farinae* allergen (Der f I) were measured in 536 dust samples collected from 424 homes across the United States.

Results: There were distinct seasonal fluctuations of Der p I and Der f I. Der p I rapidly increased to peak in July then gradually decreased through October. Der f I slowly rose to peak later, around September, before declining. Different climates in regions of the United States had no significant affect on the quantity of Der p I or Der f I. However, regional climate differences seemed to influence the prevalence of either *D. pteronyssinus* or *D. farinae*. Air-conditioning significantly reduced ($p < 0.001$) Der I mite allergens detected in the dust samples, and a tendency existed for Der f I to be higher than Der p I in air-conditioned homes. There was a significant ($p < 0.01$) interaction between air-conditioning and seasons. The most dramatic affect was observed during the summer months, the cooling season, from approximately May to September.

Conclusions: These findings show that distinct seasonal fluctuations exist of *D. pteronyssinus* and *D. farinae* mite populations, and suggest that differences in the microclimate within homes may have a dramatic affect on *Dermatophagoides* mite populations. (*J ALLERGY CLIN IMMUNOL* 1993;91:862-7.)

Key words: *Dermatophagoides*, dust mites, allergen exposure

The composition of dust from human dwellings is highly variable. For the most part this variation in dust composition is due to factors such as soils, flora, and fauna that are unique to specific geographic regions as well as different building constructions, furnishings, ventilation systems, and cleaning regimes. These factors, influenced by behavior, culture, and economics, can have a profound affect on the composition and distribution of dust in human dwellings. Despite the amorphous composition and random distribution of dust in human dwellings, allergy to dust is surprisingly constant.

Abbreviations used

Der f I: *Dermatophagoides farinae* group I allergen
Der p I: *Dermatophagoides pteronyssinus* group I allergen
RH: Relative humidity

Dermatophagoides mites are found with some frequency in dust from human dwellings, and a strong relationship between the allergenicity of dust and mite populations is evident.¹⁻⁴ The number of clinically relevant allergens from *Dermatophagoides* mites has not been firmly established; however, Der p I from *D. pteronyssinus* and Der f I from *D. farinae* have been identified as major allergens through the use of crossed radioimmuno-electrophoresis (CRIE).^{5, 6} These *Dermatophagoides* group I allergens are associated with mite fecal pellets.^{7, 8} Mite fecal pellets are approximately 10 μ m and tend to settle out of the

From Vespa Laboratories, Inc., Spring Mills, Pennsylvania.

Received for publication Feb. 21, 1992.

Revised Nov. 6, 1992.

Accepted for publication Nov. 10, 1992.

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0091-6749/93 \$1.00 + .10 1/1/44108

air rapidly, in less than 5 minutes.^{9, 10} Thus *Dermatophagoides* mite allergens are typically found in settled dust on bedclothes, carpets, and furniture. And suspension of settled dust is the primary source of airborne mite allergens.¹¹

Dermatophagoides mites produce a variety of allergens, and individuals allergic to mites can be selectively allergic to specific mite allergens.^{5, 6, 8} Sufficient data have been compiled so that guidelines applicable to most individuals sensitive to mites have been proposed.^{12, 13} Measurement of a product specifically from mite populations, such as the group I mite allergens, may be used to assess mite allergen exposure. The production of monoclonal antibodies specific for *Der p* I and *Der f* I has led to the development of sensitive and specific assays.^{14, 15} Indeed, the specificity of the monoclonal antibodies for *Der p* I and *Der f* I makes it possible to use these assays for species identification.¹⁶

Quantification of specific allergens in household dust samples can provide important information for clinical and epidemiologic studies of allergen exposure, selection of appropriate allergen control methods, and monitoring of control method efficacy and compliance. The objectives of this study were the following: (1) to quantitate *Der p* I and *Der f* I allergens in household dust samples collected during different seasons from homes across the United States, and (2) to determine if climate control systems (i.e., air conditioners), geographic location, or seasons affect the type and quantity of allergens in the dust samples.

MATERIALS AND METHODS

Household dust samples

Five hundred thirty-six dust samples were collected between September 1989 and January 1991 from 424 homes across the United States. The allergist of the individual participants recommended samples be taken from either bedding, carpet, or upholstery in each household. After receiving explicit instructions, a member of each household collected samples. The specific objects were vacuumed for 5 minutes, and the dust was collected on a filter (38 cm²; pore size, 6 μ m) in a special sampling device (ALK Laboratories, Inc., Milford, Conn.) that connects to the hose attachment of most vacuum cleaners. After vacuuming, the filter was removed from the sampling device, covered with a plastic lid, and placed in a sealable plastic bag. Then both the filter and device were returned to the laboratory. An occupant of each household was asked to complete a questionnaire to provide information on indoor climate control.

Dust extraction and allergen quantification

Aqueous extracts were prepared by diluting a measured amount of fine dust from each sample 1:10 wt/vol with

0.125 mol/L ammonium bicarbonate buffer. A minimum of 200 mg of fine dust was separated by mechanical sieving through 0.5 mm screens and then extracted by agitation on a wrist-action shaker for 2 hours at room temperature. The suspension was then centrifuged for 15 minutes at 1000 *g*. The dust extracts were decanted and stored at -60° C until analyzed for *Dermatophagoides* mite allergens.

Monospecific antibodies (ALK, Horsholm, Denmark) were used in two-site enzyme immunoassays to quantitate *Der p* I and *Der f* I.^{14, 17} The enzyme immunoassays were described in detail by Lind.¹⁴ In brief, 96-well microtiter plates (Maxisorp, NUNC, Roskilde, Denmark) were coated with monospecific rabbit antibodies against either *Der p* I or *Der f* I. A standard curve was constructed with use of a series of dilutions ranging from approximately 1 to 400 ng/ml mite extracts (SQ Mite Extracts, 4000 ng/ml; ALK). The dust extracts were diluted with 0.1 mol/L phosphate-buffered saline with 0.5% bovine serum albumin, pH 7.2, so that at least one observation was within range of the standard curve. Allergens bound to the plates were incubated with horseradish peroxidase-conjugated monospecific antibody to either *Der p* I or *Der f* I. Then o-phenylene diamine substrate was added, and the amount of soluble chromophore produced was quantitated at 490 nm with use of Bio-Tek microplate autoreader (EL 311; Bio-Tek, Winooski, Vt.).

Calculations and data analysis

Calculation of mite allergen concentration was done by interpolation from the standard curve. The data are expressed as micrograms of specific *Dermatophagoides* group I allergen per gram dust (μ g/gm). A logarithmic ($\log_{10}$) transformation of the mite allergen measurements was used to stabilize the error variances and normalize the error distribution for calculation of statistics. A general linear regression model, type I for fixed effects, was used for this multifactor study, and the *F* statistics were calculated for both interactions and main effects. Because all treatment sample sizes were not equal, the *F* statistics were calculated by the regression approach. The total group I mite allergens were calculated by addition of *Der p* I to *Der f* I (μ g/gm) before transformation to logarithm base 10 for statistical analyses. A *p* value of 0.05 was selected to discern statistically significant differences throughout this study. After calculation of statistics, mite allergen levels for some factors were expressed as geometric means.

The effects of seasonal and geographic climate differences as well as indoor climate modifying systems on *Dermatophagoides* group I allergens were evaluated in this multifactor experimental design. Four seasons were defined: January, February, and March as winter; April, May, and June as spring; July, August, and September as summer; October, November, and December as fall. General climatic features, in particular temperature and humidity, were used to sort samples from different geographic regions for data analysis. The geographic climate regions included the following: the humid intermediate climate of the Pacific Northwest; the Mediterranean-type climate of coastal California; the dry climates of the desert regions; the semiarid climate

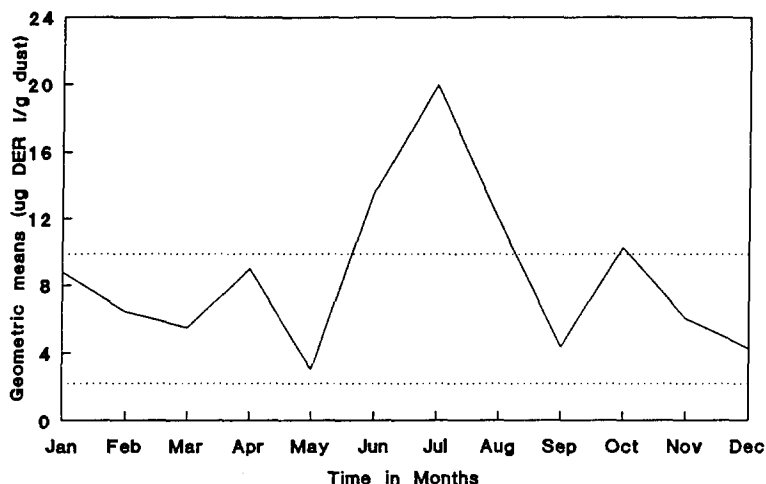


FIG. 1. Seasonal fluctuation of total *Dermatophagoides* group I allergen (*Der p I* + *Der f I*) expressed as micrograms of allergen per gram of dust. Less than 2 µg/gm is regarded as low, 2 to 10 µg/gm is regarded as moderate and represents a risk for sensitization, and more than 10 µg/gm is regarded as high and represents a risk for acute attacks of asthma in most individuals allergic to mites.^{13, 14}

TABLE I. Measurements of mite allergens in seven regions

Region*	No.	<i>Der p I</i>	<i>Der f I</i>	Total group I
: ————— µg allergen per gm dust† ————— :				
A	48	2.96 ± 0.080	1.35 ± 0.041	3.42 ± 0.089
B	23	2.47 ± 0.036	2.93 ± 0.035	5.19 ± 0.046
C	21	1.85 ± 0.033	2.82 ± 0.040	3.97 ± 0.049
D	36	1.67 ± 0.069	2.63 ± 0.088	3.18 ± 0.095
E	52	2.91 ± 0.094	1.66 ± 0.070	4.16 ± 0.106
F	177	1.82 ± 0.063	2.42 ± 0.060	3.10 ± 0.078
G	179	2.23 ± 0.093	3.67 ± 0.117	4.97 ± 0.128

*General climatic features of different geographic regions used to sort the samples. Geographic regions were as follows: A, Humid intermediate climate of the Pacific Northwest; B, the Mediterranean climate of California; C, the dry climates of the desert regions; D, the semiarid climate of the intermountain steppe region; E, the continental climate of the Great Plains; F, the humid subtropical climate of the Gulf Coast and southeastern states; and G, the modified continental climate of the East Coast.

†For statistical analyses data were transformed to logarithm base 10. Data expressed are geometric mean, micrograms of allergen per gram dust (µg/gm).

of the intermountain steppe (level, treeless) region; the continental climate of the Great Plains; the humid subtropical climate of the Gulf Coast and southeastern states; and the modified continental climate of the East Coast. The indoor climate control systems included air conditioners, humidifiers, and dehumidifiers.

RESULTS

As illustrated in Fig. 1, a seasonal fluctuation of the total *Dermatophagoides* group I allergens was observed. The total mite group I allergens rose sharply in June, reached a peak in July, then declined through September. Evident in this study were distinct seasonal fluctuations of both *Der p I* and *Der f I* mite allergens as illustrated in Fig. 2. A. *Der p I* rapidly

increased to peak in July then gradually decreased through October, whereas *Der f I* slowly rose to peak later, around August. Also, as depicted in Fig. 2, A, there appeared to be some fluctuation in *Der f I* concentrations during the change of seasons around April and October. However, the interaction among seasons and geographic climate regions was not significant ($p = 0.21$), suggesting that no distinct seasonal differences existed of *Dermatophagoides* group I allergens among the climatic regions across the United States.

Although the concentration of total *Dermatophagoides* group I mite allergens was not significantly different ($p = 0.09$) among household dust samples from the different geographic climate regions, re-

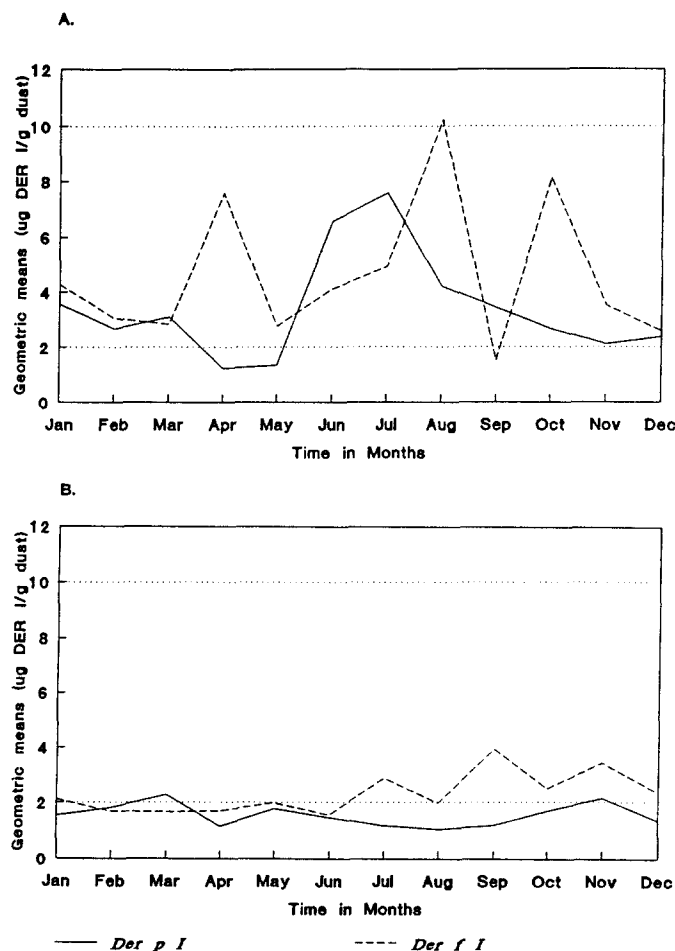


FIG. 2. A, Seasonal fluctuation of *Der p I* and *Der f I* in household dust samples from homes with no air conditioning. B, Distribution of *Der p I* and *Der f I* in household dust samples from homes with air-conditioning.

gional differences in climate did appear to influence the distribution of group I allergens from the different *Dermatophagoides* species (Table I). Significant variations occurred in the concentrations of *Der p I* ($p < 0.02$) and *Der f I* ($p < 0.01$). In general, when the effect of seasons and indoor climate control were removed, *Der p I* tended to predominate in humid regions with moderate climates, whereas *D. farinae* was usually dominant in regions characterized by drier climates. However, the magnitude of variation of mite allergen concentrations among individual homes within the same region was most often larger than differences observed between regions.

Indoor climate control systems, in particular air conditioning, had a significant ($p < 0.001$) effect on the quantity of allergens from the different *Dermatophagoides* mite species (Fig. 2, B). The concentration of total *Dermatophagoides* group I allergens was lower and *Der f I* tended to predominate in homes

with air-conditioning (Fig. 2, B). Also, there was a significant ($p < 0.01$) interaction between air-conditioning and seasons. The most dramatic effect was observed during the summer months, the cooling season, from approximately May to September. Unfortunately, the number of dust samples from households that use a humidifier or dehumidifier on a regular basis were too small to make appropriate comparisons.

DISCUSSION

The house dust mite species, *D. pteronyssinus* and *D. farinae* are reported as frequent inhabitants of house dust in all parts of the world. In several studies measurement of *Dermatophagoides* mite excrement allergens suggest that changes in climate throughout the seasons of the year have a dramatic effect on the distribution and population densities of the specific mite species.¹⁵⁻²⁰ In the United States *Dermatophagoides* mite populations reach a peak in the summer

months, which correlates with an increase in humidity.¹⁸⁻²¹ In this study we observed a peak in total *Dermatophagoides* group I allergens during the summer months, which would correspond to peak *Dermatophagoides* mite populations reported in the other studies.¹⁸⁻²⁰ We also observed distinct seasonal fluctuations of both *Der p* I and *Der f* I, which may reflect the species-specific humidity and temperature requirements for optimum mite growth.

Several investigators have reported that humidity appears to be the primary determinant of the presence and population densities of *Dermatophagoides* mite species.^{16, 20-23} We were unable to detect differences in mite allergen levels in different regions of the United States. A larger sample size may have made it possible to discern interactions between seasons and climates in different geographic regions. However, the results of our study suggest regional climates did influence the prevalence of specific *Dermatophagoides* mite species. *D. farinae* tends to predominate over *D. pteronyssinus* when the relative humidity (RH) remains approximately 60%.^{4, 22} Although regional climatic conditions appeared to affect the prevalence of *Dermatophagoides* mite species, the magnitude of variation observed in this study suggests that the climatic conditions within individual homes, the microclimate, may be a more critical factor affecting population densities of *Dermatophagoides* mite species.

The microclimate maintained within homes may not necessarily reflect the climatic conditions of the region, especially in well-insulated, energy-efficient homes. In this study we observed that the use of air-conditioning to modify indoor climates during the cooling season appeared to significantly reduce mite populations and subsequent allergen production. Carpenter et al.²⁴ reported that air-conditioning can markedly reduce mite density if it is run constantly and if it reduces RH below 50%. Conventional air-conditioning systems decrease indoor temperature and in the process tend to reduce the moisture content of the air. RH below 50% would not be conducive to *Dermatophagoides* mite growth.²² We observed that *D. farinae* tended to predominate in air-conditioned homes. Air-conditioning systems may reduce temperature and humidity and thus tend to favor *D. farinae* over *D. pteronyssinus*.²²⁻²⁴

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Anaphylaxis to measles, mumps, and rubella vaccine mediated by IgE to gelatin

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Background: Allergic reactions to measles, mumps, and rubella (MMR) vaccine are rare; some have been attributed to allergy to trace quantities of egg proteins. We report a 17-year-old female who had an anaphylactic reaction to MMR vaccine. A primary vaccination with MMR at age 15 months had been uneventful. She is not allergic to eggs; however, ear and throat pruritus and tongue swelling develop after she eats gelatin. MMR vaccine contains gelatin as a stabilizer.

Methods and Results: Prick skin tests were positive to 1:10 wt/vol dilutions of MMR vaccine and gelatin but negative to egg. By immunoassay, her serum IgE antibodies were elevated to both MMR vaccine and gelatin, but not to isolated MMR antigens. IgE binding to the gelatin carrier could be inhibited in a dose-dependent fashion by addition of not only MMR vaccine but also gelatin from a variety of animal sources. Immunoblotting confirmed the presence of IgE antibodies to multiple gelatin components as well as to MMR vaccine components.

Conclusions: We conclude that the patient has an anaphylactic sensitivity to gelatin, and that her anaphylaxis to MMR vaccine was caused by the gelatin component. This sensitivity may explain other cases of MMR anaphylaxis. (*J ALLERGY CLIN IMMUNOL* 1993;91:867-72.)

Key words: MMR, allergy, gelatin, IgE antibody

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The Chief, Navy Bureau of Medicine and Surgery, Washington, D.C., Clinical Investigation Program sponsored this study no. S-92-007, as required by HSETCINST 6000.41.

Supported in part by the Mayo Foundation.

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, nor the Government.

Received for publication July 14, 1992.

Revised Nov. 6, 1992.

Accepted for publication Nov. 11, 1992.

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1/1/44150

Abbreviation used

MMR: Measles, mumps, rubella

At least 28 reports exist of immediate and/or anaphylactic reactions to measles vaccine or combination measles, mumps, and rubella (MMR) vaccine.¹⁻⁵ Two of these occurred in patients allergic to egg and were attributed to allergic reactions to egg protein in the vaccine.³ The remainder have occurred in patients who tolerate eggs and are presumed to be due to some other vaccine constituent. It is not generally appreciated that in addition to MMR viral antigens, the vaccines contain neomycin, sorbitol, and gelatin.⁶